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Streetlight Damage Detection and Alerting System Using IoT Technologies

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Abstract:

The proposed Street light Damage Detection and Alerting System Using IoT Technologies offer an innovative solution for smart streetlight damage detection with use of IoT and cloud Technologies. Streetlights are most important for road safety and people security. In many of the area's streetlight damages are unnoticed due to lack of real time data. Even they are noticed they are maintained by human this human involvement takes more time and cost. This proposed model gives a good real time maintenance by using IoT technologies. In addition to this, the system includes the cloud technology for faster and better real time maintenance on the health of the street light and also connecting this system with AWS SNS(SIMPLE NOTIFICATION SERVICE) for sending alert to concern authorities for fast and quick repair of the faulty or damaged lights by this technology the maintenance of streetlight and fixing of them became easy and it's also take less time to fix them because we have an accurate location of the exact faulty streetlight.

Keywords: Internet of Things (IoT), Street Light Monitoring, Damage Detection, LDR Sensor, Current Sensor, ESP8266, Cloud Computing, Smart City, Automation, Fault Alert System.

INTRODUCTION

Bad light or darkness is one of the major causes of the road accidents across the world, especially during night-time and low -visibility conditions. Proper Streetlights are very important because they provide sufficient visibility for drivers, pedestrians, Speed breakers, and cyclists to clearly see the road environment. Streetlights help in identifying road signs, obstacles, road junctions, and people crossings, thereby reducing the chance of road accidents. In addition to improving road safety, street lighting also contributes to public security by reducing crime rates, improving night-time visibility in residential areas and improving overall quality of life. Despite of these advantages, in many regions' streetlight are still controlled and maintained using traditional manual method. Manual inspection of streetlights is a time-consuming process and takes more cost. In this manual method a person has physically inspect the streetlight conditions. Many of the faulty streetlights are unnoticed even though they are noticed manual inspection takes more time and every expensive. This traditional method often leads to delay in faulty detection such as light damage or wiring issues.Manual inspection has so many limitations. Maintenance Workers cannot continuously monitor all streetlight due to the large number of streetlights across the geographical area. If a streetlight stops working after inspection, it may remain faulty until the next inspection. Another major issue is that there is no real-time monitoring. Due to the large number of streetlights installed across cities and highways, many faulty streetlights remain unnoticed for long periods. Authorities only know about the fault after receiving complaints from the public or after physical checking. This delay increases risks on the road accidents and wastes manpower and resources. It also becomes difficult to find the exact location of the faulty streetlight quickly. With the growing demand for smart cities and intelligent infrastructure, there is a strong need for automated system for monitor the health of the streetlight continuously. Internet of Things and Cloud technologies provide an effective and reliable solution for this problem statement. By integrating smart sensors, embedded systems, and cloud platforms, streetlight monitoring can be automated and made more efficient. This method overcomes the limitations which are faced in the traditional method. IoT enables use of sensors and smart devices to continuously monitor the conditions of the streetlight and cloud platforms enable and allow the real-time data processing, storage and analysis of the sensor data. In this proposed system, sensors such as Light Dependent Resistor (LDR), current sensors are deployed on each streetlight to monitor the health of each streetlight. These sensors continuously collect the important parameters such as light intensity, power. A microcontroller is responsible to process the data and transmit the collected data to cloud platform using the internet. The cloud platform analyses the received data to detect the faults such as light failure power fluctuation.

This system uses the AWS cloud platform to handle the data processing the data being collected by the microcontroller and real time alert generation. AWS IoT core is responsible for receiving sensor data using the MQTT communication protocol. When a fault is detected, AWS Lambda functions are triggered to process the event, and AWS Simple Notification Service (SNS) sends real-time alerts to the concern authorities through SMS or notifications with the location of the faulty streetlight. As a result, maintenance workers can quickly identify and reach the exact location of the faulty streetlight without any unnecessary delays. This process significantly reduces the repair time and improves maintenance efficiency. By adopting IoT and cloud-based solutions, manual inspections are greatly reduced, and continuous monitoring became possible. This system operates automatically at all the times, including during night hours. Overall, the proposed system enhances the road safety, reduces the energy consumption, lowers maintenance costs, and provides an efficient and reliable solution for smart streetlight management.

