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An IoT-Based Smart Street Lighting System to Lower Energy Consumption

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Abstract: - Smart Lighting System is an automated and intelligent lighting control system that can be deployed across multiple locations or in one location, utilizing various IoT connection protocols, devices, and sensors. The system is able to intelligently adjust to changes in ambient light conditions, traffic patterns, and pedestrian activity through the integration of Internet of Things (IoT) technologies. IoT-enabled sensors are installed in every street light, creating a network that connects to a central control unit. Using real-time data, this system dynamically modifies street light brightness to maximize energy efficiency and improve safety. It provides a simulation and optimization tool for street light placement, considering factors such as street length, light distance, and the number of lights ahead. This tool aids in visualizing the power consumption implications of different configurations, promoting efficient urban planning. Demonstrates the energy-saving potential of the proposed system. As the street light intervals and the number of lights ahead decreases, the optimal street light power significantly reduces, leading to substantial energy savings. The system's ability to dim or turn off lights during low-traffic or well-lit periods contributes to reduced operational costs and enhanced sustainability.

Keywords: Automated, IoT, Urban, Sustainability.

I.INTRODUCTION:

With more than 70% of the world's population expected to live in cities by 2050, our reliance on information and communication technologies (ICT) has increased, making critical infrastructure management essential. The smart city idea completely addresses these issues by combining intelligent ICT solutions. Ensuring energy efficiency is a critical component of a smart city enabled by the Internet of Things. The reason for this is that there are limited resources available, and as the population increases, so does the need for power. In both public and private dwellings, lighting is a basic electrical requirement. Approximately 10% of the energy used nowadays is used for outdoor lighting [1]. Due to increase in environmental concerns, street lighting control becomes an important issue in the reduction of electrical power consumption. Energy-related emissions count for about 80% of air emissions and serious environmental hazards and climate change [2]

Without a doubt, a smart city that makes extensive use of IoT technology needs a smart lighting system to effectively manage and control lighting systems[3]. A Smart Lighting System (SLS) is an automated and intelligent lighting control system that can be deployed across multiple locations or in one location, utilizing various IoT connection protocols, devices, and sensors. An SLS is based on the idea of an efficient lighting system and controlling how much energy homes, workplaces, and streets use. Using an SLS that is connected to the IoT can help cut down on wasted power in a smart city. There are three main parts to the design of IoT-enabled SLS: the perception or sensor layer, the communication layer, and the organization layer [4]. The light nodes' integrated sensors provide mechanical control based on factors like light intensity (using a light sensor) or human presence (using a motion sensor). These light nodes can communicate with one another and send sensor data thanks to IoT connection protocols. A management system must be able to examine the data it is provided and make decisions on its own for power management to function well.

Automating the functioning of street lights is a dependable and efficient technique known as the Smart Street Light System. Using an LDR sensor that works similarly to human eyes, it automatically switches on the lights as the amount of sunshine diminishes. An LDR sensor measures the light intensity and is used in an automated street light controller [5]. The system determines whether illumination is necessary based on an intelligent assessment of the surrounding light conditions. The street lights are automatically turned on when the darkness reaches a predefined level and turned off otherwise.

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II.METHODOLOGY:

The proposed methodology for IoT-based streetlights involves the integration of Internet of Things (IoT) technology to enhance the efficiency and functionality of street lighting systems. With this method, IoT-enabled sensors and communication devices are installed in every street light. In order to communicate with a central control system, the streetlights are made to be networked together. Real-time data on ambient light levels, traffic patterns, and pedestrian activity can be gathered via the Internet of Things sensors integrated into the street lights. Subsequently, these data are sent to the central control system, which can be an online platform.
The streetlights operation is dynamically adjusted by the central control system using the data it receives[6]. For instance, the system can dim or switch off specific street lights to save energy during times when there is little traffic or when ambient light from nature is sufficient. On the other hand, for increased safety and visibility in busy places or at night, the system can raise the light's brightness.
The Internet of Things-based Street light system additionally enables remote management and monitoring[7]. Through a user interface, municipalities or other relevant authorities can access the central control system and monitor each street light's status, identify problems or malfunctions, and effectively schedule maintenance tasks. This suggested solution has several advantages, such as substantial energy savings, lower operating expenses, and enhanced sustainability through the reduction of light pollution. Furthermore, the adaptable nature of the technology enhances urban area's safety and security.

III.PROPOSED SYSTEM AND RESULTS DISCUSSION

In this a graphical user interface (GUI) is used for simulating and optimizing street light placement along a main street. The input parameters such as street length, street light interval, and the number of street lights ahead.

The simulation is then displayed on an axes object, where the main street is represented as a horizontal line, and street lights are shown as markers. The simulation includes the appearance of street lights and their visibility, considering the specific distance between them and assuming standardized power-consuming LED street lights are placed and regular traffic conditions.

Additionally, calculating and plotting the power consumption for both full street lighting and an optimized scenario where only necessary street lights are turned on. To simulate a main street with street lights, consider factors such as street light distance and the number of street lights ahead. The simulation aims to optimize power consumption by dynamically controlling the activation of street lights based on the presence of other lights nearby.

