IOT CENTRALIZED MONITORING SYSTEM FOR SOLAR STREETLIGHT APPLICATION USING MICROCONTROLLER WITH LORA

A Project Study Presented to the Faculty of

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In Partial Fulfillment of the Course Requirements for the Degree of

Bachelor of Science in Electronics Engineering

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ABSTRACT

Solar panels are now normal and used in many different industries, including street lighting. Despite these advancements, low efficiency remains a problem for solar street lighting. This study describes a LoRa wireless communication based IoT centralized monitoring system for solar streetlights in the Philippines. The technology intends to develop the community in the Philippines that has been utilizing conventional streetlights that frequently lack a monitoring mechanism. The system covers the monitoring of LED, solar panel, and battery using the current, voltage, temperature, and luminosity sensors of a standalone solar streetlight. LoRa wireless communication is used because of its long-range capabilities (up to 12 km) and low power consumption, and the Arduino Nano is used to gather and transmit data to the NodeMCU, which serves as the system's receiver or central server that provides data to a web-based interface to offer real-time monitoring of solar streetlight parameters such as current, voltage, temperature, battery SOH and SOC, and luminance.

In a result of LoRa network it has a delay of maximum 5-6 seconds in a range of 500m line of sight communication. The study attained an accuracy of 98.12% for monitoring test parameters. This demonstrates that the system is appropriate for integration with existing solar street lighting for an effective preventive maintenance schedule.

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CHAPTER 1

THE PROBLEM AND ITS BACKGROUND

This chapter describes the problem, background of the study, and setting to show how the research can be conducted. This contains the following sections: Introduction, Background of the Study, Research Gaps, Research Objectives, Significance of the Study, Scope and Limitations of the Study, and Definition of Terms.

1.1 Introduction

It intended to monitor some things to guarantee their long-term viability, whether manually or not. “In the case of failures or malfunctions, a monitoring system is software that assists system administrators in monitoring their infrastructure, such as devices, traffic, applications, and sound alerts” (Paessler, 2022). And technology has progressed significantly over time. The monitoring system has also been moved to the internet with the use of technology, notably the internet. “Monitoring is simple and convenient via the Internet of Things (IoT). Various research projects have been conducted in line with the monitoring system. One of them is the streetlight monitoring system. Once a typical streetlight is turned on, it stays that way until a worker turns it off” (Maguluri et al., 2017). In Li et al., (2022) gave emphasis on the STMF103 and LoRa-based smart streetlamp centralized control system, which combines wireless communication technology and Internet of Things design. The centralized control system uses the streetlamp's longitude and latitude as the fundamental conditions for switching the lamp in terms of controlling the streetlamp. To accomplish "on-demand lighting" and conserve a significant amount of electricity resources, it automatically adjusts the brightness of streetlights based on factors such as location, traffic flow, ambient brightness, and variations in parameters like particulate matter (Li, et. Al, 2022). On the other hand, traditional street lighting is one of the major causes of high energy usage. Additionally, it calls for increased administration and supervision. Because of this, several towns have switched to employing solar lamps to solve the problem, especially regarding climate change. Solar Street Lights are activated through photovoltaic (PV) panels that have a rechargeable battery that can be loaded with electrical power when a light source from the sun is detected (Industry Today, 2021). To ensure its sustainability, lots of monitoring systems were put in place. Most of these systems keep track of the solar panels' and battery's condition. A study shows the system monitoring the solar panel and battery status live online, and using GSM (Global System for Mobile), it indicates the detected fault in the system by sending an SMS to the maintainer (Bentabet & Sonaskar, 2019).

However, it is worth noting that previous studies lack the aspect of intelligent management where humans and computers interact with each other.

In aiding that gap, this study aims to design a real time centralization of the monitoring system where it can supervise the sustainability of the solar streetlights such as the voltage, current, temperature, luminosity, and the condition of the batteries itself that will be installed along the streets of barangay Saluysoy, Meycauayan, Bulacan, and to help the community with their problem of the absence of streetlights.

1.2 Background of the Study

Monitoring Systems is responsible for monitoring and controlling a company's technology (hardware, networks and communications, operating systems, or applications, among other things) to analyze its operation and performance. as well as detecting and warning about potential errors before they occur (PandoraFMS, 2022). Some of the benefits of having a Monitoring System include the ability to detect underlying problems before they have a negative impact, detect problems that affect a user's productivity, collect data when a problem occurs for the first time, and allow you to establish a baseline for comparison (IBM, 2022).

This study will include journals related to the advantages of having a Monitoring System to the whole Solar Streetlights but not limited to battery, LED, and the network to be used.

Traditional streetlamps are frequently operated in manual control mode, time control mode, or light control mode. Although each method of control has advantages, they all lack human-computer interaction and intelligent management. Furthermore, it is inconvenient for remote monitoring and management. The solar streetlamp system, which is based on GPRS and ZIGBEE technology, can not only set the lamp work mode, but also query the real-time operating state and fault conditions of streetlights (Hu et al, 2016). ZIGBEE oversees wireless assembly and gathering state information for transmission to the central node, GPRS sends remote state data to the monitoring and management computer. Finally, the monitoring and management software provides a human-machine management interface. Because of its low cost, high efficiency, and intellectualization (Su et al, 2012). In remote applications, wireless monitoring via a communication network and sensors is critical. The development of a health monitoring system for a solar lamp post will aid in data collection in the absence of personnel. The findings show that the end-user can view the health status of the post, including the battery, solar panel, and LED lamp, from any location if it is connected to the cloud (Catimbang et al., 2017).

An Internet-based monitoring system will allow multiple users to monitor the performance of the solar streetlights at various levels of the hierarchy, which is a significant improvement over existing monitoring procedures because information about the system is available to all and the possibility of missing critical fault warnings is reduced. Also, reduction of labor is offered by this kind of monitoring system as the maintenance details is sent real-time to the authorities (Madhan et al, 2014).

The battery to be utilized is a lithium-iron phosphate battery, which is one of the lithium-ion batteries that must be monitored for overheating and balancing. When it comes to temperature and nominal voltage, lithium-iron phosphate batteries have an operational limit. To prevent battery overcharge and over discharge, lithium-iron phosphate batteries must maintain the maximum nominal operating voltage with active balancing at 3.65V (Nizam et al, 2019). To avoid lowering cell effectiveness, the temperature must not exceed 40 degrees Celsius. Monitoring the temperature of lithium-iron phosphate batteries will prolong the battery life cycle and efficiency (Patel et al, 2010). In comparison to Sealed Lead-Acid batteries, these batteries take 12 to 16 hours to reach 100 percent capacity, which is an acceptable downside because solar radiation often lasts several hours during the day and the slow charge rate allows for efficient battery charging. Unlike lead acid batteries, lithium-iron phosphate batteries are regarded as more practical because they can be charged in less than an hour and have a higher nominal voltage. Lithium-iron phosphate is a better alternative for solar panel energy storage (Brasil & Melo, 2017). A Monitoring System implementation will detect the health of the lithium-iron phosphate battery in real-time.

Moreover, the main purpose of the Monitoring System is to display the status of the solar panels and batteries online, and the system also detects and reports faults in the system using GSM. This system has a dual advantage in terms of new energy utilization and energy savings. Also, it provides an efficient transmission and intelligent synthesis of the Internet of Things; the system can obtain real-time information about battery and solar voltage and then transmit it. (Bentabet & Sonaskar, 2019).

However, the parameters for Monitoring System in several studies that include ZIGBEE, and GSM have limitations. Some disadvantages of Zigbee include short range, low complexity, and low data speed, high maintenance cost, lack of total solution, and slow materialization, low transmission, and low network stability, are also some of its disadvantages that put it behind others. Zigbee is not secure like WiFi-based secured systems (ECSTUFF4U, n.d). The most significant disadvantage of GSM is that multiple users must share the same bandwidth. When there are enough users, the transmission may experience interference. As a result, faster technologies, such as 3G, have been developed on networks other than GSM, such as CDMA, to avoid such bandwidth constraints (Wheeler, 2019).

1.3 Research Gap

Various streetlights already use solar panels as source of energy, battery for energy storage and LED for illumination. Existing researchers are now including battery monitoring system and IOT application to make solar streetlight to make its maintenance much easier and to make it efficient and sustainable. The existing monitoring systems only show the status of solar panels and the charge and discharge rate of the batteries on web or on application. Some of the monitoring systems also lack long distance communication and centralization. Thus, this study will improve the distance for better coverage and adds centralization of the system. In addition to this, the proposed system has sensors to monitor the solar panel, power consumption on the battery and illumination of the LED.

1.4 Research Objective

The general objective of this research is to create an interconnected system that monitors parameters from streetlights and manages the real time data that is centralized wirelessly and is accessible through mobile applications or on the internet.

Specifically, this study also aims:

1. Development of the circuit design integrating the voltage sensor, current sensor, temperature sensor, luminosity sensor and the solar streetlight together with its algorithm for BMS.
2. Development of Centralized Monitoring device using the microcontroller together with the transmitter and receiver of LoRa.

3. Development of website for the centralized monitoring system with geographic location of each solar streetlights.
4. Test and evaluate the developed system from this research in accordance with the ISO 9126.

1.5 Significance of the Study

Because of poor illumination or the absence of streetlights, the findings of this study will address rural areas. The implementation of this study is critical to the development of new rural areas and for sustainability. Night illumination improves people's night lives in rural places while also ensuring their safety at night.

The administration of a specified local region which is called Local Government Unit (LGU) that is a subdivision of a larger governmental body. Each community has its own LGU. The LGU will make this study accessible to the community, particularly in rural areas.

The centralization of monitoring systems using solar streetlights has the potential for a successful start-up. The more centralized the monitoring system of streetlights is adapted, the more the community will develop and grow. This will be of considerable assistance in the development of communities, particularly rural areas.

In Sustainable Development Goals, this research will address objective 9 (industries, innovation, and infrastructure) throughout the world. Together with innovation and infrastructure, inclusive and sustainable industrialization may unleash dynamic and competitive economic forces that produce employment and revenue. This research has a significant role in introducing and promoting modern technology, facilitating international trade, and enabling resource efficiency. Innovation and technical development, such as better resources and energy efficiency, are critical to finding long-term solutions to both economic and environmental concerns.

In Harmonized National Research and Development Agenda, this research will aid in the development of rural areas to have long-lasting streetlights, for safety and to advance technology in the area under the Industry, Energy and Emerging Technology Research and Development Agenda. The goal of HNRDA is to strengthen these sectors through Research and Development funding, human resource and institution development, information and technology dissemination, and policy development.

This research will add to the body of knowledge provided to future researchers. The study will be made available to anybody who desires to grow and improve on this project. Future researchers will be able to enhance this project using the study's recommendations as a reference.

1.6 Scope and Limitation

This study aims to focus on the design and usage of the centralized smart monitoring system for capturing parameters in real time with the use of microcontroller. The system covers the monitoring of the present condition of the battery together with its current, voltage and luminosity of standalone solar streetlights. The researchers will provide a website that can run in any browser with the use of any smart technology where it will show the real time data of each parameter, also with the use of the database of IoT function the parameters may send in fast transaction as the focus of researchers is to provide a real time data of each parameter. For a network design of the study, LoRa network will be used as the centralization of the monitoring system has a long-range area for sending real time parameters. The study will be conducted in Barangay Saluysoy, Meycauayan Bulacan. The researchers chose this place due to the lack of solar streetlights in the area.

However, the maintenance of the project study will not cover if the defects of the devices are outside the monitoring system of the study. The researchers will also only provide three running prototypes due to the lack of funds that will be needed for the construction of the study.

1.7 Definition of Terms

Basic service set identifier (BSSID) - Wireless Network, it define the use of WLAN

Controller area network (CAN) - A critical control network for automobile technology

Control mode - fixing the problem by the controller

Depth of discharge - Use to get the State-of-Health of the battery

GPRS - Old generation network, commonly used in cellular networks.

Internet of Things (IOT) - The use of the internet over hardware, software, and any invented technology.

Lithium-ion battery - The root type of battery that is used in the system, commonly found in electric vehicles and solar street lights.

LoRa - Is a module for Long Range, Most commonly used in IoT.

LoRaWAN - Wide Long Range Network that uses a gateway.

LPWA - use for interconnecting the nodes to its geographical places.

Manual control mode - Control can’t access it, it is manually accessed by the person.

Microcontroller unit (MCU) - A microcontroller (MCU) is a tiny computer built on a single metal-oxide-semiconductor (MOS) VLSI integrated circuit (IC) chip.

Photovoltaic - It was an energy from the sunlight.

RSSI - It indicates how the signal was in the receiver node.

Sampling rate - The sample rate is the number of samples of a sound captured per second to represent the event digitally in the development of an audio sound for computers or communications.

Specific service set identification (SSID)- it is the name of the WLAN.

State of Charge- It indicates the charge percentage of the battery.

Threshold – The limit capacity of the materials.

Transmission - a one-way, linear process in which a sender encodes a message and transmits it to a receiver who decodes it over a channel. Environmental or semantic noise may interfere with the message's transmission.

UDP - (User Datagram Protocol) is a communications protocol that is primarily used on the internet to establish low-latency and loss-tolerant connections between applications. UDP speeds up transmissions by allowing data to be transferred before the receiving party has agree

CHAPTER 2

Review of Related Literature and Studies

This chapter presents the related literature and studies gathered after the researchers conducted a thorough and in-depth search. Several works by authors from the PH and abroad were examined to create a solid foundation for the current study. Only those that were relevant were investigated.

2.1 Monitoring Systems

A monitoring system is a piece of software that assists system administrators in monitoring their infrastructure. These tools keep an eye on system devices, traffic, and applications and sound the alarm if anything goes wrong (Paessler, 2022). Monitoring is the process of keeping an eye on the entire internal network, including devices, traffic, and servers. This assists in identifying and resolving potential issues as they arise, preventing network problems (Worldwide Services, 2019).

2.1.1 *Monitoring Systems in Electronic Vehicles*

Batteries have been widely used in many high-power applications, including electric vehicles (EVs) and hybrid electric vehicles, where a suitable battery management system (BMS) is critical in ensuring safe and reliable battery operation (Liu et al, 2018).

A secondary battery with a long cycle life, low energy loss, high power density, and sufficient safety level is required for EV and HEV applications. EV batteries include lithium-ion (Li-ion), lead acid, nickel-cadmium (NiCd), and nickel-metal hydride (NiMH), among others. Table # shows some of the most important characteristics of these common battery types. Li-ion batteries are clearly superior to other types of batteries, particularly in terms of high cycle life, which is critical for EVs' long service life (e.g., 6–10 years). Furthermore, Li-ion batteries are made of environmentally friendly materials and have a high level of safety. As a result, Li-ion batteries have become the most popular power source for electric vehicles (Liu et al, 2018).

Table 2. 1 Commonly used batteries in electronic vehicles

Battery type	Service life /cycle	Nominal voltage/V	Energy density /(W·h·kg^{-1})	Power density /(W·kg^{-1})	Charging efficiency/%	Self-discharge rate /(%·month^{-1})	Charging temperature/°C	Discharging temperature/°C
Li-ion battery	600–3000	3.2–3.7	100–270	250–680	80–90	3–10	0 to 45	–20 to 60
Lead acid battery	200–300	2.0	30–50	180	50–95	5	–20 to 50	–20 to 50
NiCd battery	1000	1.2	50–80	150	70–90	20	0 to 45	–20 to 65
NiMH battery	300–600	1.2	60–120	250–1000	65	30	0 to 45	–20 to 65

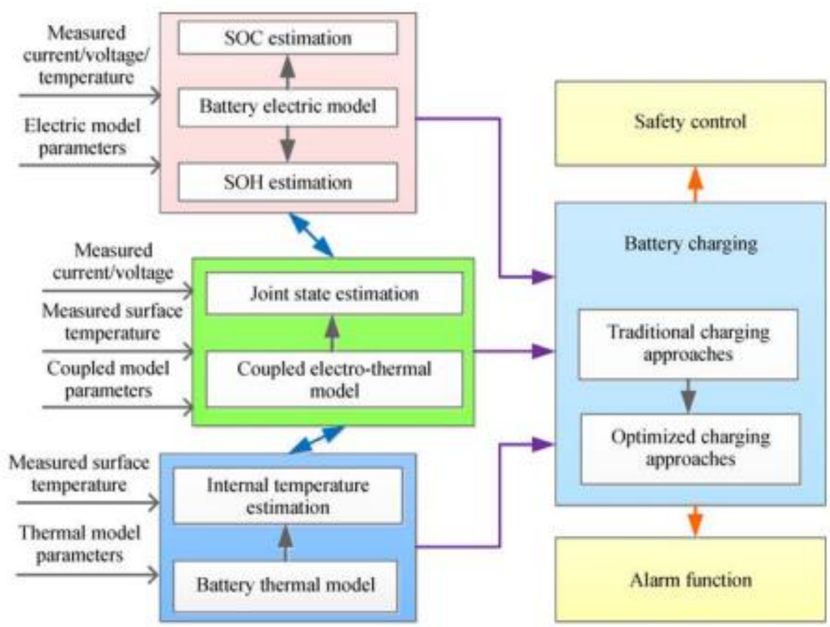

Figure 2.1 Key technologies in relation to battery monitoring system of E-vehicles

Figure 2.1 depicts the relationship between these key technologies. In EV applications, battery current and voltage can be directly detected by on-board current and voltage sensors, and surface temperature of the battery pack can be conveniently detected by temperature sensor or thermocouple. The well-trained battery models, in conjunction with appropriate estimation methods, can then be used to achieve independent or joint state estimations of battery SOC or internal temperature (Liu et al, 2018).

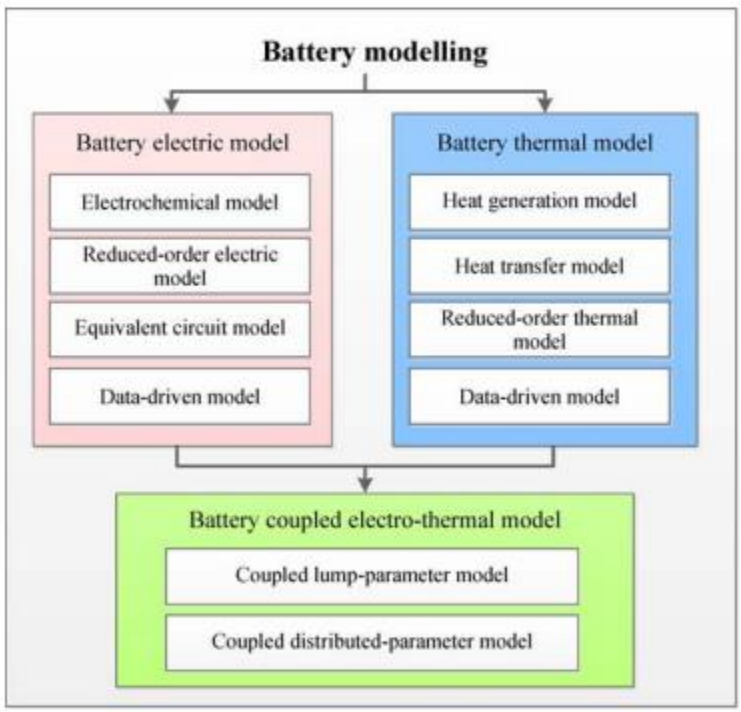

Figure 2.2 Classifications of Battery Modeling

Creating a proper model is usually the first step in BMS design, control, and optimization. Numerous battery models with varying degrees of accuracy and complexity have been developed over the years. These models are primarily classified as battery electric models, battery thermal models, and battery coupled models, as shown in Figure (Liu et al, 2018).

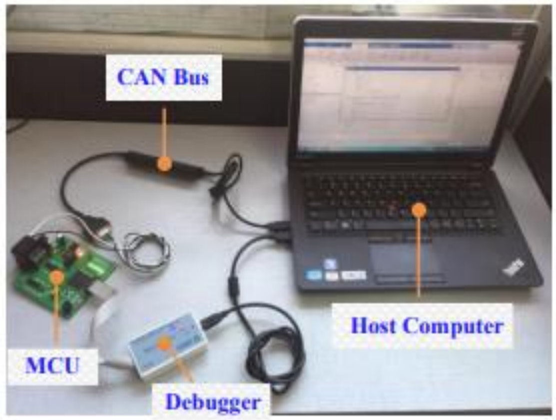

Figure 2.3 Battery monitoring system

A microcontroller unit (MCU), a debugger, a controller area network (CAN) bus, and a host computer comprised the BMS used to validate the developed methods (Figure 2.2). MPC5644A is the MCU model, which is commonly used in vehicles due to its high computation capability. The MCU's maximum clock frequency (MCF) is 150 MHz, indicating a fast calculation speed. The MCU has 4 MB of flash memory and 192 KB of random-access memory (RAM). The MCU performs single-precision floating-point calculations with a precision of 7 significant digits (Xiong et al, 2019).

Any single value stored in the MCU requires thirty-two bits of memory. The CAN bus's maximum communication speed (MCS) is 1 M/s, indicating high communication capability. The developed methods' coding was written on the host computer, then debugged and downloaded to the MCU. The CAN bus was used to connect the MCU to the host computer. The debugged code executes in the MCU. Aside from code writing, the host computer can also be used for data storage and display of results (Xiong et al, 2019).

A Battery Monitoring System (BMS) is the main component of a pack of batteries that monitors a load current, voltage, and temperatures, as well as assessing usable energy, state of charge (SOC), and state of power (SOP), to keep cells in safe working ranges and extend cell life. The BMS's primary role is cell protection, which includes overcharging or discharging, overheating, short-circuiting, and other issues. Excessive charging a battery can cause overheating and potentially an explosion or a blaze whereas draining a battery can cause irreversible capacity loss or hasten aging (Ren et al, 2018).

The Battery Monitoring System guarantees that the battery functions within the parameters that have been set. The BMS will supply the maximum allowable current, voltage, or power from or to the battery depending on the working circumstances. Slow charging lowers electric vehicle accessibility, but quick charging produces significant heat loss and fast temperature rise. The BMS's second most significant function is the battery energy gauge. If the BMS can offer an accurate battery state of charge indicator over the whole battery operation range, drivers will feel more assured and have less range anxiety. As a result, the BMS serves a significant part in assuring safety and improving battery efficiency and performance (Ren et al, 2018).

An active charge balance system is used on the battery system to improve the total efficiency of the battery pack and to maintain voltage and State of Charge (SOC) uniformity in the cell strings. Charge balance commands from the BMS control the activation of cell balancing via the dual active bridge DC/DC converter (Ren et al, 2018).

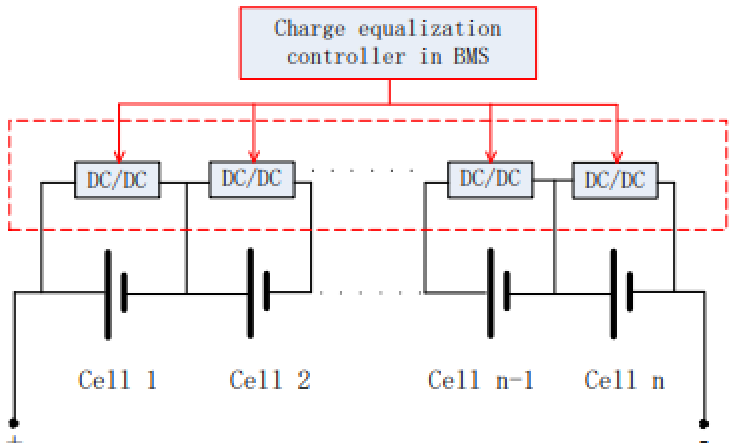

Figure 2.4 Equalization architecture of battery packs for BMS

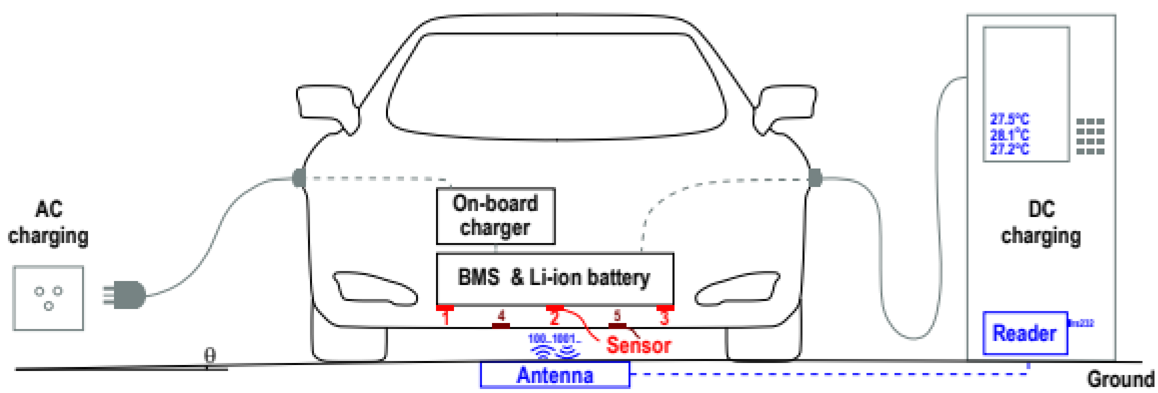

Figure 2.5 Schematic representation of typical EV battery charging in stations, as well as the installation of the proposed system in the station

Typically, there are two types (AC and DC) of EV charging schemes in the charging station, as shown in Fig. 2.5 During charging, the battery cells would be heated up rapidly, especially for DC fast charging (e.g., 400–600 V, up to 300 A) using an off-board battery charger (Wang et al, 2019).

The device's system diagram is depicted in Fig. 2.6, which includes a power management unit (PMU) to harvest incoming RF energy and power the tag, a digital baseband for system control, an on-chip temperature sensor, and a modulator/demodulator module. For EV battery monitoring, a moderate sensing precision (2 C) and resolution (0.1 C) are sufficient, while the sampling rate (e.g., >20 Sa/s) is required to capture transient temperature changes (Wang et al, 2019).

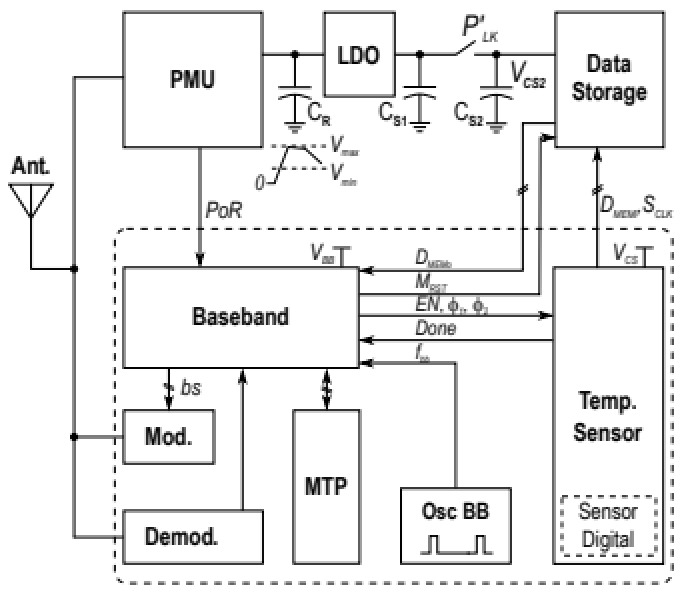

Figure 2.6 UHF RFID sensing device schematic

The UHF RFID protocol has the potential to be used for future EV battery thermal monitoring while charging, particularly for DC fast charging in stations. The performance of the device is evaluated in-house. In comparison to existing wireless sensing solutions, the proposed system exhibits high accuracy, long reading distance, safe deployment, long-term robustness, and low cost and minimal infrastructure renovation for large-scale deployment (Massoud et al, 2019).

In the study *Electric Vehicle Monitoring using Matlab/App Designer* by J.M.G Valle et al., (2017), it focuses in developing of an app that can monitor and control different electric vehicle. The use of Matlab represents the GUI for monitoring and evaluating the parameters of the electric vehicle from the current and motor sensors. The App that is used for monitoring could help to determine the and monitor the situation of the electric vehicle such as the speed, issues etc. The app can also be able to detect the replacement of the current device through simultaneous reading for the vehicle control and development of systems that needs to improve (Valle et al, 2017).

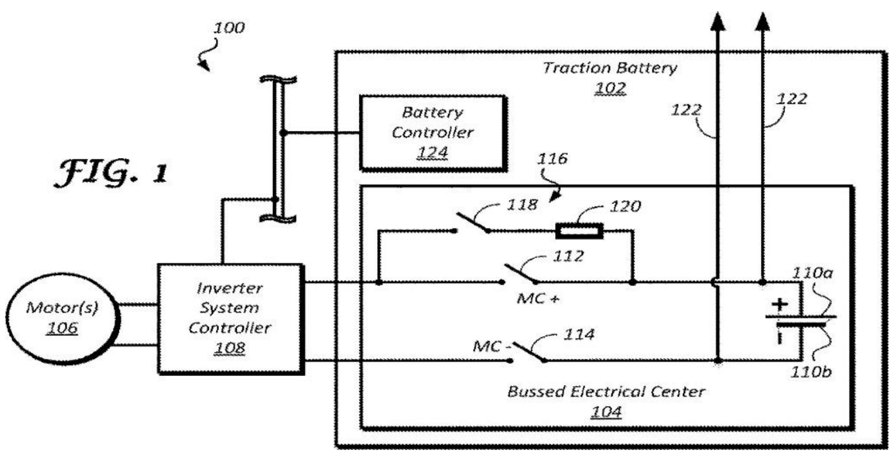

Figure 2.7 Bussed electrical center

In the Figure 2.7 shown above, when closed; contactors connect a traction battery to a vehicle bus, and a controller is configured to issue an over discharge alert and open the contactors in response to a battery temperature rate of change, measured during battery discharge and while a battery state of charge (SOC) exceeds a first threshold, being greater than a predefined rate (Wang et al, 2020).

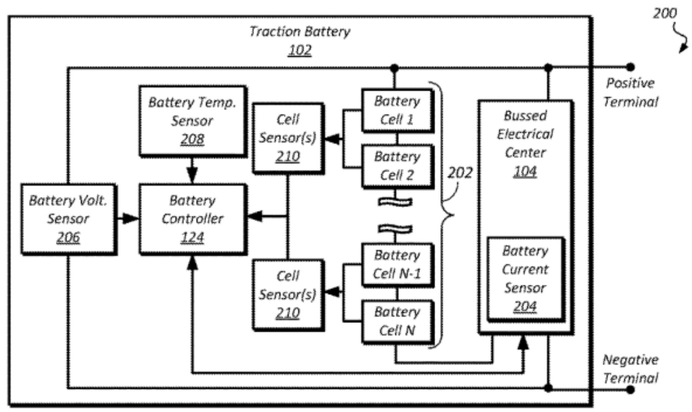

Figure 2.8 Traction battery patent schematic diagram

The controller issues an over discharge alert and commands open contactors that electrically connect a traction battery to a vehicle bus when closed in response to a battery temperature rate of change measured during battery discharge and while a battery state of charge (SOC) is greater than an alert threshold, being greater than a predefined rate (Wang et al, 2020).

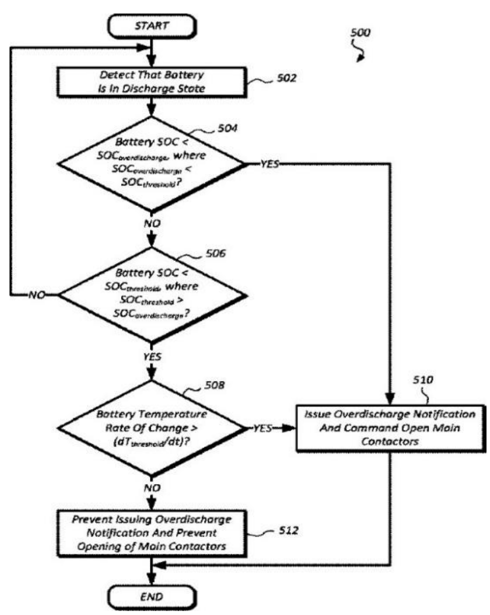

Figure 2.9 Flowchart depicting an algorithm for detecting a battery over discharge condition

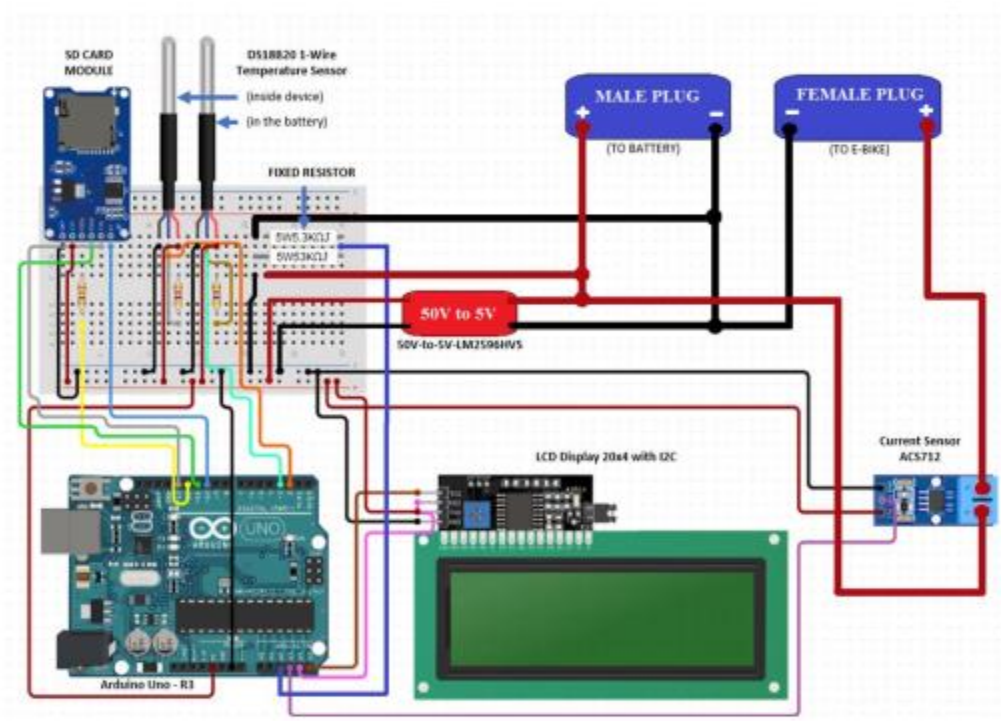

Figure 2.10 Batt-Man Arduino Based

In Figure 2.10, it is the monitoring of the battery discharge cycle of an e-trike or an e-vehicle. With the use of Arduino Uno together with the sensors it detects the battery status and upload to the app. The data was store in a SD card, as the technology is a real time monitoring of the battery's e-vehicle status (Thio-ac et al, 2021).

