***IJACSSE**Journal- International Journal of Advanced Computer Systems and Software Engineering*

E-ISSN: 2716-5256 online

SMART STREETLIGHT SYSTEM USING IOT PLATFORM

Mohamad Faiz Md Jamin[b], Mohd Helmy Abd Wahab[a,d], Norhafizah Ismail[c], Radzi Ambar[b], Muhammad Mahadi Abdul Jamil[b]

[a] *Advanced Telecommunication Research Center, Faculty of Electrical and Electronics Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia*
[b] *Department of Electronics Engineering, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia*
[c] *Department of Information Technology and Communication, Politeknik Mersing, Johor, Malaysia*
[d] *Center of Excellence on Advanced Computing (ADVCOMP), Universiti Malaysia Perlis, Perlis, Malaysia*

* *Corresponding author: author@xxx.xxx*

ARTICLE HISTORY
Received: 9 March 2021
Accepted: 5 April 2021
Published Online: 29 April 2021

KEYWORDS
IoT platform
MQTT protocol
Node-RED application

ABSTRACT

Maintenance of broken streetlights is crucial to ensure safety and convenience among road users. Most of the broken streetlights were maintained by the authorities depending on the receipt complaints from users, especially in the village area. The analysis is required to improve the quality of existing street lighting maintenance services such as the development system that can detect and store data of broken streetlights. Therefore, this system is developed to detect broken streetlights using an Internet of Things (IoT) platform. The main objective of the development is to design a wireless notification system to check the status of streetlight. In this project, the Light Dependent Resistor (LDR) sensor reads light intensity values and transmit them to Node-RED applications using the Message Queuing Telemetry Transport (MQTT) protocol. The MQTT broker connects between the sensor and Node-RED applications using Wi-Fi. The Node-RED application becomes a programming tool for integrating hardware devices with database systems. A database system stores streetlight information such as identification number, streetlight location, and streetlight status. The system can be accessed through the login authentication system. To sum up, in future, utilisation of antenna of Wi-Fi needs to be considered to improve the coverage and strength of Wi-Fi signal.

Keywords ; Smart Streetlight System, broken streetlights, wireless notification system, database

1.0 INTRODUCTION

Smart cities and green technology have become one of the world agendas in preparing for a better use and needs to address urban issues. The issues of population growth, crowding, and traffic congestion using communication and network technologies are pertinent to take into consideration in smart cities enabling technology (Ejaz, Naeem, Shahid et al., 2017; Gharaibeh et al., 2017). Previous streetlight designs ignored the importance of environmental issues such as carbon dioxide emission in its implementation. In this regard, the pollution could occurs and yields negative implications to the world (Yusoff et al., 2013).

Many methods have been used in the previous research to develop systems to detect faulty streetlights in the world. The practice of passive infrared sensor is important to provide safe night time surroundings to the road users (Ramli, Yamin, Ghani, Saad & Sharif, 2015). Moreover, the consumption of solar powered streetlighting system has contributed positive implications to decrease air pollution (Ramachandran, Ponnusamy & Zaman, 2016). In Vietnam, the application of LoRaWAN Streetlight technology has nurtured awesome features as anti-obstruction with low power consumption and publicize spectrum applied to ensure effective streetlights maintenance and security features (Tung, Huy, Phong, Huy & Tuyen, 2019). Malaysia already has a method used to monitor street lighting systems using iSCADA Streetlighting, Monitoring, Alerting, and Control (iSMAC). The iSMAC system developed by Devices World Sdn.Bhd provides real-time monitoring and an overview of the streetlight feeders.

The streetlight allow users to drive at night in helping users determine the efficiency of sight while driving vehicles and safe for users to stop on the roadside in case of vehicle damage. Lately, broken streetlights have caused fatal accidents to consumers (Kuzlu, Pipattanasomporn, & Rahman, 2018).