Street illumination is approached dynamically using IoT principles in the suggested methodology. The ambient light, traffic, and pedestrian activity could all be detected by sensors installed in each street light. Real-time brightness adjustments for the streetlights would be possible because of the sensor's communication with a centralized control system. In reaction to traffic patterns and environmental circumstances, the system only turns on the lights that are absolutely necessary in an effort to improve energy efficiency.

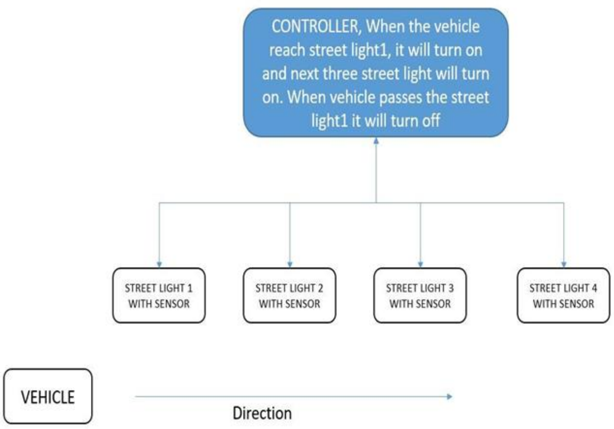

Figure 1.: Proposed Block Diagram

The block diagram 1 shows the controller that operates the street lights based on the vehicle's position, you can use a simple illustration with sensors and control logic. Here's a basic explanation:

Vehicle Sensor (VS): A sensor is placed on the road to detect the presence of a vehicle. This could be a variety of sensors such as infrared sensors, ultrasonic sensors, or other types of proximity sensors.

Controller (C): The controller processes the input from the vehicle sensor and decides when to turn on and off the street lights. It contains the logic to control the lights based on the vehicle's position.

Street Light 1 (SL.1.) with Sensor: Street Light 1 is equipped with a sensor (SL.1. Sensor) to detect the presence of a vehicle. When the vehicle is detected by the sensor at Street Light 1, the controller triggers the following actions:

Turns on Street Light 1.

Activates sensors for Street Light 2, Street Light 3, and Street Light 4.

Street Light 2 (SL2) with Sensor:

Street Light 2 has its own sensor (SL2 Sensor) to detect the vehicle's presence. When triggered by the controller, it turns on Street Light 2.

Street Light 3 (SL3) with Sensor:

Street Light 3 has its own sensor (SL3 Sensor) to detect the vehicle's presence. When triggered by the controller, it turns on Street Light 3.

Street Light 4 (SL4) with Sensor:

Street Light 4 has its own sensor (SL4 Sensor) to detect the vehicle's presence. When triggered by the controller, it turns on Street Light 4.

Sequential Activation: As the vehicle progresses along the street, the sensors for each street light are activated in sequence. . For example: When the vehicle reaches Street Light 1, SL.1. turns on, and sensors for SL2, SL3, and SL4 are activated. When the vehicle passes Street Light 1, SL.1. turns off, and sensors for SL2, SL3, and SL4 remain active. The same sequence occurs for each subsequent street light.

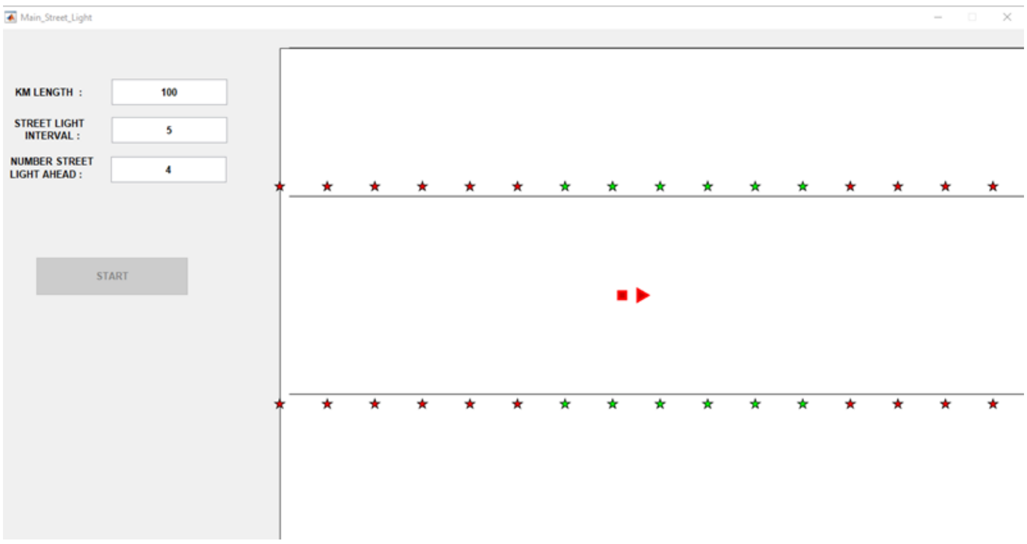

Figure 2: Street Light City Scenario 1

Streetlights are displayed using different colors to indicate whether they are turned on or off:

Red Color: Represents a turned-off street light.

