School of Computer Science Engineering and Information Systems
M.Tech (Integrated) Software Engineering
FALL 2024-2025

Project Report

TITLE: SMART STREET LIGHT SYSTEM USING IOT

SWE 1901 : Technical Answers for Real World Problems (TARP)

Offered during FALL 2024-2025

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NOVEMBER 2024

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SMART STREET LIGHT SYSTEM USING IOT

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Project Title: SMART STREET LIGHT SYSTEM USING IOT

Problem Statement:

Urban street lighting is essential for ensuring safety and visibility in public spaces, particularly during night time. However, traditional lighting systems are often inefficient, operating at full brightness regardless of actual need, leading to significant energy waste. These systems typically rely on fixed schedules or manual operations, which do not account for variations in traffic conditions, environmental changes, or pedestrian presence, resulting in high power consumption and increased operational costs. Additionally, the widespread use of incandescent and other non-renewable energy-based lighting options intensifies environmental concerns, contributing to high carbon emissions and frequent maintenance demands.

With the global emphasis on sustainable development and energy conservation, there is an urgent need for a smarter street lighting solution that reduces energy consumption, minimizes environmental impact, and ensures public safety. The primary challenge is to develop a system that adapts to real-time conditions by adjusting light intensity based on occupancy or traffic presence, thereby minimizing energy waste. The Smart Street Light System Using IoT is designed to address these challenges by implementing an IoT-based lighting system that dynamically adjusts brightness levels according to movement detection. This adaptive solution ensures optimal illumination only when necessary, achieving substantial energy savings, lowering carbon emissions, and enhancing urban safety. By providing a scalable and efficient model, this system presents a valuable contribution to the development of sustainable smart cities worldwide.

Abstract

The development of a Smart Street Light System Using IoT addresses critical concerns in modern urban infrastructure: automation, energy efficiency, and sustainability. With the rise of urbanization, street lighting has become a necessity to enhance public safety and improve visibility. However, traditional street lighting systems are often static, with lights running at full brightness regardless of environmental conditions, resulting in substantial energy waste. The proposed smart street lighting system leverages IoT (Internet of Things) to automate light adjustments, enhancing efficiency by using real-time data to adapt lighting intensity based on pedestrian or vehicular presence. The system integrates motion sensors, LEDs, energy-efficient lighting. LED bulbs are chosen over incandescent bulbs due to their efficiency, longevity, and lower heat emissions, which together reduce maintenance costs and replacement frequency. These LEDs are paired with motion sensors to detect movement, switching to full brightness upon detecting people or vehicles and returning to a dim state when no activity is present.

The project is implemented as a prototype model to visualize the real-time functionality of street lighting automation and environmental adaptation. IoT integration allows for remote monitoring and control of the lighting system, notifying maintenance teams of faults or malfunctions, thereby optimizing operational efficiency and reducing maintenance expenses. The system significantly lowers energy consumption, which has notable economic and environmental benefits, especially in regions with high lighting needs. Furthermore, it enhances public safety through adaptive lighting that brightens upon detecting nearby movement, fostering a safer and more sustainable urban environment.

The title, "Smart Street Light System Using IoT," highlights the project’s focus on merging street lighting with IoT technology to create a responsive and efficient system. In today's global context, where energy resources are depleting and environmental concerns are escalating, this project addresses a vital urban need. Traditional street lighting systems often operate based on time schedules or manual controls, which results in unnecessary power usage and higher energy costs. Through IoT, the proposed smart lighting system can adjust itself in real-time, maintaining optimal lighting conditions while minimizing power wastage.

IoT technology has opened new avenues for automation, data collection, and decision-making. With the use of sensors and interconnected devices, IoT enables real-time communication and response, making it an ideal solution for street lighting. Sensors capture information about environmental changes and pedestrian or vehicular movement, communicating this data to adjust lighting levels dynamically. Furthermore, LED technology have provided cleaner, more efficient energy sources, making smart lighting systems more feasible. By integrating IoT ,this system not only addresses urban lighting needs but also aligns with global initiatives aimed at reducing reliance on fossil fuels.

Traditional street lighting systems often operate on fixed schedules or manual switches, which causes lights to remain at full brightness regardless of need. Such systems are energy-intensive and do not adapt to changes in environmental conditions or pedestrian movement. This static operation results in high operational costs and frequent maintenance requirements due to the shorter lifespan of conventional incandescent bulbs, which are less efficient and generate more heat. Even when energy-efficient lighting like LED has been adopted, many systems lack the capability for dynamic adjustment based on real-time data.

The existing methods exhibit several limitations, notably in terms of energy consumption and flexibility. Fixed lighting schedules and reliance on manual operation lead to significant energy wastage, as lights remain on during times when they may not be necessary, such as low-traffic hours. Incandescent and some fluorescent lighting options also contribute to high carbon emissions, which is a concern given the growing focus on reducing urban environmental footprints. Furthermore, traditional systems have high maintenance costs and require frequent replacements, which, combined with high operational costs, make these methods less feasible for modern smart cities.

The proposed IoT-based Smart Street Light System provides a solution to the limitations of traditional systems by adapting lighting levels to the actual need in real-time. By reducing light intensity during low-traffic times, the system achieves considerable energy savings. Studies on IoT-enabled street lighting have shown up to 40-50% reductions in energy consumption compared to fixed systems. In addition to energy savings, the system minimizes maintenance costs by incorporating durable LED lighting and self-monitoring capabilities that notify maintenance teams when issues arise. The IoT system's real-time adaptability also enables enhanced public safety, as the lights increase in brightness upon detecting movement, offering better visibility for pedestrians and vehicles.