LITERATURE REVIEW

The study represents an IoT Smart Streetlight System for Semi-Urban Areas with Fault Detection **[1]**. However, one major limitation of the existing system is the absence of an automated alert mechanism.In this research there is no alert to the concern authority all time the team must monitor the health of streetlight continuously there is not communication to mobile through SMS and as well as there is no direction to find the accurate location of the faulty streetlight. To overcome the limitation of the existing system, a smart solution that provide real time alerts and exact location of the faulty streetlights. **[2]** This research paper investigates that the live tracking of faulty streetlights and overall usage of the current, voltage and intensity of every streetlight in a dashboard. However, the major drawback the system is lack of real time alert via mobile communication the monitor team has to continuously monitor the health of the each and every streetlight it is very difficult to monitor to overcome this drawback we integrated the entire system with AWS SNS(SIMPLE NOTIFICATION SERVICE) to send the real time alerts of the faulty streetlights to concern authorities to make the work easier. **[3]** This research work represents a Smart Streetlight Fault Detection and Location Tracking System using BYNK IoT App the major disadvantage of the project is lack of real time analysis and limited scalability it does not cover the wide range of streetlights. To overcome this issue, we came up with this smart system. **[4]** This research provides a system called "A Distinctive Centralized Street Light Fault Monitoring System Embedded with Reconfigurable WSN." In this system there are some major disadvantages, one is high maintenance cost and there is no reading of the intensity level of the streetlight to predict whether streetlight is damaged or not only using current and voltage sensors not enough to predict the fault in the street. **[5]** This proposed system "Centralized System for Streetlight Location Tracking and Fault." Detect the faulty streetlights and as well as sends real time alert notification to concern team using GSM module and as well as GPS module. However, the proposed model has so many drawbacks with the use of basic controller called Arduino it does not support Wi-Fi communication and as well as this limited to short range of communication only and there is no visual dashboard to see the health of the streetlights. **[6]** This study represents an "Deep Learning-Based Object Detection for Street Light Control with Energy Management and Fault Detection Using IoT."

To detect the faulty streetlights. There are so many limitations encountered with this proposed model there is no usage of current and voltage sensors if there is any problem with power supply the model treats it as failure of the streetlight its leads to the false prediction this cannot detects the electrical issues and this system requires an camera its leads to more maintenance cost and this model is heavily depended on deep learning models. This system can make false predictions, and this system fails during fog, rain, and dust on the camera, and this cannot send alert notifications leads to lack of real time alert. **[7]** Smart streetlight system using mobile applications: secured fault detection and diagnosis with optimal powers. In this proposed system the major drawback is absence of voltage and current sensor if its problem with power supply its treats it as light failure and there is no that much of real time monitoring of street lights and there is no live tracking of faulty streetlight and this proposed system is limited to the short range and there is no integration with cloud platforms to cover the wide range of distances. **[8]** This research study represents a system called "Centralized monitoring system for street light fault detection and location tracking." The main purpose of the system to detect streetlight damage and location tracking is to automate the monitoring but this proposed system has so many issues there is no usage of current and voltage sensors its leads to false prediction whether its problem with power supply its treats as light failure. **[9]** This study represents a Street Light Automation and Fault Detection. The main purpose of the system to Automate streetlight operation based on ambident light to detect faults in real time using sensors, enabling faster maintenance. However, this paper encountered with some set of drawbacks there is no dashboard to visualize the health of the streetlights and this proposed system is limited to short range communication only and usage of basic microcontroller Arduino uno it does not support Wi-Fi communication

And it's leads to one of the drawbacks in the system and there is no real time alerting in this proposed system. To overcome these all limitations, we proposed a model called streetlight damage detection and alerting system using IoT and cloud Technologies. **[10]** This proposed system represents a Centralized Monitoring System for Street Light Fault Detection and Location Tracking.

However, there are few drawbacks with this system there is no real time alerting and there is real time monitoring.