Delays in maintaining streetlights have caused can further endanger users who use the road. Research had found that driving in a dim environment could endanger road users through road user performance and safety aspects (Foties & Gibbons, 2018). The authorities rely on complaints from consumers to report faulty streetlights.The paper promoting the proposed solution to develop a system that can integrate the hardware and software using Internet of Things (IoT) platform that transmit data to the server containing the database system for data storage to the authorities using environmentally friendly components.

2.0 LITERATURE REVIEW

At the beginning, streetlight illuminate the streets and surroundings of the city at night throughout the day. Streetlights are also had a positive impact on the users through road decoration and play an important factor in the rate of decline in road accidents (Chunguo, Dongmei, Deying, 2007). At the outset, the streetlight is switched on and off by manual operation procedures. When dusk streetlights are switching on at dawn, it is switching off. Then, the smart controller was used that can automatically switch streetlights on and off according to sunrise and sunset based on the surrounding light intensity rate.

Due to the current urban development had conducted various studies on street lighting by following the lighting installation plan to optimize its use. For instance, lighting in a public place is often the main route of residents and areas that are focus of users in public places (Harshitha et al., 2017). Various changes occurred encompasses the development of street lighting technology from the past until now to produce more environmentally friendly street lighting technology.

Modern cities have become intelligent and more efficient in many aspects due to the development in information and communications technology (ICT). In this regard, alteration were being made to reach smart cities with the application of smart appliances. The adoption of smart devices that were significantly correlated indicates the availability of technology required to cope with shift and necessitate high costs (Mohanty, Choppali, & Kougianos, 2016). The development of urban analytics uses data collection and dissemination methods to gather usage information involving the use of smart services in urban areas. The process of data operation has two categories which are identification and sensing in IoT data collection. The IoT objectives perform as an innovation that were structured while customer-oriented smart city has offered advance service (Paskaleva & Cooper, 2018). Thus, customer-oriented smart city is crucial to modern cities' implication with each moving towards each other.

IoT allows devices to communicate together with different devices using different technique such as ubiquitous computing, embedded devices and sensor networks. IoT was a way to make much traditional communication approaches "smart" (Al-Fuqaha, Guizani, & Mohammadi, 2015). IoT requires cloud technology to store data collected from sensors. Therefore, the rapid development of cloud technology in the last few decades has increased the storage capacity and processing efficiency of sensors processing to obtain good outcomes and in line with this project. The IoT-based system in this also commensurate with previous project which had integrated web servers and databases with a sensor that reads data from the environment using the IoT platforms (Syafrudin, Alfian, Fitriyani & Rhee, 2018).

The IoT data collection has two methods by identification and detection. The identification process could be a procedure of recognizing the location and network objects ID. The sensing or detection process uses sensing devices for data collection such as actuator, smart sensor, wearable sensors, and smartphones.

This project uses streetlights that use a network of wireless sensors. The technology that can connect the information world with the physical world without borders was a wireless sensor network. A wireless sensor network system consists of sensor nodes and the internet or user information and computer transport networks. Sensors along with the use of wireless sensor network (WSN) can increase the physical world's effectiveness in the digital world because the real world automatically responds to the digital world through wireless technology. WSN provides wireless sensors to the Internet that create a sensitive and responsive electronics environment that can accelerate data transmission.

Light-emitting diode (LED) streetlights were introduced worldwide to benefit the population with their high efficiency, long-life, and cost-effectiveness from LED light sources. It also provides an opportunity for further lighting, which will provide infrastructure saving through dimming and adaptive light controls (Wood et al., 2018). This chance was the beginning of the use of streetlight LEDs in the largest cities of the world. LED technology could have a psychological impact on road users. It could also increase the alertness of street users who used it and provide a high sensed of self-safety to the public.

Street lighting monitoring to ensure that the street lights on at night by developing a notification system using the IoT platform that can detect broken streetlight. In 2015, Los Angeles declared a concept to attach all urban LED streetlights by the network systems (Sun et al., 2019). All streetlights to be introduced with mobile communication chips in order that it could connect via GSM or GPRS

(Bezbradica & Trpovski, 2014). There were many research have been done but improvement can still me made in certain aspects. This research proposed a system that can help to detect the condition of broken streetlight using the IoT platform.