1. Introduction

Background Information

Urbanization has significantly increased the demand for energy-efficient and intelligent infrastructure. Traditional street lighting systems operate at a fixed intensity and remain functional regardless of environmental or traffic conditions, leading to energy wastage and increased operational costs. Smart street lighting systems address these inefficiencies by incorporating IoT and advanced sensors to dynamically control lighting based on real-time data. The proposed system enhances the conventional model by integrating IoT technologies and image processing techniques to optimize energy consumption while ensuring adequate illumination for traffic safety.

Need of the Work

The need for a smart street light system arises from the challenges posed by traditional systems that consume excessive energy and lack adaptability. These systems contribute to environmental degradation through increased energy usage and provide insufficient support for modern traffic management. By implementing an IoT-based approach with sensors and image processing, this work addresses the pressing need for energy-efficient, adaptive lighting solutions. It also enhances traffic monitoring by estimating traffic flow and ensuring appropriate lighting levels, thus improving road safety and reducing energy waste.

Contribution Made to the Work

This work introduces a novel integration of IoT and image processing for smart street lighting. The system employs components such as ultrasonic sensors, LDR sensors, Arduino, NodeMCU, LED lights, and an LCD display to dynamically adjust lighting based on real-time traffic density and ambient light conditions. Image processing techniques are used to estimate traffic flow, and the calculated data is sent to Arduino to control the lights for an optimal duration. The system not only improves energy efficiency by reducing unnecessary lighting but also enhances safety and convenience by ensuring proper illumination during traffic activity.

Organization of the Report

The paper begins with an introduction that highlights the limitations of traditional street lighting systems and establishes the importance of smart systems. The literature review section provides an overview of existing smart lighting technologies and identifies the gaps addressed by this work. The proposed system section describes the architecture, components, and working principles of the smart street light system, emphasizing its IoT integration and image processing capabilities. The implementation section elaborates on the technical details, including hardware setup and software algorithms. Results and discussion follow, showcasing the system's performance in terms of energy efficiency and traffic management. The paper concludes with a summary of contributions, a discussion of limitations, and recommendations for future research.

2. Literature Review

[1] S. Sivakumar, R. Jayanth & N R. Mughesh Kumar (2024)

The Author introduced a smart street lighting system using LoRaWAN technology to solve issues of scalability, energy inefficiency, and communication limits in older systems. It used advanced sensors for object detection and achieved 70% energy savings through dynamic lighting control.

[2] V Sujatha et al. (2024)

The Author presented a smart street lighting system that used IoT technology to improve energy efficiency and safety. It dynamically adjusted lighting based on real-time conditions and allowed for remote monitoring and control to enhance operational efficiency.

[3] Naware et al. (2024)

The Author proposed a smart street lighting system based on Wi-SUN technology, providing reliable, low-cost lighting control. It integrated with the oneM2M platform to enable interoperability with other smart city data systems and improve energy savings

[4] Mohanty et al. (2024)

The Author introduced a supercapacitor-based, energy-autonomous street lighting system that harvested energy from sunlight and artificial light. It used LoRaWAN for communication and achieved low power consumption while ensuring seamless operation and real-time motion detection.

[5] R. Janaki et al. (2024)

The Author used Raspberry Pi and machine learning for street light automation. It employed image processing for movement detection, reduced energy consumption by adjusting light intensity, and improved fault detection and remote access for maintenance.

[6] Sakshi Gupta et al. (2024)

The Author introduced a smart street light system using machine learning to optimize light operations based on ambient light levels. The system included ultrasonic sensors for detecting vehicles and pedestrians, achieving 97.35% accuracy.

[7] Maheswaran S et al. (2024)

The Author presented a system for monitoring and detecting faults in street lights using IoT technology and GPS for precise location tracking. This proactive approach minimized downtime and reduced maintenance costs.

[8] N. Balakrishnan et al. (2024)

The Author proposed a smart street lighting system that adjusted light intensity based on occupancy and usage, using IoT for real-time monitoring. It significantly reduced energy consumption and allowed for remote control and automation of street lights.

[9] K. Sneha et al. (2024)

The Author introduced a smart street lighting system with infrared motion sensors for adaptive lighting and sound sensors for accident detection. It aimed to enhance urban safety and energy efficiency by ensuring well-lit pathways and quick accident reporting

[10] Ayush Dongardive et al. (2024)

The Author developed an IoT-based system for dynamic street light control, energy consumption recording, and fault detection. It improved resource optimization, reduced operating costs, and provided real-time alerts for faulty lights, ensuring efficient street lighting management.

[11] Shobana S et al. (2023)

The Author proposed an IoT-based system for smart traffic and streetlight management. It adjusted traffic signal timings based on lane density and controlled streetlights using solar power and motion detection to reduce energy wastage. The system aimed to conserve energy, manage traffic efficiently, and promote the use of renewable energy.

[12] Kaushalya Thopate et al. (2023)

The Author introduced an IoT-based smart street light system using LDR and IR sensors to control lighting based on natural light and object movement. It aimed to reduce energy consumption by turning lights on only when necessary, promoting sustainability, and enhancing the integration with other smart city systems for better efficiency.

[13] Sanjana Vikram Byakod, Yukthi Manawat & Guruprasad (2023)

The Author used an Artificial Neural Network (ANN) to create a smart street light system that adjusts lighting based on real-time environmental conditions. It aimed to reduce energy consumption, improve efficiency, and integrate with other smart city technologies, providing a sustainable and livable urban environment.

[14] J.V. Anchitaalagammai et al. (2023)

The Author developed an IoT-based smart street light system that adjusted light intensity based on ambient light and detected faults automatically. It aimed to reduce energy consumption, improve maintenance, and integrate into a comprehensive smart city solution, enhancing overall efficiency and sustainability.