SYSTEM OVERVIEW

System Architecture: The architecture of the system is built for to get the health of each streetlight by using IoT sensors such as LDR (Light Dependent Resistor) to capture the intensity of every streetlight, current sensor used to check the flow of the current through the poles to check the health of every streetlight. These sensors send their data to an esp8266 Microcontroller, which transmits the same data to a cloud platform through WIFI. And this cloud platform processes the data to check whether the streetlight is functioning properly. If the LDR detects darkness but the current sensor reads no current, the system identifies a fault. The same information is also reflected on a web dashboard which displays the status of every streetlight.

3.1 Cloud Integration Process

The entire system is integrated with a cloud platform to enable efficient data processing and real-time monitoring. Cloud computing offers a wide range of services, among which the IoT core service is utilized to receive sensor data transmitted from the streetlights. AWS IoT core uses the MQTT communication protocol to securely and reliably collect data from the deployed sensors for further processing and analysis.

AWS Lambda functions are employed to process the incoming data and to detect the faulty conditions in the streetlight system. As a part of the alerting mechanism, AWS Lambda invoke AWS Simple Notification Service (SNS) to send real-time notification to the concern authorities. These notifications are delivered through SMS, and it include essential details such as the location of the faulty streetlight.

METHODOLOGY

The proposed IoT-based Street Light Fault Detection and Alert System follow a structured and systematic approach consisting of several stages: Including System design, hardware implementation, software development, data transmission and cloud processing, Alert Generation and Visualization, and as well as testing and evaluation. Each stage plays a crucial role in ensuring the reliable operation, accuracy, and effectiveness of the overall system.

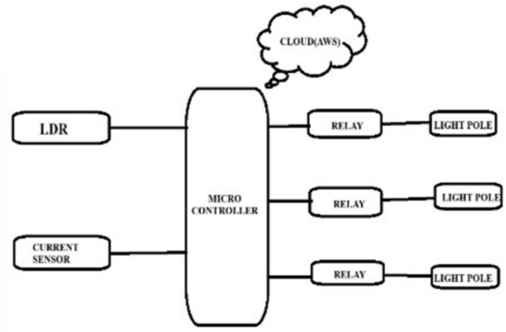

Fig1: Workflow of the System.

4.1 System design

The system is mainly designed using the network of sensors and a cloud-based platform including with a user interface to visualise the health of all streetlights. This system has mainly these three components.

The proposed system mainly consists of the following three components:

1. **Sensor and Hardware Layer** – Responsible for data collection from the streetlights.
2. **Cloud Processing Layer** – Handles data storage, analysis, and fault detection.

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3. **User Interface and Alert Layer** – Displays streetlight health information and sends real-time notifications to the concerned authorities.

1. Esp8266 Microcontroller

This is the core of this system this plays a vital role in this system. It supports 2.4Ghz wi-fi (802.11n) and Bluetooth, enabling real-time sensor monitoring, fault detection and cloud connectivity with low power consumption.

Fig2: -Esp8266 microcontroller

2.LDR (Light Dependent Resistor)

An LDR (Light-Dependent Resistor), also called a photoresistor, is an electronic component that detects light by changing its electrical resistance: resistance drops in bright light and rises in darkness, working on photoconductivity.

The LDR detects ambient light intensity by varying its resistance with high levels. It enables automatic streetlight damage detection.

Fig3: -LDR (Light dependent resistor)

The relationship between the DR resistance and light intensity can be approximated using a power-aw expression:

R_{LDR} = A·E−γ

where:

- $R_{LDR}$is the resistance of the LDR (Ω),
- $E$is the incident light intensity (lux),
- $A$is a proportionality constant dependent on the LDR material,
- $\gamma$is the sensitivity exponent of the LDR (typically 0.7–1.0).