2.1.2 *Monitoring Systems in Different Lighting Systems*

Figure 2.11 Public streetlights on-grid

Street lighting, as depicted in Figure 2.11, is one component of the infrastructure of a community that helps to illuminate the roadways in the city proper. Drivers can view the way clearly, which can help to increase road user protection. Electricity can be generated from a multitude of sources, including electrical generating, direct sunlight, and more (Adriansyah et al., 2019).

The general street lighting monitoring system is based on the Internet of Things (IoT) and is made up of numerous components such as sensors, processors, electronic communication, and a monitoring system. Figure 2.11 depicts a block diagram of the public street lighting monitoring system (Adriansyah et al., 2019).

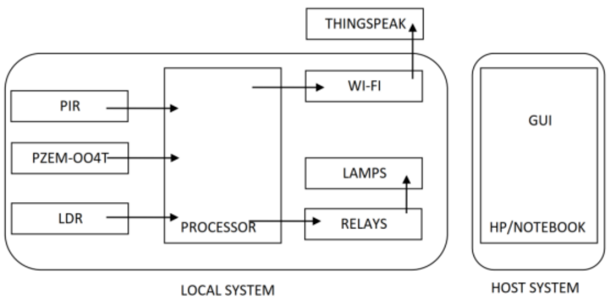

Figure 2.12 Block diagram of the monitoring system

Passive Infrared and Light Dependent Resistor are used by the system to detect exterior movement and light intensity, respectively. Sensor data is turned into microcontroller data.

The Arduino Mega 2560 is being utilized. The Arduino Mega 2560 board uses the ATMega 2560 microprocessor. This board features a large number of input/output pins, some of which may be used as PWM outputs, and 16MHz crystals. A PZEM-004T internal system sensor measures voltage, current, power, and power consumption per light in real time. The ESP8266 Wi-Fi module is utilized in wireless telecommunications systems. The ESP8266 is a Wi-Fi module that acts as an Arduino-like microcontroller improvement, allowing it to connect and establish a TCP/IP connection directly (Adriansyah et al., 2019).

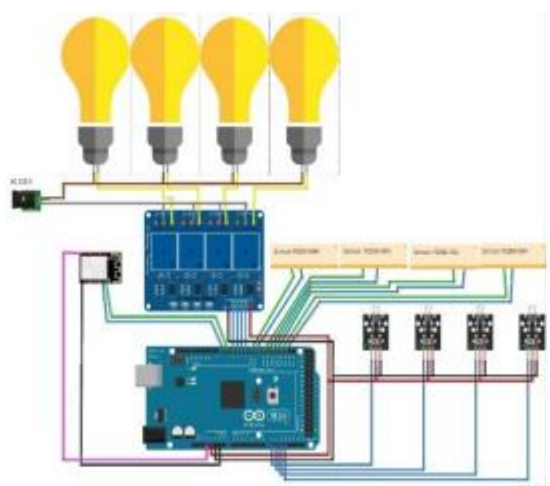

Figure 2.13 Schematic diagram of the system

Data is sent to a ThingSpeak web application via this telecommunications system. ThingSpeak is an open-source Internet of Things (IoT) application and API for storing and retrieving data from various things over the Internet or a local area network using the HTTP protocol. ThingSpeak can display real-time measurement results in the form of numbers or graphical displays on a device such as a cellphone or notebook. It is hoped that this public street lighting monitoring system will be able to display the external environmental conditions of the lights, as well as the internal conditions of each lamp, and that it will be able to control them remotely. Figure 2.12 depicts the electronic circuit of the public street lighting system (Adriansyah et al., 2019).

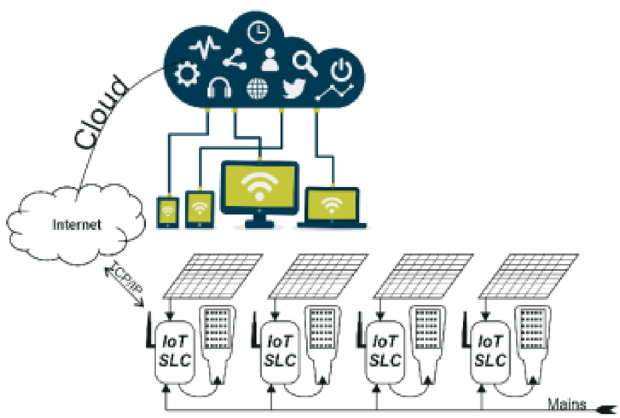

Figure 2.14 IOT street light control system structure

Figure 2.14 shows how the implementation of Solar Street Lights embedded along the Internet of Things (IoT) and how they are centrally monitored through the cloud.

An integrated hardware was created with a GSM-based TCP/IP client socket that communicates with the cloud writing. Intelligent battery charging and management structure was designed in this proposed system using a Cortex-M3 processor, a GSM data module, and a micro-SD. It was designed to be cost effective and feasible because it did not require a Programmable Logic Controller (PLC) or any external hardware (Kul 2017).

The Internet of Things-Street Light Controller Hardware (IoT-SLC-H) main processor is the CortexM3, which performs all measurements and checks. The Cortex-M3 processor was paired with the NXP LPC1769 microcontroller. TCP/IP is managed by the main processor. GSM is used for socket communication, lighting, and other traffic-related operations (Kul 2017).

The processing of the Solar Panel from the Sun's Radiation was not effective as it's place in one direction. With that, the use of IoT makes the processing of the system defined with the real time that could work and delivered a positive result. In Solar Power monitoring concern about the direction from the sun's frequent radiation that has a high power to a high grain output from its processing. As IoT defines the connection between an object with the use of wireless material with that IoT can help the Solar Panel Monitoring from real time data that would fit from the application technology between the different sensor devices that is connected to the technology. As IoT is the best for effective control from a physical technology that is distracted from a world network. (Kul 2017).

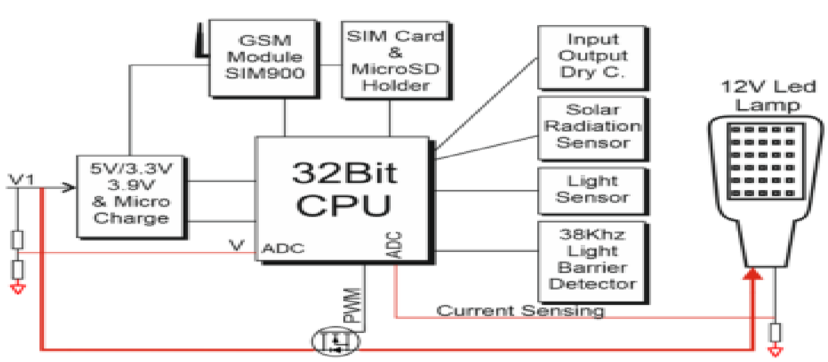

Figure 2.15 Main hardware schematic for IoT-SLC

In Figure 2.15, it shows how it will monitor the Solar Streetlight along with the GSM Module, Cortex M3, and sensors like Solar Radiation, Light, and Light Barrier Detector

The IoT-SLC processor is ARM7 Cortex-M3 LPC1769. It can handle the pulse counts from the TSOP32438 for daylight, solar radiation, and traffic vehicle transit detection, as well as TCP/IP client socket communication via GSM, PWM output for lighting, and all other operations (Kul 2017).

As a TCP / IP client socket, the IoT-SLC-H connects to the cloud. The IoT-SLC-H response is sent to the IoT-SLC-H unit that is providing the connection via the port opened by the IoT-SLC-H units (Kul 2017).

Figure 2.16 Finalized IoT-SLC Hardware (IoT-SLC-H)

Table 2.2 List of components in the system

No.	Description
1	IoT-SLC-H Main Board
2	GSM Antenna SMA Connector
3	Digital Inputs and Outputs
4	Main Power Failure Detection Module
5	Battery Charger with Load Controller
6	12 V/20 A Battery or 12V/3A Aux.battery
7	15 V/3.6 A Switch Mode Power Supply

Furthermore, the high-efficiency LED lighting is managed and monitored through the development of TCP/IP communication with centralized software on the cloud via GSM (Kul 2017).

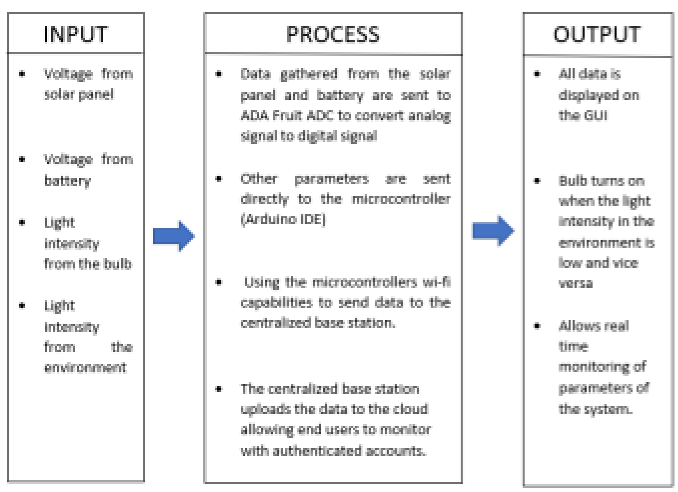

Figure 2.17 Conceptual framework of solar streetlights

Figure 2.17 depicts the model, which includes the input used in this project as well as the process used to create the output, which includes monitoring the health status of a solar lamp via IoT as well as the automatic on/off a light bulb based on ambient light. It demonstrates that the input consists of data collected from the voltage and light sensors. The microcontroller initializes these data, and the output is the project's final design (Cruz et al, 2021).

Python programming for the microcontroller and a database for data storage via server are the software requirements (Cruz et al, 2021).

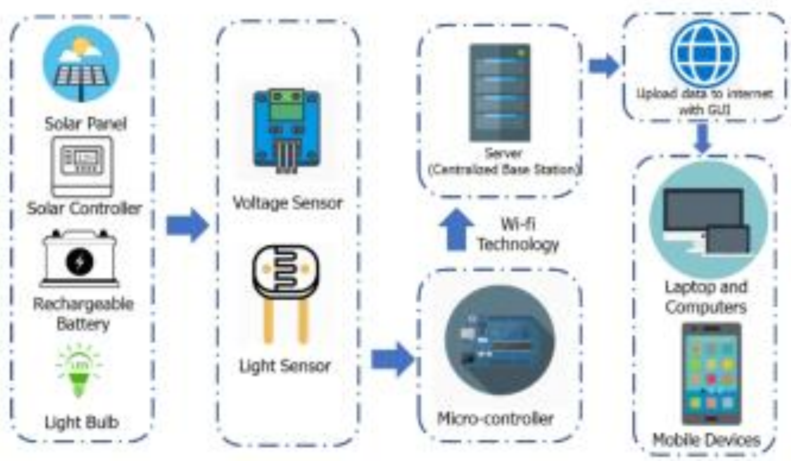

Figure 2.18 Flow of process in the monitoring system

Figure 2.18 depicts the process of gathering solar power from a solar panel, which is then controlled by a solar controller to prevent damage to the solar panel and battery. The solar controller's-controlled voltage charges the battery. The sensors measure the voltages. It collects information from the solar controller and the light bulb and sends it to the microcontroller. The data is transferred to the centralized base station via the microcontroller's wi-fi capabilities. The data is stored on an SD card in the base station and then uploaded to the internet. If the end devices have authenticated accounts, they can monitor the lamp status (Cruz et al, 2021).

A solar controller is used to control the voltage of a solar panel's generation to prevent the battery from overcharging. Once charged, the battery will be the primary source of energy for the Arduino IDE, which will implement the codes and run the system. The microcontroller will collect the data that needs to be monitored. A light sensor is connected, and when it detects that it is dark, it turns on its bulb, which has two states: off and on. To measure the voltage of the solar panel and battery, two voltage modules will be connected to Arduino (Cruz et al, 2021).

After gathering all necessary data, the data will be sent to the Arduino IDE for transmission to the base station via Wi-Fi. The gathered data will be stored on an SD card in the base station and will be uploaded to the internet in real-time. Its output will be displayed on a web-based Graphical User Interface (GUI). It will show the battery's parameter reading, the voltage of the solar panel, and the status of the light bulb (Cruz et al, 2021).

In the study "*Design of Intelligent Lighting Monitoring System Based on Polling Algorithm in Internet of Things"* By Zhang Yang, (2020), it focuses on the design of the study where the use of IoT is the foundation of this study. This design is to monitor the lighting equipment in a specific area together with collecting, processing of the real time data of the different lighting equipment for the control of the system to achieve high efficiency energy saving. In Figure 2.18 it shows the design structure with the concept of the IoT that focuses on a long range of light equipment with real time monitoring of data. The structure has hardware composed of the main controller, LCD, GPRS module and wireless communication device where all these devices are connected in the microprocessor to transmit data that can communicate with lighting equipment with the help of the RFID. The software Design is composed monitoring range control by the IoT. This design improves the efficiency of collecting and controlling data for a lighting system with the help of Poll Algorithm. This study could save energy consumption of the lighting system (Yang, 2020).

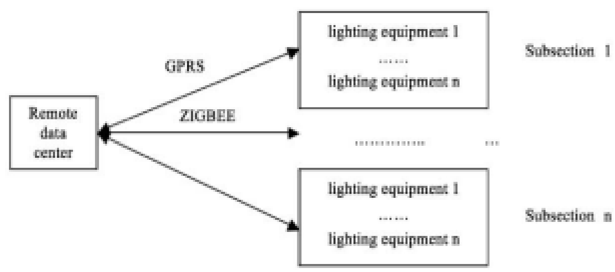

Figure 2.19 System architecture of the design of intelligent lighting monitoring system

2.1.3 *Monitoring Systems in Healthcare Systems*

The monitoring device that is commonly used in hospitals was used to monitor the condition of bedridden patients. In the study of *E-Health Monitoring System for the Aged* by A. Ibhaze et al., (2016), it focuses on a simple monitoring system of the heart rate of the patients with the use of GSM/GPRS, Temperature and Pulse Sensor. Arduino as microcontroller will be connected to the sensors and networks and the device will be attached to the finger of the patients to measure the temperature and pulse rate of the patient simultaneously. This monitoring system is one of portable system with an alert management that captures real time parameters. The monitoring system in health care is one of the advanced technologies that provide accuracy of the patients' information (Ibhaze et al, 2016).

In the study *Portable and Centralised E-Health Record System for Patient Monitoring using Internet of Things (IoT)* By Shanin et at., (2018), an electronic health record system is needed for checking, surveying, and receiving different health parameters for the health monitoring system. This study uses Internet of things where it helps to connect several types of sensors for a centralization of health monitoring together with the GPS. The IoT has a profound impact in health monitoring systems. It provides exchange of information to achieve smart identification together with the healthy improve communication between the patients and the Doctor. This study proposed a low cost, low power, and centralized portable E-Health record system where you can see the system structure of it at figure 2.19. The health monitoring system will keep records the ECG where it helps the heart for a decent shape and the data set from the sensor will be stored in cloud storage where centralization and IoT work together. With the use of RFID and GPS module the information for location and security system for the patient will identify and be monitored as well (Shanin et al, 2018).

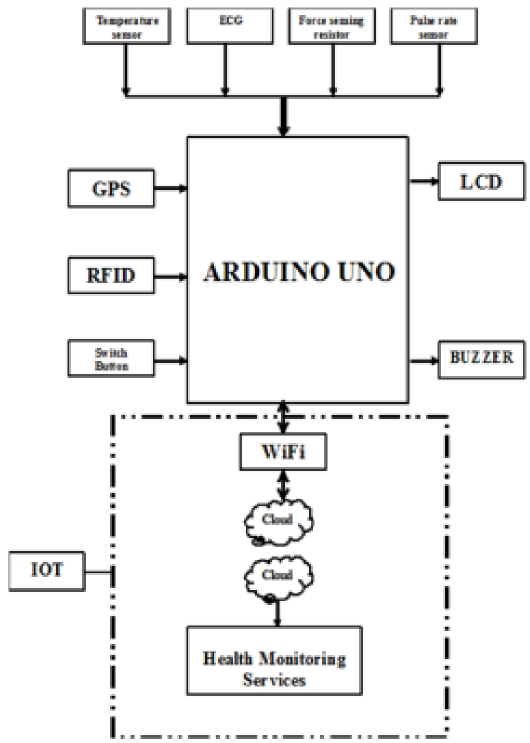

Figure 2.20 System architecture of centralized e-health record system

The system will continue to monitor the parameters of the patient through the different sensors. The real time parameters for patients can record travel, while the centralized monitoring data storage is used with the help of IoT for a smooth exchange transaction of information (Shanin et al, 2018).

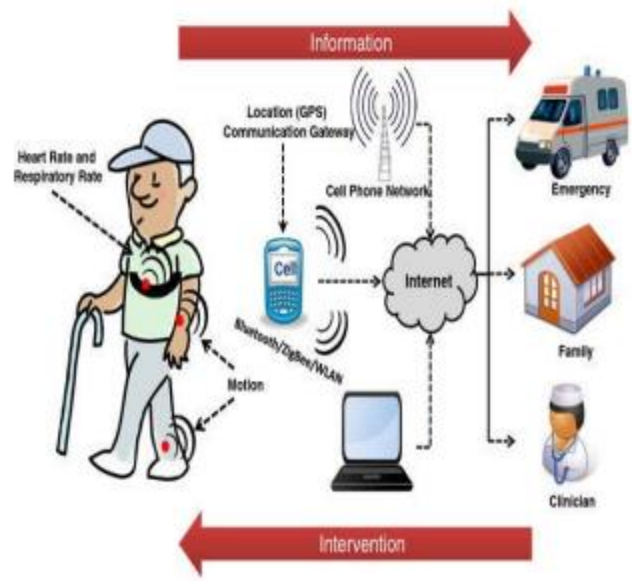

Figure 2.21 Health Monitoring System using Wearable Sensors

A study entitled *Monitoring Health Care System using Internet of Things – An Immaculate Pairing* by V. Tripathi and F. Shakeel, (2017), focuses on the IoT in the health care system where different sensors are needed to work together. Connected health care is an important application and system of the Internet of Things. Hospitalized patients with different status need close attention by continuous monitoring using the IoT. This study aims to focus on how the sensors could be used in monitoring devices for capturing data and different parameters from the patients (Tripathi & Shakeel, 2017).

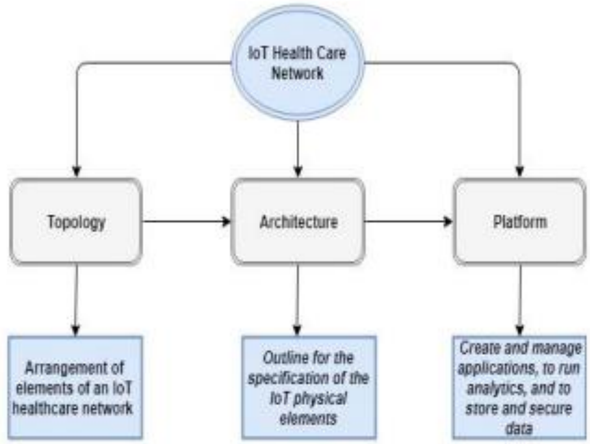

Figure 2.22 IoT health care network

In figure 2.22 it shows how the IoT, and the parameters can be gathered with the wireless sensors while being transmitted into a mobile phone. While figure 2.23 shows the IoT health topology with a health care network. The topology is about the different arrangement of the IoT health network where this topology is a heterogeneous computing grid that collects limitless vitals and parameters from the sensors. The monitoring system of this study uses a smart IoT together with an apple watch where the data that is being monitored can be stored in the IoT server (Tripathi & Shakeel, 2017).

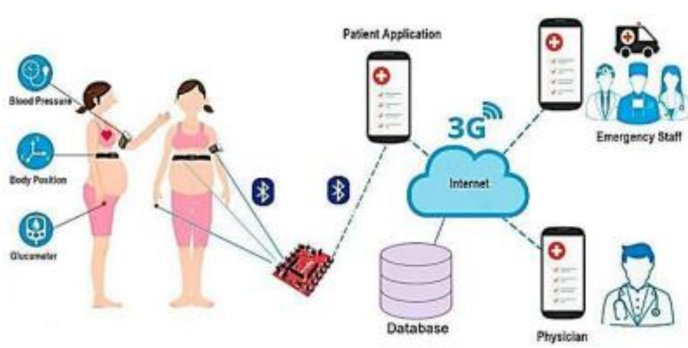

Figure 2.23 Virtual architectural model of IoT

In the study *Smart Health Care Monitoring System using Raspberry Pi on IoT Platform* by K. Seena Naik and E. Sudarshan, (2019), the IoT in health care sector creates an interconnected network for all the devices to be recognized as a renew technology. This study develops a health analysis system together with the help of different sensors that work together like temperature, BP, heart rate and ECG Sensor with the raspberry Pi and GSM for communication. The system focused on getting a perfect health parameter for the patient's condition. The Raspberry device communicates with import modules like MySQL DB for serial communication of different data. As the devices connected to the IoT server system that is shown in figure 2.23, where it controls all the devices and networks that will result to display a generated parameters from the doctor's device via internet (Naik et al, 2019).

In a patent of a centralized monitoring place in a health care system, it will be composed of a large facility and a lot of patients that need to be monitored. The centralized monitoring system works for receiving the patient's data with a collaboration of a tabletop that is also configured to the processor to convey patient's data with a lot of patients and devices that are interconnected. As centralized monitoring is invented with a lot of screens that a physician or the observer need to face that would result as a universality for a patient monitoring. In figure 2.23 it shows a hospital network that compromises most patients monitoring system that is interconnected via communication link whether it is wired or wireless (Davis, 2010).

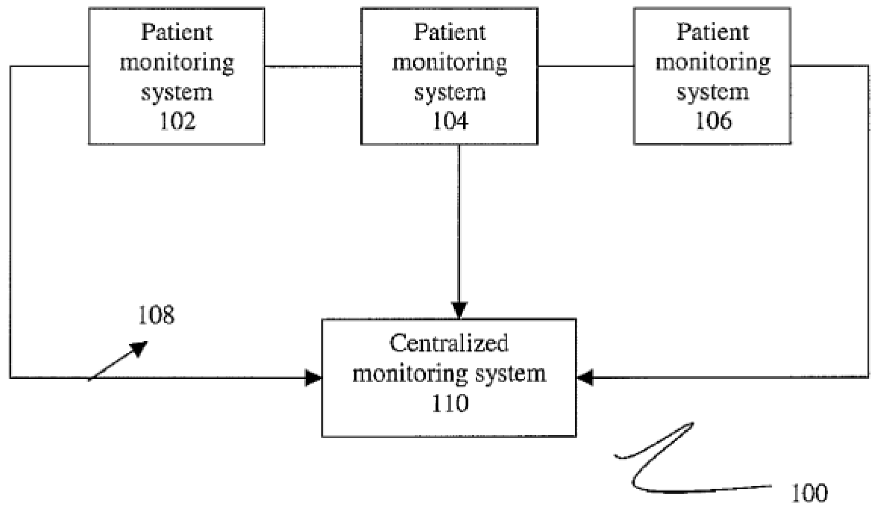

Figure 2.24 Centralized monitoring system

In the study of A *Centralized Cluster-Based Hierarchical Approach for Green Communication in a Health Care System* by G. Yang et al., (2020),), it focuses on the use of Green IoT where it has a digital and virtual connected devices that can enable for a wide range of application. As IoT is used for gathering real time data, the Green IoT emphasizes the preservation of the energy supply in each sensor for a better application while it is sensing, computing, and transmitting data. As the smart health care system that uses Green IoT or green communication for monitoring the real time parameters of the patient's data produces a low energy consumption. The use of cluster based hierarchical protocol in the health care monitoring system operate at the network layer where it makes the smart care environment more ideal from the patient's vital signs that the protocol can group or organize health monitoring devices. The use of Intra-Cluster communication where each cluster and device can only communicate with two or more devices (Yang et al, 2020).

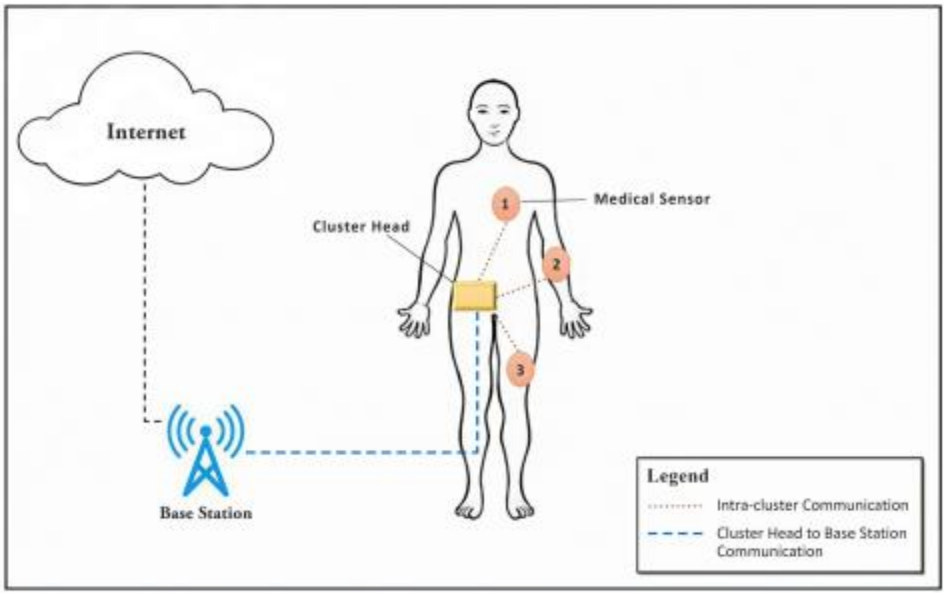

Figure 2.25 Cluster based communication in health care system

The study *Centralized Healthcare Cyber-Physical Systems' Architecture Development* by E. Sultanovs et al., (2016), it focuses on the Cyber-Physical structure of the centralized health care monitoring system where it says that this structure could help automatizing the treatment process for a continuous monitoring for each patients' conditions with the use of multiple devices. The use of IoT is needed cause the Cyber-Physical system supports a wide range of information to be exchanged that is commonly used in medical devices that can receive the patients' data information or the parameters from the different sensors. In storing data, the system will distinguish the measure of the reliability of the data. The architecture of a centralized healthcare cyber-physical system is shown in figure 2.25. Where it has three different layers that have different functionalities. It helps multiple medical facilities to be connected in one system in interchanging information about the patients' information (Sultanovs et al, 2016).

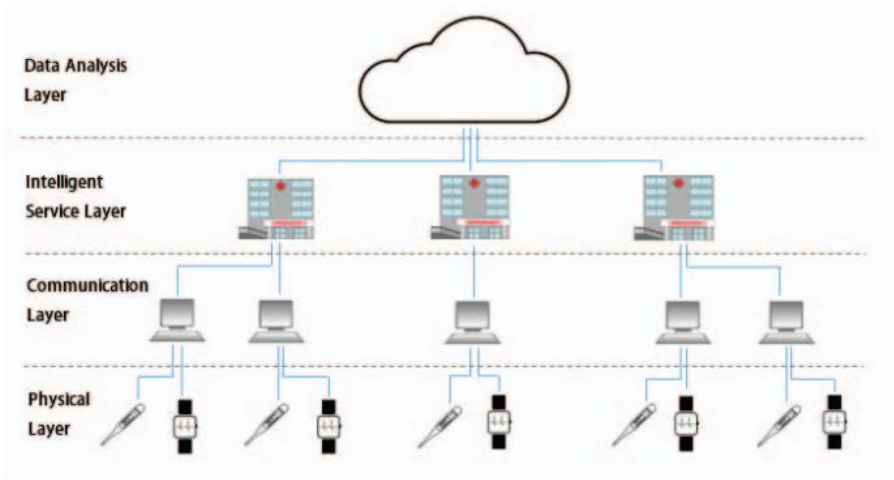

Figure 2.26 Centralized healthcare cyber-physical system architecture

Table 2.3 Comparative matrix of monitoring system

AUTHOR	YEAR	TITLE	FINDINGS	RELATIONSHIP
K. Liu, Q. Peng, and C. Zhang	2019	*A brief review on key technologies in the battery management system of electric vehicles*	In EV applications, battery current and voltage can be directly detected by on-board current and voltage sensors, and surface temperature of the battery pack can be conveniently detected by temperature sensor or thermocouple.	The proper connection of a battery monitoring system through the relationship of technologies.
R. Xiong et al..	2019	*Lithium-Ion Battery Health Prognosis Based on a Real*	MPC5644A is the MCU model, which is commonly used in vehicles	The use of Microcontroller and Lithium-Ion

		Battery Management System Used in Electric Vehicles	due to its high computation capability. The MCU's maximum clock frequency (MCF) is 150 MHz, indicating a fast calculation speed. The MCU has 4 MB of flash memory and 192 KB of random-access memory (RAM). The MCU performs single-precision floating-point calculations with a precision of 7 significant digits.	Batteries for a better capability of the battery monitoring system.
			The most important function	

H. Ren et al.	2019	*Design and implementation of a battery management system with active charge balance based on the SOC and SOH online estimation*	of the BMS is cell protection, which includes overcharging or discharging, overheating, short-circuiting, and so on. Overcharging a battery can result in overheating and even an explosion or flame, while discharging a battery can result in a permanent reduction in capacity or accelerate aging.	The proper balance system of the battery for a better efficiency of the battery pack and to maintain voltage and State of Charge (SOC) uniformity in the cell strings.
		A Wireless Battery	The UHF RFID protocol has the potential to be used	The use of wireless sensing solution for the

B. Wang, J. Hernandez Fernandez, and A. Massoud	2019	*Temperature Monitoring System for Electric Vehicle Charging*	for future EV battery thermal monitoring while charging, particularly for DC fast charging in stations. In comparison to existing wireless sensing solutions, the proposed system exhibits high accuracy, long reading distance, safe deployment, long-term robustness, and low cost and minimal infrastructure renovation for large-scale deployment	battery thermal monitoring system, that the system provides a high accuracy with a long reading distance.

J.M.G Valle et al.	2017	*Electric Vehicle Monitoring using Matlab/App Designer*	The Matlab app that is used for monitoring could help to determine the and monitor the situation of the electric vehicle such as the speed, issues etc. The app can also be able to detect the replacement of the current device through simultaneous reading for the vehicle control and development of systems that needs to improve.	The use of application for easy monitoring services of the vehicle and detection of fault of the sensors or the materials under the vehicle.

Wang et. Al	2020	*System and Method for Detecting and Responding to a Battery Over-discharge Condition Within a Vehicle*	The controller issues an over discharge alert and commands open contactors that electrically connect a traction battery to a vehicle bus when closed in response to a battery temperature rate of change measured during battery discharge and while a battery state of charge (SOC) is greater than an alert threshold, being greater than a predefined rate.	The use of controller for sending and receiving alert or data from the sensor parameters.

A. Adriansyah, S. Budiyanto, J. Andika, A. Romadian, and N. Nurdin	2019	*Public Street Lighting Control and Monitoring System ... - AIP publishing*	The public street lighting monitoring system is built on the Internet of Things (IoT) and consists of several blocks, including sensors, processing, lightning drives, telecommunication, and monitoring system	The study also uses IoT for the monitoring system together with the main controller of the Arduino Mega for better system in a large connection.
		IOT-GSM-based high-efficiency	The Internet of Things-Street Light Controller Hardware (IoT-SLC-H) main processor is the CortexM3, which performs all	In this study IoT can help the Solar Panel Monitoring from real time data that would fit from the application technology

B. Kul	2017	*LED street light control system (IOT-SLCS)*	measurements and checks. The Cortex-M3 processor was paired with the NXP LPC1769 microcontroller. TCP/IP is managed by the main processor. GSM is used for socket communication, lighting, and other traffic-related operations.	between the different sensor devices that is connected to the technology. As IoT is the best for effective control from a physical technology that is distracted from a world network.
J. C. D. Cruz, G. V. Magwili, K. C. Catimbang, T. B. S. Serrano	2021	*Solar Lamp Post Health Monitoring Using Integrated Sensors and*	A solar controller is used to control the voltage of a solar panel's generation to prevent the battery	The system also uses Wi-Fi module and a data server that collect a real time parameter from the sensors

and P. C. L. Reyes		*Wireless Network*	from overcharging. Once charged, the battery will be the primary source of energy for the Arduino IDE, which will implement the codes and run the system. The microcontroller will collect the data that needs to be monitored. The programming language they use for their system is python.	that is connected to the Arduino.
		Design of Intelligent	It focuses on the design of the study where the use of	This design is to monitor the lighting equipment

Z. Yhang	2020	*Lighting Monitoring System Based on Polling Algorithm in Internet of Things*	IoT is the foundation of this study. This design improves the efficiency of collecting and controlling data for a lighting system with the help of Poll Algorithm. This study could save energy consumption of the lighting system	in a specific area together with collecting, processing of the real time data of the different lighting equipment for the control of the system to achieve high efficiency energy saving.
A.E Ibhaze, E.C Eleanor and F.E Idachaba	2016	*E-Health Monitoring System for the Aged*	Body Temperature and Heart rate monitoring with the use of GPRS/GSM/ GPS.	The use of Arduino for the different sensors.
			The use of RFID for unique	

Shanin et al.	2018	*Portable and Centralised E-Health Record System for Patient Monitoring using Internet of Things (IoT)*	identification of the electronic health record of the patient with a GPS Tracking and use of cloud computing under the hospital management system.	The use of real time parameters under the cardiac diseases and ECG with the IoT database and portable health monitoring system.
V. Tripathi and F. Shakeel	2017	*Monitoring Health Care System using Internet of Things – An Immaculate Pairing*	Wearable devices for monitoring health care condition of the patient. With automated information.	Sensor devices with the use of IoT. Wi-Fi Module for the connected devices will be used.
	2019	*Smart Health Care Monitoring System using*	Raspberry Pi will be use in this study for a low energy power. It works as the multi-processor from the	The use of different health sensor together with use of IoT function.