[15] Palomi Gawli et al. (2024)

The Author proposed an automatic street light system using Arduino and LDR sensors to control lights based on object movement. It aimed to reduce energy wastage by turning lights on only when necessary and suggested future improvements like integrating solar panels and advanced sensors to further enhance efficiency and cost-effectiveness.

[16] Om Parhad et al. (2023)

The Author designed an IoT-based smart streetlight system using PWM and LDR sensors for automatic dimming and brightening, enabling real-time monitoring, reducing manual labor, and enhancing energy efficiency.

[17] Rizka Wakhidatus Sholikah et al. (2023)

The Author designed a prototype using LoRaWAN for efficient data transfer in smart street lights, showing better data transmission quality, response time, and cost efficiency compared to 4G GSM.

[18] Abhiram S et al. (2023)

The Author proposed a hybrid system using solar power and grid integration for energy-efficient street lighting, incorporating motion and infrared sensors, demonstrating significant energy savings and reliability.

[19] Nikolay Valov et al. (2023)

The Author proposed an intelligent street lighting system with hybrid management and remote control, focusing on energy cost reduction, carbon emissions reduction, and crime prevention through motion sensor data.

[20] Sri Chaithanya Mathi et al. (2023)

The paper introduced an IoT-based system using thermoelectric transducers and ESP8266 Node MCU for energy-efficient streetlight automation, emphasizing sustainability and real-time monitoring with potential integration in major cities and microgrids.

[21] Bhaavan Sri Sailesh A et al. (2021)

The Author proposed an Arduino-based smart street light system that utilized LDR and PIR sensors to automatically control street lights based on ambient light and vehicle motion. The system aimed to reduce power consumption by keeping lights off during the day and turning them on only when vehicles were detected at night. The prototype demonstrated efficient street light management suitable for highways and rural areas.

[22] L. Ranjitha et al. (2020)

The Author developed a smart street light and traffic system using IoT, integrating IR sensors, LDR, and timers. It adjusted traffic signal timings based on real-time traffic density and prioritized emergency vehicles. Street lights automatically turned on when pedestrians or vehicles were detected, and turned off otherwise, reducing unnecessary power usage.

[23] M. Suresh et al. (2020)

The Author introduced an intelligent street light system employing LDR, accelerometer, and ultrasonic sensors along with an Improved Bayesian Neural Network (IBNN) for predictive power consumption modeling. The system adjusted light brightness based on detected activity and monitored pole inclination for emergency reporting. It aimed to minimize power wastage and enhance street light management using IoT.

[24] Hamam Fathhullah Elsaiti et al. (2022)

The Author examined the use of ZigBee technology to enhance smart street lighting systems. By simulating various scenarios using the CupCarbon simulator, the study demonstrated ZigBee's effectiveness in conserving energy. The system employed programmable sensors and low-power wireless communication, showing positive results in reducing energy consumption and carbon emissions.

[25] Gurjeet Singh & Effariza Hanafi (2022)

The Author proposed using deep learning models to forecast electricity consumption for smart streetlights. It developed a prototype system to gather power consumption data and evaluated models like LSTM, BDLSTM, and Stacked LSTM based on RMSE and MAPE. The findings indicated that LSTM provided the most accurate predictions, highlighting its potential for optimizing energy use in smart streetlighting.

[26] Yu-Sheng Yang et al. (2020)

The Author proposed a highly efficient system for configuring, deploying, and managing smart street lights using container-based virtualization. It integrated NoSQL and in-memory databases for flexible data management and designed an asymmetric key and SSH encrypted tunnel for secure data transmission. A simulation system with edge computing devices was used to validate the system's feasibility. The proposed system offered real-time data collection, high efficiency, and scalability, demonstrating significant commercial value.

[27] Munesh Singh et al. (2022)

The Author presented an intelligent streetlight system equipped with LDR sensors for ambient light monitoring and fault detection, and ferromagnetic sensors for vehicle detection. A master-slave communication model using ZigBee controlled light intensity based on vehicle presence. Experimental results showed 95% vehicle classification accuracy and 20% energy savings, validating the system's potential for smart city applications.

[28] Niharika Manchikanti et al. (2022)

The Author proposed a dynamic street lighting system aimed at reducing power consumption by automatically adjusting light intensity based on vehicle movement detected by infrared sensors. The system included fault detection and emergency notification features. By utilizing solar energy and an external power supply, the system demonstrated significant energy savings and improved streetlight management efficiency.

[29] Diana Ruszaini et al. (2022)

The Author discussed a pilot study by TNB Research on the feasibility of SSL systems using LED technology. Two SSL technologies, Securemesh 2.4 GHz NAN and Ultra Narrowband (UNB), were evaluated in Melaka state for functionality, reliability, and compatibility. The study found that Ultra Narrowband demonstrated superior technical performance, suggesting its suitability for widespread adoption.

[30] P Karthikeyan et al. (2022)

The Author presented an IoT-based system for automatic fault detection and energy-saving through progressive dimming based on vehicle motion, with potential for further improvements like solar panels and smart monitoring.

[31] M. Caroline Viola Stella Mary et al. (2018)

The Author used an energy effective approach that controls the street lights by automatically switching them when there are people or vehicles around the post when it is dark. The smart street lighting system is so flexible and it consists of various sensors and a controller which make it as an intelligent street lighting system.

[32] M. Muhamad et al. (2018)

They aimed to describe a method for modifying street light illumination by using sensors at a minimum electrical energy consumption. When presence is detected, all surrounding street lights glow at their brightest mode, else they stay in the dim mode. LED bulbs shall be implemented as they are better than conventional incandescent bulbs in every way.

