iMOST: An IoT Framework for Energy Efficient Street Lights

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***Abstract*—The amount of greenhouse gas emissions from streetlights is equivalent to 2.6 million cars with as many as 26 million streetlights in the United States. The proposed IoT controller integrates sensors to make these streetlights as hubs for smart environment monitoring with effective energy usage. Conservation of energy is one of the main concerns in the modern era, and energy coming from the sun can be utilized efficiently alongside a smart streetlight management system instead of conventional streetlight management techniques. Additionally, with streetlights being present throughout a city, the opportunity to collect city-wide weather data is proposed. To this end, a solar-powered IoT-based smart street lighting and environmental monitoring system is proposed. The proposed energy-efficient IoT-based system uses a microcontroller to control light-emitting diode (LED) streetlights depending on lighting conditions and vehicle detection, ensuring that the streetlights can be turned on when needed.**

***Index Terms*—smart lighting, smart city, IoT**

I. INTRODUCTION

The concept of a smart city is defined by several different elements such as good governance, mobility, economic stability, and energy efficiency which each play vital roles in the process of maintaining sustainable city life [1], [4]. According to the worldwide forecast report, the size and population of cities are increasing day by day. Without proper energy management, the ideal goals of a smart city cannot be realized. A smart city needs to be energy efficient, and technology, such as renewable energy, must be leveraged in a way that ensures the sustainable energy management of a smart city. Different interventions, such as solar gain factor, thermal transmittance, and dye solar absorbance coefficients, have been assessed as potential ways to increase building energy efficiency [2]. Other approaches involving solar energy include an IoT-based approach for solar energy power management using LoRa wide area networks have been proposed [3]. By combining renewable resource energy harvesting with smart street lighting control and weather monitoring, the main objective of this paper is to propose a framework for an energy-efficient streetlight control and environmental monitoring system.

II. SYSTEM LEVEL OVERVIEW

For this research, an IoT smart streetlight control and weather monitoring system are being proposed. This design combines two major aspects of prior smart city applications: smart street lighting control and environmental monitoring while offering an expandable framework that can support future sensor integration. Additionally, the proposed system incorporates motion detection to detect the presence of vehicles and save additional energy by switching off lights when there are no vehicles. To further increase the system's energy efficiency, a solar panel and integrated battery are also included to power the streetlight, microcontroller, and connected sensors. All these subsystems will be integrated into the final system, providing a unique proposal of effectiveness.

A. *Proposed framework for smart street lighting*

The proposed method, outlined in Figure 1, provides the solution framework for a workable and efficient solution for streetlight control, automation, and weather monitoring. The system consists of an LDR, an RCWL-0516 microwave motion sensor, a DHT11 temperature-humidity sensor, relays, a solar panel, an integrated battery, and a web interface for system monitoring and control. In terms of control and networking, the design makes use of a Wi-Fi-capable ESP8266 microcontroller module to operate the relays controlling the state of a streetlamp's LED bulbs. To achieve this, the module monitors the LDR and motion sensors to determine the exterior lighting conditions and the presence of passing vehicles to determine if the relays should be activated or not.

B. *Environmental monitoring and energy harvesting*

For each streetlight, a battery and solar panel charging system is included to further reduce system-wide energy usage

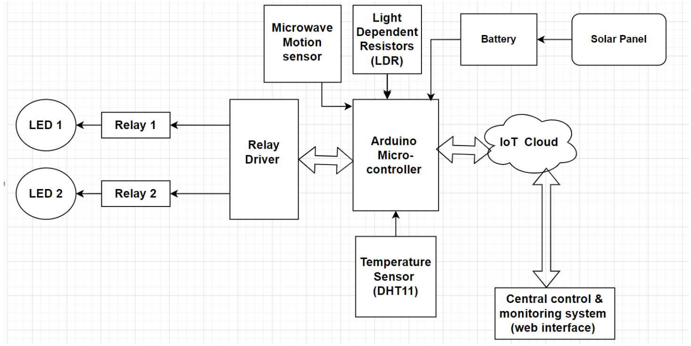

Fig. 1. Proposed iMost System Architecture

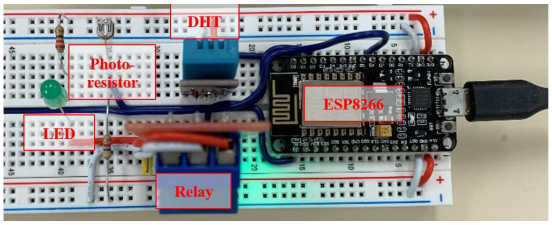

Fig. 2. Detailed streetlight controller prototype.

by leveraging environmental renewable resources. During daylight hours and favorable weather conditions, the solar panel will be utilized to charge the integrated battery. Then, during nighttime and unfavorable weather conditions, the streetlight IoT controller, and auxiliary sensors pull power from the battery for operational purposes.