K. Seena Naik and E. Sudarshan		*Raspberry Pi on IoT Platform*	different sensor devices. With the use of GSM.	
G. Yang et al.	2020	*Centralized Cluster-Based Hierarchical Approach for Green Communication in a Health Care System*	The use of Green IoT for preserving energy with the application design of the cluster-based hierarchical architecture of the flow of energy and communication of the devices.	The system also uses IoT for the health care system with the approach of the monitoring devices that attached at the patients' body.
E. Sultanovs et al.	2016	*Centralized Healthcare Cyber-Physical Systems' Architecture Development*	The use of the design structure of the cyber physical system for the exchanging of information or parameters in a machine-to-machine system.	The use of different sensors and the fast transactions for the real time parameters.

C.C DAVIS	2010	*Collaborative Tabletop for Centralized Monitoring System*	The Collaborative of Tabletop is the main function of the patent for the formation of centralized monitoring system, as the design of tabletop will show the condition of the patient in each monitor from a main network.	The use of Centralization with different patients' channel that connected into a one source.
Maltezo, Melbern Rose C., August C. Thio-ac, Anna May C. Castillo, Leandro E. Gattu, Carmine Ella A.	2021	"Arduino-based battery monitoring system with state of charge and remaining	The prediction of the Battery Health status is the main program of the technology with a real time parameters.	The use of Coulomb counting method for getting battery State of Charge together with sending real time data to the application.

Hernandez, Jonarld John C. Labuan, Leonard F. Navales et al..		useful time estimation”		

2.2 Wireless Networking Protocol

Wireless monitoring plays an important role in the communication network of sensors in various remote applications. In public street light system, control switch set on the streetlamps are implemented. This conventional way of control is ineffective as it uses a large power consumption as it was difficult to control the opening and closing time of the system. According to Yue et al.., as cited by Adriansyah et al.., the manual control of a public street lighting system may encounter various problem such as the supply of electricity and checking of light conditions as it may produce a very high maintenance cost (Adriansyah et al, 2020).

Various methods in addressing these problems have been conducted, which includes the adding various type of sensors and communications systems, implementing alternative energy, and utilizing maintenance and computer systems, does not produce an optimal result. Different studies propose an integrated system which will address the issues concerning public street lighting, this is composed of a compact processor connected to a wireless internet-based communication system and utilizes a graphical user interface (GUI) display for the users (Cruz et al, 2021; see also Adriansyah et al, 2020). Another study addresses the same problems but introduces the use of ZigBee network and GPRS wireless communication (Ke & Xiao, 2016).

From the study conducted by Bouras et al.., a comparison of LoRaWAN and Wi-Fi as wireless technologies implemented in a monitoring system and data transmission in smart devices creates an exceptional solution. It is stated that LoRaWAN is used for modules with sensors, it is also ideal in long range transmission while using low power consumption and low bandwidth for communication. On the contrary, Wi-Fi technology is more productive in working in short distances such as devices and the gateway (Bouras et al, 2019).

2.2.1 *Systems that uses Wi-Fi Technology*

Wi-fi is an internet protocol (IP)-based technology that has been often used in a variety of applications including personal computers, video game consoles, cellphones, digital cameras, tablet computers, smart TVs, digital music players, and printers. Several research are under underway to develop a solution through effective remote monitoring based on the Internet of things (IoT). IoT is a mash-up of numerous domains, including sensor networks, embedded systems, data processing and fusion, intelligent control, job scheduling and allocation, and so on.

The wireless local area network serves as the network's backbone. The battery data from the sensors is received, and the calculation and analysis steps are carried out in the microcontroller. Furthermore, the data is sent to a Wi-Fi card (WizFi) utilizing a UART protocol in our suggested system. Figure 2.27 depicts the pin map detailed schematic of our suggested system, together with the appropriate inputs and ports, for a clear representation and operating technique. It should be noted that in our suggested system, communication between the various sections of the system is accomplished using WLAN technology, considering the mobility of the vehicles and batteries in an industrial setting (Rauniyar et al, 2017).

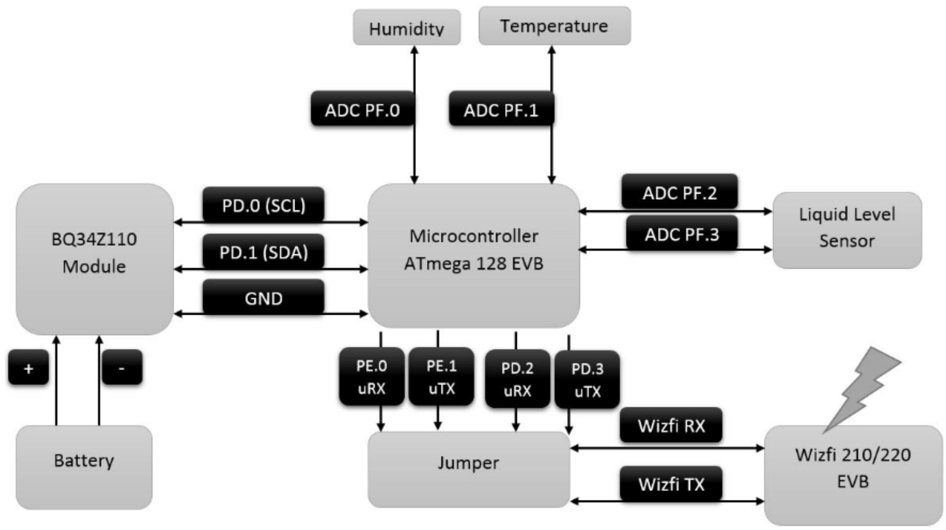

Figure 2.27 Pin map detailed diagram of the proposed system with the corresponding input

Rauniyar, Ashish et al.. have used a WizFi210 for transmitting the battery data over WLAN. The WizFi210 allows users to add WI-FI functionality quickly and simply to various devices. The module includes a serial UART interface for connecting to embedded systems that use an 8/16/32-bit microcontroller. The module also offers a transmission rate of up to 11 Mbps and is 802.11b compatible. The WizFi210 module's Serial2WiFi interface may direct the Wi-Fi radio to scan for access points and ad hoc networks with a specific service set identification (SSID), basic service set identifier (BSSID), and/or channel for a defined scan period for access point scanning. The WizFi210 also supports TCP and UDP operations. There are a total of 16 connections that may be defined during the compilation process (Rauniyar et al, 2017).

Muhendra, Rifki et al.. used a wifi-based lighting controller's processors and communication modules is ESP8266. It is a TCP/IP stack that runs on a CPU. The ESP8266 operates at a frequency of 2.4 GHz, has 16 GPIO pins, and may be programmed to do a variety of operations based on firmware settings. All processes operating on the sensor nodes, both internally and externally, will be managed by the ESP8226. Internal features of the ESP8266 include capturing sensor readings and sending them to the network, as well as setting the turn on/off and dimmer. The ESP8266's exterior role is to create a mesh network with nodes surrounding it and maintain data transfer running smoothly (Muhendra & Arzi, 2017).

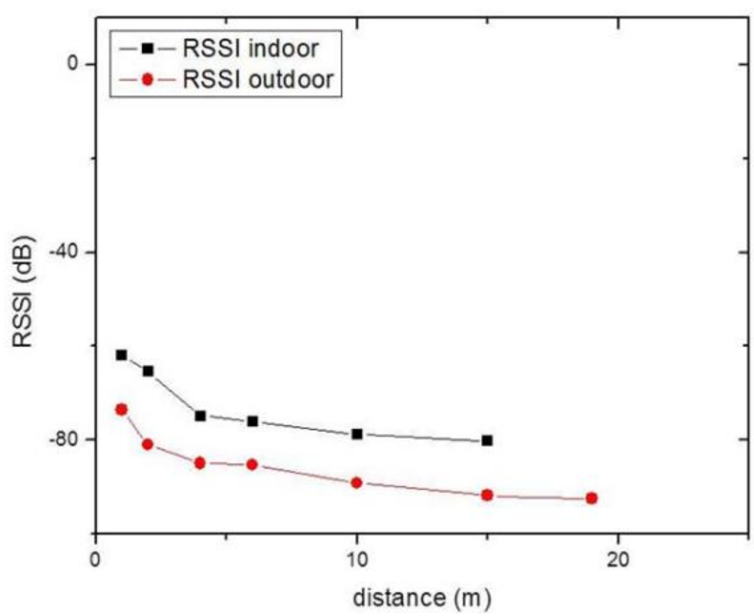

Figure 2.28 Measurement of RSSI

Muhendra, Rifki et al.. measure RSSI inside and outside the room in a wi-fi mesh network. Its purpose is to calculate the maximum distance a node can transport data without using intermediaries to other nodes. Figure 2.28 shows a graph of RSSI measurements from inside and outside the room for wi-fi mesh networks. This graph depicts the link between wi-fi signal strength and distance. The maximum data transmission distance is 15 meters inside the room and 19 meters outside. The wi-fi signal strength declined as the data transmission distance increased, as indicated in the graph. Noise, interference, fading, and attenuation all contribute to this reduction.

The Wi-Fi module ESP8266 is used in the wireless telecommunications system. The ESP8266 is a Wi-Fi module that works as an Embedded system microcontroller improvement, allowing it to connect immediately and establish a TCP/IP connection. Data is delivered to a ThingSpeak web application via this telecommunications infrastructure. ThingSpeak is an open-source Internet of Things (IoT) application and API for storing and retrieving data from a variety of devices over the Internet or a local area network using the HTTP protocol. ThingSpeak can display measurement findings in real-time on a cellphone or notebook in the form of numbers or graphical displays (Adriansyah et al, 2020).

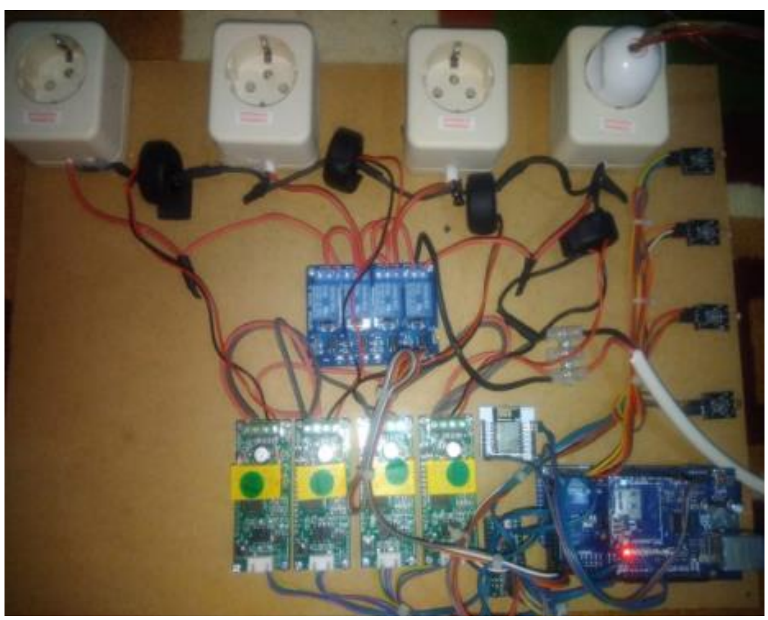

Figure 2.29 Street lightning monitoring system implementation

It has been completed the design of a public street lighting monitoring system. Figure 2.29 shows the prototype findings of the experiment design with four sets of systems. Three sensors, one relay, one Wi-Fi module, and one lamp make up each set of the system. The first test is a network interconnection test to determine whether the devices and systems are connected to the internet network. The interconnection test is performed by connecting a notebook to a mobile phone's Wi-Fi hotspot. Because it was previously configured, Arduino is instantly connected to the Wi-Fi Hotspot Network. Testing the interconnection between the notebook and the IP installed on the notebook and vice versa is possible. The notebook must be linked to the Mobile's Wi-Fi Hotspot for this test (Adriansyah et al, 2020).

A solar powered system is made up of a PV module, power converters, and storage devices. It is the power harvester that converts sunlight into energy. This method differs significantly from the usual method, which uses fossil fuels to generate electricity. Although traditional means of power transmission and distribution are used, PV arrays are constructed by combining PV modules; such PV arrays are known as PV generators when placed in series and parallel configurations. They are then mounted in such a way that they are directly exposed to sunlight. The inverters convert the direct current (DC) power generated by the PV generator to alternating current (AC). This electricity can be used directly or transmitted to the energy grid via the transmission network (Sharma et al, 2020).

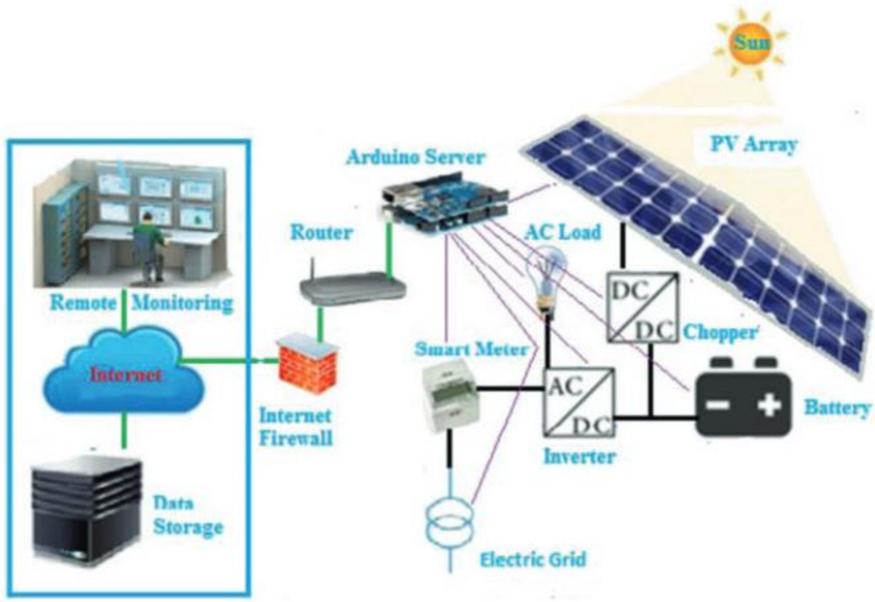

Figure 2.30. IoT-aided layout for photovoltaic system

Nonetheless, instead of being transferred, the energy might be stored using batteries. Solar powered models are classified into two types: off-grid and on-grid models, which are based on various types of functional components. Figure 2.30 depicts the configuration of the functioning of the photovoltaic system. Using a web-based technology, a remote monitoring system based on IoT makes it much easier to supervise the whole functioning of the solar power plant. The Internet of Things improves energy efficiency and profitability by collecting historical modeling data. This increases the efficiency of energy generation in terms of both price and logistics. (Sharma et al, 2020).

2.2.2 *Systems that uses ZigBee Technology*

ZigBee is a wireless communication system with limited range and low power consumption, also known as a wireless individual domain network with a low data transfer rate. It is also a wireless communication technology that is bidirectional, short-range, low complexity, low power consumption, and low cost, which determines its application prospects. The ZigBee network coordinator is the "brain" of the whole ZigBee network, as it is at the center of everything. Its responsibilities include network setup, maintenance, and management, as well as network address assignment (Long & Miao, 2019).

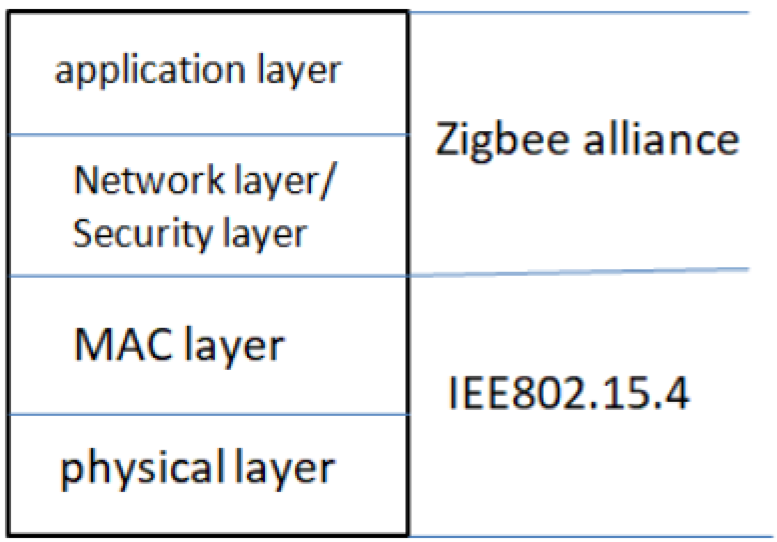

Figure 2.31 Zigbee Network Architecture

In Figure 2.31 from bottom to top, the ZigBee network layer consists of the physical layer, media access control layer (MAC), network layer (NWK), and application layer. The IEEE802.15.4 defines the physical layer and MAC layer, while the ZigBee alliance defines the network layer and application layer. And each layer provides data and management services to its upper layer (Long & Miao, 2019).

	Band	Using range	Data transfer rate	Channel number
2.4 GHz	ISM	All over the world	250 kbps	16
868 MHz		European	20kbps	1
915 MHz	ISM	In North America	40kbps	10

Figure 2.32 ZigBee frequency band and data transmission rate

For the distribution working frequency band, IEEE802.15.4 defines two physical standards, which are the physical standard layer of 2450 MHz (known as 2.4 GHz) and the physical layer of 868/915MHz. They employ the same physical layer packet structure and are based on direct sequence spread spectrum, but they differ in operating frequency band, modulation method, and transmission rate. The 2.4GHz frequency range is a worldwide unified ISM frequency band with no applications, which helps to promote ZigBee equipment and lower manufacturing costs. By using high-order modulation technology, the physical layer of this frequency band may give a transmission rate of 250 kbps, which helps to achieve faster throughput, reduce communication latency, and shorter cycle times, as well as accomplish the goal of energy conservation. In Europe, the ISM frequency band is 868MHz, but in the United States, it is 915MHz (Long & Miao, 2019).

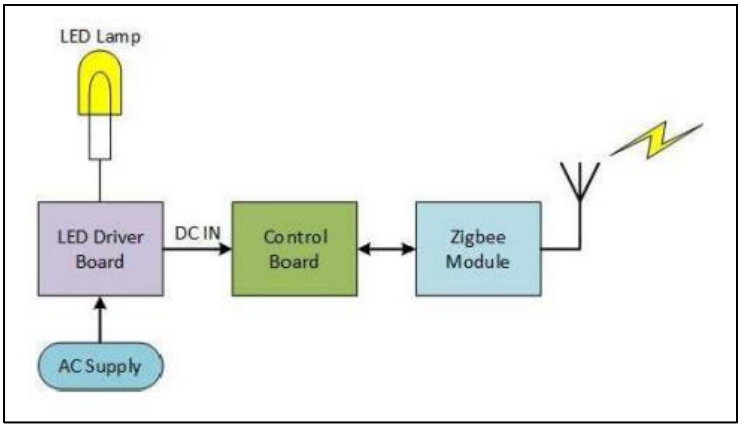

Figure 2.33 Transmitter block diagram

Where the transmitter block diagram is shown in figure 34 every node will function as a transmitter because it has a ZigBee module for transmitting data. It has an LED bulb connected to the LED driver board, as well as a temperature sensor, a ZigBee module, and a light sensor connected to the control board. The light intensity is determined using a light sensor, the current is measured with a current sensor coupled to a line, and the power is measured with an ADE chip, and all of these are then combined and shown on the LCD, and then wirelessly sent to the receiver, which is really connected to a control center to make the appropriate choice (Prasanth et al, 2022).

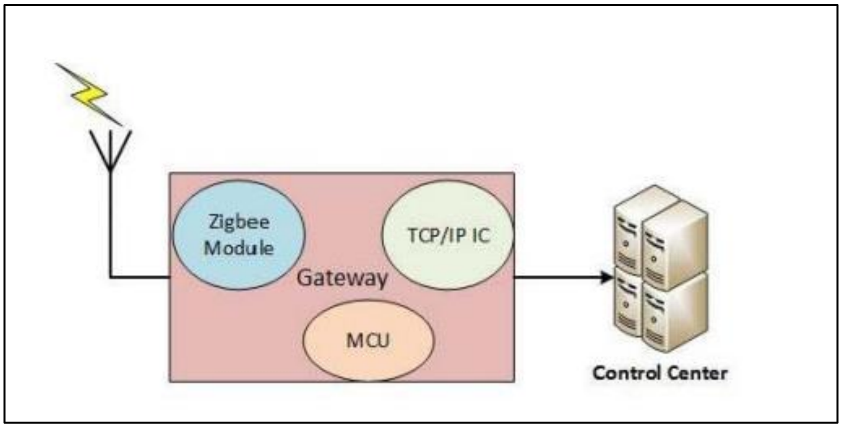

Figure 2.34 Receiver block diagram

On its receiver side, which is shown in figure 34, consists of the ZigBee module, gateway, and personal computer (PC). The ZigBee module is responsible for receiving data from each lighting node. The gateway serves as a connection between the wired and wireless networks. It has a ZigBee module, a TCP/IP connection, and a microcontroller. It links the ZigBee module to Ethernet, allowing the server to retrieve data from the wireless sensor network through TCP/IP, making it accessible to many users. The PC is used to display network transmissions and to indicate the status of a light, which is marked if it has a defect and can then be readily removed. It is connected to Ethernet via a gateway, so we can access it from anywhere on the globe (Prasanth et al, 2022).

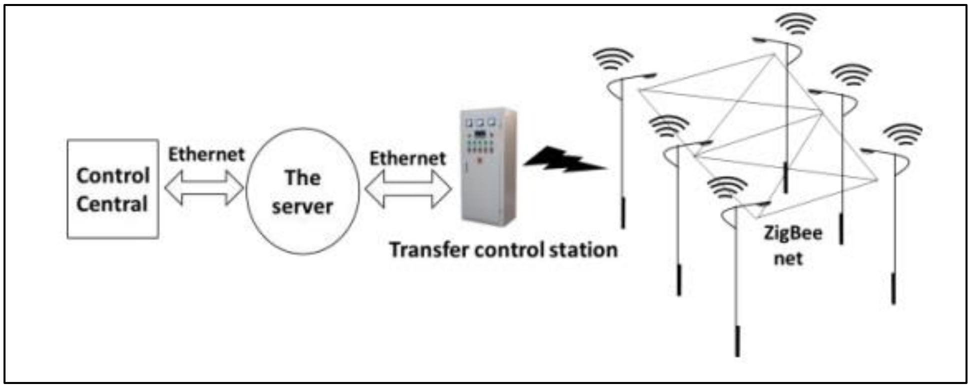

Figure 2.35 Overall System architecture based on GPRS and ZigBee technology

The overall system is based on GPRS and ZigBee technology and comprises of the control center, the transfer control station, the streetlamp terminal unit, and the communication interface as shown in figure 2.36. It says that the control center receives the information from the streetlamp terminals in real time and displays it in a visual interface. The control center also sends the data to the server and forwards it to the station. The transfer control station acts as a ZigBee network coordinator and is responsible for the establishment and configuration of the ZigBee network. The data instruction is provided to the streetlamp terminal via ZigBee when the data is confirmed by the transfer control station. It can also be seen from the figure that it is a two-way communication path between each lamp terminal and the control center, guaranteeing the transmission of control signals and the status of any lamp (Wu et al, 2018).

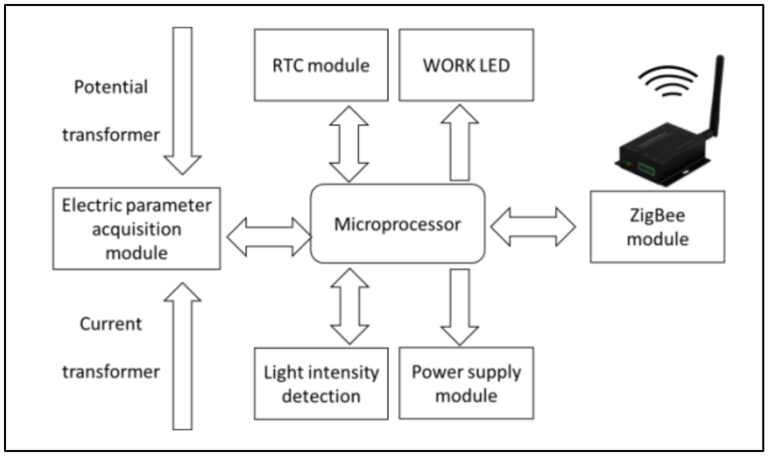

Figure 2.36 Streetlamp terminal structure

Figure 2.36 shows the Street Lamp terminal structure that is composed of the core control panel, electrical parameter acquisition module, light intensity detection unit, RTC, and ZigBee module. The STM32 control panel can then detect voltage and current signals, which are then sent to the STM32 control module. These commands and data collected by the STM32 control panel can be sent to the server through the ZigBee module and the GPRS network. The street light terminal system, which also serves as a ZigBee network router, is installed within the lamp pole, and is used to operate and close the streetlamp (Wu et al, 2018).

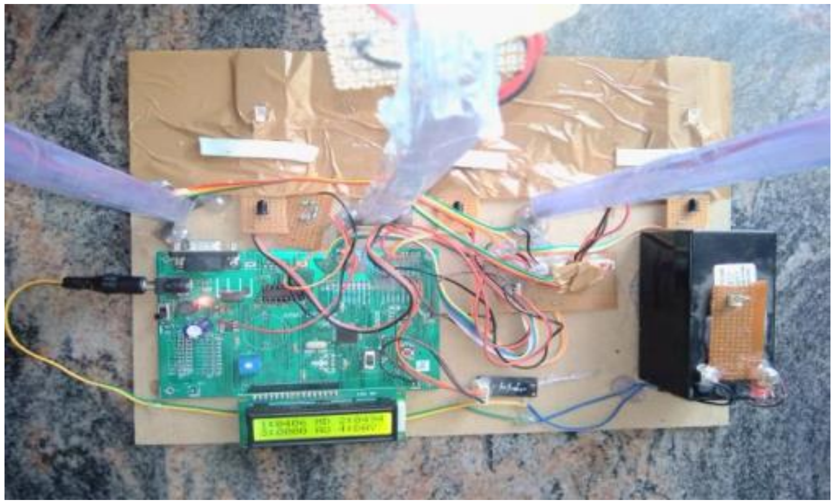

Figure 2.37 Complete hardware setup of intelligent solar street lighting system using ZigBee network

The sensors are placed and interfaced with the ARM7LPC2148, and the data or values are received from the sensors and displayed on the 16X2 LCD display. The IR sensors are also placed in such a way to detect vehicles and pedestrians effectively. A microcontroller LPC2148, a power supply unit, an LCD, ZigBee, an LDR sensor, an IR sensor, a battery, a solar panel, and several streetlights make up the street light component. The IR sensor and LDR sensor were used as input units, while the relay driver circuit was used as an output unit. The values of the parameters are sensed by the LDR and given to the ADC unit, which converts them to digital form, which is then sent to the microcontroller (Bharath & Srinivasulu, 2017).

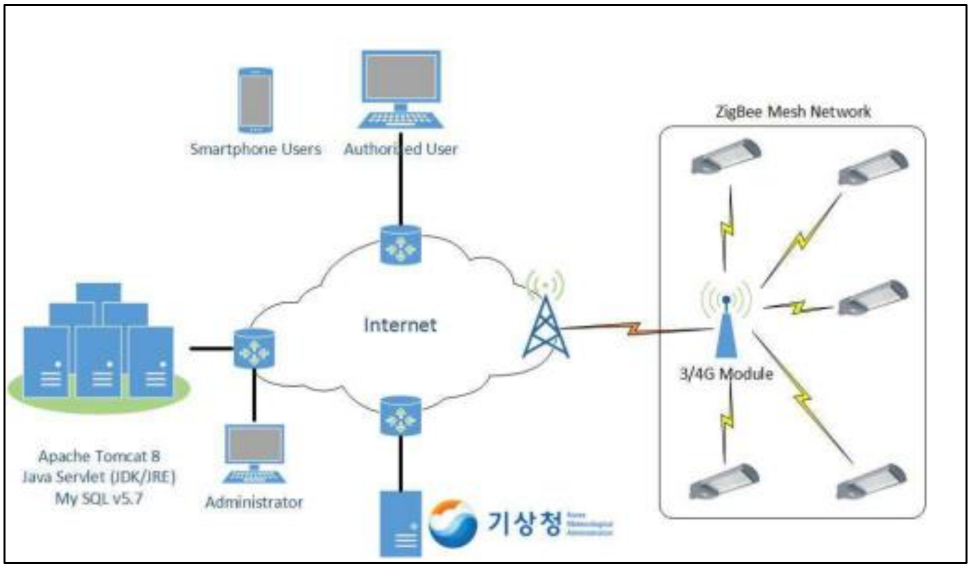

Figure 2.38 Design network topology and configuration

Satrya et al.., used MySQL 5.7 for the database and a Java application on a server based on Tomcat Servlet 8. On its hardware side, the ZigBee sensors are connected to the existing LED streetlights, and the users can see them directly from the administrator or smartphone. They provided a username and password to access the system. Their suggested system consists of four components: 1) *Color Temperature Varying LED Streetlight* that will be based on the data from humidity, PM10, and weather warnings, which can change the color temperature of the LED. 2) a *Public Weather Data API* that takes climatic data from the web and/or public weather data networks and sends it to an LED streetlight remote control and monitoring center. According to the admin's initial criteria, all hardware LEDs on the street must be registered with their corresponding GPS positions. 3) *Remote Control/Monitoring Server* that can do 24/7 monitoring from a computer or smartphone that can also provide commands directly to the coordinates of the point where the LEDs are, like information about voltage, current, temperature, and humidity. 4) *Communication* *between LED streetlights and a server,* where the server can request the data related to the previously mentioned parameters and can also turn off and turn on LED streetlights directly (Satrya et al, 2017).

2.2.3 *Systems that uses LoRaWAN technology*

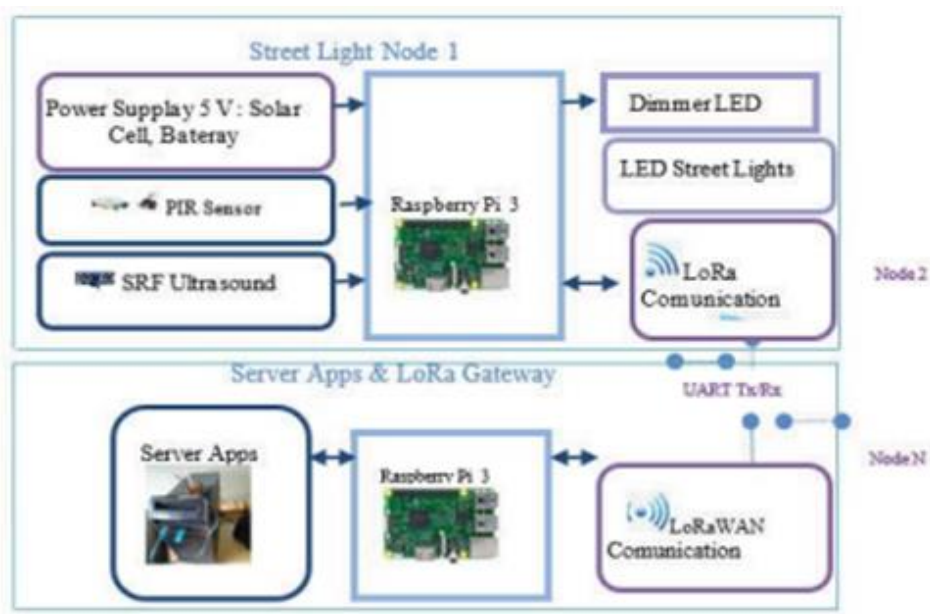

Figure 2.39 Architecture system for the transmitter of smart Streetlight using LoRaWAN

In Figure 2.39, shows the entire system of the smart Streetlight using LoRaWAN along with the Internet of Things (IoT) installation (Siagian & Fernando, 2020).

Lora technology, invented by Semtech, is now the most extensively utilized for different Internet of Things research. This technology operates without a license in the sub-GHz band, is open, and lacks the power to govern radio frequency regulators.

Lora technology is simple to employ across long distances of many kilometers. This technology is being used in a limited number of scientific domains (Siagian & Fernando, 2020).

The Python programming language may be used by the Raspberry Pi 3 (RPi3) to interface with ultrasonic SRF and metal models. The Raspberry Pi 3 requires 5V electricity to operate and features a GPIO Pin that may be utilized or adjusted for certain tasks. Lora uses the UART port to connect with the Raspberry Pi 3. There are two UART ports: PL010 and micro UART. UART Rx DO (GPIO11, PIN15) and UART TX DO (GPIO11, PIN15) ports (GPIO12, PIN6) (Siagian & Fernando, 2020).