Rearranging the equation, the light intensity can be expressed as:

$$E = \left(\frac{A}{R_{LDR}}\right)^{\frac{1}{\gamma}}$$

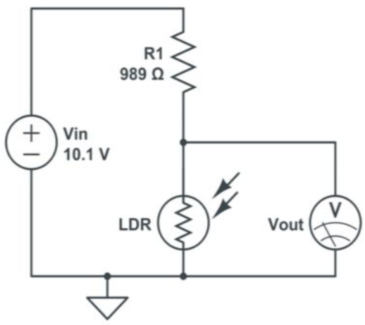

Fig4: -LDR Circuit

3.Current sensor (AC S712)

A current sensor detects and converts electric current into a measurable output (voltage, current, digital signal) proportional to the flow, using principles like magnetic fields (Hall Effect) or voltage drop.

The current sensor (ACS712) measures the electric current flowing through the streetlight circuit. It helps detect faulty, such as no power when the current if off or excessive current during the short circuit.

Fig5: - Current sensor (ACS712)

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The ACS712 Current sensor is based on the Hall Effect it senses the magnetic field created by current flowing through an internal conductor and converts that to a proportional voltage.

Basic Working Principle

1. Current flows through an internal copper conductor.
2. The magnetic field B generated around it induces a **Hall voltage** in the integrated Hall sensor.
3. The Hall voltage is proportional to the magnetic field, which is proportional to current.

The fundamental Hall effect relation:

$$VH = \frac{I.B}{q.n.d}$$

Where:

- V_H= Hall voltage,
- I= current through the sensor conductor,
- B= magnetic flux density produced by the current,
- q= electron charge,
- n= charge carrier density,
- d= thickness of sensor layer.

In ACS712, the sensor electronics linearize this and provide

$$I = \frac{Vout - Voffset}{S}$$

Where:

- V_{out}= analog output voltage,
- V_{offset}= zero-current output (about half the supply, e.g., ≈2.5 V for 5 V supply),
- S= sensitivity (e.g., 66 mV/A for ±30 A version).
- I= current flowing through the conductor (A)

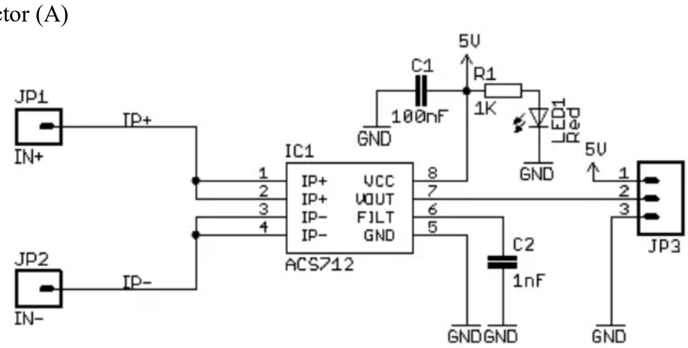


Fig6: - Current Sensor Circuit (ACS712)

Fault Detection Formula: -

- E= measured light intensity (lux)
- E_{th}= minimum light intensity threshold
- I= measured current (A)
- I_{th}= minimum current threshold

Fault Condition

$$F = \begin{cases} 1, & \text{if } (E < E_{th}) \wedge (I > I_{th}) \\ 0, & \text{otherwise} \end{cases}$$

Where:

- $F = 1$→ Streetlight is FAULTY
- $F = 0$→ Streetlight is NORMAL

Table 1: Working Condition of Streetlight Based on LDR and Current Sensor Readings

Light Condition	Current supply	LDR Status	Status
ON	Good	Good	Working
OFF	No flow	No reading	Power supply fault
OFF	Good	Good	Light fault
ON	Unstable	Unstable	Connection fault

Light Condition: Determined by the LDR sensor (detects whether light is glowing or not).

Current Supply Status: Determined by the current sensor (detects whether current is flowing).

The system compares these two inputs to decide:

- If both are normal → Working
- If mismatch occurs → Fault Detected

4.2 Hardware Implementation

The hardware setup connects the LDR (Light dependent resistor) and current sensor to the esp8266 microcontroller. The sensors are balanced to ensure the accurate readings. And developed a 3d model of the road and the streetlights. The LDR is used to measure the ambient light intensity, while current sensor monitors the power consumption and flow of current throughout the circuit. The ESP8266 microcontroller collects and process the sensor data and transmits it to the cloud platform using its built-in WI-FI capability.