III. IMPLEMENTATION RESULTS AND OBSERVATIONS

To test the proposed streetlight IoT framework, a prototype module for street lighting control was implemented as shown in Fig. 2. To test the framework, the ESP8266 module was programmed using the Arduino IDE with both the control code and the HTML code for the streetlight server. This was done for simplicity, but the HTML server code is easily portable over to an external platform (ex: Amazon Web Services, Microsoft Azure, etc.) and interfaced with GET and POST requests. During prototype bootup, the ESP8266 was connected to a selected Wi-Fi network (specifically a mobile hotspot during testing) using provided access credentials. Once the ESP8266 was connected, the streetlight control program began operating. In this program, if the voltage across the photoresistor/LDR, measured by the ESP8266's analog to digital converter, dropped below a certain threshold corresponding to low-light conditions, the relay controlling the state of the LED would be enabled through a digital output pin of the controller, but the relay would not be turned on or closed. Then, if the motion was detected by the motion sensor, the relay would be turned on, or closed, and provide power to the connected LED. For testing, a single 3.3 V LED was used as shown in Fig. 2, but the utilized relay module was capable of switching AC voltages drawing up to a maximum of 20 A of current.

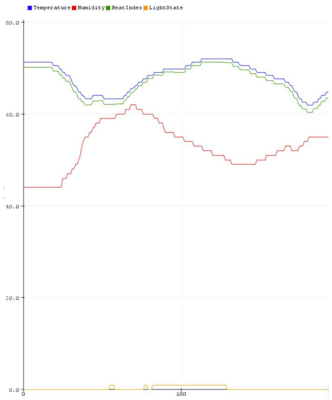

Fig. 3. Sample sensor temperature, relative humidity, heat index, and light state data graphs

The temperature data recorded from the system was accurate to within 2-5 °F of reported weather data. The temperature would noticeably drop in the event cloud cover reduced the amount of direct sunlight reaching the prototype, as expected. The recorded relative humidity data during testing was accurate to within 5-10 percent of reported weather data depending on the windspeed (lower windspeeds resulted in lower variance in the humidity readings). During additional outdoor prototype testing, the microwave motion sensor was tested for its operating distance range. Without external shielding, this sensor was capable of 360° motion detection.

IV. CONCLUSION AND FUTURE WORK

As the smart city concept continues to be implemented, methods to improve the energy efficiency of existing city systems and data collection that benefits the users of these interconnected city systems will be necessary. To this end, this paper has laid out the proposal for an IoT-based controller for smart streetlighting and environmental monitoring that looks to reduce the energy consumption of city streetlight systems through adaptive control of LED-based illumination using external lighting conditions and vehicle detection.

REFERENCES

[1] G. Battista, L. Evangelisti, C. Guattari, C. Basilicata, and R. de Lieto Vollaro, "Buildings energy efficiency: Interventions analysis under a smart cities approach," Sustainability, vol. 6, no. 8, pp. 4694–4705, 2014.

[2] M. Mendez, J. Carrillo, O. Martin, C. Tchata, P. Sundaravadivel and J. Vasil, "EasyYard: An IoT-Based Smart Controller for a Connected Backyard," 2019 IEEE International Symposium on Smart Electronic Systems (iSES) (Formerly iNiS), 2019, pp. 257-261, doi: 10.1109/iSES47678.2019.00064.

[3] J. Wang, "Zigbee light link and its applications," in IEEE Wireless Communications, vol. 20, no. 4, pp. 6-7, August 2013.

[4] M. S. Ahmed, R. Mukherjee, P. Ghosh, S. Nayemuzzaman and P. Sundaravdivel, "FPGA-based assistive framework for smart home automation," 2022 IEEE 15th Dallas Circuit And System Conference (DCAS), 2022, pp. 1-2, doi: 10.1109/DCAS53974.2022.9845625.