Green Color: This represents a turned-on street light.

This color scheme provides a visual representation of the state of each street light, making it easy to identify which lights are active (green) and which are inactive (red) during the simulation. The simulation dynamically adjusts the activation of street lights based on certain conditions, aiming to optimize power consumption while maintaining visibility.

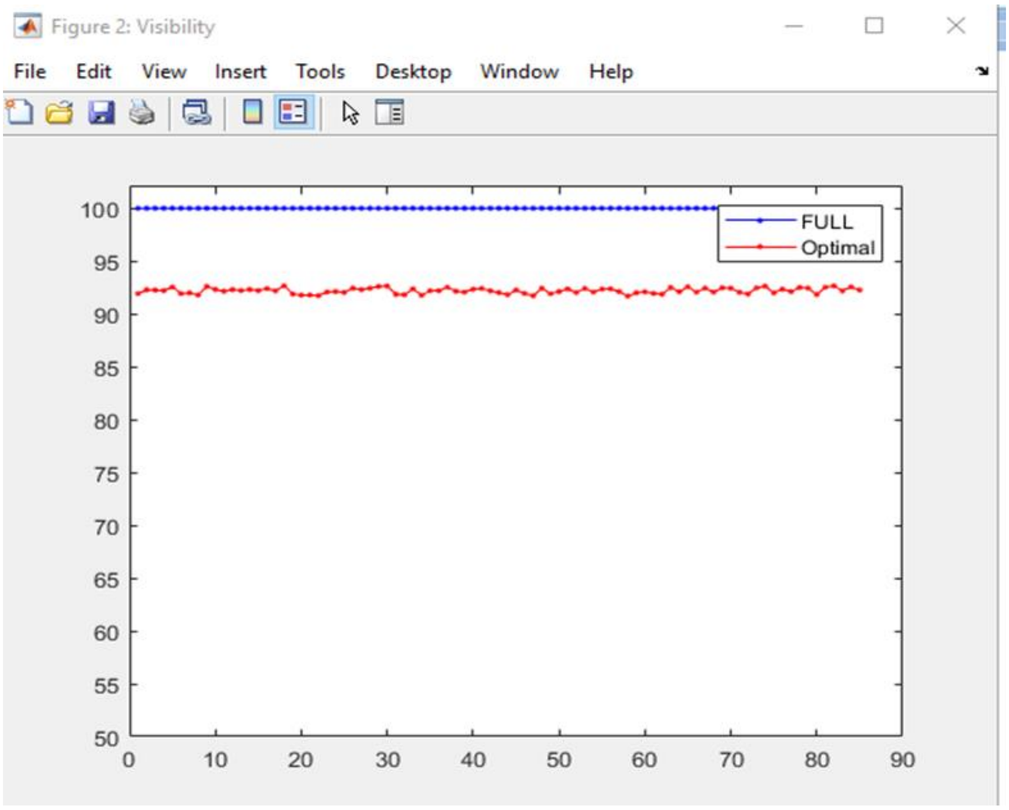

Figure 3: Full and optimum visibility for street intervals 5 and number of lights ahead is 4

Figure 3, which involves the full and optimum visibility for street intervals, considering 5 light intervals and 4 lights ahead, in the context of a simulated scenario for a city.