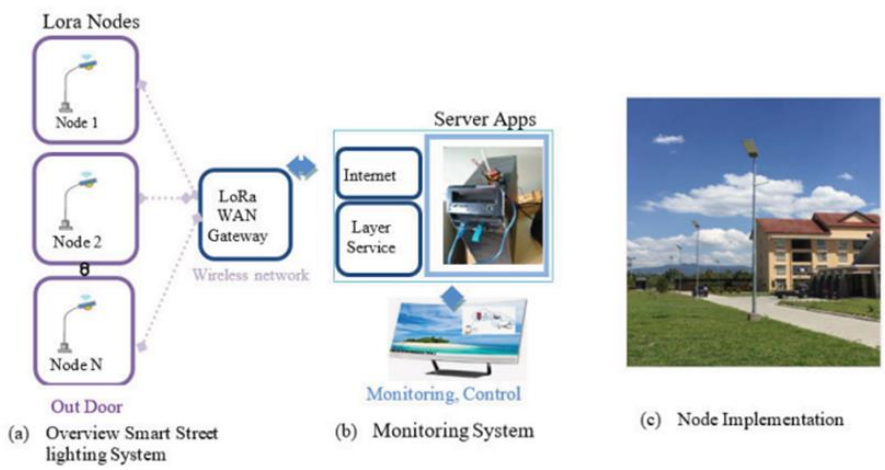

Figure 2.40 Implementation overview smart street lighting system and monitoring system

Figure 2.40 depicts an overview of the Smart Street Lighting System and Monitoring System incorporated along the Internet of Things (IoT) installation (Siagian & Fernando, 2020).

This design was created utilizing Ultrasonic SRF, LDR, PIR sensor, and LoRaWAN technologies, as well as an RPi3. This system includes solar panel sensors, additional sensors, and a lighting system that employs LEDs to modulate light intensity and conserve energy on each lamppost pole. The energy utilized is produced naturally from sunshine, which is highly ecologically beneficial. This is accomplished using solar panels, which are stored in DC batteries. The system may be powered by a fully charged DC battery (lights, sensors, and other devices). This gadget will function automatically thanks to the SRF ultrasonic sensor and the PIR sensor (Siagian & Fernando, 2020).

Figure 2.41 System overview

Figure 2.41 depicts a system overview of the LoRaWAN-powered Smart Street Lamp System. This diagram depicts how LoRaWAN works in this setup (Saokaew et al, 2021).

When compared to other wireless technologies such as WiFi, Bluetooth, Zigbee, Z-Wave, LTE-M, and NB-IoT, Long Range Wide Area Network (LoRaWAN) utilizes less energy while giving an incredibly long-range connection. LoRaWAN is suited for long-distance wireless communications that doesn't require high-speed transmission and consumes minimal power. LoRaWAN is commonly referred to as appropriate technology applications in Internet of Things (IoTs) that require minimal-speed remote communication, low power consumption, a big connection budget, and improved interference resistance (Saokaew et al, 2021).

When the AI image processing recognizes no people walking, bikes, motorcycles, or automobiles in the vicinity of the Internet Protocol (IP) camera looked out sites, the system saves energy by reducing the brightness of the streetlamps to 50%. When the surveillance camera identifies things (people, vehicles, bicycles, and motorbikes), the LoRaWAN gateway sends a signal set to the LoRaWAN network to increase the brightness of the street lights to 100% for a brief amount of time before reverting to 50% to conserve energy. This cycle is continued throughout the night to ensure pedestrian safety and security while saving energy. (Saokaew et al, 2021).

Figure 2.42 An Arduino code for the LoRa node

Figure 2.42 depicts the Arduino code that was programmed into the LoRa nodes to allow the LoRa nodes and the gateway to communicate with one another (Saokaew et al, 2021).

As shown in Figure 2.42, certain information must be included in the arduino code before it can be programmed into the LoRaWAN nodes. DeviceEUI, AppEUI, and AppKEY are required parameters for the node to connect with the gateway. The gateway and nodes must be preprogrammed with the same DeviceEUI, AppEUI, and AppKEY. Any discrepancy in information will prevent both devices from communicating with each other. Because the node units are powered by an alternating current (AC), the LoRaWAN class can be configured to either A or C. LoRaWAN class A will use more energy because both devices (gateway and nodes) are always on. Class C LoRaWAN is required for battery operation. Because both gateways and nodes only broadcast and receive at predetermined intervals, LoRaWAN class C requires the least amount of power when compared to classes A and B (Saokaew et al, 2021).

Figure 2.43 Basic topology of LoRaWAN

Figure 2.43 depicts the fundamental LoRaWAN architecture, known as star topology, which reduces complexity compared to other mesh topologies (Sahoo & Patnaik, 2017).

LoRaWAN technology is an open standard, low-cost, wide-area coverage IoT platform with a limited use and scope. This technique operates on the 900MHz frequency band, which does not require a spectrum license. This device is far less expensive than others that use advanced modulation methods such as CDMA, FSK, GFSK, MSK, and GMSK. The extraordinary aspect of this technology is its extraordinarily low power consumption. The RF-LoRa-868 module provides 89dB blocking immunity, a built-in RF switch, and a maximum link budget of 157dB with a receiver current of 10mA (Sahoo & Patnaik, 2017).

A Wi-Fi/LoRa and ESP module can provide a safe, secure, and economical way for electrical device control and monitoring. In terms of electricity consumption in remote areas, it can be minimized using IoT devices with LoRa & Network services. Data from sensors can be transmitted through LoRa gateways to the master control stations. An innovative design will provide an option to manually monitor and control via mobile or web-based portal. Also, by providing feedback of the faulty devices to the concerned authority through sensors to quickly fix the issue (Fathoni et al, 2020).

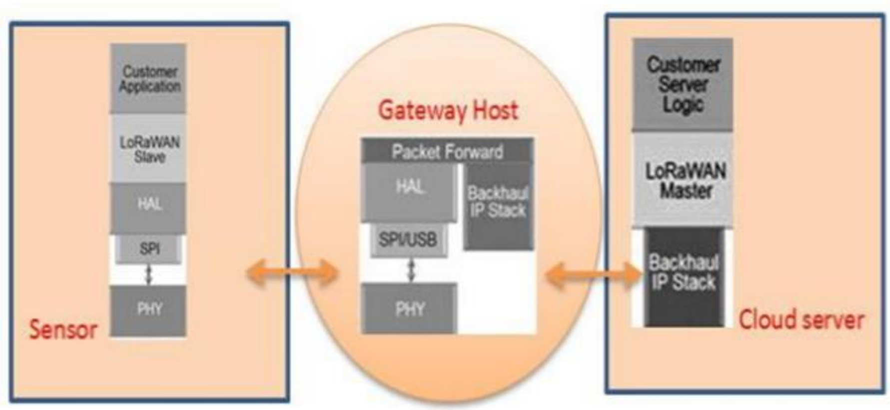

Figure 2.44 LoRaWAN protocol stacks

Figure 2.44 depicts the LoRaWAN protocol stacks, as well as the sensor, gateway host, and cloud server that will be utilized in the design and execution of a remote monitoring system for solar lanterns based on LoRaWAN and cloud technologies (Nizam et al, 2019).

Endpoint mobility is a built-in characteristic of LoRaWAN, making it ideal for IoT. Other aspects of this technology include a range of 12-16 km in rural areas and 3-5 km in urban areas. The maximum number of nodes per gateway is 15,000, with a maximum data throughput per terminal of 50kbps. LoRaWAN's average latency is one second. LoRaWAN has a flexible frequency range. It is 863-876 MHz/915-921 MHz for Europe, 865-867 MHz for India, 470-510 MHz for China, 920-928 MHz for Japan, 902-928 MHz for North America and Brazil, and 917-923.5 MHz for Korea in the industrial, scientific, and medical (ISM) range (Sahoo & Patnaik, 2017).

Figure 2.45 Data visualization uses GRAFANA

Figure 45 depicts Grafana, which is used to view Lora Technology data. This solution makes monitoring more convenient and effective by utilizing mature LoRa communication technology and long-distance characteristics. Lora technology does not matter if the technology is delivering pH, DO, conductivity, temperature, or other sensor data if the numbers are all aggregated into a string. Lora technology can be transferred, and the cost is lower when compared to Wifi transmission technology. Not only does it not require any cables, but Lora technology also has compact volume. The steady remote transmission eliminates data loss and allows for more precise recording and analysis. As a result, LoRa is the current mainstream trend. The sophisticated Grafana visualization tool was employed shortly after the data was available to show the data on an attractive and easy-to-use dashboard, allowing management to quickly absorb all the information (Fathoni et al, 2020).

Long-distance transmission is possible with the LoRa water quality monitoring system presented in this article. The quality of the water can be comprehended and evaluated using a huge amount of data in the field environment, and the data can be swiftly communicated to the back-end storage and processing using MQTT and LoRa. This demonstrates that LoRa communication is dependable and secure. Finally, Grafana is utilized to clearly display the data trend and the benefits of our technology in these specific domains (Fathoni et al, 2020).

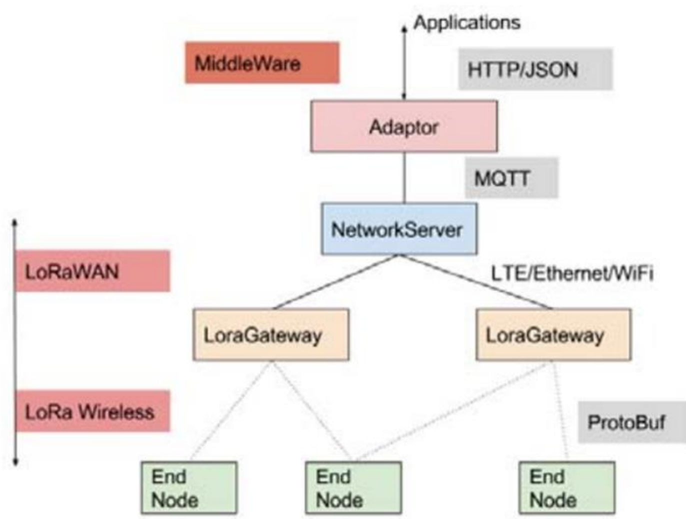

Figure 2.46 Lora network setup

Figure 2.46 depicts the Lora Network Topology and its gateway configuration (Tsyani et al, 2018). LoRa, which stands for Long Range, is a radio that operates at sub-gigahertz frequencies (in the 865Mhz band). Its advantages include a long range, low power consumption, and inexpensive cost. Every standalone streetlight module includes a LoRa radio (the im880b is based on Semtech's SX1272 LoRa Module). Every LoRa Radio (End Node) in the 865 to 867 MHz frequencies may communicate with a LoRa gateway through one of three 125 kHz uplink channels (Ramesh et al, 2019).

A LoRa gateway can listen to several channels and spread factors at the same time and push the payload onto the Network Server, which effectively feeds the payload into the radio's unique database and allows it to be sent to any applications that require it (Ramesh et al, 2019).

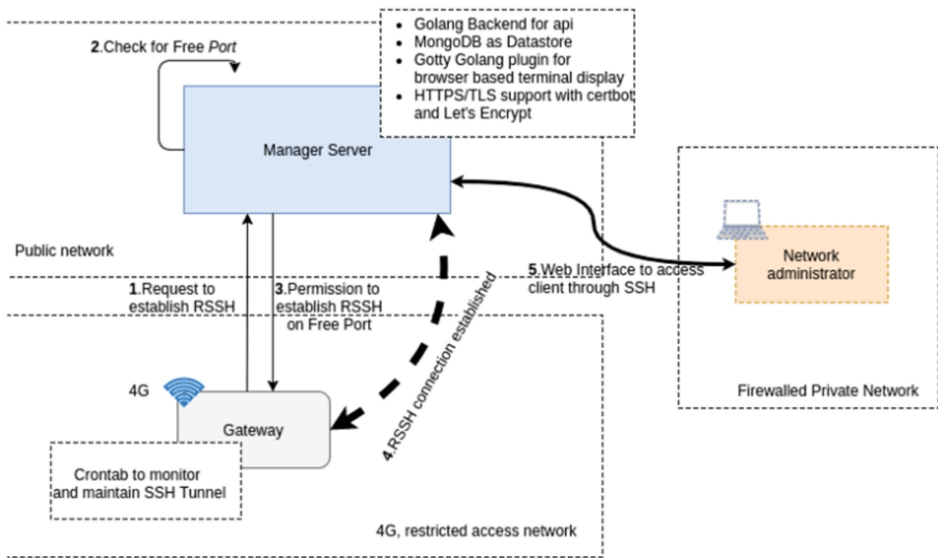

Figure 2.47 LoRa infrastructure management life cycle

The LoRa Network Infrastructure management is depicted in detail in Figure 2.47 (Ramesh et al, 2019).

LoRa Networks are vital in a network deployment that the LoRa Network Service Provider has constant access to their LoRa gateway infrastructure for monitoring and troubleshooting. A LoRa gateway is often connected to a 4G/LTE network to feed data obtained from LoRa end nodes to any middleware. Because most incoming ports on

4G networks are banned, an SSH connection request to the LoRa gateway cannot be made (Ramesh et al, 2019).

To deal with such situations, the researchers created a network management service that allows administrators to SSH to these machines easily. As illustrated in Fig. 2.47, the researchers do this by instructing the gateway to construct a reverse SSH tunnel to a Management Server, from which a client web browser can open a terminal supported by a Web Service running on the management server (Ramesh et al, 2019).

The LoRaWAN network is used for data transfer between sensor nodes and backend cloud services in this system. Data from sensor nodes is sent to LoRaWAN base stations, which then send it to The Things Network (TTN) platform. The TTN is an open platform for LoRaWAN devices (sensing nodes) and base station registration (gateways). LoRaWAN includes all essential backend services for LoRaWAN base station operation, such as all data, and transport layer functions, as well as all relevant security layers. The TTN platform collects, formats, and reroutes data from sensor nodes to our cloud services while ensuring data integrity and security. When the TTN platform gets a message from a base station, it formats it with a specified custom formatter and routes it to cloud services, which oversee data storage, visualization, and analytics (Davcev et al, 2018).

This system was created for agricultural uses, where there is a requirement for many sensors that generate streams of data that must be processed. Aside from its primary application in agriculture, this system is easily adaptable to other social and production processes with similar requirements (Davcev et al, 2018).

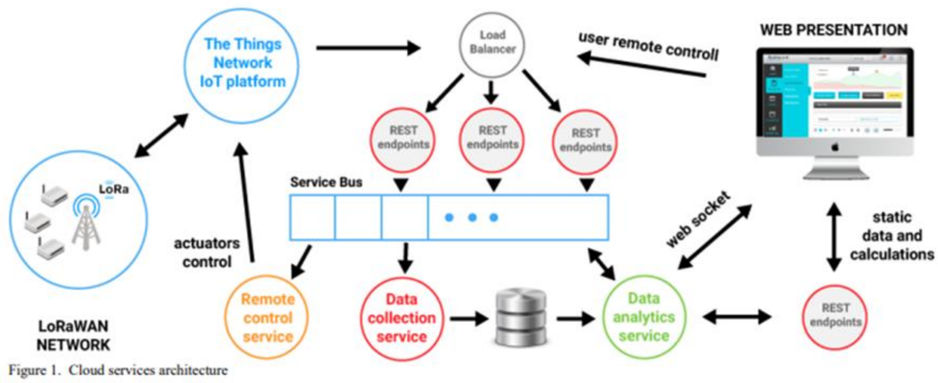

Figure 2.48 Cloud services architecture

Figure 2.48 shows how the Cloud Services Architecture relates to LoRaWAN Network (Davcev et al, 2018).

The LoRaWAN network was created primarily for IoT applications, with the goal of linking thousands of sensors, modules, and appliances over a vast network. LoRaWAN is a network protocol that is mostly utilized in Smart City applications where large network coverage is required but is beginning to be applied in all other social aspects where its qualities meet their requirements (Davcev et al, 2018).

LoRaWAN differs from other IoT protocols such as ZigBee or NRF in several ways, including network structure, data transmission range, and performance. LoRaWAN's physical layer is based on CSS (Chirp Spread Spectrum) modulation, which retains the same low power characteristics of FSK modulation while increasing communication range. The transmission range is heavily dependent on the environment and its obstacles; however, LoRa and LoRaWAN have a higher link budget (measured in dB) than any other defined communication method. LoRaWAN has a data transmission range of 2-5 km in cities and up to 15 km in suburbs. Aside from long transmission ranges, CSS modulation provides low power characteristics, implying that LoRaWAN can be employed in applications that do not require an external power source. LoRaWAN applications can run for years on battery power. One downside of the LoRaWAN network is its low data rates, or throughput, which hinders it from being employed in real-time and high-throughput applications like VoIP and video transmission (Davcev et al, 2018).

The goal of LPWA networks is to enable long-distance communications by linking devices spread across a vast geographic region. LPWA networks are an alternative to M2M (Machine-to-Machine) communications using 2G/3G/4G technology. Support for 2G technologies is set to be phased out soon, posing a challenge in providing connectivity to low-power sensors and modules (Lavric & Petrariu, 2018).

With communication distances in the tens of kilometers and a battery life of 10 years, LPWA technologies are ideal for attaining minimal maintenance costs. The vast communication radius is acquired at the price of the transfer rate (which is normally in the tens of kilobytes per second). Furthermore, the delay is typically considerable, lasting seconds or even minutes. Thus, LPWA technologies are not ideal for IoT applications that cannot tolerate delays or demand a high rate of data transfer (Lavric & Petrariu, 2018).

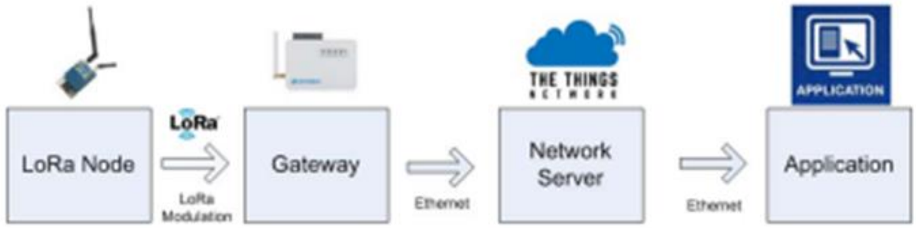

Figure 2.49 LoRaWAN

Fig 2.49 The LoRaWAN architecture is shown, which comprises the Lora Gateways, Lora end modules, Lora Server, and Application Server. The LoRa Gateway can receive messages from thousands of LoRa End Nodes, allowing it to cover a wide geographical region. Using the spreading factor approach, the packets are transmitted at varying data speeds. The spreading factor mechanism is particularly effective in separating physical channels. As a result, two packets broadcast on the same channel at the same time with different spreading factors will not interfere with each other and will be successfully received (Lavric & Petrariu, 2018).

When a packet is sent from the End LoRa node, the Gateway module receives the packet and retransmits the packet to the Network Server. This data service aggregator provides the information to the user (Lavric & Petrariu, 2018).

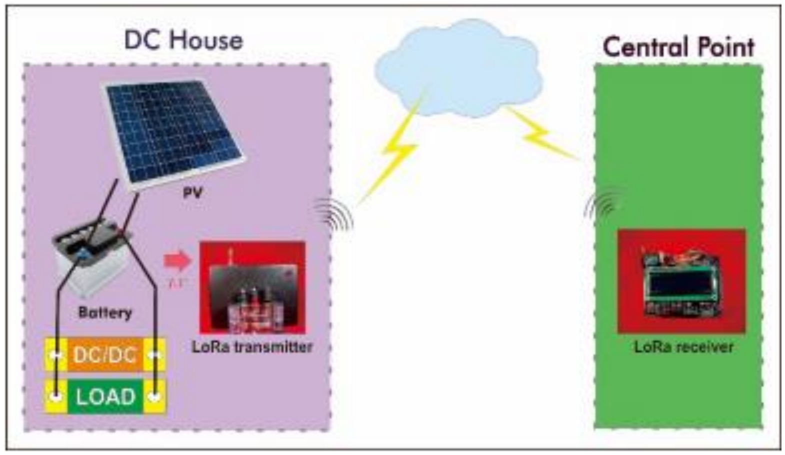

Figure 2.50 BMS with LoRa

In Fig 2.50. Monitoring the Lead Acid battery in a long-distance area with the use of LoRa for the wireless communications. As LoRa works in a low bandwidth because of its power limitations. LoRa works with different frequency in every different country that can range from 430 to 915 MHz with a 15 km catch up in rural area. This study uses LoRa to monitor the Lead Acid battery in different point area. Lora radio module is a type of transceiver module of a lora technology. The study use spring for automatic detection of the RF signal and frequency. The form of this wireless communication produces a great bandwidth through the help of the antenna (Tsyani et al, 2018).

Table 2.4 Comparative matrix for networking protocols

Author	Year	Title	Findings	Relationship
Andi Adriansyah, Setiyo Budiyanto, Julpri Andika, Arif Romadlan, and Nurdin Nurdin	2020	*Public Street Lighting Control and Monitoring System Using the Internet of Things*	This study states the limitations of ESP8266. In their study, the maximum data transmission distance is 15 meters inside the room and 19 meters outside. The wi-fi signal strength declined as the data transmission distance increased, as indicated in the graph. Noise, interference, fading, and attenuation all contribute to this reduction.	The researchers have the idea on the limitation on the device they might use in the study. And the same with this study, the ESP8266 will be used to make the study connected to the internet and make it IOT project.

Z. Ke and C. Xiao	2016	*Research of Intelligent Street Light System Based on ZigBee*	This study uses ZigBee and GPRS as its wireless protocol on their solar streetlight monitoring system.	This study will also create solar monitoring system but will use LoRa instead of Zigbee because of its distance limitation.
C. Bouras, A. Gkamas, V. Kokkinos, and N. Papachristos	2019	*Using LoRa Technology for IoT Monitoring Systems*	In this study, Wi-Fi and LoRa is compared as wireless technology for IOT Monitoring systems. Both LoRaWan and Wi-Fi is good, but they have specific uses.	The same application will be used in this study. The LoRa will be used to collect data from monitoring systems with

			LoRaWan is better for its range and Wi-Fi is used as gateway to the internet.	great distance and with the help of Wi-Fi, the data can be uploaded to cloud to have online data base.
R. Muhendra and Y. H. Arzi	2017	*Development of Street Lights Controller using Wifi Mesh Network*	ESP8266 is used in this study. The researchers of this study utilized the used of this module to create a mesh network for smoother data transfer.	This study gives the researchers idea on different topology that can be used in the study.
Rauniyar, Ashish & Irfan, Mohammad & Saputra, Oka & Kim, Jin Woo & Lee, Ah &	2017	*Design and Development of a Real-Time Monitoring System for Multiple Lead–*	This study used Wi-Fi card or WizFi to be specific to transfer data over WLAN. Its interface may	

Jang, Jae & Shin, Soo		*Acid Batteries Based on Internet of Things.*	direct the Wi-Fi radio to scan for access points and ad hoc networks	
Sharma, Meera & Singla, Manish & Nijhawan, Parag & Ganguli, Souvik & Rajest, Suman.	2020	*An Application of IoT to Develop Concept of Smart Remote Monitoring System.*	This study developed an IOT-aided photovoltaic system. With this, they can monitor the functioning of the photovoltaic system.	This study will be improved by the researchers. They will not only monitor the photovoltaic system but the whole solar street light system and will also develop web-based technology for remote monitoring.
S. Long and F. Miao	2019	*Research on ZigBee wireless communication*	ZigBee fills the gap in the market for low cost, low power	This study will help the researchers in terms of

		technology and its application	consumption, and low-rate wireless communication. Its typical applications include wireless data transmission combining ZigBee and GPRS, medical monitoring system, wireless meal ordering system and intelligent traffic control system	choosing what kind of wireless network they will use. And how will it apply to the current study.
S. G. Varghese, C. P. Kurian, V. I. George, A. John, V. Nayak, and A. Upadhyay	2019	*Comparative study of zigbee topologies for iot-based Lighting Automation*	This study found out that the star topology with DSR protocol offers the best performance in terms of end-to-end delay, throughput, and jitter. And for	This study can help the researchers of the current study in determining what topology they will

			the IoT application with indoor lighting and building automation, where the emphasis is on saving energy especially in idle mode, we find that the mesh protocol is more sustainable	implement on the wireless network side.
T. Prasanth, T. M. Thameem, M. Kalaiyaras, A. Sajili, and M. Nandhini	2022	*Solar Street Light Control System using ZigBee Network in all Climatic Conditions*	This study developed a smart LED streetlight where it can remotely monitor and control the streetlights. Their readings show that to maintain illumination level of 200 Lux for 75 W lamp, it only uses 49.23 W. And	This study can help the current study by including the control of the luminosity of the Solar Street Light depending on the climatic conditions.

			the has the capability to reduce the power consumption by adopting the environment.	
C. Wu, Y. Deng, L. Yin, B. Yang, Y. Xiang, J. Bai, X. Gu, J. Shi, R. Yang, Y. Wu	2018	*Design of Intelligent Street Lamp Control System Based on Wireless Network*	This study had an intelligent streetlamp control system based on the combination of GPRS and ZigBee for wireless network control. The structure is convenient to install, the cost of maintenance is low, and the energy consumption is low.	This study is also somehow like the researcher's study, the same with the parameters. However, the researchers will be using solar streetlight instead of the normal streetlights that we see.
A. Bharath Kumar and D.	2017	*Designing An Intelligent*	This study is about implementing a a	This study will be improved by

Srinivasulu Reddy		*Solar Street Lighting System using ZigBee Network*	solar based streetlighting system where it can save energy by using some smart things. It has specific features which are automatic on/off, dimming control and manual on/off control.	the researchers. It will not only monitor in getting the maximum charge from the sun but also have mobile and web page on tracking the parameters of the solar streetlights
G. B. Satrya, H. T. Reda, K. J. Woo, P. T. Daely, S. Y. Shin, and S. Chae	2017	*IOT and public weather data-based monitoring & control software development for variable color*	This study implemented a project work on weather data aware remote monitoring for correlated color temperature LED streetlight system with the help of IoT. The	In relation to the current study, this study can be helpful in terms of the weather system, where they can adjust the luminosity of the LED to

		temperature led streetlights	researchers used ZigBee based wireless sensor nodes on each streetlight to provide periodic updates of temperature, humidity, and weather data to the server through TCP/IP communication protocol.	avoid any accidents on the streets.
P. Siagian and E. Fernando	2020	*LoRaWAN Intelligent Outdoor Smart Street Lighting*	This study compared ordinary LED bulbs to the suggested system and found a tendency toward large energy savings, particularly 33	The purpose of this research is to use LoRaWAN as a centralized network for streetlights. This study has almost identical

			percent to 60 percent savings.	components to those required for this project.
N. Saokaew, N. Kitsatit, T. Yongkunawut, P. Ayudhya, E. Mujjalinvimut, T. Sapaklom, P. Aregarot, J. Kunthong	2021	*Smart Street Lamp System using LoRaWAN and Artificial Intelligence PART I*	The gateway was able to consistently send downlink signals to the LoRaWAN receiver node to switch on/off and regulate the light brightness from more than 500 meters.	This study illustrates LoRaWAN's capabilities in terms of distance, which is useful for this project.
U. K. Sahoo and B. Patnaik	2017	*Design and Implementation of Remote Monitoring system of Solar Lanterns, based on LoRaWAN and Cloud Technology*	Unlike ZigBee, Wi-Fi, and Bluetooth, this technology has a large network coverage area; thus, a maximum of 15000 solar lanterns can be managed efficiently	This study demonstrates that a maximum of 15000 solar lanterns can be managed by a single gateway, which will aid in the

			through a single LoRaWAN gate way.	development of solar streetlights with monitoring systems capable of managing many solar streetlights.
H. Fathoni, H.-Y. Miao, C.-Y. Chen, and C.-T. Yang	2020	*A Monitoring System of Water Quality Tunghai Lake Using LoRaWAN*	The quality of the water can be comprehended and evaluated using a huge amount of data in the field environment, and the data can be swiftly communicated to the back-end storage and processing using MQTT and LoRa.	This research will assist this project in learning about the capabilities of LoRaWAN through the usage of MQTT.

R. Ramesh, S. Acharya, V. Rajaraman, A. Babu, A. Joglekar, A. Sharma, B. Amrutur, and P. Namekar	2019	*Interoperable middleware for smartcities - Streetlighting on LoRaWAN as a case study*	The device can communicate with a gateway/server in real time to determine the quality of signals on the downlink and uplink using characteristics like as packet error rate (PER), RSSI, and SNR.	This study demonstrates the real-time communication of the LoRa network, which will aid in the development of a real-time monitoring system for solar streetlights.
D. Davcev, K. Mitreski, S. Trajkovic, V. Nikolovski and N. Koteli	2018	*IoT agriculture system based on LoRaWAN*	This study created a system that is adaptable and extendable in terms of adding new services and integrating with other IoT platforms.	This research employed many sensors in an agriculture system using LoRa, which will aid in the development of solar streetlights that will use

				multiple sensors in a LoRa network.
A. Lavric and A. I. Petrariu	2018	*LoRaWAN Communication Protocol: The New Era of IoT*	LoRa technology is a viable option for implementing the Internet of Things idea. According to the results, the LoRaWAN communication protocol has a high degree of performance.	According to this study, LoRa modulation uses a spread spectrum technique, which will aid this research in developing a high-performance monitoring system for solar streetlights.
D. N. Tsyani, A. Kurniasari and C. Hudaya	2018	*Battery Monitoring System with LoRa Technology*	LoRa technology with the use of spring antenna, can be a result of great bandwidth in the	The researchers use one lora transmitter and receiver for sending of data

			area. The study use one lora as transmitter and one lora as receiver where the central point in in between of the five point houses. The result of the study conclude that monitoring the lead acid battery in a far distance using lora would have a 0.023% of low measurement error.	to be measured in the battery, they use spring antenna for a great frequency of the study.

CHAPTER 3

METHODOLOGY

This chapter includes the Research Design, Research Process Flow, Statistical Analysis, and Project Work Plan, as well as how the research will conduct this study.

3.1 Research Design

This study is developmental research that monitors the health of *Solar Panels* in the solar streetlamps, along with the condition of the *lithium-iron phosphate battery* and the *LEDs*. A developmental study is a systematic study that focuses on meeting the criteria of consistency and effectiveness through the design, development, and evaluation of programs and projects. This study will monitor the system using microcontroller, different sensors like voltage, current, temperature, and luminosity, along with the LoRa that will be used to conduct this study.

INPUT

SOFTWARE REQUIREMENTS

1. Arduino IDE
2. EasyEda
3. Visual Studio Code
4. Mongodb

HARDWARE REQUIREMENTS

1. Microcontroller
2. Sensors: Voltage, Current, Luminosity, and Temperature
3. LoRa Module
4. Solar Panel
5. LED
6. Lithium-iron Phosphate Battery

KNOWLEDGE REQUIREMENTS

1. Basic Programming Skills such as HTML, and advanced ones like JavaScript and designing CSS.
2. Basic Programming of Arduino specifically the use of C/C# language in order to debug and test.
3. Schematic design, PCB Layout, and soldering of electronics components.

PROCESS

HARDWARE DEVELOPMENT

Design a device that will track and record data on the solar streetlight component's power, voltage, current, luminosity, and temperature. Moreover, to assess the batteries' State of Charge (SoC) and State of Health (SoH)

MONITORING SYSTEMS DEVELOPMENT

Interconnect all the monitoring devices and create one database that will store all the parameters that are gathered.

APPLICATION DEVELOPMENT

Develop a website application that will show the collected parameter from the different monitoring systems.

TEST AND EVALUATE

Test and evaluate the device on its deployment site for its performance, functionality, and efficiency.

OUTPUT

IOT CENTRALIZED MONITORING SYSTEM FOR SOLAR STREETLIGHT APPLICATION USING MICROCONTROLLER WITH LORA

Figure 3.1 IPO diagram of the study

This study aims to develop a real-time and centralized monitoring system that primarily focuses on the health of solar streetlamps, but not limited to Lithium-iron Phosphate batteries, and the LED to be used. This will determine, monitor the whole system, and notify if there are underlying problems. The following framework shown above summarizes the parameters for input, the processes needed, and the expected results or output of the system.

3.2 Research Process Flow

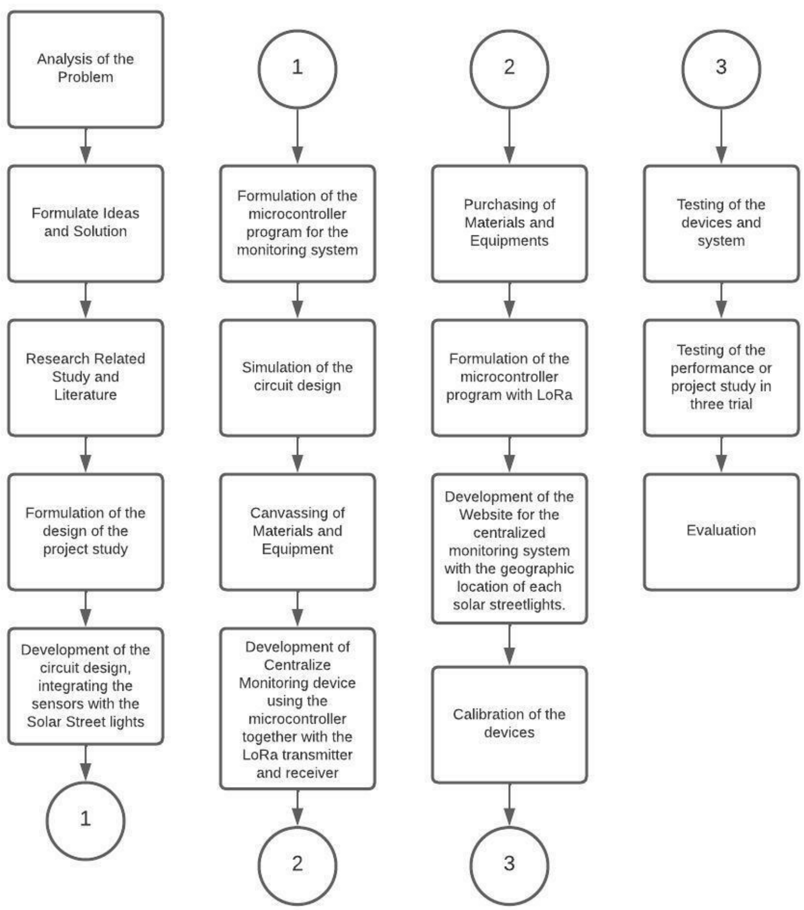

Figure 3.2 Research process flow diagram

For the Figure 3.2, it represents the process and flow of the study that will be needed to accomplish for the completion of the research study. The First phase of the study will start in Analysis of the Problem, formulating ideas and solution and researching related studies and literature for the formation of a new innovative design of the study's prototype. The simulation and choosing program language that will be use in Arduino will be needed for the formation of the devices and paper works.