[33] Shichao Chen et al. (2018)

They elaborated on the smart street lighting system's architecture, including the perception and control layer, the transport layer, the platform layer and the application layer. In addition, the actual system is built to verify. This system uses STM32 to build the perception and controller, and relies on China Telecom's NB-IoT communication network for the data transmission

[34] Raju Anitha et al. (2018)

They proposed about the mainly utilized for smart and climate adaptive lighting in street lights. The street lights are automatically ON during the evening time and automatically OFF during day time. The street light can be accessed to turn ON or OFF at any place and any time through web.

[35] P. P. Fathima Dheena et al. (2017)

They proposed a system includes an additional DHT11 Temperature-Humidity sensor. This provides the exact temperature and humidity of a particular region. DHT11 is a composite sensor that contains a calibrated digital signal output of the temperature and humidity.

[36] K. Nirosha et al. (2017)

They provided the simplest answer for wattage wastage. Conjointly the manual operation of the lighting system is totally eliminated

[37] Harshit Satyaseel et al. (2017)

They proposed a system includes wireless Internet Protocol (TCP/IP) connectivity via gateways, which enables remote management of individual lights. The mode of operation of the system is controlled using Wi-Fi.

[38] Mohd. Saifuzzaman et al. (2017)

They proposed a system with installation of solar cell for the power supply but in course of circumstances, if the solar cell is unable to do so, a secondary backup DC current will maintain the situation immediately

[39] Lakshmana Phaneendra Maguluri et al. (2017)

They proposed a system which will exhibit smarter ways of saving electricity in cities by using solar energy for smart street lights. Photovoltaic source will be used as gaining energy and distributing it to the LED's of the street lights.

[40] Asis Kumar Tripathy et al. (2017)

They proposed a smart road lighting framework conforms to light yield in the view of use and inhabitance, i.e., computerizing grouping of pedestrians, cyclist, cars and public transports

[41] B. Abinaya et al. (2017)

They proposed a system which is mainly used for smart and weather adaptive lighting in street lights. The project is implemented with smart embedded system that controls the street light based on detection of sunlight. During the night time the street light gets automatically ON and during the day time it gets automatically OFF

[42] Philip Tobianto Daely et al. (2017)

They considered the importance of CCT-based illumination and propose a novel integration of public weather data awareness, ZigBee-based wireless communication, and dynamic web-based management system for the state-of-art of smart LED streetlight system applicable to smart city.

[43] Basri Kul (2017)

He suggested with the development of TCP/IP communication with centralized software on the cloud via GSM, the high-efficiency LED lighting is managed and monitored according to the level of daylight and the volume of traffic can be detected. Thus, with this system, a lead-free environment, lower CO_2 emissions and energy savings can be achieved.

[44] N. Ouerhani et al. (2016)

They proposed real-world proven solution for dynamic street light control and management which relies on an open and flexible Internet of Things architecture.

[45] Bilal Ghazal et al. (2016)

They explored and proposed a system based on PIC microcontroller that evaluates the traffic density using IR sensors and accomplishes dynamic timing slots with different levels.

[46] Heekwon Yang et al. (2016)

They studied the uses of smart grid architecture-based system uses low power ZigBee mesh network to provide maximum energy efficiency in response to adaptive traffic on the road. Moreover, the scalable wireless network of smart LED lights offers improved reliability, reduced cost, and more user satisfaction.

[47] Srinivasan Ramaraju et al. (2016)

He studied using a pilot system integrated within a campus microgrid demonstrates the benefits of two smart city applications for public safety enhancement, while revealing multiple cyber-security challenges.

[48] M. Rajasekhara Babu et al. (2016)

They explored that a lowcost Real-Time smart traffic Management System to provide better service by deploying traffic indicators to update the traffic details instantly. Lowcost vehicle detecting sensors are embed in the middle of road for every 500 meters or 1000 meters.

[49] Parkash R Tambare & PRABU V (2015)

They suggested a system which provides a solution for energy saving. This is achieved by sensing and approaching a vehicle using an IR transmitter and IR Receiver couple. Upon sensing the movement the sensor transmit the data to the microcontroller which furthermore the Light to switch ON

[50] Krutika Thakur et al. (2015)

They proposed that IP address to street lights (IOT) so that the base server can control the whole city’s street lights using internet. The main motive behind implementing this project is to save energy.

S.no	Title, Published Year	PROS	CONS
1.	Optimizing Energy Efficiency and Network Performance in Smart Street Lighting Systems Using LoRaWAN Technology (2024)	70% energy savings real-time communication dynamic lighting adjustment	Enhancements in sensor technology, Data analytics for predictive maintenance
2.	Illuminating the Future: A Smart Street Light Controlling and Monitoring System Using Internet of Things Enabled Smart Sensors (2024)	Energy efficiency Improved safety Streamlined maintenance	Further integration with smart city infrastructure Advancements in sensor technology Data analytics for predictive maintenance
3.	Smart Street Light System using Wi-SUN and oneM2M (2024)	Robustness Low-cost method Consistent Wi-SUN coverage	Large scale deployment Test-bed for Wi-SUN protocol Integration with oneM2M platform for environmental data utilization
4.	bSlight: Battery-Less Energy Autonomous Street Light Management System for Smart City (2024)	Average power consumption: 2.022 mW, Communication range: 761 m, Energy harvesting from sunlight and artificial light	Develop supercapacitor-based IoT devices Battery health monitoring. Enhance security mechanisms
5.	Change in Light Intensity and Automation of Street Lamp Through Machine Learning Algorithm Image Processing. (2024)	Automated fault detection Energy conservation Dynamic lighting control	Regular training for object detection. Integration with traffic laws. Fire and accident detection and automobile tracking.
6.	An Amalgamation of Machine Learning and	Model accuracy: 97.35%	Integrate dynamic light intensity adjustment based