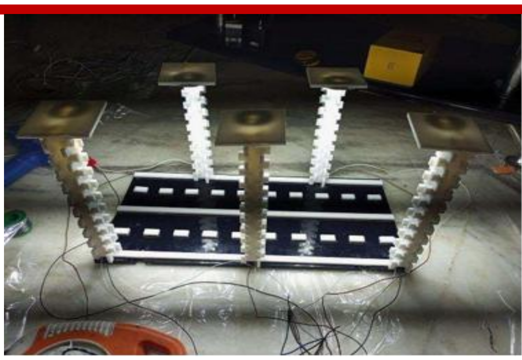


Fig6: - Hardware implantation and prototype of the project

4.3 Software Development

For this project programming is done using the Arduino IDE. The microcontroller code performs the following functions:

1. Read and process the sensor data
2. Compare it with the maximum threshold.
3. Check the flow of current through the circuit by using the current sensor
4. Detects the faulty based on the Ldr and current sensor readings.
5. Sends the data to the cloud platform through WI-FI. And the same display in the web interface.

4.4 Data Transmission and Cloud Processing

Sensor data are transmitted to AWS IoT Core using MQTT communication protocol. It checks both sensor values and both sensor's data are processed by the AWS Lambda and its trigger the AWS SNS it indicates the street is damaged and it sends the location of the faulty streetlight to the concern authorities. AWS Lambda functions process the sensor data and continuously check both sensor readings to identify fault conditions. When abnormal values are detected, indicating a damaged or malfunctioning streetlight, the Lambda function is triggered. As a result, AWS Simple Notification Service (SNS) is invoked to send real-time alerts to the concerned authorities. These notifications include details about the fault along with the exact location of the faulty streetlight, enabling quick and efficient maintenance action.

Fig7: - cloud design

4.5 Alert Generation and Visualization

Upon detecting a faulty streetlight, the AWS SNS sends automatic notification to the maintenance person or concern authority person with live location of the faulty streetlight. That location of the faulty streetlight is very useful to the person and saves lot of time.In addition to alert generation, the system provides a web-based user interface that displays live updates of all streetlights. The web interface offers a clear and interactive visualization of the streetlight network, allowing authorities to easily monitor the system status. The interface includes the following features:

- The status of each streetlight.
- Pie chart representation of good vs faulty streetlights.
- Map based navigation with "Get Direction" option.

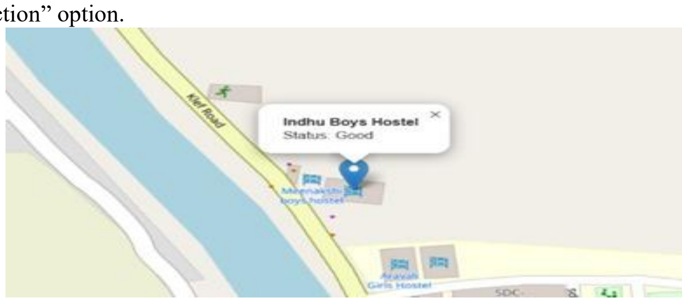


Fig8: - Location and status of the streetlight

In this above figure it represents the status of every streetlight with nearby location name. Here in the above image its status is good

Streetlight Status

ID	Location	Status	Actions	
1	Indhu Boys Hostel	Good	View	Directions
2	KGH Girls Hostel	Faulty	View	Directions
3	Administrative Block	Good	View	Directions
4	Central Auditorium	Faulty	View	Directions
5	Engineering Workshop	Good	View	Directions

Fig9: -web interface

4.6 Testing and Evaluation

The prototype is tested under various operation conditions, simulated faults, and night/day cycles to validate accuracy and reliability of the system, Performance detection speed, communication delay, and alert response time.

System performance was evaluated based on key parameters such as fault detection speed, communication delay between the sensors and the cloud platform, and alert response time. This comprehensive testing confirmed the effectiveness and robustness of the proposed IoT-based streetlight fault detection and alert system.