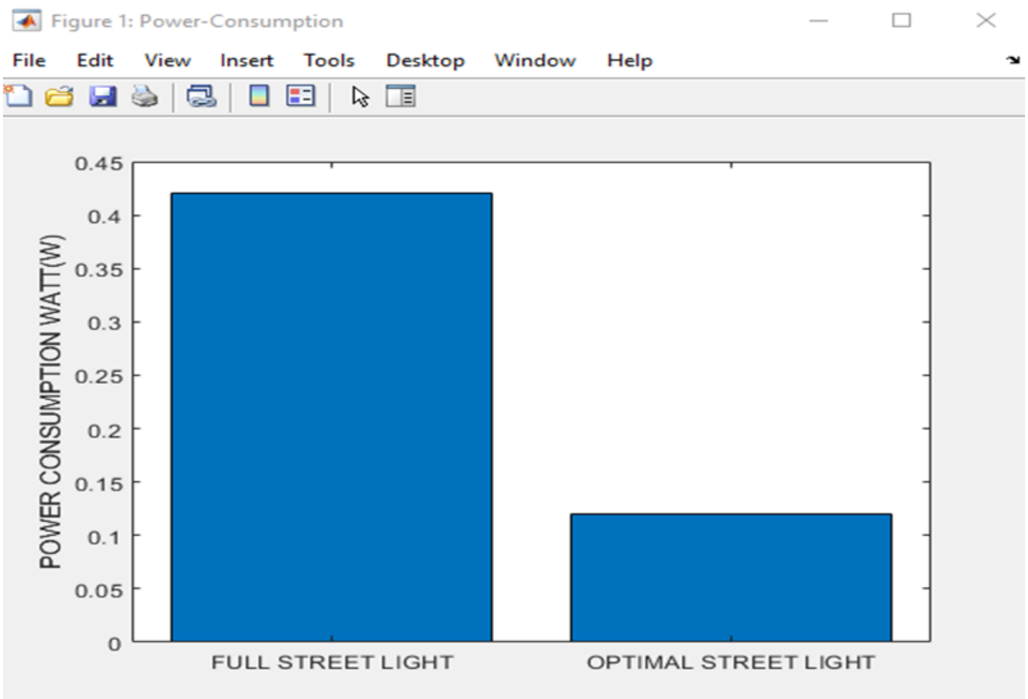

Figure 4: Power consumption for street intervals 5 and number of lights ahead is 4

Figure 4, which involve the power consumption for street intervals, considering 5 light intervals and 4 lights ahead.

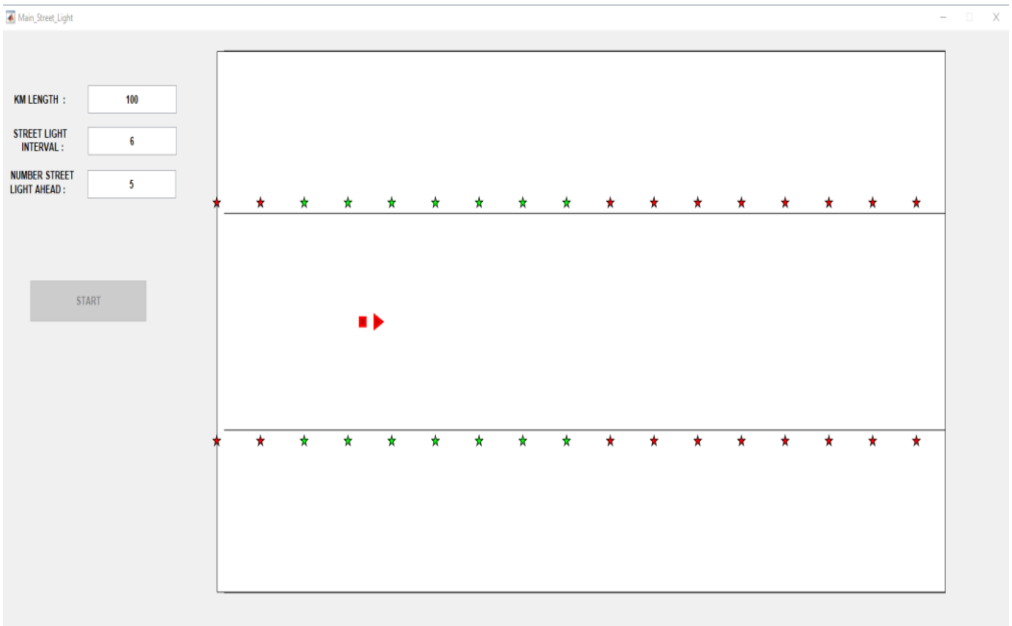

Figure 5 Street Light City Scenario 2

Figure 5, which involve a city scenario with 2 street lights. The color scheme is used to represent the state of each street light: This color scheme visually indicates the active (green) and inactive (red) states of each street light during the simulation. The dynamic adjustment of street light activation is aimed at optimizing power consumption while ensuring visibility.

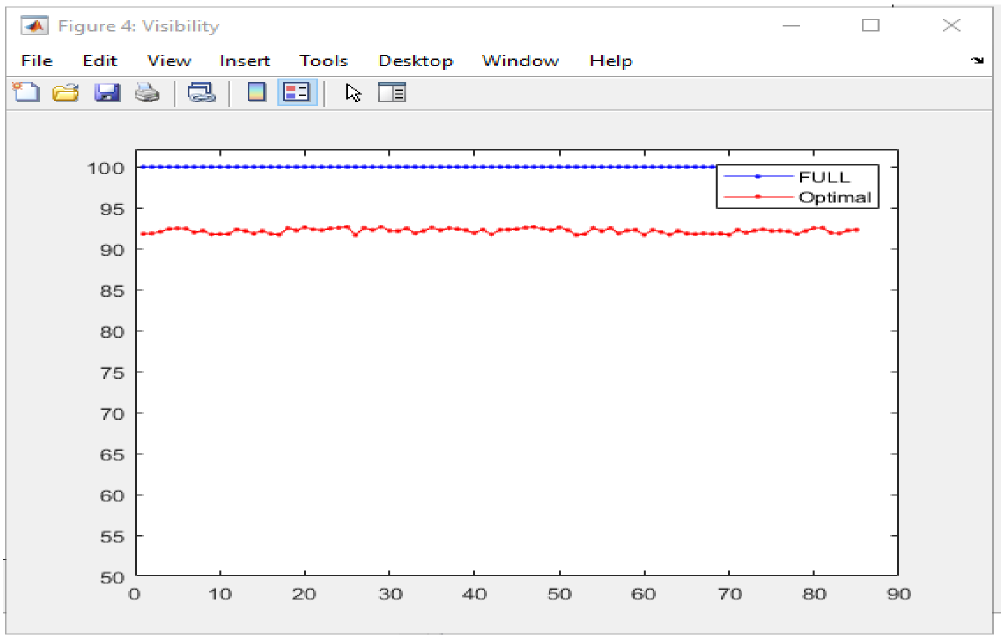

figure 6: Full and optimum visibility for street intervals 6 and the number of lights ahead is 5