After the finalization of the design and innovation of the study, the canvassing of the equipment will be the next together with a proper budgeting of each material. After it, the researchers will start to buy the equipment and materials that will be needed for the monitoring system such as the sensors, microcontroller etc. As the equipment and materials are ready, the researchers will start to test and calibrate each equipment for the preparation of the development of centralization of the study.

As the centralization is develop, the researchers will also start to create the data base of the system with the IoT function together with the development of the website for the real time parameters of the sensors under the centralization and monitoring system. After everything is settled, the testing of the equipment and the system will be conducted for a three trial which will be conducted with the professional under the main topic of this project study. After that Evaluation will be the next and final step in accordance with the ISO 9126, evaluation form will be given to at least 30 people.

3.3 Development of the circuit design integrating the voltage sensor, current sensor, temperature sensor, luminosity sensor and the solar streetlight.

3.3.1 *Development of the schematic design of microcontroller and LoRa connection for the centralized monitoring system.*

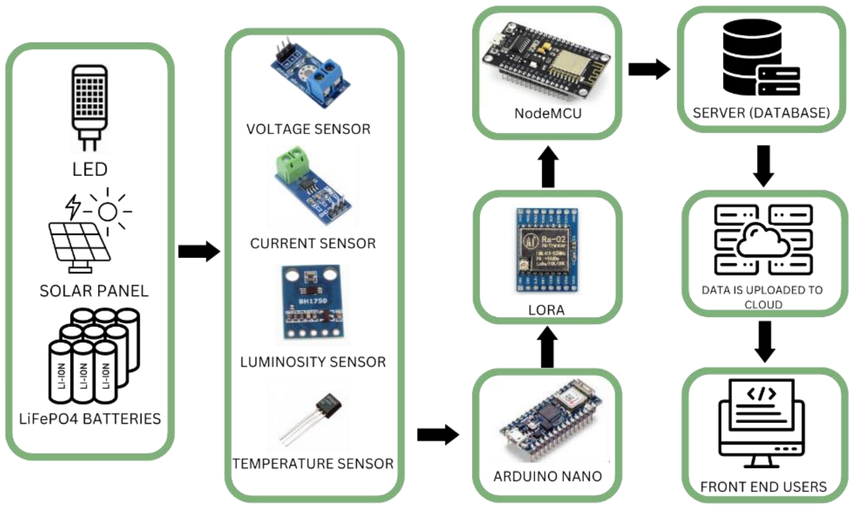

Figure 3.3 Architectural framework of the centralized monitoring system

The primary structural framework of the centralized monitoring system is depicted in figure 3.3. It will be embedded along with the necessary sensors, such as voltage, current, temperature, and luminosity, in the three devices that need to be monitored (solar panel, LED, and lithium-iron phosphate battery). Microcontroller will be used to receive the remaining flow. It will transmit data to a server and upload it to the internet, enabling real-time monitoring via web application.

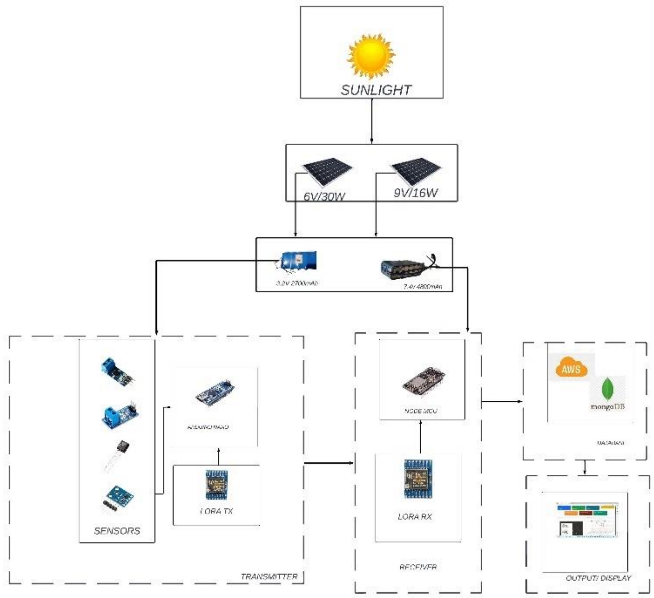

Figure 3.4 Block Diagram

Figure 3.4 shows the block diagram of the study and describes how each component works in the system. On the transmitter side, it comprises a solar panel, a lithium-iron phosphate battery, sensors, a microcontroller, and a LoRa module. The sensors are connected to the battery and solar panel to detect the data. The microcontroller will gather the data needed and send it to the LoRa module of the transmitter. On the receiver side, it also has a solar panel and a lithium-ion battery. The LoRa module on the receiver side will receive the gathered data from the transmitter side. The NodeMCU will upload the transmitted data to the database. From the database, it transfers the data to the back end. And from the back end to the front-end, where it displays, it will display the output on a website application.

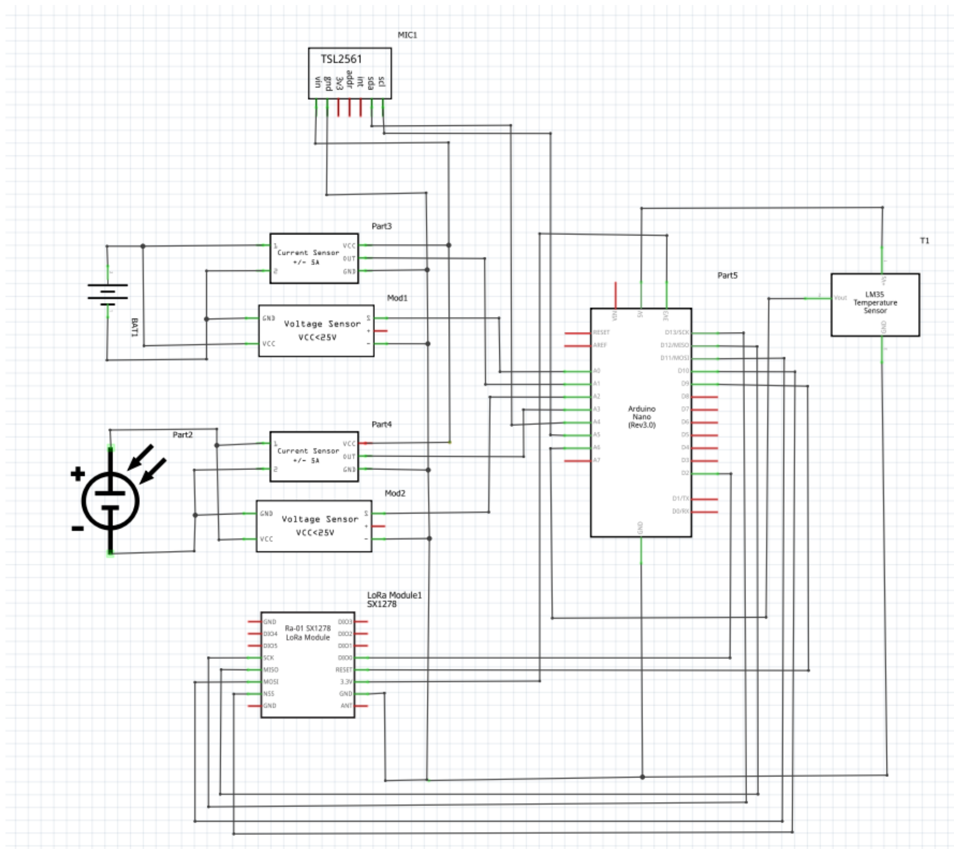

Figure 3.5 Schematic design of LoRa and microcontroller with sensors

Figure 3.5 shows the schematic design of LoRa and microcontroller with current, voltage, luminosity, and temperature sensor.

3.3.2 *Purchasing of sensors for centralized monitoring system.*

Table 3.1 Material and equipment of a solar streetlight parameter monitoring device.

MATERIALS/EQUIPMENTS
Microcontroller
Voltage Sensor
Temperature Sensor
Current Sensor
Luminosity Sensor
Solar Streetlight

The table above shows the materials that are needed for the construction of the monitoring system. The microcontroller as the main controller for the system together with the connection of the different sensors that are used to monitor the specific devices or components that are needed under the monitoring system.

Table 3.2 Specification of the Solar Street Light

CODE	SPECS
Solar Panel	6V/30W Monocrystalline Silicon
Solar Panel Size	530*350*16mm
Battery	3.2V/30AH LiFe PO4
Battery Life	5-8 Years
LED Chip Brand	Bridgelux
Number of LED	150 pcs
Light Output	20,000lm
Lifetime	50,000 hours
CCT	3000k-6500k
Lamps Material	Aluminum
Charging Time	6-8 hours (by Sun)
Discharging Time	12-16 hours
IP Rating	IP 66
Mounting Height	5-6m
Lighted SQM	350 sqm

In the table above, it shows the specification of the streetlight and its solar panel, where it shows the required data for the solar streetlight that will give a sustainable light and energy for the deployment area.

3.3.3 Programming of microcontroller for Solar, Battery, and LED monitoring

Figure 3.6 Arduino IDE

When the connection of the sensors has been established, programming the microcontroller is required to complete the working schematic. Arduini IDE is the software that will be use in programming the microcontroller. This ensures that the code will be utilized in the actual monitoring system of the solar streetlight. The devices that must be monitored with microcontroller are the LED for the luminosity sensor, the solar panel for the current and voltage sensor, and the battery for the current, voltage, and temperature sensor.

3.3.4 *Battery Health Measurement*

The Voltage and Current will be taken for the computation of the battery State-of-Charge and State-of-Health. For calculating the SOC and SOH the formula for the equation 1 and 2 will be used from the guide of Coulumb Counting method. The initial charge of the battery is known, to get the SOC,

$$ICB = I \times T$$

$$SOC = ICB \times BCapacity$$

Equation 1. Current Integration under Coulumb Counting

For SOH,

$$SOH_{CHARGE} = \left(1 - \frac{C\ actual}{C\ initial}\right) X\ 100 \text{ or } SOH_{charge} = \left(1 - \frac{E\ actual}{E\ initial}\right) X\ 100$$

3.3.5 Calibration of the sensors for the required monitoring system

After the microcontroller has been programmed and the sensors have been physically connected to the solar streetlight, the calibration procedure begins. Verifying that the data collected in the actual circuit corresponds to the projected outcomes obtained by simulations or predetermined parameters is essential. This allows for the detection and correction of any measurement inconsistencies or inaccuracies.

Various devices and tools are used during calibration to check and correct the sensor data. These instruments might include an oscilloscope, power supply, and multimeter. Electrical parameters including voltage, current, and resistance are frequently measured with a multimeter, enabling researchers to compare the sensor data with the predicted values. The power supply makes sure that the microcontroller and sensors are receiving the necessary electrical power within the specified range. An oscilloscope can also be used to examine and view the electrical signals generated by the sensors, helping to spot any outliers or variations from the intended behavior.

Researchers can verify the quality and dependability of the sensor measurements in the actual circuit by carrying out a thorough calibration process. This process is essential for gathering reliable information that can be utilized for analysis, evaluation, and making decisions about the solar streetlight system.

3.4 Development of the centralized monitoring device using microcontroller together with the transmitter and receiver of LoRa.

3.*4.1 Purchase materials needed for the centralization (Lora Module, microcontroller, NodeMCU)*

Table 3.3 Material and equipment for centralized monitoring device system and local data base

MATERIALS/ EQUIPMENTS
LoRa Module

Microcontroller
NodeMCU

Microcontroller and LoRa are the materials and equipment that will be employed in the building of a centralized monitoring device system. The LoRa will serve as the monitoring system's primary mode of communication. LoRa sends and receives long-range data, which is then sent to the server's database.

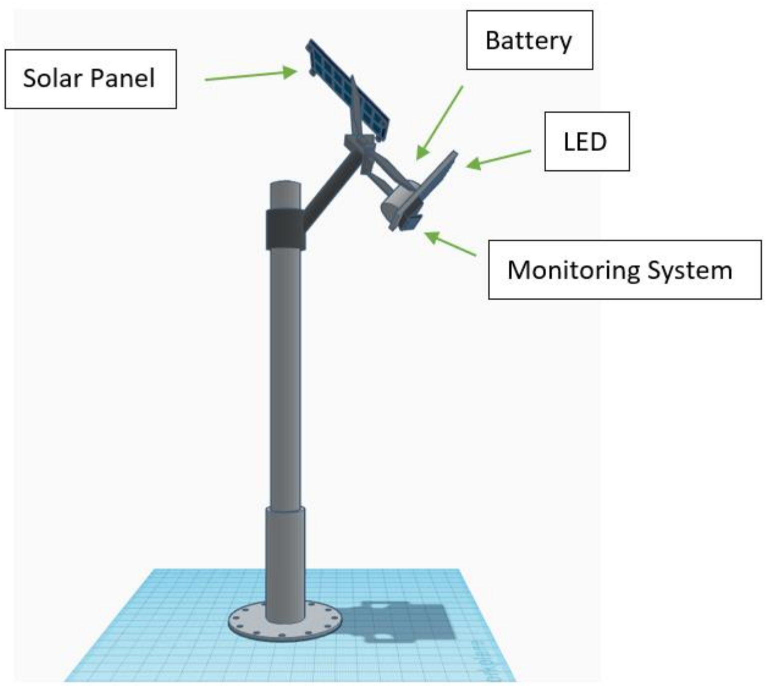

Figure 3.7 Side View of 3D model of the Streetlight Monitoring

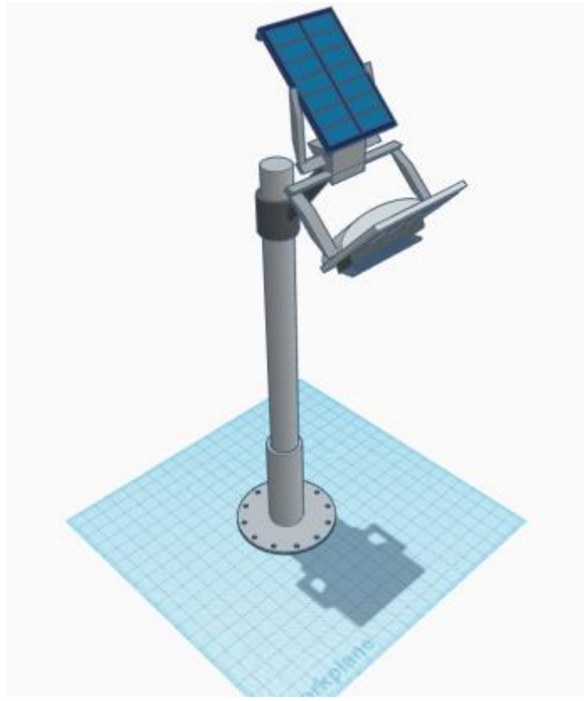

Figure 3.8 Top View

Figures 3.7 and 3.8 shows the 3D model of the Streetlight Monitoring system that comprises of the Solar Panel, LED, Battery, and monitoring system. The Solar Panel is placed at the top of the pole, facing 45° from the sunlight. The LED is facing downward to have a wider coverage of the light. The monitoring system is placed in front of the LED to prevent the sensors from overheating.

3.4.2 *Additional coding on microcontroller for slave Lora module*

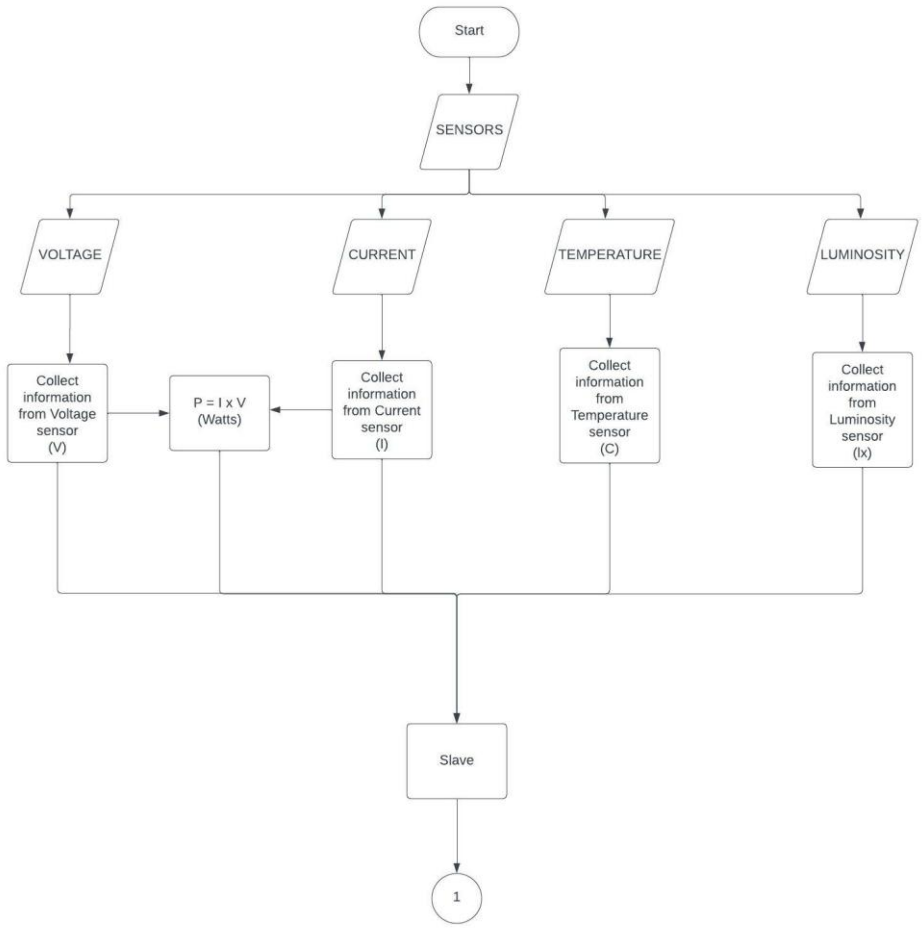

Figure 3.9 Flowchart of slave Lora

It comprises of slave Lora module together with the programmed microcontroller and sensors, additional coding is added to be able to transmit the gathered data from the sensors to the receiver side. From the Start, each sensor is running which are the Voltage, Current, Temperature, Luminosity. To get the parameters for power it is indicate that it is the product between Voltage and

Current. The LoRa Slave will get the readings and will transmit to the LoRa receiver.

3.4.3 Additional coding on microcontroller for master Lora Module

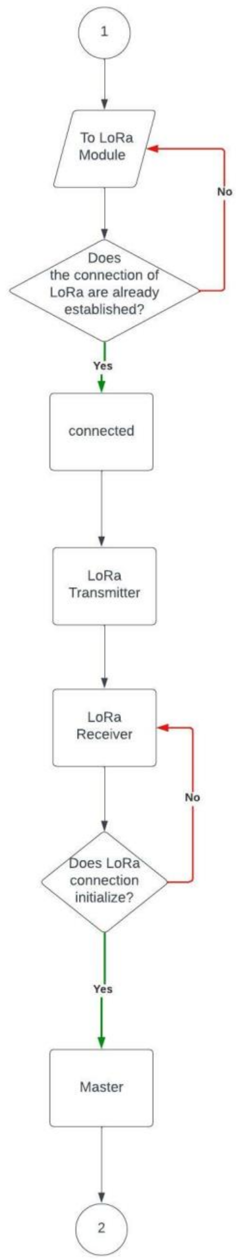

Figure 3.10 Master LoRa Flowchart

From the original code, some additional programming on microcontroller for the master Lora module is needed to be able to receive the transmitted data from the transmitter side. Together with the NodeMCU module it will also serve as the transmitter to the cloud database. From the LoRa Receiver side, the program will identify if the LoRa module is running or not, if it is running it will be connected to the Master LoRa as it will receive the reading parameters from the LoRa slave after that the Master LoRa will transfer the reading data to the cloud direct to the website.

3.4.4 Testing of transmission of data using LoRa Module Slave – Master Connection

The testing of the transmission of data using Lora Module is to identify if the Lora Module can be able to receive and send data through the microcontroller. The researchers conducted an ocular testing around the vicinity of barangay in which the researchers attached the LoRa on the tip of bamboo wood that is 3-4m tall and tested whenever the device will stop. The LoRa module master will remain stationary, while the LoRa Module Slave will move to determine the distance of their transmission. LoRa transmission is tested by point-to-point location to determine if the LoRa still communicates even when the antenna is not in line-of-sight. The testing is also done by continually walking away from the receiver to check how far the LoRa can communicate.

3.4.5 Geographical mapping of the deployment area

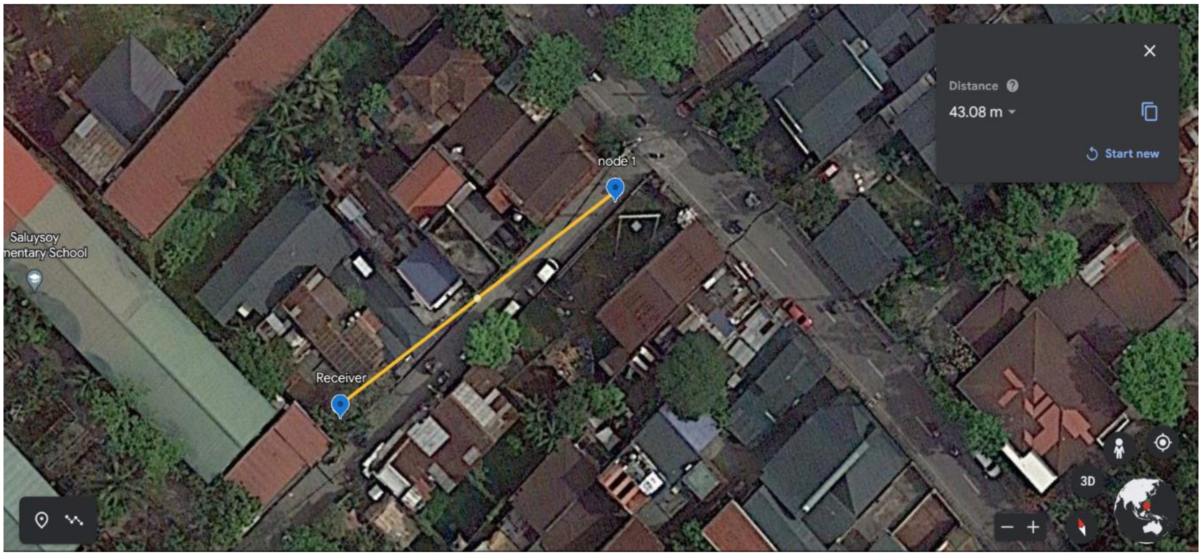

Figure 3.11 First Street Light Deployment and Distance map

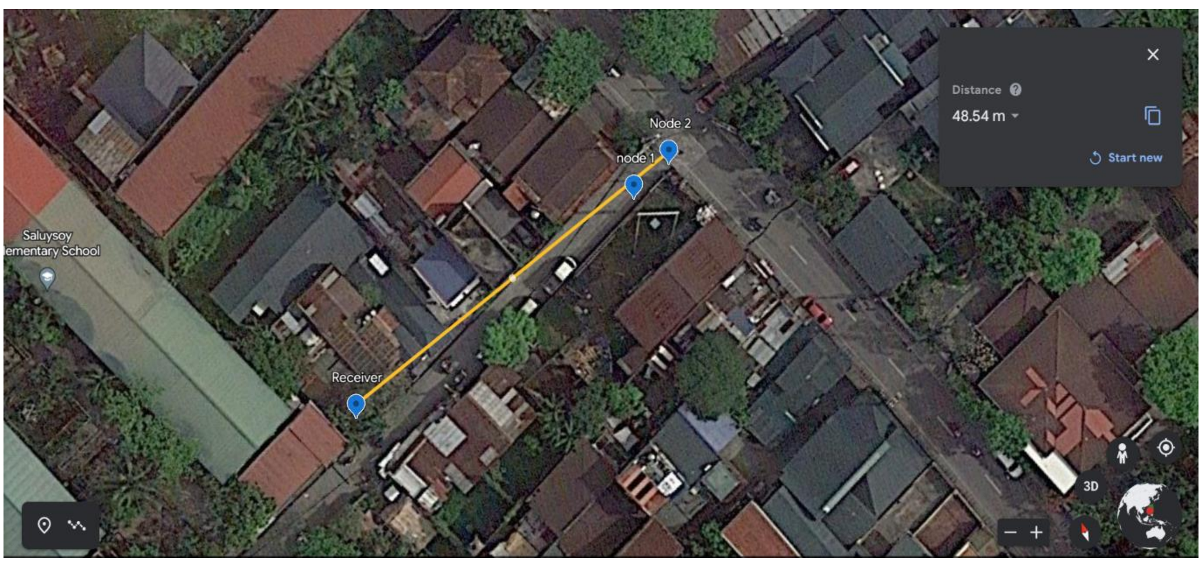

Figure 3.12 Second Street Light Deployment and Distance

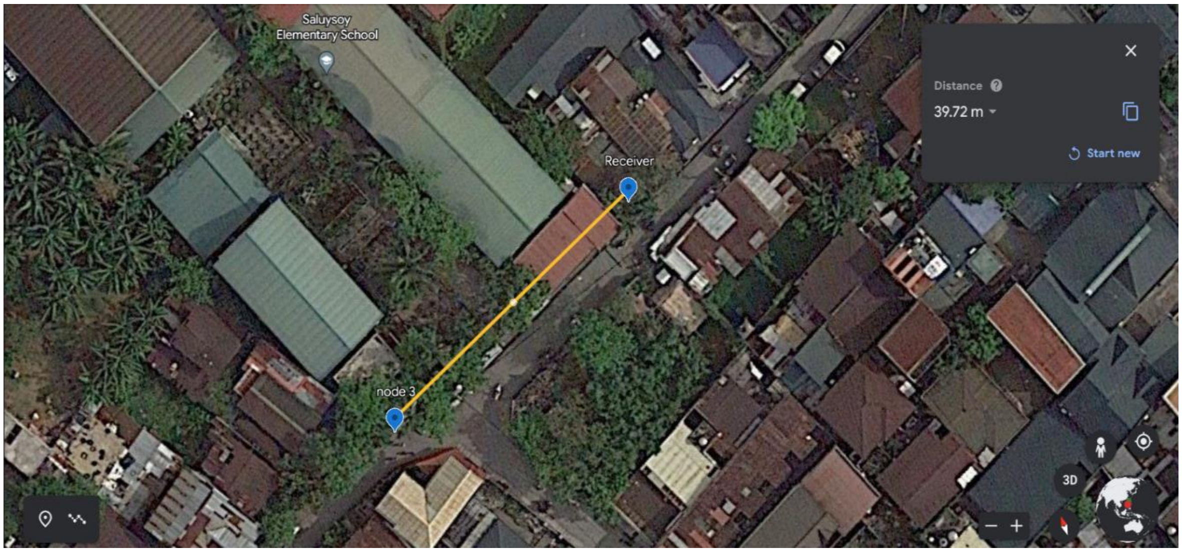

Figure 3.13 Third Street Light Deployment and Distance

Figures 3.11, 3.12, and 3.13 depict the geographic distribution of the streetlights to be installed. The receiver is now in use in the old barangay hall. Node 1 is 43.08 meters away from the receiver, node 2 is 48.54 meters away from the receiver, and node 3 is 39.72 meters away from the receiver.

3.4.6 Testing of overall system

After all the development of the system with calibration of devices, the testing of the whole monitoring system will be done to see if the connections and data of the study are all working. The testing must be needed before it will deploy to the designated deployment area. The system will be tested to see if the LoRa connection's transmission is continuous. The transmission is checked using the Arduino IDE to monitor.

3.5 Development of website for the centralized monitoring system with geographic location of each solar streetlights.

3.5.1 Development of Front End (UI/UX Development)

Figure 3.14 Visual Studio Code

The development of Front End is to give a reality face of the systems of the study, where the data can be seen in a website. The platform for developing the system's frontend will be Visual Studio Code. ReactJS will be used for programming. The website can be run in any browser of any smart technology.

3.5.2 Creative Database using MongoDB

Figure 3.15 MongoDB & Amazon Web Services

The database is the memory of our systems, this is where the data is stored and updated as it will display on the front end. MongoDB will be used as a database for the system. The system has a history of the data, the amazon cloud is the one who manage all the real time data that will display to the Website.

3.5.3 Development of Back-end (Servers, application programming interfaces (APIs), back-end logic, and architecture).

The back end is used to be the skeleton and support of the front-end with the data of our systems. Using AWS CloudFormation for the API, AWS Lambda and AWS Amplify for the serverless architecture of the Backend and Frontend.

3.5.4 Back-end to Front-end Integration Using the Developed Website via Front End

The working combination of the system once the back end and front-end is done. This part is to test the working website with working real time database.

3.6 Test and evaluate the developed system from this research in accordance with the ISO 9126

3.6.1 Testing of performance of the system to be given to the residents, LGU officers, and experts.

The testing of the performance of the system will be conducted with the professionals who are into our study. This testing may serve as the three trials of the system before it will be turned over to the Barangay.

3.6.2 Formulate an evaluation form to be given to the residents and barangay officials of the deployment area.

The study will be executed on Barangay Saluysoy, Meycauayan Bulacan. Interviews done with the members of the community in their homes, as well as select barangay authorities in the barangay hall showed there is an issue when it comes to having enough electricity to power the streetlights in their barangay. Hence, the researchers chose to conduct the study in the said barangay as the study focuses on centralized monitoring system with application of Solar streetlights.

NAME: ____________________ AGE: __________________
ADDRESS: ____

CONTACT NUMBER: __________ E-MAIL (OPTIONAL): ______________
OCCUPATION: ______________ DATE: __________________

Dear Ma'am/Sir,

The following questions below are for the evaluation of the project, entitled ***IOT Centralized Monitoring System for Solar Street Lights using Microcontroller and LoRa.*** Please rate the following by grading 1 to 5 (5 = Strongly Agree, 4 = Agree, 3 = Neither Agree nor Disagree, 2 = Disagree, 1 = Strongly Disagree) by putting a check on the box provided. For any questions or suggestions please do write it our comment section locates below of the last page.

	5	4	3	2	1
EFFICIENCY					
1. The voltage status of the battery is being monitored in real time.					
2. The status of the battery is being monitored in real time.					
3. The Temperature status of the battery is being monitored in real time.					
4. It detects fault devices or components.					
RELIABILITY					
1. Sending real and fast notification of status of the battery.					
2. Sending real and fast notification of status of Solar streetlight.					
3. The system accurately measures the condition of the LED.					
4. The system accurately provides information about the fault devices.					
FUNCTIONALITY					
1. The system can run 24 hours daily.					
2. Can the system interact with other system?					
3. Can the system perform the required task?					
4. The system measures the accurate parameters.					
USABILITY					
1. Can the user learn to use the system easily?					
2. Can the user, use the system without much effort?					
3. Does the website is user friendly?					
MAINTAINABILITY					
1. Does the system modify the problem when it arises?					
2. Does the sensors work properly?					
PORTABILITY					
1. Does the system support the green technology?					
2. Can the machine be able to adopt changes in technology when in need of an upgrade?					

COMMENTS AND SUGGESTIONS:

____
____
____
____
____

____
SIGNATURE OVER PRINTED NAME

Figure 3.16 Evaluation form

3.6.3 Installation and testing of the developed system in the deployment area.

The testing of the system will be conducted to determine the sustainability and accuracy of the monitored system with the specific parameters needed. Data will be gathered and collected for a span of 4 weeks which is equivalent to a month. It is tested in triad after the system is being deployed.

Table 3.4 Voltage readings

DATE	TIME	MANUAL VOLTAGE	TANGLAW VOLTAGE

The researchers will collect data of the battery voltage and solar voltage of the system. To indicate the time from battery charging to battery discharging. It will show the different reading of the voltage per day. For the Solar voltage it will be tested in nighttime as it will produce zero reading. It will also show the difference between the readings of the data gathered from the monitoring system and the readings from the multimeter. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

Table 3.5 Current readings

DATE	TIME	MANUAL CURRENT	TANGLAW CURRENT

The researchers will collect the data of battery current and solar current of the system. It indicates the comparison between the charging and discharging pace of the system. For the solar current it will be tested in nighttime as it will produce zero reading. It will also show the difference between the readings of the data gathered from the system and the readings from the multimeter. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

Table 3.6 Light and Temperature readings

DATE	TIME	LUX			Celsius		
		N1	N2	N3	N1	N2	N3

The researchers will collect temperature data from the different time that the system will encounter. It will show the difference between the reading temperature in daytime and nighttime.