3.0 METHODOLOGY

The project consists of two parts that are a software development and hardware development. In hardware development, Light Dependent Resistor (LDR) as a sensing element and Node MicroController Unit (MCU) acts as a microcontroller. LDR as a sensor that could detect broken streetlights. Node MCU ESP8266 was in control of all components and as wireless communication. Wireless communication to transmit data from the LDR sensor to the Message Queuing Telemetry Transport (MQTT) broker.

A database had been developing to store data for client information and authorized person. The database server had been developing and had information that needs to be filled in, such as streetlight name using a streetlight identification code. Only the database server could change all the information in the database system. The client only could view the webpage of the database system and know the status condition of a streetlight.

The computer acts as a web server that stores web server component files like Hyper Text Markup Language (HTML) documents, PHP files, and JavaScript files. Turn on the phone hotspot to connect NodeMCU ESP8266 with a computer. The LDR sensor transmits data wirelessly to the computer and the computer requests to the database server. After that, the database server responds to the message, and database updates the status of streetlight.

Figure 1 shows a flow chart for initializing NodeMCU ESP8266 to sensor reading from LDR sensor. After that, connect the NodeMCU ESP8266 to MQTT broker and transmit data to the database system.

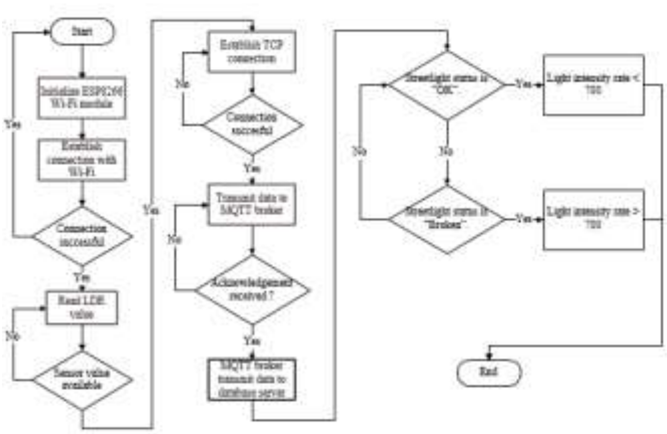

Figure 1. Flowchart for smart streetlight system

Figure 2 shows a block diagram that tells the whole process in this system. The process description of smart streetlight system works by connecting from hardware to database management system.

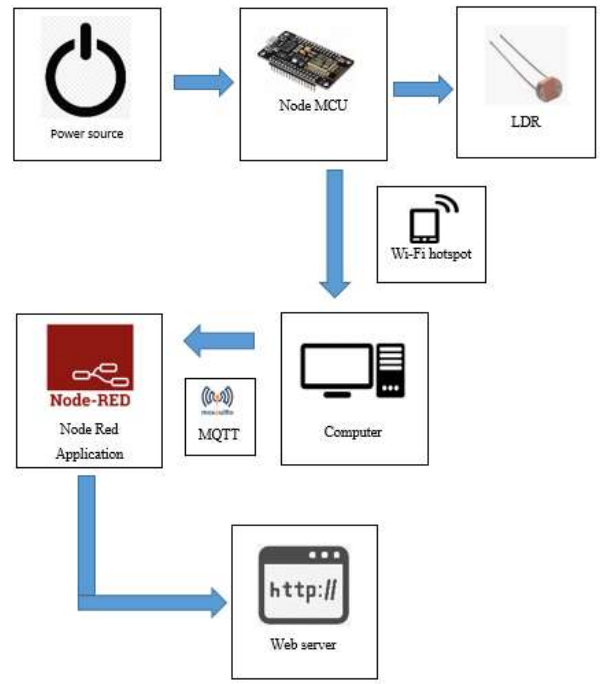

Figure 2. Block diagram for smart streetlight system

3.1 Hardware development

Hardware development involving sensors for detector devices and wireless modules to connect to the web server. Both of these components were important for data transmission on the database system.

