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DESIGN AND IMPLEMENTATION OF AN INTELLIGENT STREET LIGHT SYSTEM FOR ENERGY SAVING AND SECURITY

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Abstract:
The city and town we currently reside is being developed into smart cities as a way of incorporating IoT into our day-to-day life. As a process a large number of street lights are being installed. Due to the rising rate of lights being installed, it is very hard to monitor all of them manually. The proposed system is a comprehensive solution primarily focused on enhancing the fault tolerance of street lamps and their location tracking through the utilization of a Wireless Sensor Network (WSN). To cover a large area, the street lamps are organized into clusters, each led by a designated cluster head. Thermistors are installed at each lamp to detect faults, and their readings are consistently monitored. Additionally, the street light system aims to provide security and adhere to power consumption criteria.
To achieve these objectives, a camera is integrated with each street lamp, enabling the system to operate effectively. Therefore, an Artificial Intelligence-based street light system can be implemented using our proposed model.

KEYWORDS: THERMISTORS, WSN, FAULT TOLERANCE

1. INTRODUCTION

The Internet of Things (IoT) integrates sensors and communication capabilities into everyday objects, transforming networking and data transmission. This network enables remote control, real-time data collection, and analysis, unlocking potential for automation, efficiency, and innovation across industries. IoT transforms ordinary devices into intelligent assets, enhancing decision-making, optimizing predictive maintenance, and opening new applications and services.
A thing or a node in the internet of things can be any wearable, a smartphone, temperature sensor or man-made object that can be interconnected and could transfer data over a network to a central node or an IoT platform.

2. WIRELESS SENSOR NETWORKS AND IoT

Distributed autonomous sensor nodes operate together to monitor a range of physical or environmental factors as part of Wireless Sensor Networks (WSNs). These nodes can gather data from their environment and wirelessly send it to a central node or base station since they have sensing, processing, and communication capabilities. WSNs are very adaptable for applications in environmental monitoring, industrial automation, healthcare, and other industries because of their decentralized nature, which enables them to efficiently monitor and collect data from remote or inaccessible places. The concept known as the "Internet of Things" (IoT) encompasses a broader spectrum of networked devices beyond sensors, incorporating actuators, cameras, household appliances, and various other intelligent gadgets.

3. IoT IN STREET LIGHT MANAGEMENT

There are several advantages to implementing an Internet of Things (IoT)-based street light control system, such as increased energy efficiency, lower expenses, and better upkeep.

Street lights can be remotely monitored and controlled from a central location by connecting them to a central management system via cellular networks, Wi-Fi, or LoRa wireless communication protocols. The management system should incorporate necessary functions including automated problem identification, energy consumption tracking, and real-time street light operation and condition monitoring. Through the use of data analysis from sensors and street light controllers, this system finds regions that require optimization in addition to usage trends and patterns of energy consumption. Adopting an Internet of Things-driven street light control system can help towns improve energy efficiency, increase public safety, and save a lot of money.

4. LITERATURE SURVEY

The swift expansion of the social economy and urbanization has caused a surge in energy consumption, resulting in a shortage of power resources. In response, a study [1] has devised an innovative street light management system that utilizes wireless sensor networks and IoT technology. This system acquires real-time environmental data from street lamps and transmits it through the LoRa network to a cloud monitoring platform via NB-IoT technology. WEBGIS technology is employed to visually depict street lamp status data on electronic maps. Should anomalies occur, the system conducts analysis, localization, and issues alerts, ensuring seamless communication between street lights and the cloud platform. Experimental findings validate the system's stability, efficiency in energy conservation, reduction in consumption, and cost-saving advantages in management, operation, and maintenance.

An Implementation of High Efficient Smart Street Light Management System for Smart City [2] The paper presents a system for configuring, deploying, and managing smart street lights using container-based management. It enables rapid deployment and scalability through virtual deployment, integrating NoSQL and in-memory databases. The system uses an asymmetric key and SSH encrypted tunnel for data transmission, with token authentication for legitimacy verification. It addresses data throughput, low latency, configuration flexibility, and smart city objectives. The system also includes a

simulation system for street lighting, incorporating edge computing devices for real-time environmental data collection, live image streaming, and historical data retrieval. The system demonstrates the feasibility of concurrent operation of multiple container-based services on these devices.

IOT based smart street light management system [3], The IoT-driven automated streetlight management system aims to conserve energy by mitigating electricity wastage and reducing reliance on manpower. While streetlights play a vital role in ensuring city safety and illumination of public areas, they also consume a considerable amount of electricity. Through automated light control, the system efficiently manages energy consumption, diverting resources towards residential, commercial, and transportation needs. The project employs Light Emitting Diodes (LEDs) as a replacement for traditional HID lamps, allowing for adjustable intensity levels, a feature unattainable with HID lamps. LEDs emit light in specific directions, enhancing streetlight efficiency. Additionally, the system integrates a DHT11 Temperature-Humidity sensor to provide precise temperature and humidity readings for a designated area. This combined sensor, digitally calibrated, ensures high accuracy and stability over time. Implemented using an Arduino board, the system dynamically adjusts light intensity according to different timeframes, offering superior performance compared to conventional systems.