Figure 6, which involve full and optimum visibility for street intervals, with 6 intervals and 5 lights ahead.

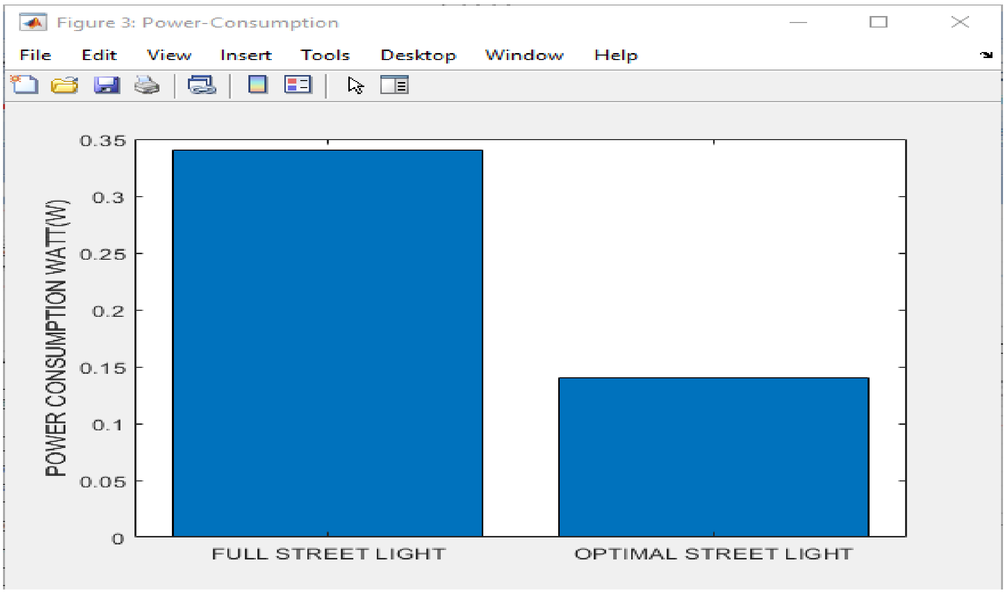

Figure 7: Power consumption for street intervals 6 and number of lights ahead 5

Figure 7, specifically regarding power consumption for street intervals with 6 intervals and a number of lights ahead is 5.