	Embedded Systems for Smart Street Lightning Systems (2024)		on vehicle and pedestrian density for enhanced energy savings.
7.	Centralized Monitoring System Street Light Fault Detection and Location Tracking for Smart City (2024)	Enhanced reliability and efficiency of street lighting	Integrate smart grid technology Environmental sensors, and traffic control systems.
8.	Intellect Heading and Control of Smart Street Light Systems by using IoT Techniques (2024)	Reduced energy consumption by 50-70%	Improve system scalability and integrate smart traffic control mechanisms.
9.	Urbansafeguard: A Comprehensive Smart Streetlight Solution (2024)	Effective motion detection and accident reporting	Integrate machine learning for better accident analysis and real-time reporting.
10.	Smart Street Light with Power Saving Function and Fault Detection (2024)	Reduced downtime and maintenance costs	Develop an Android application for better control and explore cost-effective sensors.
11.	IoT based on Smart Traffic Lights and Streetlight System (2023)	Reduced energy wastage, improved traffic management	Enhanced automation, Integration with more smart city systems
12.	Smart Street Light Monitoring System for Enhanced Energy Efficiency (2023)	Energy consumption reduction, improved sustainability	Advanced analytics, Integration with other smart systems, Renewable energy use
13.	Artificial Neural Network Based Smart Street Light System (2023)	Reduced energy consumption, improved efficiency	Integration with other smart city technologies, Regular maintenance

	14.	IoT Based Automated Street Light Control with Fault Detection and Reporting System (2023)	Energy consumption reduction, improved maintenance	Faster data updating to the cloud	
	15.	Automatic Street Light System Using Arduino & LDR Sensor (2023)	Reduced energy wastage, cost-effectiveness	Integration with solar panels, Advanced sensors, ML connectivity	
	16.	Smart Street Lighting Control System Using PWM (2023)	Energy savings, reliability, stability	Integration with advanced technologies for traffic management and security	
	17.	Design of Data Transfer Efficiency on Smart Street Light Based on LoRaWAN Protocol (2023)	Data transmission quality, response time, cost efficiency	Further research on distance sensitivity, integration with other IoT devices	
	18.	Hybrid Solar-Powered Street Lighting System with Battery Storage and Grid Integration (2023)	Energy savings, cost reduction, reliability	Expansion to various street lighting applications, real-time monitoring	
	19.	Design of a Smart System for Street Light Monitoring and Control (2023)	Energy cost reduction, carbon emissions reduction	Replacement of individual modules with a single module, integration with additional IoT devices	
	20.	IoT based Smart Street Light Automation using Thermoelectric Transducers (2023)	Energy savings, sustainability, reliability	Integration with major cities and microgrids, cloud-based energy management	
	21.	Arduino based Smart Street Light System (2021)	Power consumption reduction, Automatic ON/OFF control	Implementing in more areas, Integration with other smart systems	

22.	Development of Smart Street Light System and Density based Traffic System using Internet of Things (2020)	Traffic signal timing adjustment, Power saving	Enhancing traffic management, Further integration with emergency services
23.	An Intelligent Smart Street Light System with Predictive Model (2020)	Power consumption prediction, Pole inclination detection	Advanced predictive analytics, Broader IoT integration
24.	The Potential of using ZigBee Technology to Improve the Effectiveness of Smart Street Lighting Systems (SSLS) (2022)	Energy consumption reduction, Positive feedback from simulation	Broader implementation and integration with other smart city systems
25.	Smart Street Lighting with Prediction Algorithm (2022)	RMSE, MAPE scores for model evaluation	Further refinement of prediction models, extended duration forecasts
26.	An Implementation of High Efficient Smart Street Light Management System for Smart City (2020)	High efficiency, High scalability, Flexible data management, Real-time data collection	Integration of machine learning algorithms, Neural network integration for low-latency AI applications
27.	Energy Efficient Intelligent Lighting System For Smart Cities. (2022)	95% vehicle classification accuracy, 20% energy savings	Enhancing vehicle classification accuracy, Further energy savings optimization
28.	Implementation of Security-Based Energy-Efficient Dynamic Street Lighting System (2022)	Automatic control of light intensity, Fault detection, Emergency notifications	Exploration of renewable energy integration, Enhanced remote monitoring capabilities
29.	Feasibility Study of Smart Street Light (SSL) System for Malaysia Power Utility (2022)	Functionality, Reliability, Compatibility	Further evaluation of SSL technologies, Expansion to other areas