Design and Implementation of Smart Street Light Automation and Fault Detection System [4], Street lighting stands as a crucial source of illumination utilized by individuals for various activities, particularly along walkways and streets during low-light conditions. In traditional street light setups, identifying malfunctioning bulbs and implementing energy-saving measures through systematic on/off switching requires human intervention and consumes considerable time. Often, street lights remain illuminated at full brightness throughout the night, even when vehicular traffic is minimal or absent, resulting in significant energy wastage. To address this challenge, a system was proposed to automatically detect non-operational street lights and transmit this information, along with their respective locations, to an android application via IoT technology.

5. PROPOSED SYSTEM

A. BLOCK DIAGRAM

The figure 1 shows the proposed system model.

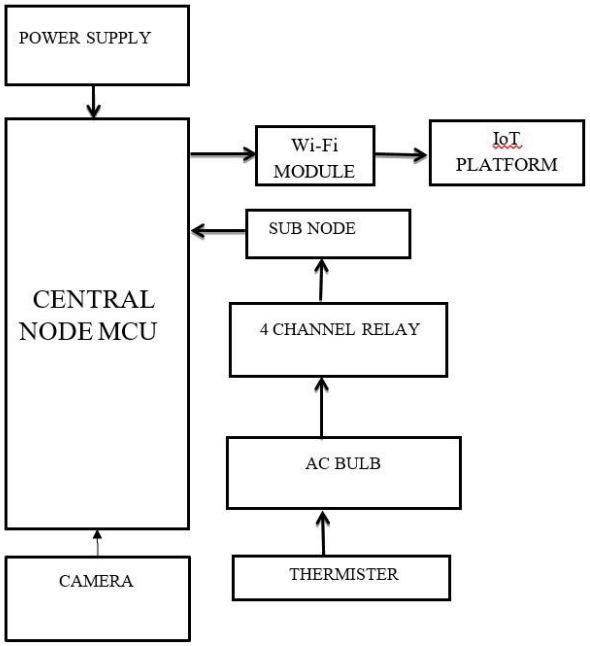

Fig 1. Block Diagram

B. COMPONENTS USED

B.1 ESP8266

The ESP8266 is a versatile Wi-Fi module by Espressif Systems, featuring an integrated microcontroller for seamless internet connectivity. It supports various sensors and peripherals, and has GPIO pins, ADC, and UART, SPI, and I2C support. It's suitable for battery-operated devices and IoT projects, including smart home gadgets, environmental monitoring tools, and DIY projects. Its compatibility with Arduino IDE and OTA updates simplifies development

Fig 2. ESP8266 module

B.2 4 CHANNEL RELAY

A 4-channel relay module is a versatile device used in automation, control setups, and electronics projects. It consists of four switches, each managing an independent electrical circuit. Operated by a microcontroller or digital signal, it allows for remote or automated management of various electronic devices, offering flexibility and ease of use across various applications.

Fig 3. 4 Channel Relay

B.3 THERMISTOR

A thermistor is a semiconductor device that measures temperature by adjusting its electrical resistance. It is classified as negative temperature coefficient (NTC) or positive temperature coefficient (PTC) and is used in various fields like industrial processes, automotive engine monitoring, electronic devices, medical equipment, and environmental monitoring. They offer precise temperature measurement and control due to their sensitivity, accuracy, and reliability.

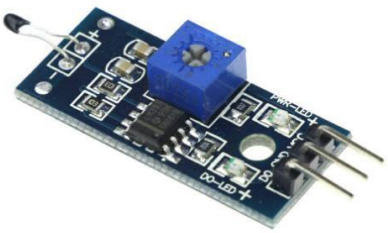

Fig 4. Thermistor

B.4 I2C AND LCD

I2C is a serial communication protocol that links multiple devices on a bus using only two wires: a serial data line (SDA) and a serial clock

line (SCL). It facilitates synchronous, bidirectional data transfer between a master

device and slave devices, enhancing connectivity and functionality across embedded systems and consumer electronics.

Fig 5. I2C and LCD

B.5 CAMERA

Cameras are optical devices used for capturing and storing images, typically recorded by light onto a photosensitive surface or sensor. They come in various types, including digital, film, and professional-grade models.

Fig 6. Camera module

C. WORKING MODEL

In the proposed system, the Node MCU acts as the central controller, directing all operations namely Temperature sensing, Fault Tolerance mechanism and Power Consumption measures like Object detection. Three ESP8266 modules are interconnected with the main node in this configuration to establish the basic connectivity between the nodes of this network of street lights.