The components used were light dependent resistor (LDR) and NodeMCU ESP8266. The LDR was a streetlight sensor that checks the status of the streetlight. This project had selected this sensor as a component to detect light intensity rates.

LDR provides a large change in resistance for changes in light level. It was very sensitive to the presence of light. Therefore, this component acts as a light intensity detector on streetlights to transmit data to the database system.

Table 1. LDR specification

Parameter	Description
Maximum operating voltage.	Maximum voltage is 100V.
Resistance when illuminated.	A minimum and maximum resistance are given under certain light conditions.
Dark resistance	These may be specified after the given time because it takes a while for the resistance to fall.

This project requires a Wi-Fi module used to integrate the hardware systems to a database system. Therefore, NodeMCU ESP8266 used to connect between the two systems using wireless communication. It was also used as a microcontroller to control LDR.

Arduino software used to program the hardware system. The LDR was programmed to read light intensity level and the NodeMCU was programmed to connect between the hardware system and the IoT system using the MQTT protocol.

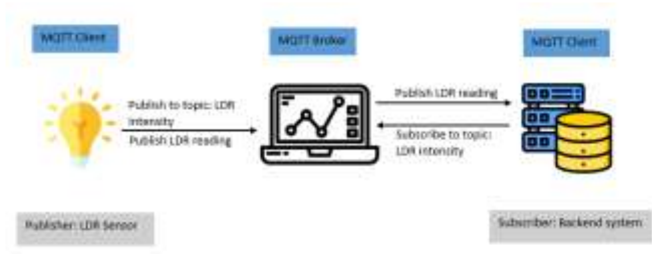

Figure 3. MQTT architecture

MQTT architecture in Figure 3 shows the integration of the hardware system and the database system. LDR sensor transmits the LDR reading value to the MQTT broker. MQTT broker connects to the Node-RED application using Wi-Fi to integrate hardware and software systems. In the Node-RED application, the MQTT brokers connected to the MQTT client that was the database server.

3.2 Software development

Software development had front-end and back-end development. Front-end development was a web server that displays data to the public. The other was back-end development that requires system to store data such as a database system and Node-RED application.

3.2.1 Front-end development

Front-end development was web server development. A webpage was often used to provide information to the user. The webpage used dynamic webpage development that used low-level languages like HTML and JavaScript.

There were two forms in this web server development. The first from was the user interface contains information to enter as seen in Figure 4.

Figure 4 shows the web server interface of the system. There was an instruction to notify users to login into the system. This project featuring "Welcome to Smart Streetlight System. Please login to the system". Specify labels for user information such as usernames and passwords. Besides, the login button works for the user able to enter the second form of the web server.

Figure 4. Web server first form

The second from of the web server was database information for the street lighting systems. This form contains information related to the streetlight lists. The system displays the user's identification numbers, location, status, and date to the users as shown in Figure 5. All streetlight location data available in the database were dummies data. There were some elements that users need such as adding streetlights, refresh, and the logout button.

Figure 5. Web server second form

3.2.2 Back-end development

Back-end development was database management system. The database system was used to store data. The data was stored on the database server using phpmyadmin. The database also had two categories of data stored. First, protected data for user authenticity. The other was to insert data in the list of streetlights.

In order to maintain the authenticity of the users who used it, data needs to be protected to ensure that only the right users could enter the webpage. Management determines the usernames and passwords to this system to allow only selected users to enter the system.

Figure 6 shows the algorithm used for login authentication. When the user enters the data in the login and password. The user submits this from by clicking the login button. If the usernames and password were correct. Users can enter in the database system.