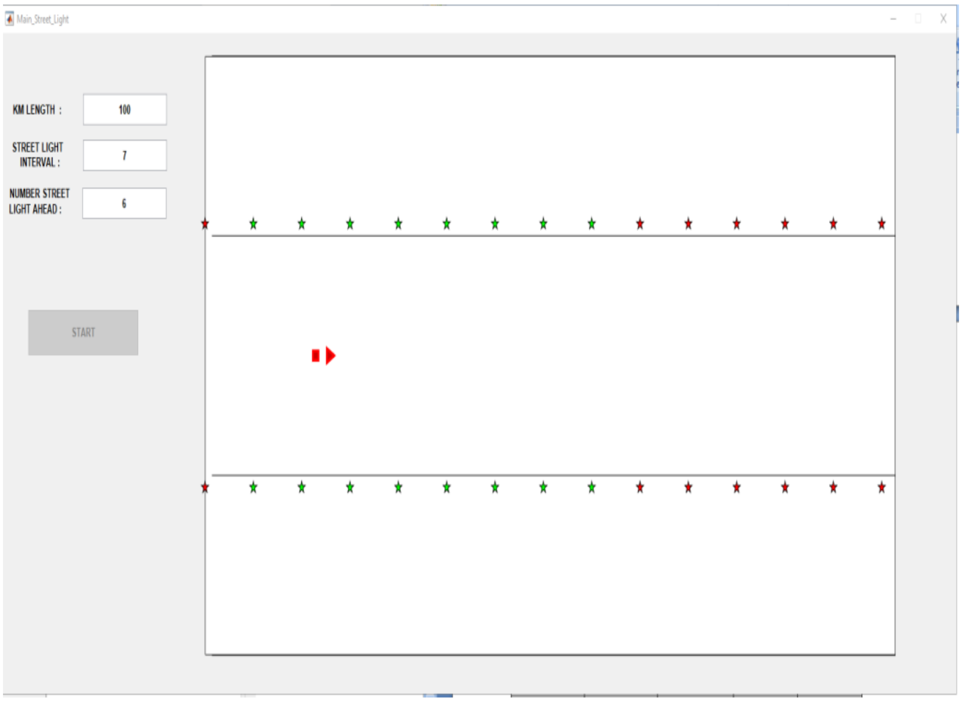

Figure 8: Street Light City Scenario 3

Figure 8, specifically concerning the street light city scenario 3,

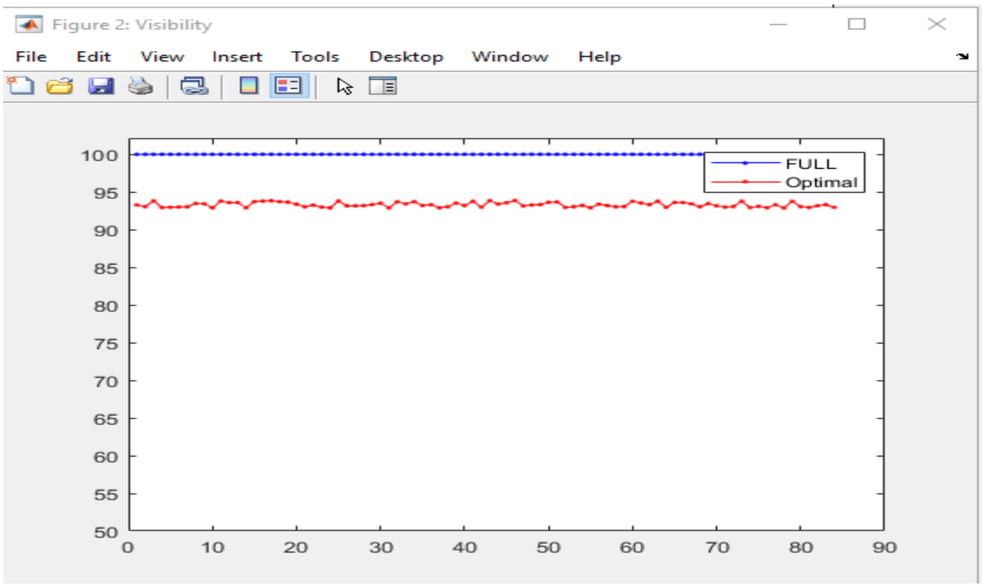

Figure 9: Full and optimum visibility for street lights intervals 7 number of light ahead is 6

Figure 9 illustrates the visibility conditions along the main street with a specific configuration of street lights. The street intervals are set at 7, with 6 lights positioned ahead. The color-coded scheme distinguishes between turned-on (green) and turned- off (red) street lights, providing a visual representation of their status during the simulation.

Figure 10: Power consumption for street lights intervals 7 number of lights ahead is 6

Similarly, figure 11 and Fig 12 shows different scenarios respectively.