RESULTS

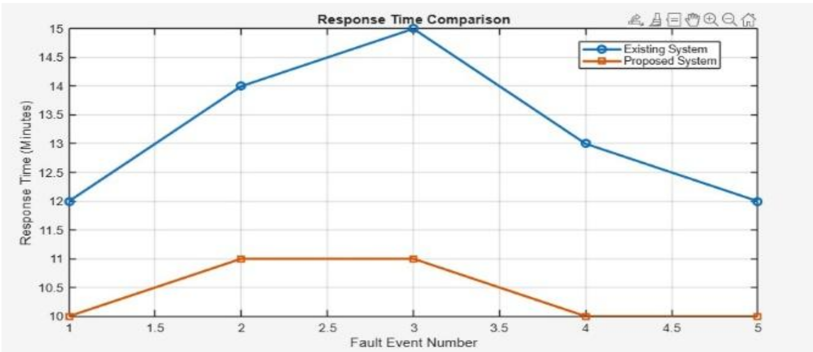
Comparative analysis with existing work

Parameter	Existing System	Proposed System
Monitoring	Manual inspection	IoT-based automatic monitoring
Fault Detection	After public complaints	Real-time sensor-based detection
Alert Mechanism	No instant alerts	Real-time alerts using cloud (AWS SNS)
Response Time	High	Low
Human Intervention	High	Minimal
Fault Location	Not accurate	Exact location identification
Data Storage	No centralized data	Cloud-based data storage
Scalability	Limited	Highly scalable
Energy Efficiency	Low	Improved
Reliability	Less reliable	High reliability

Centralized Monitoring System for Street Light Fault Detection & Location Tracking using Android Application

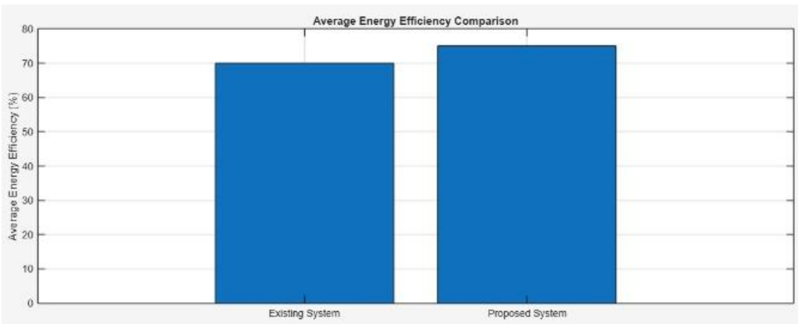
The proposed system successfully implemented and tested under various conditions to evaluate its performance, and reliability. The ability to display the status of each streetlight and it represents on the maps along with the working status.

The system detects the streetlight faults in real time by using LDR and current sensors which transmits data to the AWS cloud platform for monitoring and alerting



Fig

The above graph shows the respond time comparison between the existing system and the proposed system under different fault conditions. The blue line represents the response time of the existing system, while orange line response time of the proposed system.The existing works takes lot of respond time due to the no involvement of the cloud technologies and poor in the real-time monitoring. Proposed system takes less time rather than the existing work due to latest cloud technologies.



Fig

The above figure shows the comparison of average energy efficiency between the existing system and the proposed system. The bar representing the existing system indicates an average energy efficiency of approximately 70%, while the proposed system achieves a higher efficiency of around 75%.The lower energy efficiency of the existing work is mainly due to the manual inspection, absence of real-time monitoring, which often leads to unnecessary power consumption.In contrast, the proposed system improved energy efficiency as it integrates IoT sensors and cloud-based monitoring. Real-time fault detection helps to reduce the energy wastage. As a result, the proposed system achieves better energy efficiency and improves overall performance of the proposed system.