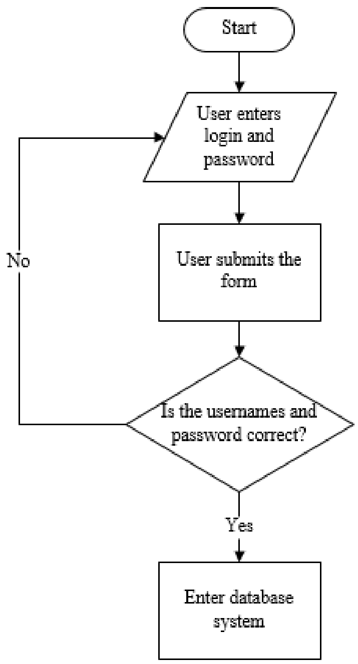

Figure 6. Login authentication algorithm

Figure 7 shows the processes in the database system. The database system allows the database server to insert the information provided. The provided information in this project was ID number, location, and status. Verification of data in the system according to the settings made by the server. The stored data remains in the database.

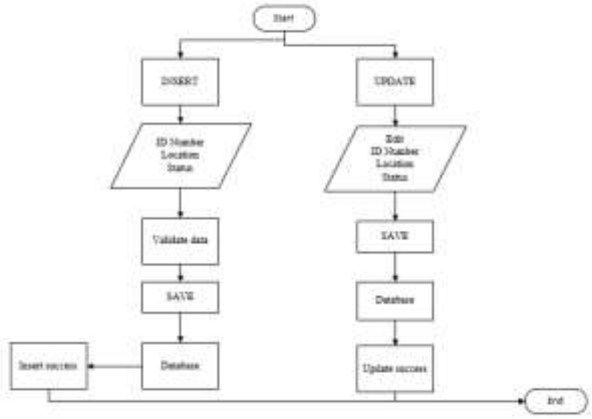

Figure 7. Databases process algorithm

4.0 RESULTS AND DISCUSSION

Each component performs a test before using it to develop a project. This project requires Wi-Fi to integrate the hardware and database system for data transmission. After testing each component, making a prototype to test the entire system for testing the effectiveness of this project was working.

4.1 Testing component

Component testing was important to make sure the component were in the best conditions. NodeMCU ESP8266 and LDR uses simple source code testing. The purposes of this test for components can work well before performing the next step.

4.2 Testing MQTT

MQTT test to ensure MQTT brokers could communicate with MQTT clients via wireless communication. Test using led control through LED turning on and off operation. The MQTT broker connects with input. After that, connect the MQTT broker with Node-RED application. MQTT client received data from Node-RED and it responds. MQTT client sends back a response to MQTT broker to publish in Node-RED application. Figure 8 shows a dashboard that had on and off buttons to control the LED.

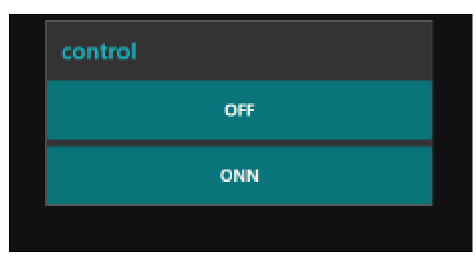

Figure 8. Node-RED dashboard

In a context of Node-RED controlling LED, there are two conditions involved which are on and off. The different implications of these condition are depends on the button installed on the dashboard and LED roles as shown in Table 2.

Table 2. Node-RED controlling LED

Condition	Figure	Explanation
ON 	 **Figure 9.** Turn on LED	Turn on the LED by pressing the turn on button on the dashboard, The LED turn on.
OFF 	 **Figure 10.** Turn off LED	When pressing the turn off button on the dashboard, so the LED was turned off.

4.3 Testing Wi-Fi

Wi-Fi testing determines the device's accessibility level to determine the extent to which the sensor can transmit data into the database system. Table 3 shows the normal condition of Wi-Fi accessibility.

Table 3. Normal condition

d (meter)	Signal strength (dBm)	Wi-Fi strength (%)	Explanation
2	-52	95	Good signal
4	-70	60	Moderate signal
6	-77	32	Weak signal
8	-82	14	Very weak signal

Wi-Fi strength levels measurement using Wi-Fi signal meter application. Table 4 shows the rainy condition of Wi-Fi accessibility.