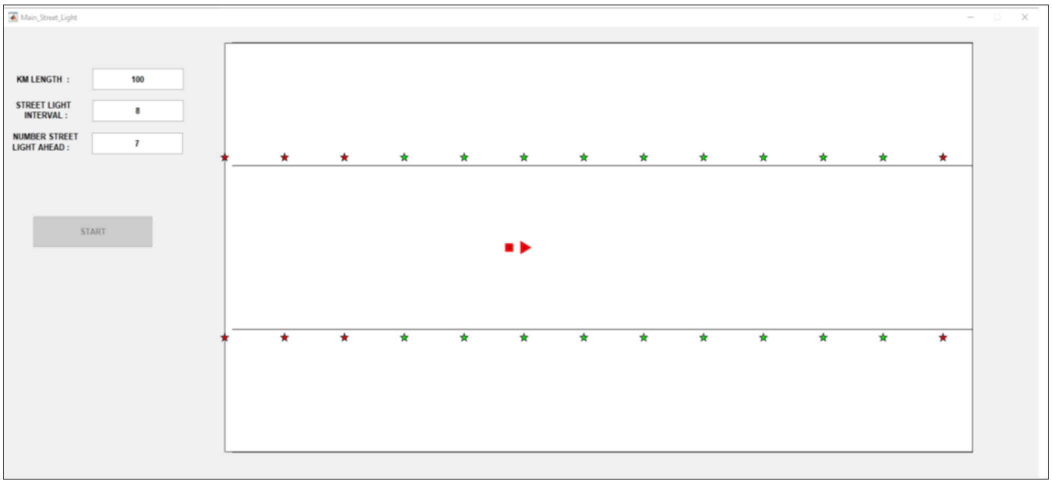

Figure 11 Street Light City Scenario 4

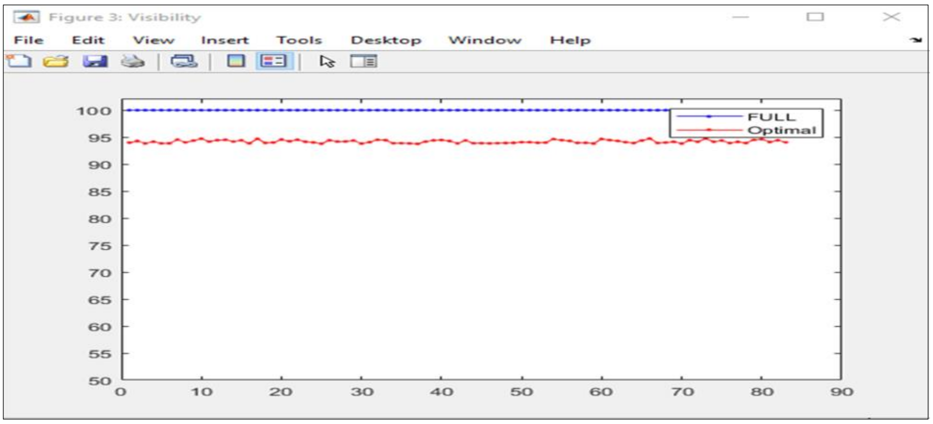

Figure 12: Full and optimum visibility for street lights intervals 8 number of lights ahead is 7

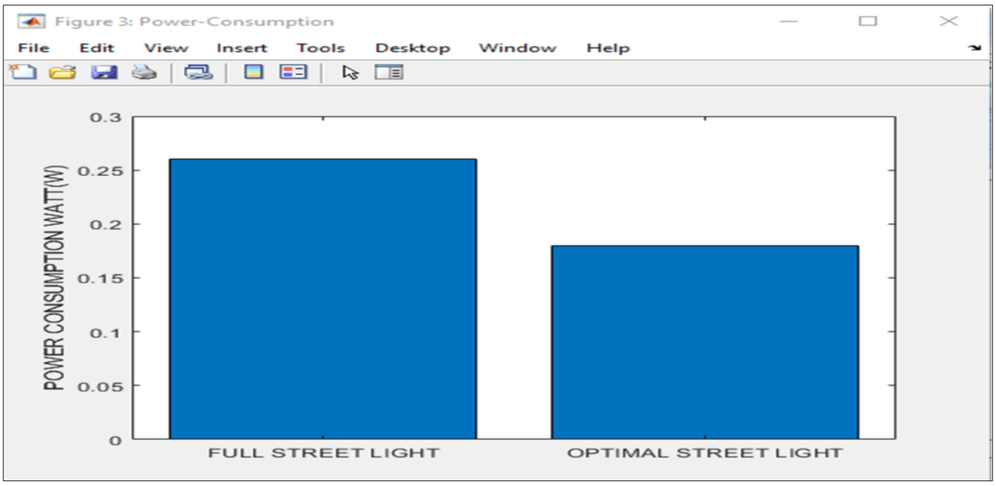

Figure 13: Power consumption for street lights intervals 8 number of light ahead 7

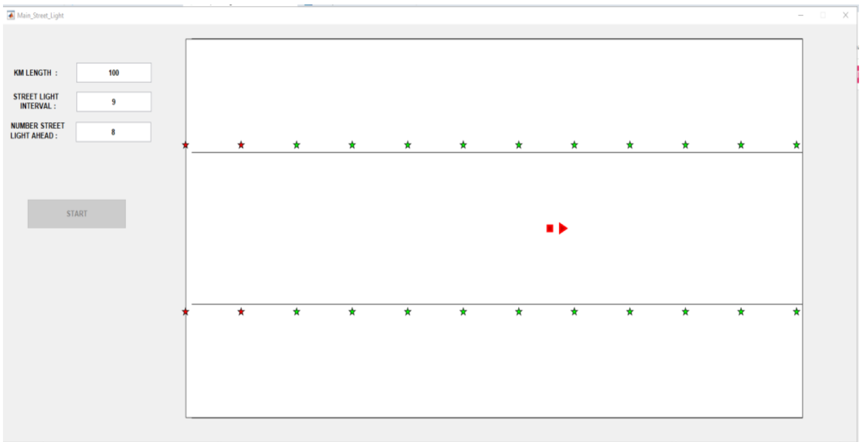

Figure 14: Street Light City Scenario 5

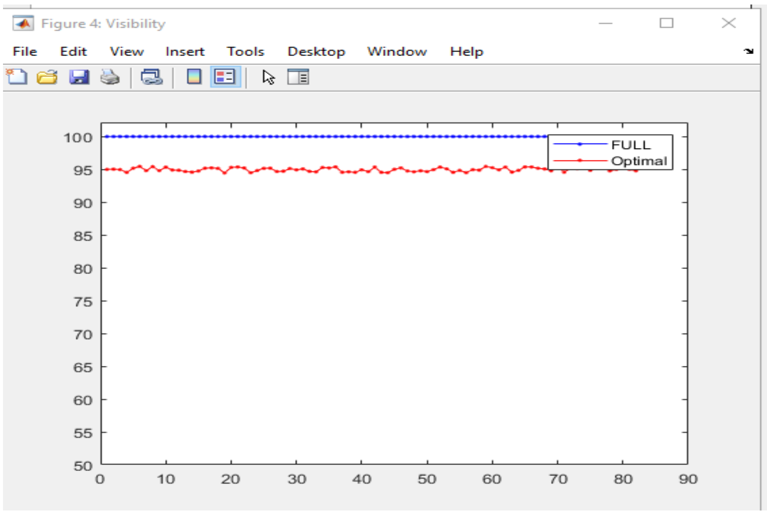

Figure 15: Full and optimum visibility for street lights intervals 9 number of lights ahead is 8