Temperature Sensing: A thermistor is utilized to monitor the temperature of the transmission lines, with temperature data consistently updated on the IoT platform. A basic Street light should produce about 1500 to 3000 Lumen of light intensity. The glowing of street light always results in wastage of energy through heat. So, a properly working street light would always emit a standard amount of heat around it. If a light failure occurs, leading to a temperature decrease below the specified threshold level in the IoT software, say 30°C, an alert is triggered at the central node stating that the specific node with lower temperature has failed.

Power Consumption: In addition to incorporating a fault tolerance mechanism, the proposed approach enhances security

while reducing power consumption. The integration of cameras plays a pivotal role in achieving this objective. Positioned at regular intervals, these cameras capture street images. These cameras are placed to cover the objective of Object detection and Action.

Basic object detection methods using simple motion sensors or speedometers can be used to detect any vehicle or human moving across the lights. Upon detecting any movement like bike, car or even people walking along the street, the system activates the corresponding light above and in front of the moving object. After the vehicle or object has crossed the lights, the street lights can be operated at low power or low intensity to maximize power consumption and minimize loss of power due to heat and other factors. Regular monitoring of the street by the cameras facilitates dynamic system control, promoting both energy efficiency and security through periodic image capture.

On a large scale, to span a wide area, nodes can be organized into clusters, each linked to a central control centre. Consequently, identifying the location of a malfunctioning light becomes more straightforward.

D. HARDWARE IMPLEMENTATION

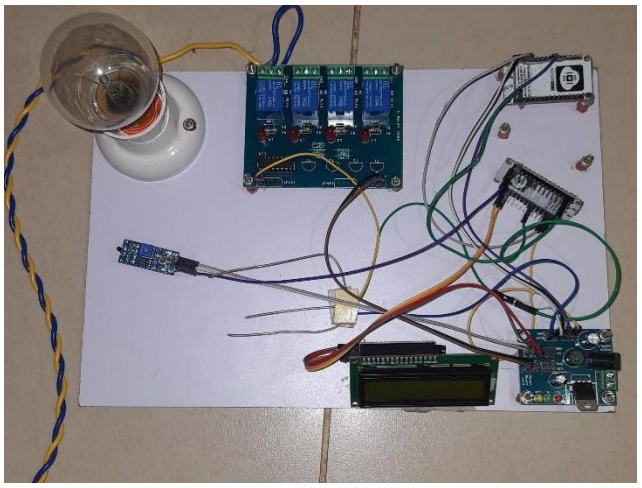

Fig 7. Hardware Implementation

For practical demonstration the phase wires are shorted.

When shorted, the fault would be displayed in the LCD board and the same would be updated in the IoT platform .They are as shown below.

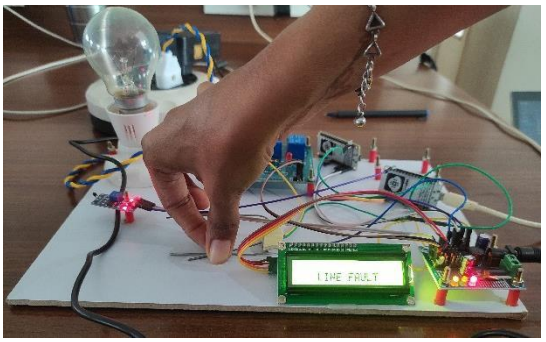

Fig 8. Node fault detected

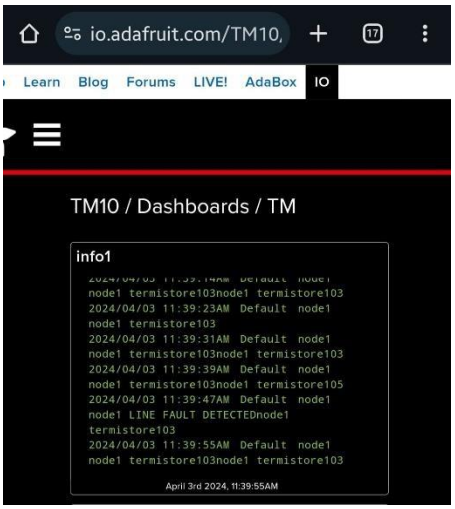

Fig 9. Output in IoT platform

CONCLUSION

A sophisticated street light management system, integrating IoT, wireless sensor networks, and artificial intelligence, can improve urban lighting infrastructure by enhancing fault tolerance, energy efficiency, security, and operational costs. This system enables remote monitoring, real-time data analysis, and dynamic control of street lights, fostering safer, more sustainable, and smarter cities. Investing in these systems is crucial for efficient resource utilization, public safety, and environmental sustainability

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