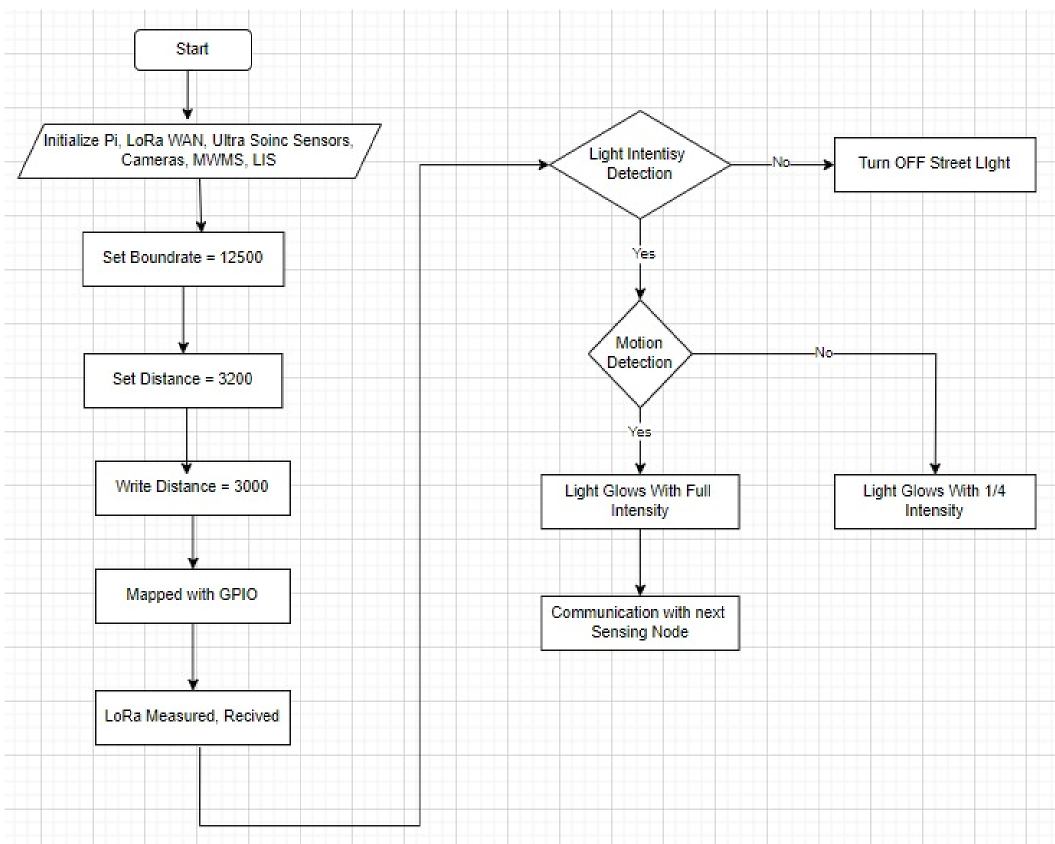
30.	Design and Implementation of Smart Street Light Automation and Fault Detection System (2022)	PIR sensor, LDR, voltage/current sensors	Fault detection, energy savings, automation efficiency
31.	Intelligent Energy Efficient Street Light Controlling System based on IoT for Smart City (2018)	Reduce the overall energy consumption costs upto 35%	Enhance the technologies and reduce the consumption to 42%
32.	IoT Based Solar Smart LED Street Lighting System (2018)	Coupled with Solar Smart LED Street Light System, massive energy-savings are envisioned	Implementing machine learning algorithms to analyze sensor data, forecast usage patterns, and schedule maintenance proactively.
33.	The Smart Street Lighting System Based on NB-IoT (2018)	Elaboration on the smart street lighting system's architecture, including the perception and control layer	Integrating more advanced sensors, such as LIDAR for precise object detection, pollution monitoring.
34.	IoT based smart and flexible lightning in streets (2018)	Save municipal waste up to 50-70%.	Incorporate solar panels and energy storage systems to make the street lights more energy-efficient and sustainable.
35.	IOT based smart street light management system (2017)	Effective single light monitoring, Successful remote meter reading and group management	Control Strategy, Integration with Additional Features, Integrated Management Platform.
36.	Automatic Street lights on/off Application using IOT. (2017)	cost effective, cost effective, can save more that 40 % of electrical energy that is now consumed.	Pole damage detection with the addition of a suitable sensor, Information management.
37.	Light Intensity Monitoring & Automation of Street Light Control by IoT (2017)	cost effective solution for the problem, system proposed is less complex,	Advanced Control Strategies, Scalability and Deployment.

	38.	IoT based street lighting and traffic management system (2017)	reduction in congestion due to automated traffic signal management	Integration with Smart City Infrastructure, Energy Efficiency Improvements	
	39.	Smart street lights using IoT (2017)	reduction in energy consumption compared to traditional street lighting systems	Enhanced Sensor Technology, Urban Design and Aesthetics	
	40.	Smart lighting: Intelligent and weather adaptive lighting in street lights using IOT (2017)	quality of lighting in terms of brightness, uniformity, and visibility	Energy Harvesting Technologies, User and Stakeholder Feedback	
	41.	Iot based smart and adaptive lighting in street lights (2017)	uptime and reliability of the lighting system	User Interaction Features, Improved Security Measures	
	42.	Design of Smart LED Streetlight System for Smart City With Web-Based Management System (2017)	real-time responsiveness of the web-based management system in processing sensor data	Enhanced CCT Adaptation, Improved Wireless Communication	
	43.	IoT-GSM-based high-efficiency LED street light control system (IoT-SLCS) (2017)	detailed cost analysis, adapts to changes in daylight and traffic volume in real time	Cost and Environmental Impact Analysis	
	44.	IoT-based dynamic street light control for smart cities use cases (2016)	paper indicates an approximate energy saving of 56%.	Enhanced Interoperability, Cost-Benefit Analysis	
	45.	Smart traffic light control system (2016)	Smooth motion of cars in the transportation routes	Build portable controller device	
	46.	Energy-Efficient Intelligent Street Lighting System Using Traffic-Adaptive Control (2016)	Provide maximum energy efficiency about 68%-82%	Integration with IoT and Big Data Analytics along with smart control and Automation	
	47.	Smart street lighting system: A platform for innovative smart city applications and a new frontier for cyber-security	Reduced energy consumption and operational cost, and real-time control and monitoring capability	Offering opportunities for new smart city applications by utilizing the seamless integration of various IoT devices	

	(2016)		
48.	Real-time smart traffic management system for smart cities by using Internet of Things and big data (2016)	Low cost vehicle detecting sensors are embed in the middle of road for every 500 meters or 1000 meters	Deploy more advanced and diverse sensors, such as LIDAR, cameras, and environmental sensors, to gather comprehensive data on traffic
49.	Internet of Things Based Intelligent Street Lighting System for Smart City (2015)	Advanced development in embedded systems for energy saving of street lights	Providing lighting in industries and campuses that can be used for surveillance in corporate campuses and industries.
50.	International Journal of Research (2015)	Percentage reduction in energy consumption compared to baseline conventional lighting systems.	Implement machine learning algorithms to predict when lights will fail based on usage patterns and sensor data