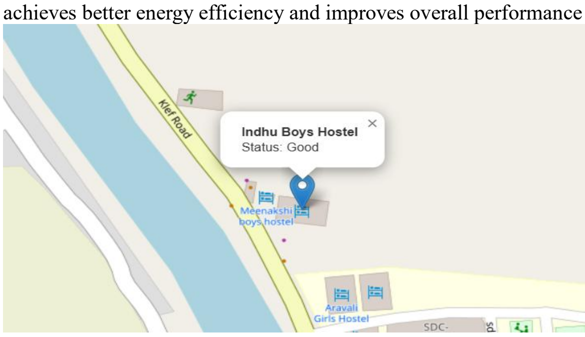


Fig11: - Map view

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Streetlight Status

ID	Location	Status	Actions	
1	Indhu Boys Hostel	Good	View	Directions
2	KGH Girls Hostel	Faulty	View	Directions
3	Administrative Block	Good	View	Directions
4	Central Auditorium	Faulty	View	Directions
5	Engineering Workshop	Good	View	Directions

Fig12: -web interface

This is the dashboard of the entire project it holds the information of every streetlight with its nearby location name and status of every streetlight either good or bad. And it locates the streetlights on the map along with the working status.

If we click on view of a particular streetlight, it locates the streetlight on the map and shows its working status. If we click on direction its redirect to the google maps and its shows the direction to the faulty streetlight from your current location.

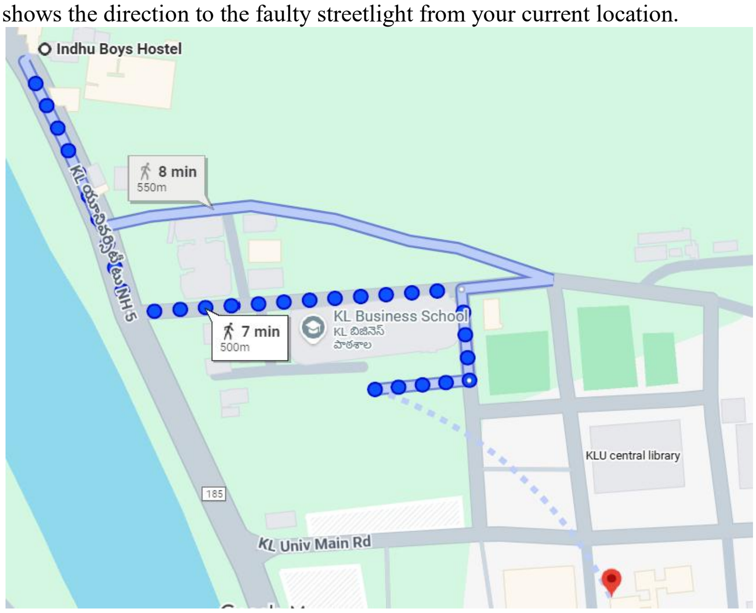

Fig13: - Direction to faulty streetlight

When the Direction option is clicked, the system automatically redirects the user to Google Maps. It then displays the navigation route from the user's current location to the selected streetlight. This feature helps the maintenance person easily reach the faulty streetlight without wasting time searching for the location.