The tables above show the reading of each monitoring device together with its respective time and date. For the Table 3.6, the researchers will collect data from the luminosity reading between daytime and nighttime. The luminosity will be test in nighttime while the system LED is off as it will produce a reading zero. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

Table 3.7 Percentage Error of each Nodes

Node	During Charging	During Discharging	Percentage Error (%)

$$\%error = \frac{|measured - real|}{real}\ x\ 100\%$$

The readings of each node will be collected, and it will separate from the reading of charging and discharging of the system to get the percentage error for each node. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

Table 3.8 Battery State-of-Charge

TIME	VOLTAGE	FORMULA	TANGLAW	% PERCENTAGE ERROR

The battery state-of-charge of the system battery will be collected and compare from the manual monitoring and the project monitoring together with its percentage error. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

Table 3.9 Battery State-of-Health

CYCLE	STANDARD EQUATION	TANGLAW	% PERCENTAGE ERROR

The battery cycle will be collected to perform the standard equation to get the Battery State-of-Health. The data from standard equation will be compare from the data gather from the system. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

Table 3.10 LoRa's Time and Delay Record

DISTANCE	TIME-DELAY	MEASUREMENT OF OBSTRUCTION (HEIGHT)

The data from the LoRa's transmission will be collected same as the measurement obstruction. The table will show the result of the transmission delay per distance and obstruction of the surrounding. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter.

3.6.4 Comparison between the results of before and after deployment

Table 3.11 Comparison of the area before and after of deployment

BEFORE	AFTER

The comparison of the deployment area before when the old streetlights are being used of the barangay to the after deployment of the project study. The area's capacity of light, and the security and sustainability of the streetlights. The data will show comparison and accuracy to the manual monitoring and the system monitoring to identify the significant differences of each parameter

3.7 Statistical Test

This study will have Descriptive Statistics as its statistical test. The mean of responses from the survey conducted will be calculated and analyzed using descriptive statistics. Descriptive statistics provide a summary of the collected data by describing its central tendency and dispersion. In this case, the mean will measure the average response from the survey participants. By utilizing descriptive statistics, the researchers can summarize and present the survey findings concisely and informally. These statistical measures will enable the researchers to describe the central tendencies and variability in the responses, helping to identify any notable patterns, trends, or variations among the participants. This will help the researchers plot the data in a more understandable visual hence the researchers can analyze if the system is performing the expected outcome of the statistical test.

$$X = \frac{\Sigma x}{N}$$

3.8 Project Workplan

			YEAR 2022 TO 2023														
	TASK	PERCENTAGE (%)	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MARCH	APRIL	MAY
1	PROJECT PLAN																
2	CONCEPTUALIZATION	2%															
3	GATHERING OF DATA	3%															
4	CHAPTER 1 : PROBLEM AND ITS SCOPE AND LIMITATION	3%															
5	CHAPTER 2: RESEARCH RELATED LITERATURE AND STUDIES	3%															
6	DEVELOPMENT OF THE CIRCUIT DESIGN INTEGRATING THE SENSORS WITH THE SOLAR STREET LIGHT	15%															
7	FORMULATION OF ARDUINO PROGRAM FOR THE MONITORING SYSTEM	10%															
8	SIMULATION OF THE CIRCUIT DESIGN	5%															
9	CANVASSING OF THE MATERIALS AND EQUIPMENT	2%															
10	DEVELOPMENT OF CENTRALIZED MONITORING DEVICE USING ARDUINO MEGA TOGETHER WITH TRANSMITTER AND RECEIVER OF LORA	15%															
11	PURCHASSING OF MATERIALS AND EQUIPMENT	2%															
12	FORMULATION OF ARDUINO MEGA PROGRAM WITH LORA	10%															
13	DEVELOPMENT OF WEBSITE FOR CENTRALIZED MONITORING SYSTEM WITH GEOGRAPHIC LOCATION OF EACH SOLAR STREET LIGHTS	15%															
14	CALIBRATION OF THE DEVICES	5%															
15	TESTING OF THE DEVICES AND SYSTEM	8%															
16	EVALUATION	5%															

CHAPTER 4

RESULTS AND DISCUSSION

This chapter presents the project technical description, project structural description, project capabilities and limitations, project evaluation, tabulation of results, and interpretation of project findings.

4.1 Project Technical Description

This study is about monitoring the condition of solar streetlights including their voltage, current of the battery and solar panel. It includes real time monitoring from the centralization of the streetlights using the use of LoRa point to point communication.

In the hardware part, the use of microcontroller as measuring the system was the one that will work for the working parameters in the battery and the solar panel, voltage, current, temperature, luminosity. The said parameters were used to be able to monitor the streetlights' condition. For the communication part, the Node MCU together with the LoRa act as the receiver of the data and Arduino Nano with LoRa as a transmitter of the data.

In the software part, the use of MongoDB will be the database, this is where our data will be stored and will be placed on the website which is the User Interface using Java Script React.

4.2 Project Structural Organization

4.2.1 Prototype Design

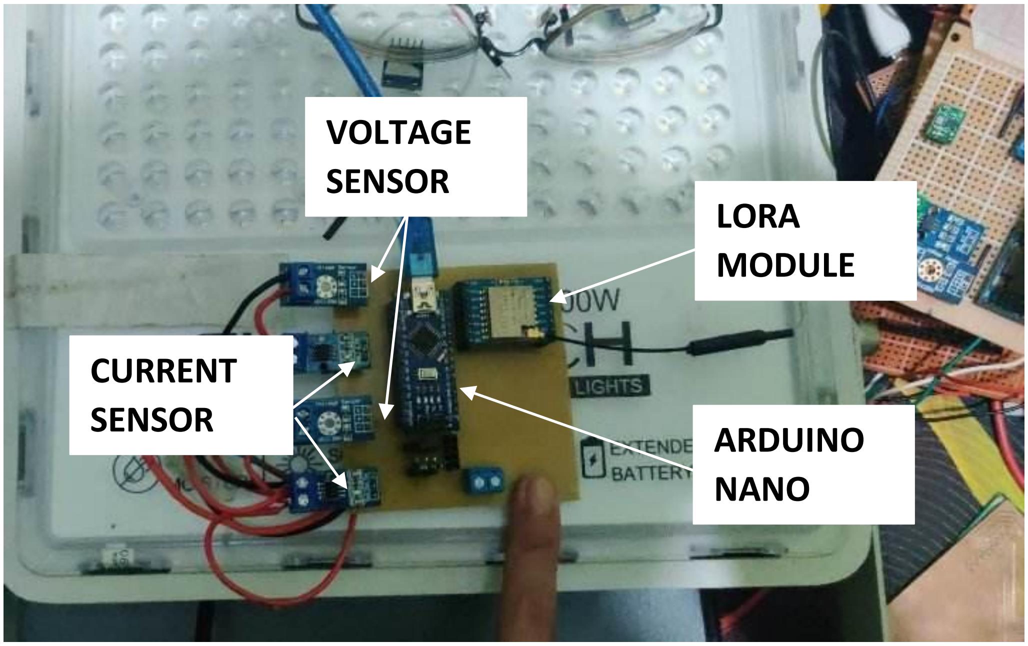

Figure 4.1 PCB Circuit Design of the monitoring system

Figure 4.2 Node 2

Figure 4.3 Node 1

Figure 4.4 Node 3

4.2.2 *Graphical User Interface*

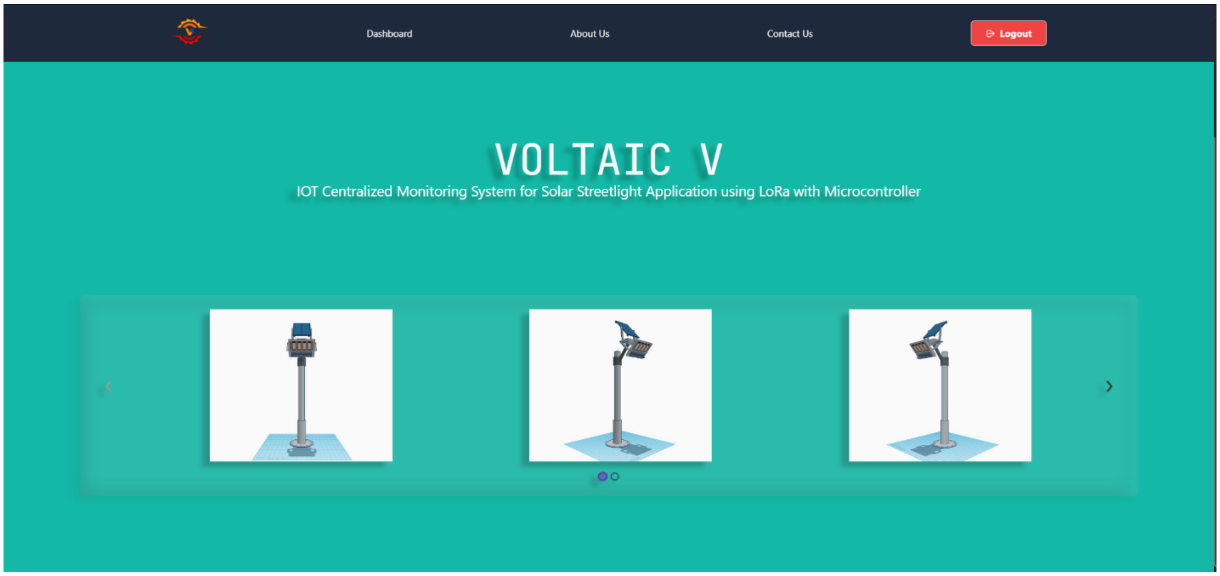

Figure 4.5 Welcome Window

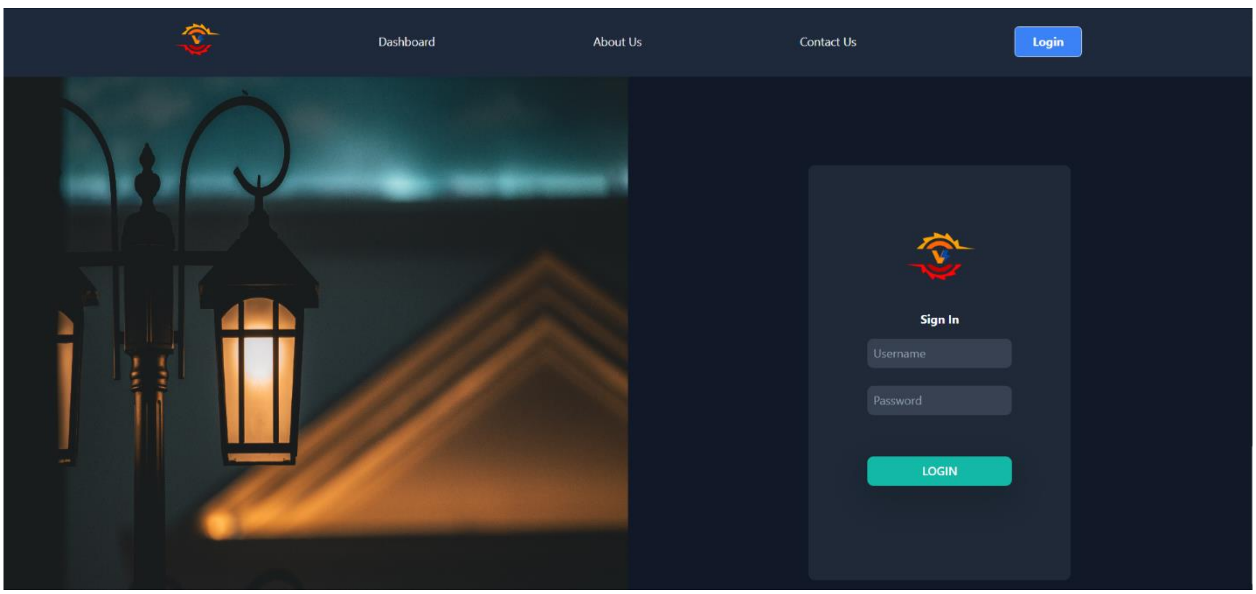

Figure 4.6 Log-in Window

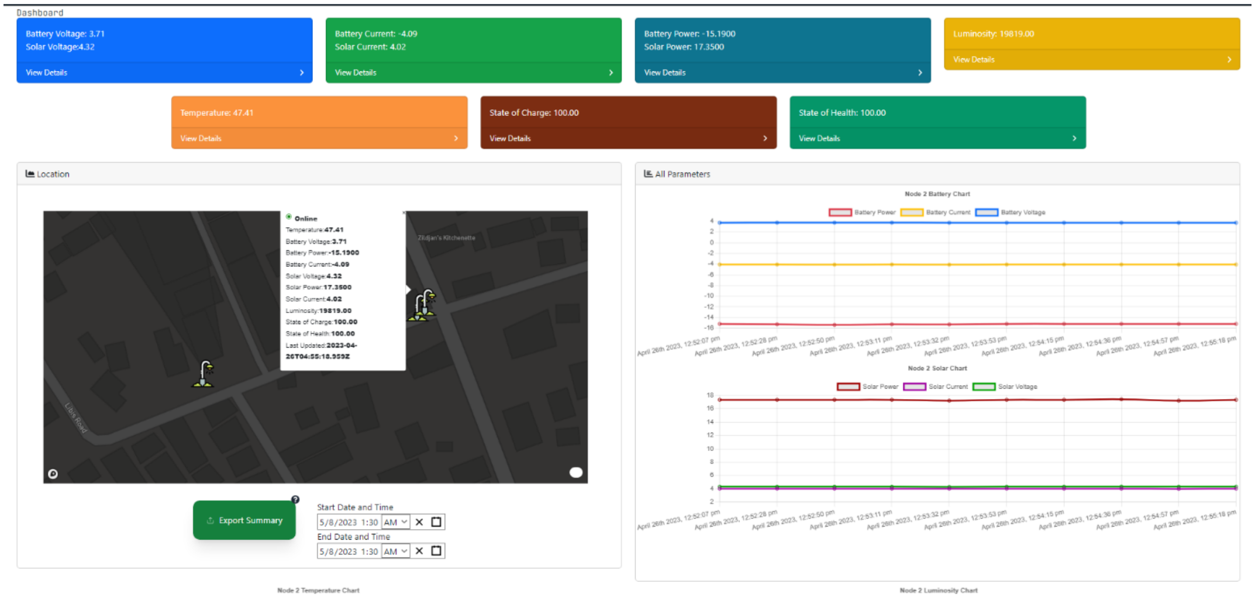

Figure 4.7 Dashboard Window

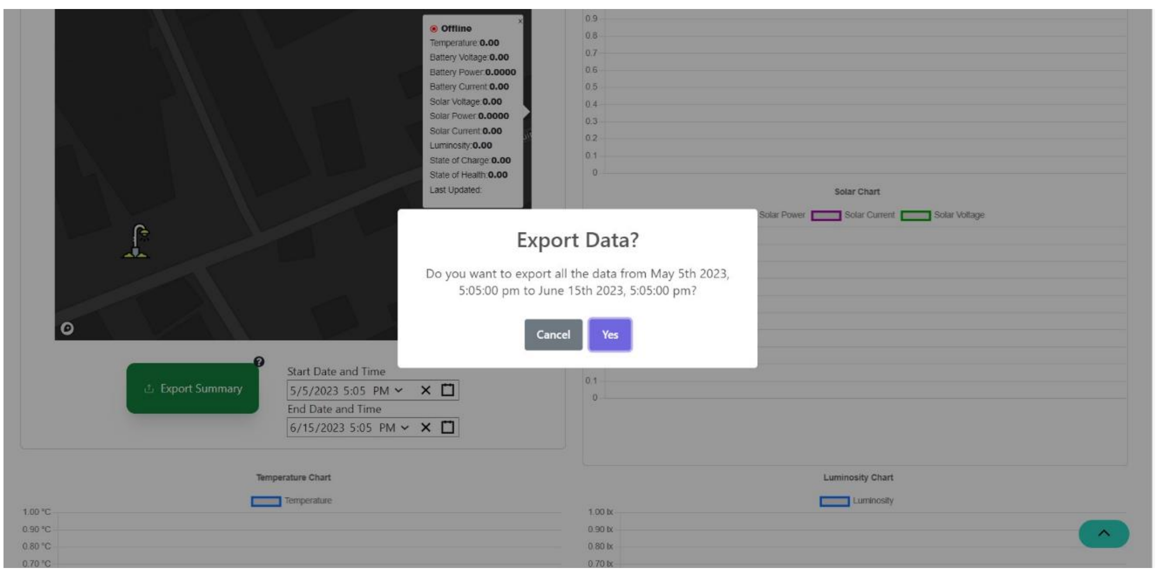

Figure 4.8 Exported Data

4.2.3 Location Elevation of the Barangay

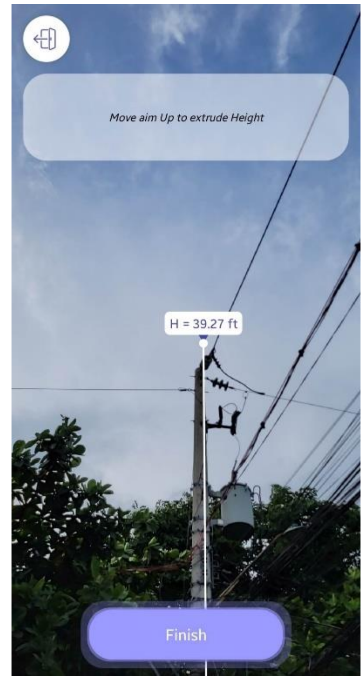

Figure 4.9 – 4.11 Measurement of the Buildings Surrounds the Barangay

4.2.4 Area Before and After Installation of System

Figure 4.12 Node 3 Location Before Installation of System

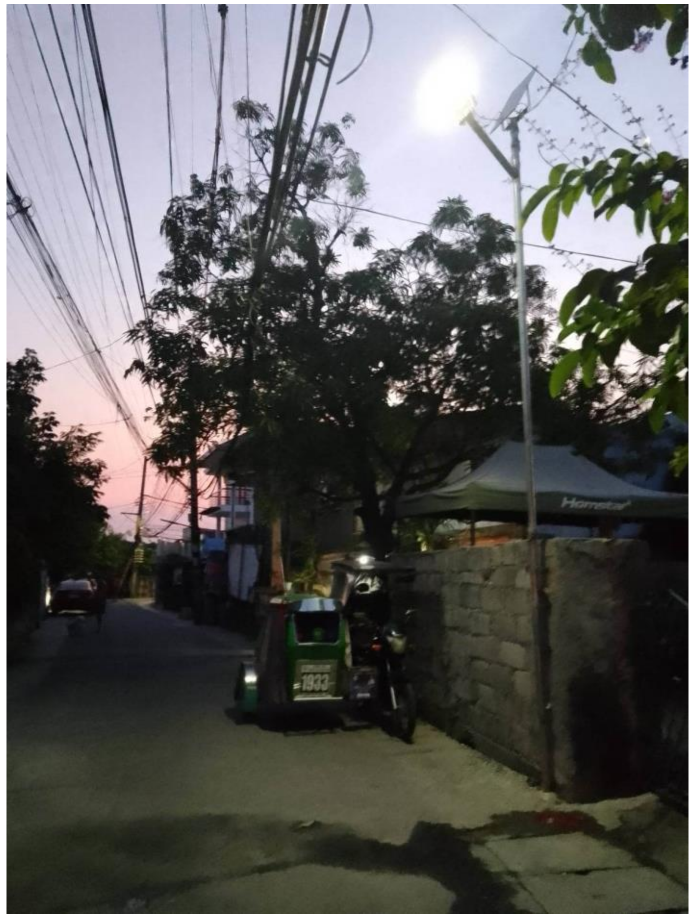

Figure 4.13 Node 3 Location After Installation of System

4.3 Project Limitation and Capabilities

The purpose of this study is to provide a monitoring of the Solar Street lights with different parameters: Voltage, Current, Temperature and Luminosity of the battery and Solar panel. It gives the current condition and reading the solar streetlight and the Lithium-Iron Phosphate. For the communication part the use of LoRa with a point-to-point connection will be in use together with the Node MCU and Arduino Nano that will act as receiver and transmitter of the system. The LoRa communication will be applicable for line-of-sight communication, the use of antenna is being attached in the system.

After the parameters are being read by the sensors and sent with the transmitter and receiver using LoRa, the data will be stored in the database using Mongodb and will be uploaded to the website with real time data.

The measuring system is an Arduino-based Voltage sensor, Current sensor, Luminosity sensor and Temperature sensor. The sensor is being calibrated with an oscilloscope and multi meters before it is attached to the circuit.

4.4 Project Evaluation

The project evaluation has been conducted by the researchers over a period of 4–weeks. As a result, the data gathered is presented in the following tables:

Table 4.1 Reading of Luminosity and Temperature Sensors in Nighttime

DATE	TIME	LUX			Celsius		
		N1	N2	N3	N1	N2	N3
May 19, 2023	6:00 PM	8223	10200	6250	46.88	41.5	31.5
May 20, 2023	9:00 PM (close LED)	0	0	0	29.2	29.5	31.4
May 26, 2023	10:00 PM (close LED)	0	0	0	27.8	27.8	29.8
May 27, 2023	11:00 PM (close LED)	0	0	0	25.9	25.3	226.3
June 02, 2023	12:00 AM	7654	8232	6244	31.3	29.5	29.5
June 04, 2023	1:00 AM	6553	7332	6320	31.1	30.2	36.8

June 06, 2023	2:00 AM (close LED)	0	0	0	28.5	29.6	29.4
June 08, 2023	3:00 AM	6310	6924	6231	38.5	39.1	33.5
June 09, 2023	4:00 AM	5211	5464	4230	38.4	40.2	36.5
June 10, 2023	5:00 AM (close LED)	0	0	0	27.5	26.42	24.5

Table 4.1 shows the data results of the Luminosity and Temperature gathered during the night. It shows that during the nighttime, the Luminosity and temperature decrease as the sensor detects only the light from the LED and the temperature of the surroundings cools down. For luminosity, it automatically reads zero (0) at nighttime as the LED was purposely switched off.

Table 4.2 Reading of Luminosity and Temperature Sensors in Day time

DATE	TIME	LUX			Celsius		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**
May 19, 2023	6:30 AM	6772	13046	4331	23.75	31.77	19.5
May 20, 2023	8:30 AM	9942	14546	5565	32.79	35.19	30.23
May 26, 2023	9:30 AM	10501	14533	7653	33.5	35.4	30.7
May 27, 2023	10:30 AM	10457	14980	9602	33.22	35.8	31.5
June 02, 2023	11: 30 AM	14230	18200	10345	36.5	40.3	31.76
June 04, 2023	12:30 PM	20560	23450	14230	42.4	43.7	35.6
June 06, 2023	1:30 PM	20623	23458	14257	42.4	43.7	35.6

June 08, 2023	2:30 PM	21245	24221	14269	43.1	44.2	35.7
June 09, 2023	3:30 PM	22364	24346	15231	43.6	45.8	36.4
June 10, 2023	5:00 PM	16201	19874	10213	38.3	41.4	31.4

In Table 4.2 it displays the readings of the Luminosity and Temperature during the daytime. As shown in the results, the reading of the luminosity increases as the Luminosity sensor detects the light from the sun. The temperature also increases during the daytime as the temperature of the surroundings gets hotter as the sun rises.

Table 4.3 Reading of Battery Voltage in Charging Time

DATE	TIME	MANUAL BATTERY VOLTAGE			TANGLAW BATTERY VOLTAGE		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**
May 19, 2023	**5:30 -6:00 AM**	3.27	3.22	3.13	3.32	3.31	3.14
May 20, 2023	**9:00 AM**	3.37	3.32	3.36	3.37	3.33	3.36
May 26, 2023	**11:00 AM**	3.35	3.32	3.36	3.37	3.32	3.35
May 27, 2023	**12:00 NN**	3.37	3.36	3.36	3.37	3.36	3.35
June 02, 2023	**1:00 PM**	3.37	3.36	3.36	3.37	3.35	3.36
June 04, 2023	**2The :00 PM**	3.35	3.36	3.33	3.37	3.35	3.35
June 06, 2023	**3:00 PM**	3.35	3.36	3.36	3.37	3.36	3.35
June 08, 2023	**4:00 PM**	3.35	3.34	3.36	3.37	3.36	3.35

June 09, 2023	**5:00 PM**	3.35	3.36	3.36	3.37	3.33	3.36
June 10, 2023	**6:00 PM – 6:30 PM**	3.35	3.34	3.36	3.37	3.36	3.36

Table 4.3 presents the data results gathered from the reading of the battery voltage during the charging time. It shows that the battery voltage charges up as the time goes on and hits its peak charging during noontime. It also shows that there are slight discrepancy between the readings of the manual and the Tanglaw battery voltage.

Table 4.4 Reading of Battery Voltage in Discharging Time

DATE	TIME	MANUAL BATTERY VOLTAGE			TANGLAW BATTERY VOLTAGE		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**
May 19, 2023	**6:45 PM – 7:00 PM**	3.35	3.34	3.36	3.36	3.36	3.35
May 20, 2023	**9:00 PM**	3.35	3.34	3.36	3.36	3.35	3.35
May 26, 2023	**10:00 PM**	3.35	3.33	3.36	3.36	3.35	3.35
May 27, 2023	**11:00 PM**	3.33	3.33	3.33	3.34	3.35	3.33
June 02, 2023	**12:00 AM**	3.31	3.33	3.33	3.4	3.33	3.33
June 04, 2023	**1:00 AM**	3.31	3.30	3.33	3.31	3.33	3.33
June 06, 2023	**2:00 AM**	3.31	3.30	3.28	3.31	3.31	3.29
June 08, 2023	**3:00 AM**	3.28	3.30	3.28	3.31	3.31	3.29

June 09, 2023	**4:00 AM**	3.28	3.28	3.21	3.25	3.28	3.29
June 10, 2023	**5:00 AM**	3.28	3.28	3.21	3.25	3.28	3.25

The readings of the data gathered about the battery voltage during its discharging time are shown in Table 4.4. It shows that the voltage of the battery decreases as time goes by and the battery is discharging. The difference between the readings in the manual and the Tanglaw shows a slight discrepancy.

Table 4.5 Reading of Battery Current in Charging Time

DATE	**TIME**	**MANUAL BATTERY CURRENT**			**TANGLAW BATTERY CURRENT**		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**
May 19, 2023	**5:30 -6:00 AM**	0.37	0.39	0.37	0.39	0.43	0.41
May 20, 2023	**9:00 AM**	0.39	0.41	0.41	0.43	0.43	0.42
May 26, 2023	**11:00 AM**	0.39	0.41	0.41	0.43	0.45	0.42
May 27, 2023	**12:00 NN**	0.42	0.45	0.45	0.45	0.47	0.45
June 02, 2023	**1:00 PM**	0.42	0.45	0.45	0.45	0.45	0.45
June 04, 2023	**2:00 PM**	0.42	0.45	0.45	0.45	0.47	0.46
June 06, 2023	**3:00 PM**	0.42	0.45	0.45	0.45	0.47	0.46
June 08, 2023	**4:00 PM**	0.39	0.41	0.42	0.43	0.42	0.46

June 09, 2023	**5:00 PM**	0.39	0.41	0.40	0.43	0.42	0.46
June 10, 2023	**6:00 PM – 6:30 PM**	0.37	0.37	0.39	0.41	0.41	0.45

Table 4.5 shows the readings of the battery current during its charging time. As the sun rises, the battery current increases during the daytime. It also shows in the table that there is a little bit of a slight difference in the readings between the manual and Tanglaw.

Table 4.6 Reading of Battery Current in Discharging Time

DATE	TIME	MANUAL BATTERY CURRENT			TANGLAW BATTERY CURRENT		
		N1	N2	N3	N1	N2	N3
May 19, 2023	**6:45 PM – 7:00 PM**	0.39	0.40	0.39	0.41	0.43	0.39
May 20, 2023	**9:00 PM**	0.37	0.42	0.39	0.39	0.39	0.39
May 26, 2023	**10:00 PM**	0.37	0.39	0.35	0.39	0.39	0.37
May 27, 2023	**11:00 PM**	0.35	0.39	0.35	0.39	0.39	0.37
June 02, 2023	**12:00 AM**	0.35	0.39	0.35	0.37	0.39	0.37
June 04, 2023	**1:00 AM**	0.35	0.39	0.35	0.37	0.39	0.37
June 06, 2023	**2:00 AM**	0.35	0.39	0.35	0.37	0.37	0.37
June 08, 2023	**3:00 AM**	0.35	0.39	0.35	0.36	0.37	0.37

June 09, 2023	**4:00 AM**	0.35	0.39	0.35	0.36	0.37	0.33
June 10, 2023	**5:00 AM**	0.35	0.39	0.35	0.36	0.37	0.33

Table 4.6 presents the results of the readings of the data gathered from the battery current during its discharging time. The battery current decreases as the time goes to midnight, and it supplies the current for the LED. The difference between the reading of the manual and the Tanglaw shows slight discrepancy.

Table 4.7 Reading of Solar Voltage in Charging Time

DATE	TIME	MANUAL SOLAR VOLTAGE			TANGLAW SOLAR VOLTAGE		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**
May 19, 2023	**5:30 -6:00 AM**	3.68	3.71	3.71	3.70	3.71	3.71
May 20, 2023	**9:00 AM**	3.71	3.73	3.73	3.71	3.73	3.75
May 26, 2023	**11:00 AM**	3.73	3.75	3.75	3.81	3.75	3.79
May 27, 2023	**12:00 NN**	3.79	3.81	3.77	3.81	3.82	3.81
June 02, 2023	**1:00 PM**	3.79	3.81	3.79	3.79	3.82	3.81
June 04, 2023	**2:00 PM**	3.79	3.81	3.79	3.81	3.79	3.79
June 06, 2023	**3:00 PM**	3.78	3.81	3.79	3.82	3.79	3.79
June 08, 2023	**4:00 PM**	3.75	3.76	3.75	3.79	3.76	3.76

June 09, 2023	**5:00 PM**	3.73	3.76	3.73	3.76	3.76	3.76
June 10, 2023	**6:00 PM – 6:30 PM**	3.70	3.73	3.70	3.74	3.75	3.73

In Table 4.7, it shows the results of the readings of the solar voltage during its charging time. The solar panel's voltage is increasing and charging during the daytime, its peak reaches 3.79V at 12PM-2PM, while the lowest reading generated has a result of 3.7V at 6:00 PM.

Table 4.8 Reading of Solar Current in Charging Time

DATE	**TIME**	**MANUAL SOLAR CURRENT**			**TANGLAW SOLARCURRENT**		
		N1	**N2**	**N3**	**N1**	**N2**	**N3**
May 19, 2023	**6:45 AM – 7:00 AM**	0.39	0.41	0.41	0.40	0.42	0.42
May 20, 2023	**9:00 AM**	0.41	0.43	0.41	0.42	0.45	0.42
May 26, 2023	**10:00 AM**	0.41	0.45	0.46	0.42	0.45	0.48
May 27, 2023	**11:00 AM**	0.41	0.45	0.46	0.42	0.45	0.48
June 02, 2023	**12:00 PM**	0.45	0.48	0.48	0.46	0.46	0.48

June 04, 2023	**1:00 PM**	0.45	0.48	0.48	0.46	0.46	0.46
June 06, 2023	**2:00 PM**	0.42	0.45	0.46	0.41	0.43	0.48
June 08, 2023	**3:00 PM**	0.42	0.45	0.46	0.41	0.43	0.46
June 09, 2023	**4:00 PM**	0.42	0.45	0.43	0.41	0.43	0.46
June 10, 2023	**5:00 PM**	0.42	0.45	0.43	0.41	0.43	0.46

The result of the readings of the solar current during charging time is shown in Table 4.8. The solar currents increase as time goes by in the afternoon. And the difference between the readings from manual testing and system monitoring are almost the same. The solar panel's current is increasing and charging during the daytime, its peak reaches 0.45A at 12PM-2PM, while the lowest reading generated has a result of 0.39A at 6:00 AM.

Table 4.9 Average Percentage Error for Node 1

Percentage Error (%)		
Node 1	During Charging	During Discharging
Battery Voltage	0.30	0.54
Battery Current	1.62	8.33

Solar Voltage	0.37	0.00
Solar Current	2.44	0.00
Total	2.27	%

The parameters of Node 1 were tested during Sunny, Cloudy and Rainy Seasons during April up to first week of June 2023. The reading error percentage is 2.27%. after collecting and getting the average of 10 samples. It shows that the system monitoring generated almost the same reading of each parameter.

Table 4.10 Average Error Percentage of Node 2

Percentage Error (%)		
Node 2	During Charging	During Discharging
Battery Voltage	0.12	0.32
Battery Current	0.93	1.25
Solar Voltage	1.32	0.00
Solar Current	2.98	0.00
Total	1.16	%

The parameters of Node 2 were tested during Sunny, Cloudy and Rainy Seasons during April up to first week of June 2023. The reading error percentage is 1.16% after collecting and getting the average of 10 samples. It shows that the system monitoring generated almost the same reading of each parameter.

Table 4.11 Average Error Percentage of Node 3

Percentage Error (%)		
Node 3	During Charging	During Discharging
Battery Voltage	0.30	0.31
Battery Current	0.93	8.33
Solar Voltage	0.26	0.00
Solar Current	3.04	0.05
Total	2.21	%

The parameters of Node 3 were tested during Sunny, Cloudy and Rainy Seasons during April up to first week of June 2023. The reading error percentage is 2.27% after collecting and getting the average of 10 samples. It shows that the system monitoring generated almost the same reading of each parameter.

Overall, Error Percentage = 1.88 %

Total Accuracy = 98.120 %

The overall reading error percentage from the actual monitoring to Tanglaw Monitoring was 1.88 % in total with an accuracy of 98.12% reading in a total gathering and collecting the data in 4 weeks.