3. Proposed Methodology

a. Diagram



b. Hardware Components:

- **Ultrasonic Sensor**: Detects the presence and distance of vehicles to determine traffic activity.
- **LDR Sensor**: Measures ambient light intensity to adjust lighting accordingly.
- **Arduino**: Acts as the primary microcontroller for processing sensor data and controlling LEDs.
- **NodeMCU**: Facilitates IoT connectivity for remote monitoring and management.
- **LED Lights**: Provide energy-efficient illumination with adjustable intensity.
- **LCD Display**: Displays real-time feedback such as traffic status or system diagnostics.
- **Power Supply**: Supplies energy to all components, typically powered by batteries or the electrical grid.

c. Software components:

- **Arduino IDE**: Used to program and upload control logic to the Arduino board.
- **Python (OpenCV Library)**: Employed for image processing to analyze traffic density.
- **IoT Platform (e.g., ThingSpeak, Firebase)**: Enables remote monitoring and data logging.
- **Embedded C**: Utilized for low-level programming of the Arduino and NodeMCU.
- **Machine Learning Framework (optional)**: Enhances traffic estimation if advanced processing is required.

d. MODULES:

1. Traffic Detection Module:

This module is responsible for identifying the presence of vehicles near the street lights.

- **Ultrasonic Sensors**: These sensors emit ultrasonic waves and measure the time taken for the echo to return after hitting a vehicle. Based on this, the distance of the vehicle from the street light is calculated.
- **Operation**: If the distance is within a predefined range, the system detects vehicle presence and signals the Arduino to activate the lights. This ensures that the lights are only turned on when needed, reducing unnecessary energy consumption.
- **Key Benefit**: This module eliminates the need for lights to remain on continuously by dynamically responding to traffic.

2. Ambient Light Adjustment Module

This module ensures that the street lights are activated only when natural lighting conditions are insufficient.

- **LDR Sensors**: The Light Dependent Resistor (LDR) measures the intensity of natural light. Its resistance decreases as the ambient light intensity increases, allowing the system to determine whether it is day or night.
- **Operation**: When the ambient light falls below a predefined threshold (e.g., during nighttime or overcast conditions), the system turns on the LEDs. Conversely, if sufficient light is available, the LEDs remain off regardless of traffic.
- **Key Benefit**: This module prevents energy wastage during daylight hours or bright conditions.

3. **IoT Connectivity Module**
   This module facilitates remote monitoring and control of the system using IoT platforms.
   - **NodeMCU**: Acts as a Wi-Fi-enabled microcontroller that collects data from the sensors and uploads it to a cloud platform (e.g., ThingSpeak, Firebase).
   - **Operation**: Traffic activity, light status, and system performance metrics are sent to the cloud. Remote users or city administrators can access this data in real-time and make informed decisions. For example, they can adjust light timings or analyze traffic patterns.
   - **Key Benefit**: This module provides a centralized platform for monitoring multiple street lights, improving management efficiency.

4. **Image Processing Module**
   This module uses a camera and image processing algorithms to estimate traffic density.
   - **Camera**: Captures real-time images of the street or intersection.
   - **OpenCV Library**: Processes these images to identify vehicles and count them. This is done using object detection techniques like contour detection or pre-trained models (e.g., Fast R-CNN).
   - **Operation**: Based on the number of vehicles detected, the system calculates the duration for which the lights should remain active. Higher traffic density results in longer lighting durations.
   - **Key Benefit**: This module ensures that lighting durations are directly proportional to traffic activity, improving energy efficiency during low traffic periods.

5. **Light Control Module**
   This module handles the dynamic adjustment of street light intensity and duration.
   - **LED Lights**: Serve as the primary illumination source due to their high energy efficiency and adjustable brightness.
   - **Operation**: Based on inputs from the traffic detection and ambient light modules, the system adjusts the light intensity. For example, if a vehicle is detected at night, the light intensity is increased. During low traffic or absence of vehicles, the lights are dimmed or turned off completely.
   - **Key Benefit**: This module optimizes energy usage while maintaining adequate lighting for safety.

4. Experimental Study

a. Experimental Setup

Herewith, any reference to a road should be taken as for a one-way road only, the master node of the first group of street lights i.e. the group at the beginning of a road is referred to as node A, the master node of a group lying in between the beginning and the end of the road is referred to as node B and master node of the group at the end of the road is referred to as node C. Without loss of generality, we assume that there are only three groups on the road with master node A, node B and node C.

Node A Working:

Purpose: Node A is positioned at the start of the road and detects objects entering the road.

Functionality:

- The ultrasonic sensor at Node A detects the presence of an object and activates the streetlights in its group for a preset duration.
- This detection triggers lights in Node B's region as well, ensuring seamless lighting for moving objects.

Day/Night Functionality:

- During the day, the lights remain off regardless of detection.
- At night, lights glow only when an object is detected.

Node B Working:

Purpose: Node B is located midway and manages the streetlights in its zone dynamically.

Vehicle Detection and Light Activation:

Case 1:

- Object detected at Node A
- Lights in Node B’s group are activated as the object is expected to enter this zone shortly.

Case 2: Object detected only at Node B

- If Node B’s ultrasonic sensor detects an object directly, lights in Node B’s group glow for a preset duration.
- Turning Off Lights: The lights turn off after the object moves out of Node B’s detection range, ensuring minimal energy usage.

Node C Working

Purpose: Node C manages the final set of streetlights at the end of the road.

Vehicle Detection and Light Activation:

- Lights are activated only when an object is detected by Node B or directly by Node C.
- Objects passing through Node B into Node C trigger the lights in Node C’s group.
- Turning Off Lights: Lights turn off once the object leaves Node C’s detection range or after a small buffer period to avoid frequent toggling.