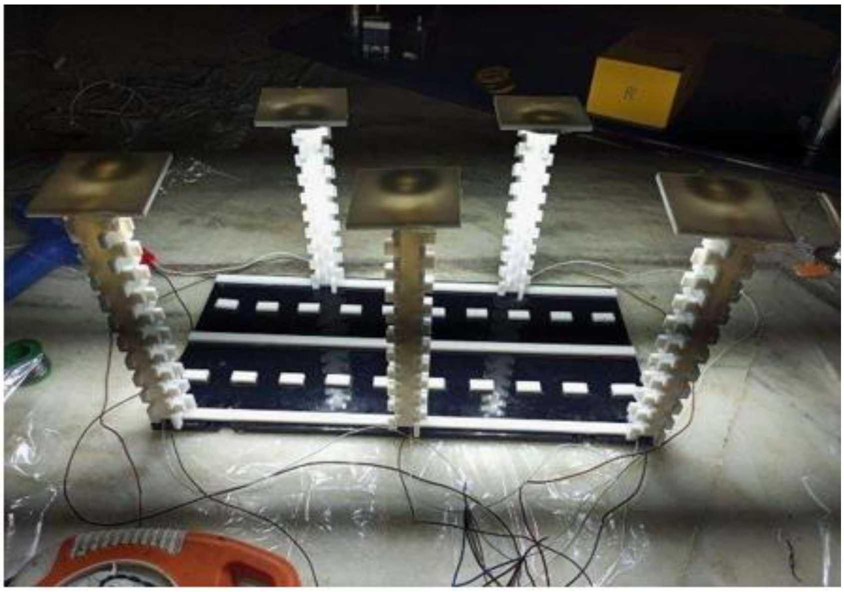

Fig14: - prototype of the project

This figure shows the prototype of the developed project. A 3D model of a street was created, and five streetlights were placed along the road. Each streetlight was assigned a unique ID along with its location. This setup helps in identifying and monitoring every streetlight individually during fault detection and testing.

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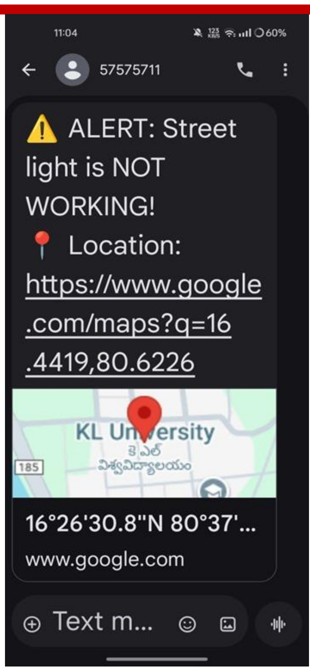

Fig15: - Real time alerting using AWS SNS

In the above figure it sends the real time alerts using AWS SNS service to send the location of the faulty streetlight to the concern authorities. AWS IoT core is main responsible for this process it takes data of every streetlight using MQTT and when the compare it with threshold values if it's found as faulty the lambda step function able to trigger the SNS to send the notification of faulty streetlight.

Fig16: - Overall ON/OF state using pie chart

This above figure represents the overall working of the streetlight in the form of the pie chart the green area represents the working streetlights and red colour area represents the faulty streetlights.

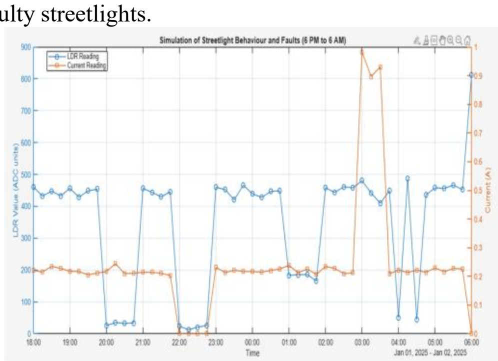

Fig17: - Simulation of streetlight behaviour

CONCLUSION

This IoT- and cloud-enabled streetlight monitoring system automates the fault detection, reduces maintenance costs and time. Integration with AWS services enables real-time monitoring, instant alerts to concern authorities, and quick fault resolution. It's mainly uses LDR and Current sensor to detect the faulty streetlights and it's integrated with web interface as well as cloud it sends the data to cloud as well as web interface. Mainly the web interface is used to monitoring the health of streetlight and cloud is used for real time alert and to send the notification with live tracking link of the faulty streetlight to enhance the real time alerting it mainly focuses on lambda, AWS IoT core and AWS SNS to send real time alerts to concern authorities by this system the real time maintenance and as well as real time alerting is increased and the detecting and fixing of faulty streetlights became more easy due to presence of real time data.

FUTURE WORK

The proposed Streetlight Damage detection and alerting system using AWS and IoT technologies can be further improved in several ways. In this proposed system we cannot capture the flickering and dimming of the streetlights using IoT technologies and in bad weather conditions and in foggy mornings the light intensity is low in this situations also the system treats as damage so we cannot identify these things using IoT

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techniques so in future we are going to integrate entire system with OpenCV and AI technologies to overcome the above mentioned problems. The system can also be scaled for smart city integration using Lora Wan, 5g, or mesh networking to support large number of streetlights across rural and urban areas. These enhancements will make the system more robust, scalable than the past proposed system.

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