Table 4.12 Reading of Battery State-of-Charge

TIME	VOLTAGE	FORMULA	TANGLAW	% PERCENTAGE ERROR
6:45 PM – 7:00 PM	3.35 V	99%	100%	1.01
9:00 PM	3.33 V	90%	90%	0
10:00 PM	3.33 V	90%	90%	0
11:00 PM	3.3 V	80%	80%	0
12:00 AM	3.28 V	70%	80%	14.29
1:00 AM	3.28 V	70%	70%	0
2:00 AM	3.25 V	40%	40%	0
3:00 AM	3.25 V	40%	40 %	0
4:00 AM	3.25 V	40%	40 %	0
5:00 AM	3.23 V	30%	30 %	0

The Battery State of Charge was being tested 24 hours, table 24 shows the difference between the standard formula in getting SOC to the Tanglaw monitoring. The average error percentage was approximately 1.53 %. The reading from 12:00 AM was about 14.29% because of the inconsistency of LoRa. The LoRa module will be inconsistent if the system does not follow the line-of-sight transmission.

Table 4.13 Reading of Battery State-of-Health

CYCLE	STANDARD EQUATION	TANGLAW	% PERCENTAGE ERROR
1st Cycle	99.9	100	0.1
2nd Cycle	99.9	100	0.1
3rd Cycle	99.9	100	0.1
4th Cycle	99.89	100	0.1
5th Cycle	99.89	100	0.1
6th Cycle	99.89	99	0.89
7th Cycle	99.89	99	0.86
8th Cycle	99.86	99	0.86
9th Cycle	99.86	99	0.86
10th Cycle	99.86	99	0.86

Table 4.13 shows the 10 cycles of the battery, and it is compared to the standard equation to the Tanglaw System and is compared through computing the percentage error. The data gathered from the Tanglaw to the standard equation is almost identical in result.

Table 4.14 Lithium ion and Lithium Iron SOH

CYCLE	Lithium Ion	Lithium Iron Phosphate
1st Cycle	99.9	100
2nd Cycle	99.82	100
3rd Cycle	98.24	100
4th Cycle	97.88	100
5th Cycle	96.24	100
6th Cycle	95.57	99
7th Cycle	94.27	99
8th Cycle	93.81	99
9th Cycle	92.51	99
10th Cycle	91.25	99.8

Table 4.14 are the experimentation for the State of Health of Lithium Iron Phosphate. The expected output would be 90% over the triads of Charge and Discharge, it has an average of 0.5% for the error percentage between the standard equation to tanglaw monitoring, while the Table 4.13 is the experimentations between the difference of a normal lithium-ion batteries to the Lithium Iron Phosphate batteries that are being used in the system. The table above shows that the Lithium-iron Phosphate batteries are efficient in battery discharging in comparison to the generic lithium-ion batteries.

Table 4.15 LoRa's Time and Delay Record

DISTANCE	TIME/DELAY	MEASUREMENT OF OBSTRUCTION (HEIGHT)
10 m	3sec	12 – 15 FT
20 m	3 – 5sec	15 – 18 FT
50 m	5 – 8sec	18 – 21 FT
100 m	10 – 16sec	18 – 21 FT
150 m	16 – 18sec	18 – 25FT
200 m	25 – 45sec	21 – 25FT
300 m	25 – 45sec	21 – 31 FT
400 m	1min	25 – 42FT
450 m	1min	25 – 42FT
500 m	1 – 15min	21– 45 FT

In Table 4.15 It was the testing of Lora point to point communication. The RA SX1276 are being used in each node. The highest delay that was get during the rainy season was about 16 minutes with a total obstruction height of three 32ft of trees and Two 22ft of house in about 350 – 500 meters of distance. The fastest transmission was about 3 seconds in 10m with an obstruction height of 12 – 15 ft. The LoRa transmission produced its fastest communication given that the node's distance is close to each other, with a minimal line-of-sight obstruction.

The LoRa Transmission are tested that the speed of transmission varies in the weather condition, building elevation that apply in line-of-sight communication and its distance.

4.4.1 Result of Evaluation under the ISO 9126

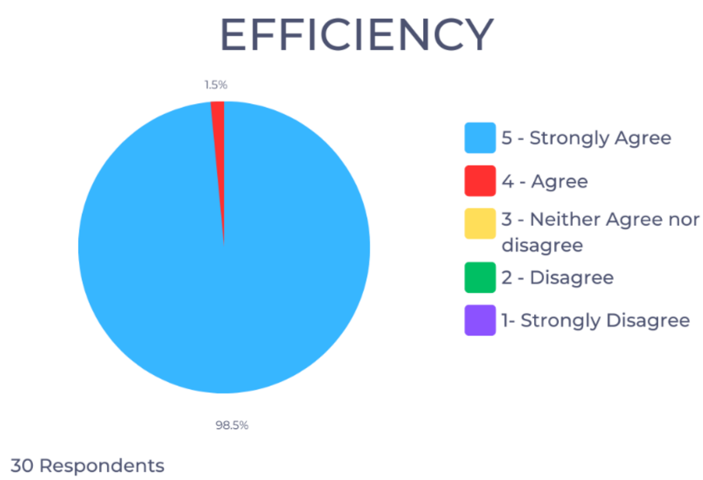

Figure 4.14 Graph for Efficiency

For the Efficiency over 30 responses from the residence of Barangay Saluysoy Meycauayan Bulacan, 98.5 % voted strongly agree for the working efficiency of the system, and 1.5% who agree for the efficiency of the system.

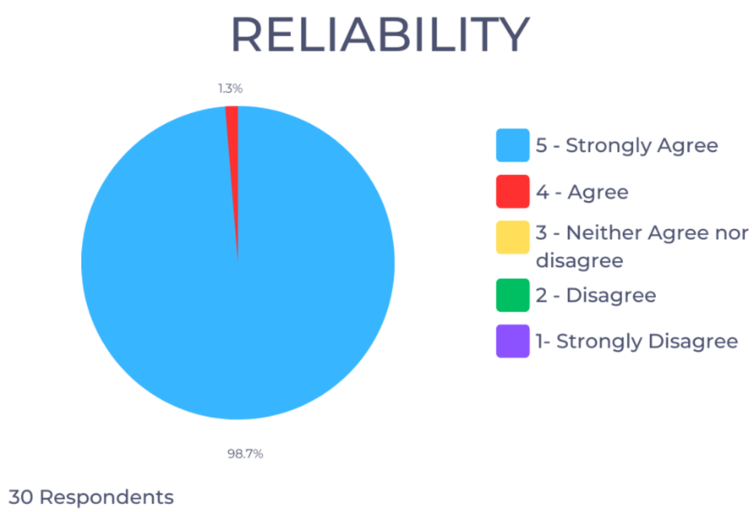

Figure 4.15 Graph for Reliability

For the Reliability using the statistical equation by getting the mean of the answer over 30 responses of the residence of Barangay Saluysoy Meycauayan Bulacan, 98.7 % voted for strongly agree that the system is reliable and 1.3% for agree.

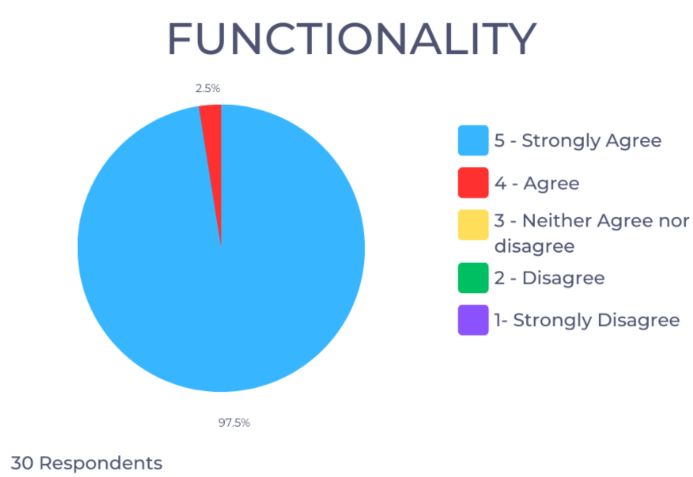

Figure 4.16 Graph for Functionality

For the Functionality using the statistical equation by getting the mean of the answer over 30 responses of the residence of Barangay Saluysoy Meycauayan Bulacan, 97.5 % voted for strongly agree that the system is well function and 2.5% for agree.

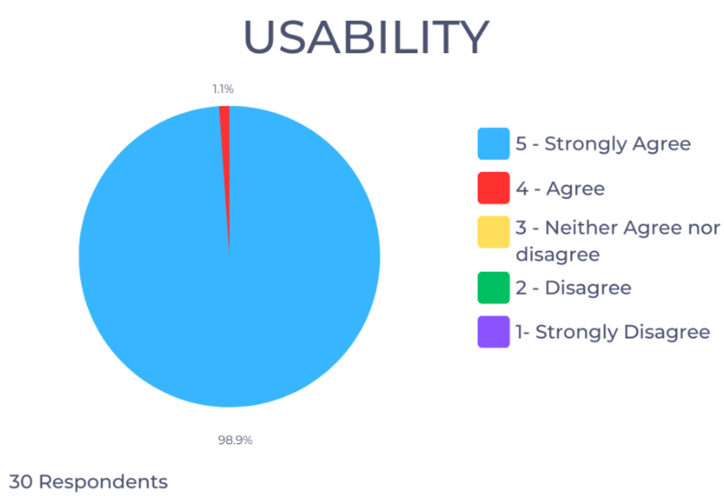

Figure 4.17 Graph for Usability

For the Usability using the statistical equation by getting the mean of the answer over 30 responses of the residence of Barangay Saluysoy Meycauayan Bulacan, 98.9 % voted for strongly agree that the system is usable and 1.1% for agree.

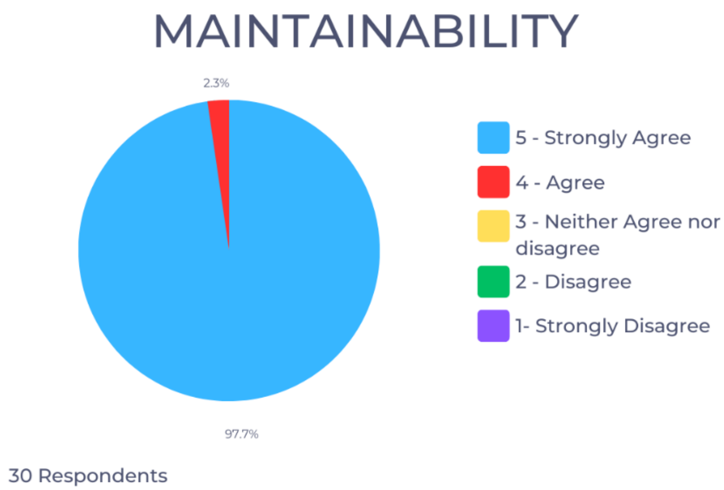

Figure 4.18 Graph for Maintainability

For the maintainability using the statistical equation by getting the mean of the answer over 30 responses of the residence of Barangay Saluysoy Meycauayan Bulacan, 97.7 % voted for strongly agree that the system Maintain its function and uses and 2.3% for agree.

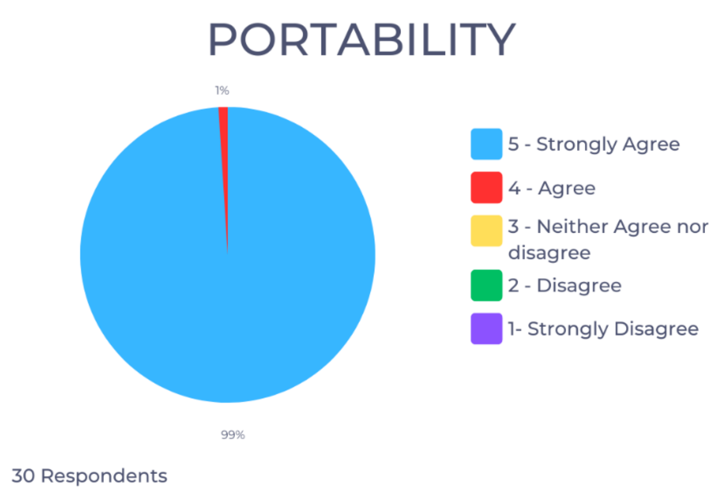

Figure 4.19 Graph for Portability

For the Portability using the statistical equation by getting the mean of the answer over 30 responses of the residence of Barangay Saluysoy Meycauayan Bulacan, 99.9 % voted for strongly agree that the system are portable and user friendly ,1% who voted for agree.

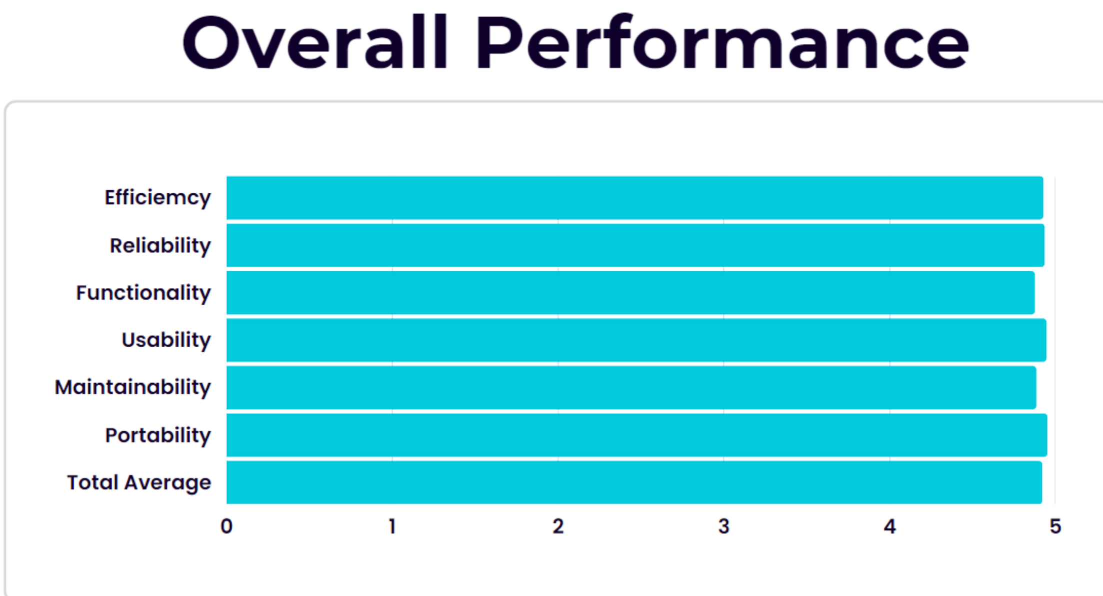

Figure 4.20. Graph for the Overall Performance

The Figure 4.20 shows the result of evaluation of the overall performance of the monitoring system under 30 respondents. The respondents are composed of LGU Officers, Barangay Police, and some Officials. The results show that the respondents strongly agree that the system is efficient, usable, reliable, portable, mobile, and well-functioning according to the ISO 9126 standard. The overall performance of the system, based on the survey conducted is 4.91 out of 5 or 98.2%.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions and recommendations of the project obtained after series of experiment and testing.

5.1 Summary Findings

First experimentation is getting the threshold of each sensor and differentiate the manual reading of the sensors to the Tanglaw Reading that was posted in our website.

The reading of battery voltage and current will sum up to the battery power same as the solar voltage and current. The threshold of the parameters is: 4V for battery voltage, 5A for battery current, 8V for solar voltage and 6A for solar current. Once the reading reaches the threshold the system will automatically send an alert to the registered e-mail address, and it will also appear to the website.

The Luminosity sensor is tested in nighttime with a reading of zero once the LED is closed. The luminosity and other sensors are being tested in different weather, with a sample data in rainy and sunny seasons, the luminosity reads low lux during the rainy season and high lux during the sunny season.

Second Experimentation is to test the LoRa communication. In this study the use of LoRa module is being tested over 500meters of distance. The LoRa has a delay of 6 to 10 seconds in a line-of-sight communication over 400 meters of distance. However, once the LoRa was used with a line-of-sight obstruction, the average delay of communication was about 1 to 15 minutes of 300 to 500 meters of distance. The LoRa module was also tested in a bad weather with a maximum delay of 16 minutes with a line-of-sight obstruction height given that the distance of each node is 300 meters.

Third experimentation was the difference between the normal Lithium-Ion battery to the Lithium-Iron Phosphate that are being used in the system. The Lithium-Ion over 10 cycles reach 91 to 90% DOD with a minimal load, while the Lithium-Iron Phosphate reach 99 to 98% of DOD with a more than three load.

5.2 Conclusions

Based on the Summary Findings the researchers came up with the following conclusions:

1. In integrating sensors to the streetlight, the parameters should all be measured and calibrated. Large consumptions of sensors will produce a low power to LED.
2. A centralized monitoring system that uses a LoRa connection is cost effective and can receive data from all three transmitters.
3. In using battery for efficiency, it is proved that Lithium-Iron Phosphate is better to sustain a low impact of decrease in SOH despite of the ages of the battery and consumptions.
4. In using LoRa module, it is tested that LoRa's antenna is way better when they positioned within its line-of sight. The frequency of LoRa matters in weather condition of the place, obstructions, and elevation of the buildings, it causes a delay of communication once the module is far from each other.
5. The system was tested by charging and discharging the solar streetlights. The system has a 98.12% accuracy. The monitoring website displays data in real time,

and the alert system is functioning based on sensor thresholds. According to the evaluation, the solar streetlight benefited the residents of the area, particularly the school community at night.

5.3 Recommendations

Here are some of the proponents' recommendations for more research on this study:

1. Modular Monitoring System. The device was created by connecting solar lighting to sensors. The modular monitoring system extends beyond the solar streetlights purchased by the proponents. It also eases installation and repairability of the system itself.

2. Local Database. The database will only be recorded when the website is connected to the internet. Local databases will assist to enhance the monitoring website by recording data even when it is not connected to the internet.

3. Anomaly Detection. This research necessitates the early detection of errors in the solar streetlight components.

4. Enhance Battery Management with Machine Learning. Enhance accuracy by integrating Machine Learning into battery State of Charge (SOC) and State of Health (SOH) calculations, optimizing performance and reliability.

5. Use alternative LoRa modules and Microcontrollers. By employing these advancements, researchers can enhance the performance and capabilities of LoRa-based systems, enabling more efficient data transmission and improved overall functionality.

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APPENDIX A
NEEDS ASSESMENT

The proponents conducted a survey for the needs of the community. The respondents of this survey were the residents of the Barangay Saluysoy, Meycauayan, Bulacan. The purpose of the survey is to know what the problems and the needs of their community are. The survey results are presented on the following pages.

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		Issue No.	01
		Revision No.	00
		Date	11192019
		Page	1 / 5
VRE-UES	COMMUNITY NEEDS ASSESSMENT FORM	QAC No.	CC-11192019

Pangalan: Arlene Pascual Petsa: April 3, 2023
Tirahan: Saluysoy Meycauayan Bulacan

Pakisagutan lamang po at ibalik sa kinauukulan. Ito ay isinasagawa upang malaman ang kasalukuyang kalagayan ng inyong barangay.

1. *Ilan ang bilang ng pamilyang nakatira sa bahay na ito?*

✓ *1 pamilya* ___ *3 pamilya* ___ *5 pamilya*
___ *2 pamilya* ___ *4 pamilya* ___ *higit sa 5 pamilya (ilagay kung ilan)*

2. *Pakilagyan ng bilang. Ilan bilang ng mga babaing may edad na sumusunod sa inyong bahay?*
(Halimbawa: 3 babae may edad 1-7; 2 babae may edad 22-28)

___ *edad 1-7* ___ *edad 22-28* ___ *edad 43-49*
✓ *edad 8-14* ___ *edad 29-35* ___ *edad 50-56*
___ *edad 15-21* ___ *edad 36-42* ___ *edad 57-63*
___ *edad 63 pataas*

3 *Pakilagyan ng bilang. Ilan ang bilang ng mga lalaking may edad na sumusunod sa inyong bahay?*
(Halimbawa: 3 lalaki may edad 1-7; 2 lalaki may edad 22-28)

___ *edad 1-7* ___ *edad 22-28* ___ *edad 43-49*
___ *edad 8-14* ___ *edad 29-35* ___ *edad 50-56*
✓ *edad 15-21* ___ *edad 36-42* ___ *edad 57-63*
___ *edad 63 pataas*

4. Lagyan ng tsek. *Ano ang karaniwang nagiging problema ng mga nasa inyong tahanan?*

	May miyembro ng pamilya na walang kakayahan para maghanapbuhay.
	May miyembro ng pamilya na may kakayahan ngunit walang pagkakataon o walang pagpupursigi sa paghahanapbuhay
✓	May miyembro ng pamilya na mayroong hanapbuhay ngunit kulang ang kinikita para sa mga pangangailangan.
	May miyembro ng pamilya na hindi malusog: _____ mga anak _____iba pang miyembro _____ mga buntis (Pakisulat kung sino)__________
	Magulang o tagapangalaga na hindi malawak ang kaalaman sa pag-aalaga ng mga bata
	Mag-asawa na marami at magkakasunod ang anak
	Miyembro ng pamilya na naapektuhan matinding pagkakasakit
	Miyembro ng pamilya na naapektuhan sa pagkawala ng hanapbuhay
	Mag-asawa/ magkapamilya na madalas na hindi magkasundo
	Mga miyembro ng pamilya na madalas hindi magkasundo.
	Mga nahihirapan sa kanilang kalagayan bilang mga magulang na walang asawa o "solo parent"

Transaction ID	
Signature	Arlene T. Pascual

Ang TUP Po ba ay nakatulong na sa inyong barangay mula ng sila ay pumunta dito?

opo

Iba pang nakitang problema:

Bahain. WALANG ILAW SA ESKINITA

Pangalan ng nag-*interview*: MA. ELAIZA D. ILAGAN

Katungkulan ng nag-*interview:* EXTERNAL COORDINATOR

Transaction ID	
Signature	[signature]

	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Ayala Blvd., Ermita, Manila, 1000, Philippines Tel No. +632-301-3001 local 409 | Fax No. +632-521-4063 Email: ues@tup.edu.ph | Website: www.tup.edu.ph	Index No.	F-UES-4.2-CAF
		Issue No.	01
		Revision No.	00
		Date	11192019
		Page	1 / 5
VRE-UES	COMMUNITY NEEDS ASSESSMENT FORM	QAC No.	CC-11192019

Pangalan: Benjamin Campos Petsa: April 3, 2023
Tirahan: Salvysoy Meycauayan

Pakisagutan lamang po at ibalik sa kinauukulan. Ito ay isinasagawa upang malaman ang kasalukuyang kalagayan ng inyong barangay.

1. *Ilan ang bilang ng pamilyang nakatira sa bahay na ito?*

__✓__ *1 pamilya* ____ *3 pamilya* ____ *5 pamilya*
____ *2 pamilya* ____ *4 pamilya*
____ *higit sa 5 pamilya (ilagay kung ilan)*

2. *Pakilagyan ng bilang. Ilan bilang ng mga babaing may edad na sumusunod sa inyong bahay?*
(Halimbawa: 3 babae may edad 1-7; 2 babae may edad 22-28)

____ *edad 1-7* ____ *edad 22-28* ____ *edad 43-49*
____ *edad 8-14* __1__ *edad 29-35* __1__ *edad 50-56*
____ *edad 15-21* ____ *edad 36-42* ____ *edad 57-63*
____ *edad 63 pataas*

3 *Pakilagyan ng bilang. Ilan ang bilang ng mga lalaking may edad na sumusunod sa inyong bahay?*
(Halimbawa: 3 lalaki may edad 1-7; 2 lalaki may edad 22-28)

____ *edad 1-7* __1__ *edad 22-28* ____ *edad 43-49*
____ *edad 8-14* ____ *edad 29-35* __1__ *edad 50-56*
____ *edad 15-21* ____ *edad 36-42* ____ *edad 57-63*
____ *edad 63 pataas*

4. Lagyan ng tsek. *Ano ang karaniwang nagiging problema ng mga nasa inyong tahanan?*

	May miyembro ng pamilya na walang kakayahan para maghanapbuhay.
	May miyembro ng pamilya na may kakayahan ngunit walang pagkakataon o walang pagpupursigi sa paghahanapbuhay
✓	May miyembro ng pamilya na mayroong hanapbuhay ngunit kulang ang kinikita para sa mga pangangailangan.
	May miyembro ng pamilya na hindi malusog: ____ mga anak ____ iba pang miyembro ____ mga buntis (Pakisulat kung sino)____
	Magulang o tagapangalaga na hindi malawak ang kaalaman sa pag-aalaga ng mga bata
	Mag-asawa na marami at magkakasunod ang anak
	Miyembro ng pamilya na naapektuhan matinding pagkakasakit
	Miyembro ng pamilya na naapektuhan sa pagkawala ng hanapbuhay
	Mag-asawa/ magkapamilya na madalas na hindi magkasundo
	Mga miyembro ng pamilya na madalas hindi magkasundo.
	Mga nahihirapan sa kanilang kalagayan bilang mga magulang na walang asawa o "solo parent"

Transaction ID	
Signature	Benjamin Campos

	TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES Ayala Blvd., Ermita, Manila, 1000, Philippines Tel No. +632-301-3001 local 409 | Fax No. +632-521-4063 Email: ues@tup.edu.ph | Website: www.tup.edu.ph	Index No.	F-UES-4.2-CAF
		Issue No.	01
		Revision No.	00
		Date	11192019
VRE-UES	COMMUNITY NEEDS ASSESSMENT FORM	Page	5 / 5
		QAC No.	CC-11192019

Ang TUP Po ba ay nakatulong na sa inyong barangay mula ng sila ay pumunta dito?

Opo

Iba pang nakitang problema:

Ilaw, Pangkalinisan

Pangalan ng nag-*interview*: Jhassey Tipalan

Katungkulan ng nag-*interview*: Project Microcontroller Programmer

Transaction ID	
Signature	Benjamin Campos

APPENDIX B
PROGRAM CODES

Frontend Codes for Homepage

```
import React, { useState, Suspense } from 'react';
import Modal from 'react-modal';
import Carousel from 'react-elastic-carousel';
import lamp1 from '../assets/A.jpg';
import lamp2 from '../assets/B.jpg';
import lamp3 from '../assets/C.jpg';
import lamp4 from '../assets/D.jpg';
import lamp5 from '../assets/E.jpg';
import { BeatLoader } from 'react-spinners';

import './css/home.css';

const Parallax1 = React.lazy(() => import('./Parallax1'));
const Parallax2 = React.lazy(() => import('./Parallax2'));
const InbetweenParallax = React.lazy(() => import('./InbetweenParallax'));
const AboutUs = React.lazy(() => import('./AboutUs'));
Modal.setAppElement('#root');

const breakPoints = [
  { width: 1, itemsToShow: 1 },
  { width: 550, itemsToShow: 2 },
  { width: 800, itemsToShow: 3, itemsToScroll: 3 },
];

function Popup(props) {
  return (
    <div className="popup">
      <div className="popup-inner">
        <button className="close-btn" onClick={props.closePopup}>
```

```
          X
        </button>
        <h2>{props.title}</h2>
        <p>{props.content}</p>
      </div>
    </div>
  );
}

function Home() {
  const items = [
    { id: 1, src: lamp1 },
    { id: 2, src: lamp2, title: 'item #2' },
    { id: 3, src: lamp3, title: 'item #3' },
    { id: 4, src: lamp4, title: 'item #4' },
    { id: 5, src: lamp5, title: 'item #5' },
  ];

  return (
    <div id="about-us">
      <div className="flex flex-col items-center bg-teal-500 p-6 md:p-12 lg:p-20 xl:p-32 h-full
relative">
        <div className="sm:text-5xl md:text-8xl">
          <h1 className="text-white uppercase drop-shadow-3xl sm:text-7xl text-5xl ">
            VOLTAIC V
          </h1>
        </div>
        <div className="text-white text-justify drop-shadow-3xl text-xl sm:text-xl md:text-2xl">
          IOT Centralized Monitoring System for Solar Streetlight Application
          using LoRa with Microcontroller
        </div>
```

```
<Carousel
  breakPoints={breakPoints}
  className="mt-10 md:mt-20 lg:mt-40 bg-white bg-opacity-10 backdrop-blur-md md:backdrop-blur-lg rounded drop-shadow-2xl md:drop-shadow-3xl p-4 md:p-6 lg:p-12 xl:p-20"
>
  {items.map((item) => (
    <div key={item.id}>
      <img
        src={item.src}
        alt=""
        className="ml-10 w-auto h-64 object-cover"
      />
    </div>
  ))}
</Carousel>
</div>
<Suspense
  fallback={
    <div>
      <BeatLoader
        className="text-gray-800"
        loading={true}
        size={50}
        aria-label="Loading Spinner"
        data-testid="loader"
      />
    </div>
  }
>
  <AboutUs />
</Suspense>
```

```
<Suspense
  fallback={
    <div>
      <BeatLoader
        className="text-gray-800"
        loading={true}
        size={50}
        aria-label="Loading Spinner"
        data-testid="loader"
      />
    </div>
  }
>
  <Parallax1 />
</Suspense>
<Suspense
  fallback={
    <div>
      <BeatLoader
        className="text-gray-800"
        loading={true}
        size={50}
        aria-label="Loading Spinner"
        data-testid="loader"
      />
    </div>
  }
>
  <InbetweenParallax />
</Suspense>
<Suspense
```

```
        fallback={
          <div>
            <BeatLoader
              className="text-gray-800"
              loading={true}
              size={50}
              aria-label="Loading Spinner"
              data-testid="loader"
            />
          </div>
        }
      >
        <Parallax2 />
      </Suspense>
      <br />
    </div>
  );
}

export default Home;
```

