Design of Web Control for Smart Streetlight System based on Supercapacitor

Cheska Abarro, Alexander Pascual, Jeong-in Kim, Angela Caliwag, Wansu Lim

Kumoh National Institute of Technology, Department of Aeronautics, Mechanical and Electronic Convergence Engineering

wansu.lim@kumoh.ac.kr

Abstract

In smart cities, smart streetlight is on the common feature in smart technologies. Despite several research efforts to develop and improve smart streetlight scheduling systems, streetlight is still prone to overcharging and excessive power usage due mainly to inefficient on/off scheduling. A discharging approach is developed in this paper to give an accurate streetlight discharging schedule while potentially reducing excessive power use. In this paper, a web-based control approach for smart streetlight scheduling is developed. The developed web-based control system allows the user to personally be able to control and set the discharging scheduling of smart streetlights wirelessly. The proposed system utilizes MeeusJs in determining sunset and sunrise time of the day. The determined time are then used for the scheduled on/off discharging of smart streetlight. Simulation shows that the proposed system is able to allow the user to wirelessly control streetlight autonomously. In addition, the proposed web-based system is able to provide a real-time wireless monitoring of smart streetlights. Simulation shows that the proposed web-based autonomous discharging scheduling control is able to control the smart streetlights wirelessly.

Keywords— smart cities, smart streetlights, web control

Ⅰ. INTRODUCTION

According to [1], 54% of the world's population currently reside in urban areas as of 2021 and it is predicted that nearly 70% of the world's population will reside in urban areas by 2050. To deal with the adverse effects of the increasing population, the transition of city to a smart city is needed to make urban areas more sustainable. So, the demand for smart cities integrated with internet of things (IoT) is expected to increase due to the factors of rising population and necessities but limited natural resources. IoT refers to "things" or technologies that are connected to the internet to transmit and receive data. IoT enables users to connect to everyday objects to the internet via various embedded devices. For instance, a simple light bulb ntegrated with necessary sensors and drivers can be turn "On" automatically based on the data collected by the sensors. One of the common uses of IoT is its integration in streetlights.

Streetlight is generally used to illuminate dark areas; thus, it must be optimal to provide a safe environment for pedestrians and drivers [2]. Traditional streetlights can fulfill this function. However, there are issues beyond ensuring the optimal operation of streetlights like power consumption which can be solved by integrating smart systems to replace the traditional streetlights with smart streetlights. Smart streetlight uses technologies, such as sensors and actuators, to make traditional streetlights more intelligent. Since smart streetlights are now able to communicate to users wirelessly, researchers started adding more features such as monitoring of environmental conditions, environmental noises, air pollution, and luminance monitoring in the smart streetlight by collecting data from the integrated sensors. Aside from monitoring of environmental parameters, monitoring the performance of supercapacitor used in smart streetlight is a must. This is to protect the supercapacitor cells from overcharge and deep discharge which often lead to a massive degradation of the supercapacitor life [3]. Thus, this paper will provide real-time monitoring of supercapacitor parameters (e.g., voltage and current) that help in supporting the operation of smart streetlight. This paper is able to provide real-time monitoring by automatically syncing the collected data to the web-based monitoring system. The proposed monitoring system reduces the cost of maintenance and provides a low-delay and real-time monitoring system for smart streetlight applications.

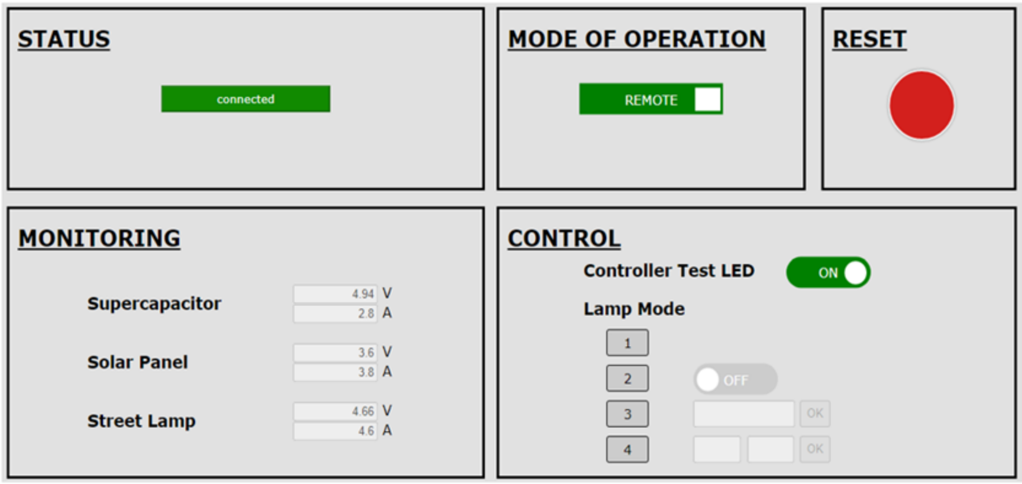

Figure 1. Web-based smart streetlight control

Ⅱ. METHODOLOGY

This paper utilizes a web page graphical user interface to control and monitor the proposed smart streetlight system, as shown in Fig. 1. In this section, the overview of the proposed web-based management center is discussed. In this study, a web-based management system that can control and monitor the proposed smart streetlights has been developed. The streetlight is composed of a solar panel, a supercapacitor, a lamp, a controller, and a Wi-Fi module. The purpose of this paper is to illustrate how to wirelessly monitor and operate streetlights using microcontrollers (MCUs) via a web-based user interface integrated in the cloud. Texas Instruments C2000-F28379D and CC3220SF are used to acquire data parameters from streetlights for data monitoring tasks and to receive control signals from the webpage over the Wi-Fi network protocol. To monitor the state of the streetlight, these data parameters include the voltage and current of the solar panel, supercapacitor, and lamp. The collected data will be transferred to a database and updated, which will then be shown on a webpage for monitoring the status of each streetlight. Furthermore, the user can control the streetlights remotely through the web-based interface by (1) turning them on and off and (2) scheduling when they are on and off. Furthermore, implementing the proposed system in the cloud enables massive data storage capacity, increased computing power, and increased system security. Advanced and complex methods and controls are easier to implement with these cloud-based functionalities.