Table 4. Rainy condition

d (meter)	Signal strength (dBm)	Wi-Fi strength (%)	Explanation
2	-70	60	Moderate signal
4	-77	32	Weak signal
6	-79	24	Weak signal
8	-84	10	Very weak signal

From comparison table, a graph of Wi-Fi accessibility was plotted. Figure 11 shows a significant difference between the normal and rainy condition.

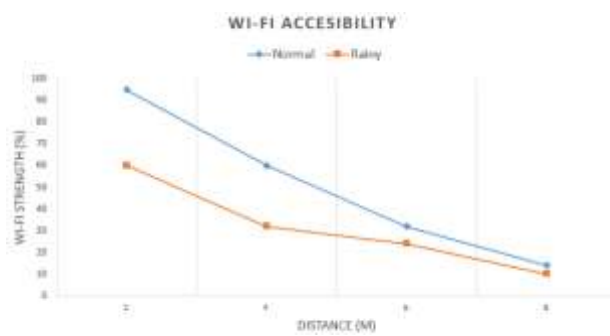

Figure 11. Wi-Fi access graph

In normal situation, Wi-Fi strength was high but it depends on the distance between the devices and the server. Within 2 meters to 4 meters, Wi-Fi strength was good and could transmit data to the server. At the distance of 6 meters, data could transmit but there was a delay in data transmission and sometimes data becomes inaccurate. However, at a distance of 8 meters, the signal was very weak and data transmission was not possible.

During the rainy situation, Wi-Fi strength becomes weak. At a distance of 2 meters, the Wi-Fi strength was moderate but could be for data transmission to the server. At a distance of 4 meters and onwards, the Wi-Fi becomes weak and it was not possible to transmit data from the sensor to the Node-RED application.

4.4 Database management system (DBMS)

The database systems could be inserted, update, and deleted the required data. Users could only view the displays on the web server. Database management inserts, updates and deletes data in this system.

4.5 Prototype

The prototypes used PVC conduit and polystyrene as seen in Figure 12. The LDR was a light detector sensor placed inside the prototype.

Figure 12. Prototype of PVC conduit and polystyrene

4.6 Project testing

Project implementation to integrate both systems. The system developed must be able to function effectively by performing various tests on it. Table 4 describes project implementation testing in different situations.

Table 4. Project implementation

Condition	Explanation
"OK" condition	Figure 13 on the condition of streetlights in good condition  **Figure 12.** Normal condition When LDR detects the light brightness, it transmits the data to the Node-RED application. Data transmission was two seconds. Every two seconds, the sensor transmits data to the Node-RED application. After that, the web server displays the streetlight status as "OK" as seen in Figure 13.  **Figure 13.** "OK" status
Broken condition	Figure 14 on the condition of streetlights in a broken state.  **Figure 14.** Broken condition LDR detects the light intensity rates. When the intensity rate of light was low, LDR transmits data to the database server as broken. After that, the web server displays the streetlight status as broken state as seen in Figure 15.  **Figure 15.** "Broken" state

5.0 CONCLUSION

This paper proposed a smart streetlight damage notification using Internet of Things (IoT) platform and database management system. The purposes of the development of smart streetlight system for the safety of user by using LDR sensors and database systems to detect broken streetlights. This system requires good internet access and good Wi-Fi signal strength to get accurate and correct results. Unstable Wi-Fi signal strength could affect data transmission to the database server. Therefore, this project is not suitable for development in areas with a weak internet connection. Thus, the future work should improve on Wi-Fi strength using an antenna to extend the coverage of Wi-Fi signal strength.

Acknowledgement

First of all, I want to express the deepest appreciation to my supervisor, Mohd Helmy Bin Abd Wahab for guiding me in completing this project. He had taught me to be patient and slowly find solutions in the challenges faced during the development of this project.

Besides, I am grateful to my family members for always supporting me spiritually to complete this project. Lastly, I would like to thank my friends always give me suggestions and advice when I needed.