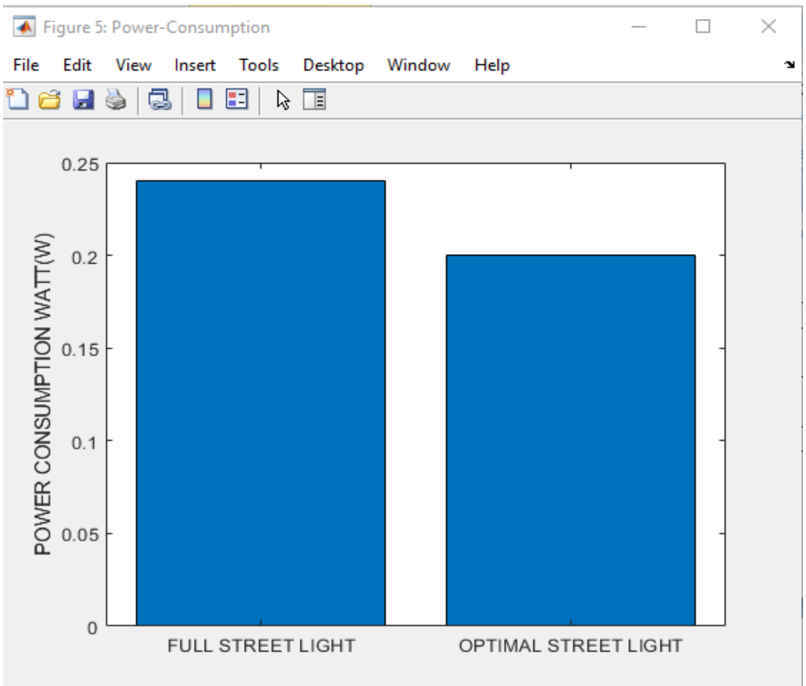

Figure 16: Power Consumption for Street lights Intervals 9 Number Of Lights Ahead is 8

Table 1: Comparison Of Full Street Light Power(W) And Optimal Street Light Power(W)

Street light intervals	Number of lights ahead	Full Street Light Power (W)	Optimal Street Light Power (W)	Total Power Saved (W)	Energy Saved (%)
5	4	0.42	0.12	0.30	71.4
6	5	0.34	0.14	0.20	58.8
7	6	0.30	0.16	0.14	46.6
8	7	0.26	0.18	0.08	30.7
9	8	0.24	0.20	0.04	16.6

Table 1 compares Full Street Light Power and Optimal Street Light Power at various street intervals with the corresponding number of lights ahead and the total power saved. The table illustrates the relationship between streetlight intervals, the number of lights ahead, optimal street light power consumption, and the total power saved. As the number of lights ahead increases, there is a corresponding increase in the optimal street light power. However, despite this increase in power consumption, the total power saved varies. This could be due to factors such as the efficiency of the lighting system and the optimization of power usage.

IV.CONCLUSION AND FUTURE SCOPE

The Smart Street Light System proposed in this study represents a significant leap forward in urban lighting efficiency and sustainability. By integrating Internet of Things (IoT) technology, the system intelligently adapts to ambient light conditions, traffic patterns, and pedestrian activity. Each street light is equipped with IoT-enabled sensors, forming a network that communicates with a central control system. This system dynamically adjusts the brightness of street lights based on real-time data, optimizing energy consumption and enhancing safety.

It provides a simulation and optimization tool for street light placement, considering factors such as street length, light distance, and the number of lights ahead. This tool aids in visualizing the power consumption implications of different configurations, promoting efficient urban planning. Demonstrates the energy-saving potential of the proposed system. As the street light intervals and the number of lights ahead decreases, the optimal street light power significantly reduces, leading to substantial energy savings. The system's ability to dim or turn off lights during low-traffic or well-lit periods contributes to reduced operational costs and enhanced sustainability.

Furthermore, a lot of work can be done to achieve a reduction in power consumption. Many aspects are interrelated to one another like the intensity of light being directly dependent on the distance between street lights, height of street lights, the wattages used by street lights, etc.

The IoT-based Smart Street Light System offers a comprehensive solution for urban lighting, addressing energy efficiency, cost-effectiveness, and environmental impact.

The energy consumption for street lighting is estimated to be about 30% of the total electricity consumption in any country [8]. The proposed methodology, supported by the simulation tool and data-driven control system, paves the way for smarter and more adaptive urban lighting infrastructure [9]. The potential benefits include significant energy savings, reduced light pollution, improved safety, and the ability for remote monitoring and management.

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