The smart streetlight is connected to the Amazon Web Services (AWS). AWS is designed to be the most flexible and secure cloud computing platform available today. Its core infrastructure is made to fulfill the security needs of the military, global banks, and other high-risk businesses[aws]. Once the data from the proposed smart streetlights has been successfully stored in the AWS, the smart streetlight and its data can now be accessed by the management center. In the management center, the users can monitor the acquired data such as supercapacitors parameters (voltage and current values). Aside from monitoring the data, the management center can also control the smart streetlights by sending data or actuators values that can be used to control the proposed smart streetlights.

The streetlights management center which includes sections such as the mode of operation section, status section, reset, monitoring section and control section. First, the web-based management system status can be controlled by the user using the mode of operation section. As illustrated in the section, it has a toggle button that can be controlled to remote and local. Second, the display of this selection can be seen in the status section. The status section determines if the webpage and streetlights are connected by turning the word "connected" to green in the status section if the user has set the method of connection to "remote.". Third, reset section is just used for resetting the mode selected back to default. Fourth, the monitoring section shows the real-time display of the supercapacitor, solar panel and streetlights voltage and current values. Lastly, the control of the streetlights based on modes 1, 2, 3 and 4, the toggle button and time are illustrated in the control section. The details of the control section will be discussed in the end of this section.

In this section, the user can choose between modes 1, 2, 3 and 4 without using the rotary switch embedded in the controller of the smart streetlights. In this study, the modes that will be discussed in this section are based on time acquired by web-based API called MeeusJs. MeeusJs is an implementation of some algorithms of the Book 'Astronomical Algorithms of Jean MeeusJs in JavaScript. The library may be used to compute the locations of the sun and moon, as well as their phases (rise, transmission, and set), with great precision. MeeusJs can predict sunset and sunrise time with great accuracy due to its algorithm in time calculation. The sunrise and sunset time for web-based wireless control used MeeusJs API where it computes the sunrise and sunset time locally.

The pseudocode for sunrise and sunset time calculation is shown in Algorithm 1. At the start of the process, the MeeusJs API will first need to get the Julian day and store in a variable as shown Algorithm 1 (line 1). The Julian day is the continuous count of days since the start of the Julian period, and it is mostly used by astronomers and in software to simply calculate the elapsed days between two events. In order to get the sun and moon time, the MeeusJs API calculates the current data and the Ecuador coordinates of my desired location for the smart streetlight as shown Algorithm 1 (line 2). The coordinates declared in the coords are the coordinates of Gumi, South Korea. These coordinates will be used to calculate the sunset and sunrise Ecuador of the sun based on Korean coordinates. Then, as shown Algorithm 1 (line 3), it will acquire the current date and compare it to the first saved epoch time that started on 1990s. Both epoch time and the coordinates will undergo of comparing it to the previous epochs and sun location saved in the API, specifically the time in Julian day. After that, Algorithm 1 (line 4) will calculate the sunrise time. In order to acquire sunrise time, the acquired sun time will then be subtracted to 54,000 (second in 24 hours) in order to get the sunrise time of the day. On the other hand, Algorithm 1 (line 5) for the sunset to be calculated, the acquired sun time will then be subtracted to 32,400. 32, 400 refers to the seconds within 9 hours. I used the value of 9 hours because Korean time is using GMT +9. Thus, the acquired sun time must be subtracted to 9 hours in order to get the sunset predicted value. Algorithm 1 (line 7-9) gets the predicted value of hour, minute, and second of the predicted sunrise time as substring while Algorithm 1 (line 10-12) gets the predicted value of hour, minute, and second of the predicted sunset time as substring. Once all the substrings are all acquired by their respective variables, Algorithm 1 (line 15-16) will set that acquired substring as the final predicted hours, minute, and seconds for sunrise. The same process also happens on Algorithm 1 (line 17-19) it will set that acquired substring as the final predicted hours, minute, and seconds for sunset. Lastly, the final acquired predicted time will be converted to epochs. Once the epoch of the current date has been compared with the saved epochs and coordinates, it will now predict the time of sunrise and sunset with more than 95% of accuracy. The time predicted will be used as the sunrise and sunset time of the web-based wireless control and will used as time basis for the chosen modes. This method is able to get the current day's sunrise and sunset as well as predict the next day's sunrise and sunset time accurately.

The developed web-based discharging control center can provide accurate time prediction and acquisition of sunset and sunrise time that is used for autonomous control and scheduled discharging of smart streetlights system. In addition, this paper is able to provide a implementation of the discussed web-based control c enter and smart streetlights system.

Ⅲ. CONCLUSION

In this paper, a smart streetlight management system with control and monitoring functionalities integrated in cloud is proposed to ensure optimal streetlight performance while reducing power consumption through a web-based user interface. Furthermore, the user can remotely access the webpage to control how the streetlight would work depending on the user's needs (turning ON/OFF, ON/OFF time scheduling, and dimming lights). Additionally, a high-level, low-cost, low-power management Wi-Fi module is used to minimize the delay in both monitoring and controlling the streetlights. Compared with onboard management systems, integration in cloud has higher computational power, enormous data storage capability, and higher system reliability which helps to ensure optimal streetlight performance.

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