References

A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of Things: A Survey on Enabling Technologies, Protocols, and Applications," IEEE Commun. Surv. Tutorials, 2015.

A. Gharaibeh, M.A. Salahuddin, S.J. Hussini, A. Khreishah, I. Khalil, M. Guizani, & A. Al-Fuqaha, "Smart cities: A survey on data management, security, and enabling technologies," in IEEE Communications Surveys & Tutorials, vol. 19, no. 4, pp. 2456-2501, 2017.

J. Chunguo, S. Dongmei, and G. Deying, "Design of streetlight monitoring and control system based on wireless sensor networks," ICIEA 2007 2007 Second IEEE Conf. Ind. Electron. Appl., pp. 57–62, 2007.

J. M. Wood, G. Isoardi, A. Black, and I. Cowling, "Night-time driving visibility associated with LED streetlight dimming," Accid. Anal. Prev., vol. 121, no. July, pp. 295–300, 2018.

K. M. Harshitha, L. Taranum, G. Mamatha, and K. V Divya, "Automatic Street Light Control, Fault Detection and Traffic Density Control," Int. J. Innov. Res. Comput. Commun. Eng., vol. 5, no. 5, 2017.

K. Paskaleva, & I. Cooper, "Open innovation and the evaluation of internet-enabled public services in smart cities," Technovation, 78, pp. 4-14, 2018.

L. F. Bednarski, B. T. Dodson, G. S. Domecus, A. Z. Levine, and M. G. Odiorne, "Case study analysis for the strategic implementation of smart street lighting in the linden neighborhood of columbus, ohio," the ohio state university, Tech. Rep., 2017.

M. Bezbradica and Z. Trpovski, "Advanced street lighting maintenance using GPS, light intensity measuring and incremental cost-effectiveness ratio," in Proceedings of the 2014 International Conference on High Performance Computing and Simulation, HPCS 2014, 2014.

M. Kuzlu, M. Pipattanasomporn, & S. Rahman, Assessment of communication technologies supporting smart streetlighting applications. In IEEE International Smart Cities Conference (ISC2) , pp. 1-7. IEEE, 2018, September.

M. Syafrudin, G. Alfian, N.L. Fitriyani, & J. Rhee, "Performance analysis of IoT-based sensor, big data processing, and machine learning model for real-time monitoring system in automotive manufacturing," Sensors, vol. 18, no. 9, 2946, 2018.

N. T. Tung, N.M. Huy, N.H. Phong, T.L.D. Huy, & N.D. Tuyen, "Development and Implementation of Smart Street Lighting System based on Lora Technology," In 2019 International Symposium on Electrical and Electronics Engineering (ISEE) pp. 328-333, IEEE, 2019, October.

N.L. Ramli, N.M. Yamin, S.A. Ghani, N.M. Saad, & S.M. Sharif, "Implementation of passive infrared sensor in street lighting automation system," ARPN Journal of Engineering and Applied Sciences, vol 10. No. 22, pp.17120-17126, 2015.

S. Fotios and R. Gibbons, "Road lighting research for drivers and pedestrians: The basis of luminance and illuminance recommendations," Light. Res. Technol., 2018.

S. P. Mohanty, U. Choppali, and E. Kougianos, "Everything you wanted to know about smart cities: The Internet of things is the backbone," IEEE Consum. Electron. Mag., 2016.

T. Ramachandran, V. Ponnusamy, & N. Zaman, "Solar Powered Smart Street Light with Maintenance Service System," In Biologically-Inspired Energy Harvesting through Wireless Sensor Technologies, pp. 102-120, IGI Global, 2016.

W. Ejaz, M. Naeem, A. Shahid, A. Anpalagan, and M. Jo, "Efficient Energy Management for the Internet of Things in Smart Cities," IEEE Commun. Mag., 2017.

Y. M. Yusoff, R. Rosli, M. U. Karnaluddin, and M. Samad, "Towards smart street lighting system in Malaysia," in IEEE Symposium on Wireless Technology and Applications, ISWTA, 2013.