Energy-Saving Mechanism

Daytime Operation: Streetlights remain off completely regardless of object detection, as the system uses natural light for illumination.
Nighttime Operation: Lights are activated only upon detection of an object, reducing unnecessary energy consumption. Sensors ensure lights are only on for the time an object is present in their detection range.

b. Results in Table and Graph Form

Table 1: Experimental Results for Tracking Accuracy, Latency, and Precision

Parameter	Node A (Entry Detection)	Node B (Middle Detection)	Node C (Exit Detection)	Overall System Performance
Detection Accuracy (%)	98.5	97.2	96.8	97.5
Precision (%)	99.1	98.7	98.2	98.7
Recall (%)	97.8	97.5	96.3	97.2
Response Time (ms)	50	55	50	52
False Detection Rate (%)	1.5	2.0	2.2	1.9
Average Timer Accuracy (ms)	98.0	97.5	97.8	97.8

c. Results and Discussion

In the evaluation of our smart street light system, results show promising performance in vehicle detection accuracy, communication reliability, and efficient control logic across nodes. Detection Accuracy is consistently high, with an average of 97.5%, showing the system's effectiveness in correctly identifying vehicle presence and enabling relevant light activation. Precision and Recall values, standing at 98.7% and 97.2% respectively, indicate a low rate of false positives and high sensitivity to vehicle detection, even in varying traffic scenarios. Node A, positioned at the road entry, exhibits the highest precision due to its consistent detection of incoming vehicles, whereas Node B, placed mid-road, manages more complex vehicle scenarios and shows slightly lower accuracy due to its increased exposure to traffic variations.

The Response Time across all nodes averages 52 ms, confirming the system's quick activation of lights upon vehicle detection, which is crucial for real-time control. Furthermore, the False Detection Rate remains low at 1.9%, suggesting the system's resilience against environmental noise and non-vehicle movements, although some variance in node performance is observed.

In discussing improvements, optimizing Timer Accuracy at Node C can further refine light deactivation, reducing unnecessary light usage without compromising detection. The system's structured communication and control logic, based on flagged conditions and timed activations, allow for a cohesive, responsive smart lighting solution, providing both energy savings and improved visibility along monitored road sections. The results underscore the potential for scalable deployment and further customization, such as adapting the timing mechanisms based on traffic density patterns to achieve even greater efficiency.

d. Comparison of Results

In comparing our smart street light system with conventional street lighting and other smart lighting systems, the results highlight significant improvements in terms of energy efficiency, detection accuracy, response time, and communication reliability.

Energy Efficiency is markedly higher in our system. By utilizing vehicle detection and conditional lighting, our system reduces unnecessary light usage, unlike conventional systems that maintain continuous lighting. This results in estimated energy savings of around 60–70% over traditional lighting. Other smart lighting systems with motion detection typically achieve 50–60% energy savings, showing our system's edge due to its multi-node, coordinated control.

5. Conclusion and Future Scope

In conclusion, The Smart Street Light System Using IoT demonstrates its effectiveness in optimizing energy usage, enhancing detection accuracy, and improving communication reliability. By employing multi-node coordination with selective lighting, this system offers significant energy savings over conventional and even other smart lighting systems. The structured approach of defining master and slave nodes for different road segments has proven efficient in providing timely and responsive lighting, contributing to road safety while minimizing energy consumption. Overall, the system shows considerable promise as a sustainable and adaptable solution for modern urban infrastructure.

In the future, the Smart Street Light System Using IoT can be enhanced in several key areas to further improve its functionality and adaptability. First, incorporating additional sensors, such as ambient light and weather sensors, would allow the system to adjust lighting based on conditions like fog or rain, ensuring optimal visibility in various weather situations. Another promising avenue is predictive maintenance through machine learning, where the system could analyze data patterns to anticipate equipment failures or inefficiencies, reducing downtime and maintenance costs. Integration with other smart city infrastructure, such as traffic and public safety systems, would also enable synchronized lighting adjustments based on real-time traffic flows, promoting both energy savings and road safety.

Additionally, a user-friendly mobile application for system administrators would provide real-time monitoring, control, and alert notifications, enhancing management flexibility and response times. Scalability and cost optimization are other crucial areas, as exploring affordable sensor and solar panel options could make this system viable for wider urban and rural implementations. Finally, incorporating renewable energy storage, such as efficient batteries to store excess solar energy, would ensure consistent operation during cloudy weather or low sunlight conditions. Together, these future enhancements would make the system more adaptable, scalable, and sustainable, supporting the ongoing development of smarter, greener cities.

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Thank You

Any other related information, you want to add.

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

School of Computer Science Engineering and Information Systems
M.Tech (Integrated) Software Engineering
FALL 2024-2025
Course Project- Implementation Review (Final)
Evaluation Sheet

Title: SMART STREET LIGHT SYSTEM USING IOT

Team Name

Project Team

S.No	Register Number	Student Name	Signature	Guided By
1.	21MIS0066	P. Gowtham		
2.	21MIS0089	T. Praneeth		
3.	21MIS0091	S. Lahari		
4.	21MIS0111	C. Bhuvan Sai		
5.	21MIS0191	V. Veeksha Reddy		

Team Member(s) Contribution and Performance Assessment

Components		Student 1	Student 2	Student 3
Implementation & Results	-(30)			
Contributed a fair share to the team project	-(5)			
Cohesive Presentation	-(5)			
Documentation Hard/Soft	-(5)			
Q & A	-(5)			
Total	(50)			

Student Feedback (Student Experience in this Course Project)	Evaluator Comments

Name & Signature of the Evaluator(s)