For Full Documentation: ***https://github.com/NCSnts30/mapbox-lamp-master-master-master-latest.git.*** Download the latest repository.

```
// Lora Transmitter Node A

// Libraries used
#include <SPI.h>
#include <LoRa.h>              // https://github.com/sandeepmistry/arduino-LoRa
#include <Wire.h>
#include <Adafruit_Sensor.h>    // https://github.com/adafruit/Adafruit_Sensor
#include <Adafruit_TSL2561_U.h> // https://github.com/adafruit/Adafruit_TSL2561
#include <EEPROM.h>

// Create Data Structure for sendng LoRa Packets
#define nodeID 1  // set up required node ID

struct __attribute__((packed)) NodeA {
  byte StructureID;  // identifies the structure type
  byte NodeID;       // ID of transmitting node
  float battery_voltage;
  float battery_current;
  float battery_power;
  float solar_voltage;
  float solar_current;
  float solar_power;
  float temperature;
  float luminosity;
  float soc;
  float soh;
};
```

```
NodeA data1 = {1, nodeID, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};

// For TSL2561

Adafruit_TSL2561_Unified tsl =
Adafruit_TSL2561_Unified(TSL2561_ADDR_FLOAT, 12345);

// For filtering analog values
const int FILTER_SIZE = 400; // number of samples to use for median filter
int samples[FILTER_SIZE]; // array to hold samples

void setup() {
  // put your setup code here, to run once:
  Serial.begin(115200);

  while (!Serial);

  Serial.println("LoRa Sender 1");
  LoRa.setPins(10, 9, 2); // Set pins 10, 9 for UNO, 53, 9 for Mega, 15, 16, for ESP8266
  if (!LoRa.begin(433E6)) { // change appropriate frequency of the module
    Serial.println("Starting LoRa failed!");
    while (1);
  }
  LoRa.setTxPower(20);    // For transmitter  power
  LoRa.setSyncWord(0x22); // Set the same value for both transmitter and receiver

  // TSL2561 Luminosity Sensor Configuartion
  tsl.begin();
```

```
  tsl.setGain(TSL2561_GAIN_1X);
  tsl.setIntegrationTime(TSL2561_INTEGRATIONTIME_402MS);
}

void read_voltage_value(int analog_pin, String source){
  //Filter Analog Reading
  for (int i = 0; i < FILTER_SIZE; i++) {
    samples[i] = analogRead(analog_pin);
    delay(10); // delay between readings to allow voltage to stabilize
  }

  // sort samples in ascending order using bubble sort algorithm
  for (int i = 0; i < FILTER_SIZE - 1; i++) {
    for (int j = 0; j < FILTER_SIZE - i - 1; j++) {
      if (samples[j] > samples[j+1]) {
        int temp = samples[j];
        samples[j] = samples[j+1];
        samples[j+1] = temp;
      }
    }
  }

  int median;
  if (FILTER_SIZE % 2 == 0) {
    median = (samples[FILTER_SIZE/2] + samples[FILTER_SIZE/2-1]) / 2;
  } else {
    median = samples[FILTER_SIZE/2];
  }
```

```
  int offset = 3;         // set the correction offset value

  double voltage_value = map(median,0,1023, 0, 2500) + offset;         // map 0-1023 to 0-
2500 and add correction offset

  voltage_value /=100;          // divide by 100 to get the decimal values

  if (median == 0) {
    voltage_value = 0;
  }

  if (source == "battery") {
    if (voltage_value >= 3.61){
      data1.battery_voltage = 3.60;
    }
    else if (voltage_value <= -3.61){
      data1.battery_voltage = -3.60;
    }
    else
      data1.battery_voltage = voltage_value;
  }
  if (source == "solar") {
    if (voltage_value >= 6.01){
      data1.solar_voltage = 6.00;
    }
    else if (voltage_value <= -6.01){
      data1.solar_voltage = -6.00;
    }
```

```
    else
    data1.solar_voltage = voltage_value;
  }
}

void read_current_value(int analog_pin, String source){
  //Filter Analog Reading
  for (int i = 0; i < FILTER_SIZE; i++) {
    samples[i] = analogRead(analog_pin);
    delay(10); // delay between readings to allow voltage to stabilize
  }

  // sort samples in ascending order using bubble sort algorithm
  for (int i = 0; i < FILTER_SIZE - 1; i++) {
    for (int j = 0; j < FILTER_SIZE - i - 1; j++) {
      if (samples[j] > samples[j+1]) {
        int temp = samples[j];
        samples[j] = samples[j+1];
        samples[j+1] = temp;
      }
    }
  }

  int median;
  if (FILTER_SIZE % 2 == 0) {
    median = (samples[FILTER_SIZE/2] + samples[FILTER_SIZE/2-1]) / 2;
  } else {
    median = samples[FILTER_SIZE/2];
```

```
  }

  const float VCC   = 5.0;          // supply voltage is from 4.5 to 5.5V. Normally 5V.
  const float QOV =   0.5 * VCC;    // set quiescent Output voltage of 0.5V

  float voltage_raw =   (5.0 / 1023.0) * median;   // Read the voltage from sensor
  float voltage =  voltage_raw - QOV + 0.017;          // 0.000 is a value to make voltage
zero when there is no current
  float current_value = voltage / 0.185;

  if (source == "battery") {
    if (current_value >= 5.01){
      data1.battery_current = 5.00;
    }
    else if (current_value <= -5.01){
      data1.battery_current = -5.00;
    }
    else
    data1.battery_current = current_value;
  }

  if (source == "solar") {
    if (current_value >= 5.01){
      data1.solar_current = 5.00;
    }
    else if (current_value <= -5.01){
      data1.solar_current = -5.00;
    }
    else
```

```
    data1.solar_current = current_value;
  }
}

void calc_power_value(String source){

  if (source == "battery") {
    float power_value = data1.battery_voltage * data1.battery_current;
    data1.battery_power = power_value;
  }

  if (source == "solar") {
    float power_value = data1.solar_voltage * data1.solar_current;
    data1.solar_power = power_value;
  }
}

void read_temperature_value(int analog_pin){
  //Filter Analog Reading
  for (int i = 0; i < FILTER_SIZE; i++) {
    samples[i] = analogRead(analog_pin);
    delay(10); // delay between readings to allow voltage to stabilize
  }

  // sort samples in ascending order using bubble sort algorithm
  for (int i = 0; i < FILTER_SIZE - 1; i++) {
    for (int j = 0; j < FILTER_SIZE - i - 1; j++) {
      if (samples[j] > samples[j+1]) {
```

```
        int temp = samples[j];
        samples[j] = samples[j+1];
        samples[j+1] = temp;
      }
    }
  }

  int median;
  if (FILTER_SIZE % 2 == 0) {
    median = (samples[FILTER_SIZE/2] + samples[FILTER_SIZE/2-1]) / 2;
  } else {
    median = samples[FILTER_SIZE/2];
  }

  float temp_read = median * (5.0 / 1023.0);
  float temperature_value = temp_read * 100;
  data1.temperature = temperature_value;
}


void read_luminosity_value(){

  sensors_event_t event;
  tsl.getEvent(&event);

  // Display the results (light is measured in lux)
  if (event.light) {
    data1.luminosity = event.light;
```

```
  }

  else {
    data1.luminosity = 0.0;
  }
}

void calc_SOC_value_OCV(float voltage) {
  int soc = 0;

  if (voltage > 3.4) {
    soc = 100;
  } else {
    int voltage_rounded = round(voltage * 100);

    switch (voltage_rounded) {
      case 335 ... 340:
        soc = round(6.92359 * sin(0.872357 - 2.97897 * voltage) + 101.162);
        break;

      case 333 ... 334:
        soc = round(43.6391 * sin(20.5166 * voltage + 1.15404) + 74.6593);
        break;

      case 330 ... 332:
        soc = round(146.792 * sin(17.3661 - 9.7377 * voltage) + 188.514);
        break;
```

```
  case 328 ... 329:
    soc = round(85.4467 * sin(232.563 - 69.5198 * voltage) + 124.158);
    break;

  case 325 ... 327:
    soc = round(28.1596 * sin(64.2848 - 20.895 * voltage) + 16.9361);
    break;

  case 323 ... 324:
    soc = round(75.7755 - 57.8438 * sin(111.516 - 36.0671 * voltage));
    break;

  case 320 ... 322:
    soc = round(33.8233 - 16.8998 * sin(66.3962 - 20.2877 * voltage));
    break;

  case 313 ... 319:
    soc = round(17.19 - 8.59272 * sin(12.9741 - 4.02357 * voltage));
    break;

  case 300 ... 312:
    soc = round(11.5678 - 7.82468 * sin(13.2953 - 4.3203 * voltage));
    break;

  default:
    soc = round(8.64652 - 8.64685 * sin(9.25664 - 3.07084 * voltage));
    break;
}
```

```
    // Clamp SOC value within the range of 0 to 100
    soc = max(0, min(100, soc));
  }

  data1.soc = soc;
}
void calc_SOH_value(float voltage, float current) {
  // Define the battery capacity
  const float batteryCapacity = 27000.0; // In mAh

  // Define the SOH calculation constants
  const float k1 = 0.0008; // Internal resistance
  const float k2 = 0.0001; // Capacity
  const float k3 = 2.8;    // Discharge efficiency
  const float k4 = 3.65;   // Charge efficiency

  // Validate input values
  if (voltage <= 0 || current <= 0) {
    // Handle invalid inputs
    // For example: return an error code or throw an exception
    return;
  }

  // Calculate the open-circuit voltage
  float openCircuitVoltage = voltage - (k1 * current);

  // Check for minimum voltage threshold
```

```
if (openCircuitVoltage < 0) {
  openCircuitVoltage = 0; // Avoid negative values
}

// Calculate the SOH
float soh = (openCircuitVoltage / voltage) * 100.0;

// Adjust SOH based on the charge efficiency
if (soh > 100) {
  soh = 100;
}
soh = (soh / k3) * k4;

// Adjust SOH based on the internal resistance
if (soh > 100) {
  soh = 100;
}
soh = soh / (1 + (k1 * current / voltage));

// Calculate the battery charge
float batteryCharge = (soh / 100.0) * batteryCapacity;

// Calculate the adjusted SOH
soh = (batteryCharge / batteryCapacity) * 100.0;

// Limit SOH to a maximum of 100%
if (soh >= 100.01) {
  data1.soh = 100;
```

```
  }
  else if (soh <= 0) {
    data1.soh = 0;
  }
  else {
    data1.soh = soh;
  }
  EEPROM.put(0, data1.soh); // store SoH in EEPROM address 0
}
void loop() {
  // put your main code here, to run repeatedly:

    read_voltage_value(0, "battery");

    read_current_value(1, "battery");

    calc_power_value("battery");

    read_voltage_value(2, "solar");

    read_current_value(3, "solar");

    calc_power_value("solar");

    read_temperature_value(6);

    read_luminosity_value();
```

```
  calc_SOC_value_OCV(data1.battery_voltage);

  if (data1.battery_voltage >= 3.3) {

   calc_SOH_value(data1.battery_voltage, data1.battery_current);

  }

  else {
   int value = EEPROM.read(0);
   data1.soh = value;
  }

 // Send readings every 10 seconds
 static unsigned long lastSendTime = 0;
 unsigned long currentTime = millis();
 if (currentTime - lastSendTime >= 10000) { //The 10 seconds delay is multiplied to
1000
  lastSendTime = currentTime;

  Serial.print("Node");
  Serial.print(data1.NodeID);       Serial.print(",");
  Serial.print(data1.battery_voltage); Serial.print(",");
  Serial.print(data1.battery_current); Serial.print(",");
  Serial.print(data1.battery_power);   Serial.print(",");
  Serial.print(data1.solar_voltage);   Serial.print(",");
  Serial.print(data1.solar_current);   Serial.print(",");
  Serial.print(data1.solar_power);     Serial.print(",");
  Serial.print(data1.temperature);     Serial.print(",");
```

```
    Serial.print(data1.luminosity);     Serial.print(",");
    Serial.print(data1.soc);            Serial.print(",");
    Serial.print(data1.soh);            Serial.print(",");
    Serial.println(" ");

    LoRa_txMode();                          // set tx mode
    LoRa.beginPacket();                     // start packet
    LoRa.write((byte *)&data1, sizeof(data1));  // transmit packet
    LoRa.endPacket(true);                   // finish packet and send it
  }
}

void LoRa_txMode() {
  LoRa.idle();             // set standby mode
  LoRa.disableInvertIQ();  // normal mode
}
```

Arduino Receiver Codes

```
#include <ESP8266WiFi.h>
#include <ESP8266HTTPClient.h>
#include <NTPClient.h>
#include <WiFiUdp.h>
#include <SPI.h>
#include <LoRa.h>
#include <time.h>
#include <WiFiManager.h>



const char* ntpServer = "pool.ntp.org";
const long  gmtOffset_sec = 18000;   //Replace with your GMT offset (seconds)
const int   daylightOffset_sec = 0;  //Replace with your daylight offset (seconds)

const char *ssid = "SSID";       //Replace SSID with your WiFi SSID
const char *pass = "PASS";    //Replace PASS with your WiFi Password

const char * host = "miexfgyli2.execute-api.ap-northeast-1.amazonaws.com";
const uint16_t port = 443;



// three different structures may be received
struct __attribute__((packed)) NodeA {
 byte StructureID;  // identifies the structure type
 byte NodeID;       // ID of transmitting node
 float battery_voltage;
 float battery_current;
```

```
 float battery_power;
 float solar_voltage;
 float solar_current;
 float solar_power;
 float temperature;
 float luminosity;
 float soc; //added parameter
 float soh; //added parameter
} data1;

struct __attribute__((packed)) NodeB {
 byte StructureID;  // identifies the structure type
 byte NodeID;       // ID of transmitting node
 float battery_voltage;
 float battery_current;
 float battery_power;
 float solar_voltage;
 float solar_current;
 float solar_power;
 float temperature;
 float luminosity;
 float soc; //added parameter
 float soh; //added parameter
} data2;

struct __attribute__((packed)) NodeC {
 byte StructureID;  // identifies the structure type
 byte NodeID;       // ID of transmitting node
```

```
 float battery_voltage;
 float battery_current;
 float battery_power;
 float solar_voltage;
 float solar_current;
 float solar_power;
 float temperature;
 float luminosity;
 float soc; //added parameter
 float soh; //added parameter
} data3;

struct __attribute__((packed)) Data {
 byte NodeID;       // ID of transmitting node
 float battery_voltage;
 float battery_current;
 float battery_power;
 float solar_voltage;
 float solar_current;
 float solar_power;
 float temperature;
 float luminosity;
 float soc; //added parameter
 float soh; //added parameter
 float rssi;
};

Data data = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
```

```
WiFiManager wifiManager;
WiFiClient client;

void setup() {
  Serial.begin(115200);

  Serial.println("conntecting to network..");
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED) {
    wifiManager.autoConnect("Tanglaw","voltaicv");
  }
  Serial.println("conntected to network..");
  configTime(gmtOffset_sec, daylightOffset_sec, ntpServer);

  Serial.println("conntecting to server..");

  while (!Serial);
  Serial.println("LoRa Receiver");
  LoRa.setPins(15, 16, 2); // 10, 9 for UNO, 53, 9 for Mega, 15, 16 for ESP8266
  if (!LoRa.begin(433E6)) {
    Serial.println("Starting LoRa failed!");
    while (1);
  }
  LoRa.setGain(6);
  LoRa.setSyncWord(0x22);
  LoRa.receive();
}
```

```
void wifi(){
  WiFi.begin(ssid, pass);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
}

void loop() {
  int packetSize = LoRa.parsePacket();

  if (packetSize) {
    byte structureID = LoRa.read();   // read first byte the structure ID
    switch (structureID) {
      case 1:
          LoRa.readBytes((byte *)&data1 + 1, packetSize - 1);  // receive data1 packet
          data.NodeID           = data1.NodeID;
          data.battery_voltage   = data1.battery_voltage;
          data.battery_current   = data1.battery_current;
          data.battery_power     = data1.battery_power;
          data.solar_voltage     = data1.solar_voltage;
          data.solar_current     = data1.solar_current;
          data.solar_power       = data1.solar_power;
          data.temperature       = data1.temperature;
          data.luminosity        = data1.luminosity;
          data.soc               = data1.soc; //added parameter
          data.soh               = data1.soh; //added parameter
```

```
    data.rssi            = LoRa.packetRssi();

    break;

  case 2:
    LoRa.readBytes((byte *)&data2 + 1, packetSize - 1);  // receive data2 packet
    data.NodeID          = data2.NodeID;
    data.battery_voltage   = data2.battery_voltage;
    data.battery_current   = data2.battery_current;
    data.battery_power     = data2.battery_power;
    data.solar_voltage     = data2.solar_voltage;
    data.solar_current     = data2.solar_current;
    data.solar_power       = data2.solar_power;
    data.temperature       = data2.temperature;
    data.luminosity        = data2.luminosity;
    data.soc             = data2.soc; //added parameter
    data.soh             = data2.soh; //added parameter
    data.rssi            = LoRa.packetRssi();

    break;

  case 3:
    LoRa.readBytes((byte *)&data3 + 1, packetSize - 1);  // receive data3 packet
    data.NodeID          = data3.NodeID;
    data.battery_voltage   = data3.battery_voltage;
    data.battery_current   = data3.battery_current;
    data.battery_power     = data3.battery_power;
    data.solar_voltage     = data3.solar_voltage;
```

```
    data.solar_current     = data3.solar_current;
    data.solar_power       = data3.solar_power;
    data.temperature       = data3.temperature;
    data.luminosity        = data3.luminosity;
    data.soc               = data3.soc; //added parameter
    data.soh               = data3.soh; //added parameter
    data.rssi              = LoRa.packetRssi();

    break;

  default:
    break;

}

Serial.print("Node");
Serial.print(data.NodeID);          Serial.print(",");
Serial.print(data.battery_voltage); Serial.print(",");
Serial.print(data.battery_current); Serial.print(",");
Serial.print(data.battery_power);   Serial.print(",");
Serial.print(data.solar_voltage);   Serial.print(",");
Serial.print(data.solar_current);   Serial.print(",");
Serial.print(data.solar_power);     Serial.print(",");
Serial.print(data.temperature);     Serial.print(",");
Serial.print(data.luminosity);      Serial.print(",");
Serial.print(data.soc);             Serial.print(","); //added parameter
Serial.print(data.soh);             Serial.print(","); //added parameter
Serial.print(data.rssi);            Serial.println(",");
```

```
String node_value       = String(data.NodeID);
String battery_voltage   = String(data.battery_voltage);
String battery_current   = String(data.battery_current);
String battery_power     = String(data.battery_power);
String solar_voltage     = String(data.solar_voltage);
String solar_current     = String(data.solar_current);
String solar_power       = String(data.solar_power);
String temperature       = String(data.temperature);
String luminosity        = String(data.luminosity);
String soc               = String(data.soc); //added parameter
String soh               = String(data.soh); //added parameter
String rssi              = String(data.rssi);

BearSSL::WiFiClientSecure client;
client.setInsecure();
HTTPClient https;

String parameter = "isOnline=true&node_id=" + node_value + "&battery_voltage=" + battery_voltage + "&battery_current=" + battery_current + "&battery_power=" + battery_power + "&solar_voltage=" + solar_voltage + "&solar_current=" + solar_current + "&solar_power=" + solar_power + "&luminosity=" + luminosity + "&temperature=" + temperature + "&soc=" + soc + "&soh=" + soh + "&rssi=" + rssi;
String body = "";
String path = "/dev/voltaic?" + parameter ;//api/read_node.php";
if (https.begin(client, host, port, path)) {
    https.addHeader("Content-Type", "application/x-www-form-urlencoded");
    https.addHeader("User-Agent", "ESP8266");
    https.addHeader("Host", String(String(host) + ":" + port));
    https.addHeader("Content-Length", String(body.length()));
```

```
        Serial.println("sending post body: "+ body);
        int httpsCode = https.POST(body);
        if (httpsCode > 0) {
          Serial.println(httpsCode);
        if (httpsCode == HTTP_CODE_OK) {
          Serial.println(https.getString());
        }
        } else {
          Serial.print("failed to POST");
        }
    } else {
      Serial.print("failed to connect to server");
      if (WiFi.status() != WL_CONNECTED) {
        wifi();
      }
    }
    https.end();
  }
}
```

APPENDIX C

BILL OF MATERIALS

Bill of Materials

MATERIAL	PRICE	QTY	COST
LoRa Module	222	4	888
Luminosity Sensor	250	3	750
Arduino Nano	850	3	2550
Voltage Sensor	45	6	270
Current Sensor	95	6	570
Temperature Sensor	98	3	294
NodeMCU	160	1	160
Solar Streetlight	3690	3	11070
Solar Panel	850	2	1700
Transmitter Casing	1850	3	5550
Receiver Casing	1000	1	1000
Li-ion Battery	20	12	240
BMS	53	1	53
Antenna for LoRa	127	3	381
IPEX to SMA	131	1	131
Polulu Step up converter	300	3	900
Wire 20 AWG	25	2	50
Wire 22 AWG	5	4	20
Header Pin Female	15	6	90
TC4056	30	2	60
Female Jack Wire	30	1	30
Female USB Wire	37	1	37
Pocket Wifi	350	1	350

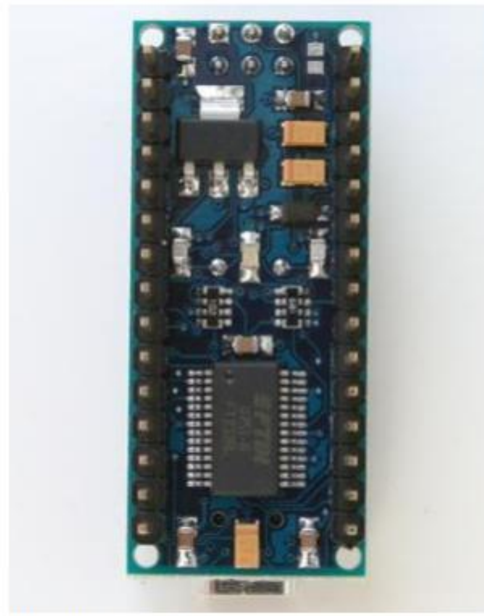
Total: **27,144**

APPENDIX D

SPECIFICATION AND DATA SHEETS

Arduino Nano

Arduino Nano Front



Arduino Nano Rear

Overview

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech.

Schematic and Design

Arduino Nano 3.0 (ATmega328): schematic, Eagle files.
Arduino Nano 2.3 (ATmega168): manual (pdf), Eagle files. *Note:* since the free version of Eagle does not handle more than 2 layers, and this version of the Nano is 4 layers, it is published here unrouted, so users can open and use it in the free version of Eagle.

Specifications:

Microcontroller	Atmel ATmega168 or ATmega328
Operating Voltage (logic level)	5 V
Input Voltage (recommended)	7-12 V
Input Voltage (limits)	6-20 V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	8
DC Current per I/O Pin	40 mA
Flash Memory	16 KB (ATmega168) or 32 KB (ATmega328) of which 2 KB used by bootloader
SRAM	1 KB (ATmega168) or 2 KB (ATmega328)
EEPROM	512 bytes (ATmega168) or 1 KB (ATmega328)
Clock Speed	16 MHz
Dimensions	0.73" x 1.70"

Power:

The Arduino Nano can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27). The power source is automatically selected to the highest voltage source.

The FTDI FT232RL chip on the Nano is only powered if the board is being powered over USB. As a result, when running on external (non-USB) power, the 3.3V output (which is supplied by the FTDI chip) is not available and the RX and TX LEDs will flicker if digital pins 0 or 1 are high.

Memory

The ATmega168 has 16 KB of flash memory for storing code (of which 2 KB is used for the bootloader); the ATmega328 has 32 KB, (also with 2 KB used for the bootloader). The ATmega168 has 1 KB of SRAM and 512 bytes of EEPROM (which can be read and written with the EEPROM library); the ATmega328 has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output

Each of the 14 digital pins on the Nano can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the FTDI USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.
- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication, which, although provided by the underlying hardware, is not currently included in the Arduino language.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Nano has 8 analog inputs, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the analogReference() function. Additionally, some pins have specialized functionality:

I²C: 4 (SDA) and 5 (SCL). Support I²C (TWI) communication using the Wire library (documentation on the Wiring website).

There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().
Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and ATmega168 ports.

Communication

The Arduino Nano has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega168 and ATmega328 provide UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An FTDI FT232RL on the board channels this serial communication over USB and the FTDI drivers (included with the Arduino software) provide a virtual com port to software on the computer. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the FTDI chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Nano's digital pins.
The ATmega168 and ATmega328 also support I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. To use the SPI communication, please see the ATmega168 or ATmega328 datasheet.

Programming

The Arduino Nano can be programmed with the Arduino software (download). Select "Arduino Diecimila, Duemilanove, or Nano w/ ATmega168" or "Arduino Duemilanove or Nano w/ ATmega328" from the **Tools**

https://www.farnell.com/datasheets/1682238.pdf

ACS712

Fully Integrated, Hall Effect-Based Linear Current Sensor with 2.1 kVRMS Voltage Isolation and a Low-Resistance Current Conductor

Features and Benefits

- Low-noise analog signal path
- Device bandwidth is set via the new FILTER pin
- 5 µs output rise time in response to step input current
- 80 kHz bandwidth
- Total output error 1.5% at $T_A = 25°C$
- Small footprint, low-profile SOIC8 package
- 1.2 mΩ internal conductor resistance
- 2.1 kV_{RMS} minimum isolation voltage from pins 1-4 to pins 5-8
- 5.0 V, single supply operation
- 66 to 185 mV/A output sensitivity
- Output voltage proportional to AC or DC currents
- Factory-trimmed for accuracy
- Extremely stable output offset voltage
- Nearly zero magnetic hysteresis
- Ratiometric output from supply voltage

TÜV America
Certificate Number:
U8V 06 05 54214 010

Package: 8 Lead SOIC (suffix LC)

Approximate Scale 1:1

Description

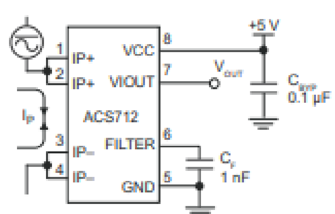
The Allegro® ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems. The device package allows for easy implementation by the customer. Typical applications include motor control, load detection and management, switched-mode power supplies, and overcurrent fault protection.

The device consists of a precise, low-offset, linear Hall sensor circuit with a copper conduction path located near the surface of the die. Applied current flowing through this copper conduction path generates a magnetic field which is sensed by the integrated Hall IC and converted into a proportional voltage. Device accuracy is optimized through the close proximity of the magnetic signal to the Hall transducer. A precise, proportional voltage is provided by the low-offset, chopper-stabilized BiCMOS Hall IC, which is programmed for accuracy after packaging.

The output of the device has a positive slope ($>V_{IOUT(Q)}$) when an increasing current flows through the primary copper conduction path (from pins 1 and 2, to pins 3 and 4), which is the path used for current sensing. The internal resistance of this conductive path is 1.2 mΩ typical, providing low power

Continued on the next page ...

Typical Application



Application 1. The ACS712 outputs an analog signal, V_{OUT}, that varies linearly with the uni- or bi-directional AC or DC primary sensed current, I_P, within the range specified. C_F is recommended for noise management, with values that depend on the application.

Description (continued)

loss. The thickness of the copper conductor allows survival of the device at up to 5× overcurrent conditions. The terminals of the conductive path are electrically isolated from the sensor leads (pins 5 through 8). This allows the ACS712 current sensor to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques.

The ACS712 is provided in a small, surface mount SOIC8 package. The leadframe is plated with 100% matte tin, which is compatible with standard lead (Pb) free printed circuit board assembly processes. Internally, the device is Pb-free, except for flip-chip high-temperature Pb-based solder balls, currently exempt from RoHS. The device is fully calibrated prior to shipment from the factory.

Selection Guide

Part Number	Packing*	T_A (°C)	Optimized Range, I_P (A)	Sensitivity, Sens (Typ) (mV/A)
ACS712ELCTR-05B-T	Tape and reel, 3000 pieces/reel	–40 to 85	±5	185
ACS712ELCTR-20A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±20	100
ACS712ELCTR-30A-T	Tape and reel, 3000 pieces/reel	–40 to 85	±30	66

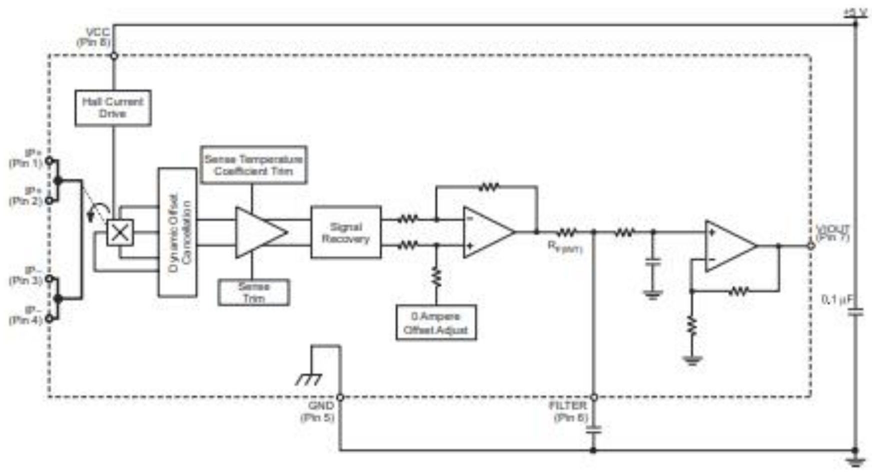
*Contact Allegro for additional packing options.

Absolute Maximum Ratings

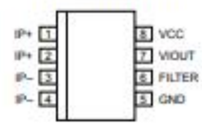
Characteristic	Symbol	Notes	Rating	Units
Supply Voltage	V_{CC}		8	V
Reverse Supply Voltage	V_{RCC}		–0.1	V
Output Voltage	V_{IOUT}		8	V
Reverse Output Voltage	V_{RIOUT}		–0.1	V
Reinforced Isolation Voltage	V_{ISO}	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	2100	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	184	V_{peak}
Basic Isolation Voltage	$V_{ISO(bsc)}$	Pins 1-4 and 5-8; 60 Hz, 1 minute, T_A=25°C	1500	V
		Voltage applied to leadframe (Ip+ pins), based on IEC 60950	354	V_{peak}
Output Current Source	$I_{IOUT(Source)}$		3	mA
Output Current Sink	$I_{IOUT(Sink)}$		10	mA
Overcurrent Transient Tolerance	I_P	1 pulse, 100 ms	100	A
Nominal Operating Ambient Temperature	T_A	Range E	–40 to 85	°C
Maximum Junction Temperature	T_J(max)		165	°C
Storage Temperature	T_{stg}		–65 to 170	°C

Parameter	Specification
Fire and Electric Shock	CAN/CSA-C22.2 No. 60950-1-03 UL 60950-1:2003 EN 60950-1:2001

Functional Block Diagram



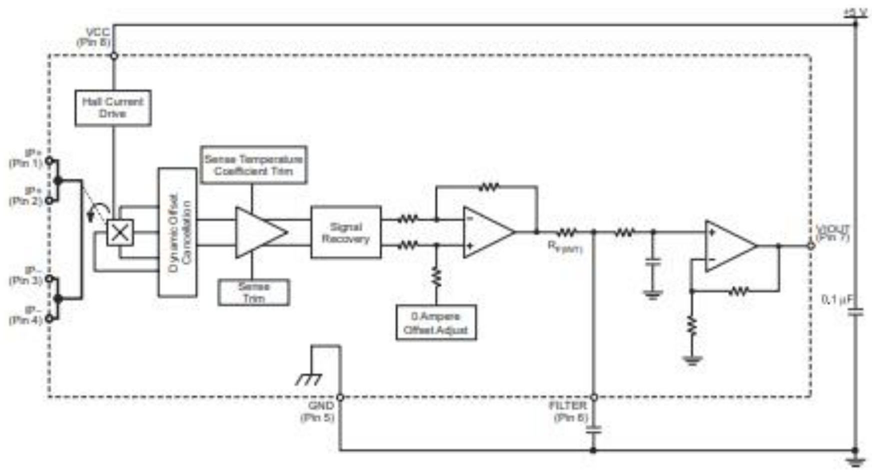
Pin-out Diagram



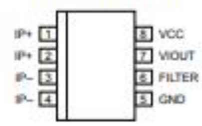
Terminal List Table

Number	Name	Description
1 and 2	IP+	Terminals for current being sensed; fused internally
3 and 4	IP–	Terminals for current being sensed; fused internally
5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

Functional Block Diagram



Pin-out Diagram



Terminal List Table

Number	Name	Description
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5	GND	Signal ground terminal
6	FILTER	Terminal for external capacitor that sets bandwidth
7	VIOUT	Analog output signal
8	VCC	Device power supply terminal

https://www.sparkfun.com/datasheets/BreakoutBoards/0712.pdf

Voltage Sensor

1688 SUNLEPHANT

Shenzhen Global Technology Co., Ltd

Voltage Sensor / Divider Board for ARDUINO developments

Model: Voltage Sensor / 170640

Description: This module is designed based on the principle of resistor divider to reduce the input voltage of the terminal interface by 5 times. The maximum input voltage of the Arduino is 5V. The input voltage of the voltage detection module cannot be greater than 5V × 5 = 25V (if 3.3V is used) System, the input voltage can not be greater than 3.3Vx5 = 16.5V). Because the AVR chip used by Arduino is 10-bit AD, the analog resolution of this module is 0.00489V (5V/1023), so the voltage detection module detects that the input minimum voltage is 0.00489V×5=0.02445V.

parameter:
Voltage input range max: DC0-25V
Voltage detection range: DC0.02445V - 25V
Voltage simulation resolution: 0.00489V
DC input interface: terminal positive terminal is connected to VCC, negative terminal is connected to GND
Output interface: "+" is connected to 5/3.3V, "-" is connected to GND, and "s" is connected to the A0 pin of Arduino.

Reference Code:

```
#include

int val11;
int val2;

void setup()
{
 pinMode(LED1,OUTPUT);
 Serial.begin(9600);
 Serial.println("Emartee.Com");
 Serial.println("Voltage: ");
 Serial.print("V");
}
void loop()
{
 float temp;
 val11=analogRead(0);
 temp=val11/4.092;
 val11=(int)temp;//
 val2=((val11%100)/10);
 Serial.println(val2);
 delay(1000);
}
```

Shenzhen City, Guangdong Science and Technology Co., Ltd. Address: China's Shenzhen Futian District, Shenzhen Huaqiang North Road

https://www.mantech.co.za/Datasheets/Products/Voltage%20Sensor-170640_SGT.pdf

LM35 – Temperature Sensor

Product Folder | Order Now | Technical Documents | Tools & Software | Support & Community

TEXAS INSTRUMENTS

LM35

SNIS159H – AUGUST 1999 – REVISED DECEMBER 2017

LM35 Precision Centigrade Temperature Sensors

1 Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C)
- Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications
- Low-Cost Due to Wafer-Level Trimming
- Operates From 4 V to 30 V
- Less Than 60-μA Current Drain
- Low Self-Heating, 0.08°C in Still Air
- Non-Linearity Only ±¼°C Typical
- Low-Impedance Output, 0.1 Ω for 1-mA Load

2 Applications

- Power Supplies
- Battery Management
- HVAC
- Appliances

3 Description

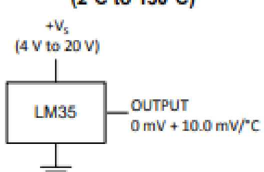
The LM35 series are precision integrated-circuit temperature devices with an output voltage linearly-proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55°C to 150°C temperature range. Lower cost is assured by trimming and calibration at the wafer level. The low-output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The LM35 device is rated to operate over a −55°C to 150°C temperature range, while the LM35C device is rated for a −40°C to 110°C range (−10° with improved accuracy). The LM35-series devices are available packaged in hermetic TO transistor packages, while the LM35C, LM35CA, and LM35D devices are available in the plastic TO-92 transistor package. The LM35D device is available in an 8-lead surface-mount small-outline package and a plastic TO-220 package.

Device Information(1)

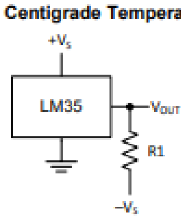
PART NUMBER	PACKAGE	BODY SIZE (NOM)
LM35	TO-CAN (3)	4.699 mm × 4.699 mm
	TO-92 (3)	4.30 mm × 4.30 mm
	SOIC (8)	4.90 mm × 3.91 mm
	TO-220 (3)	14.986 mm × 10.16 mm

(1) For all available packages, see the orderable addendum at the end of the datasheet.

Basic Centigrade Temperature Sensor (2°C to 150°C)



Full-Range Centigrade Temperature Sensor



Choose $R_1 = -V_S / 50\ \mu A$
V_{OUT} = 1500 mV at 150°C
V_{OUT} = 250 mV at 25°C
V_{OUT} = −550 mV at −55°C

https://www.ti.com/lit/ds/symlink/lm35.pdf

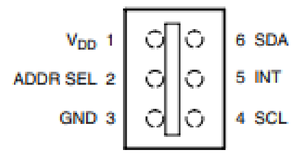
TAOS TEXAS ADVANCED OPTOELECTRONIC SOLUTIONS®

TSL2560, TSL2561 LIGHT-TO-DIGITAL CONVERTER

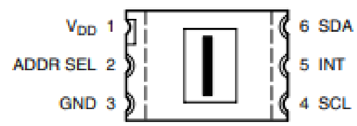
TAOS059N – MARCH 2009

- **Approximates Human Eye Response**
- **Programmable Interrupt Function with User-Defined Upper and Lower Threshold Settings**
- **16-Bit Digital Output with SMBus (TSL2560) at 100 kHz or I²C (TSL2561) Fast-Mode at 400 kHz**
- **Programmable Analog Gain and Integration Time Supporting 1,000,000-to-1 Dynamic Range**
- **Automatically Rejects 50/60-Hz Lighting Ripple**
- **Low Active Power (0.75 mW Typical) with Power Down Mode**
- **RoHS Compliant**

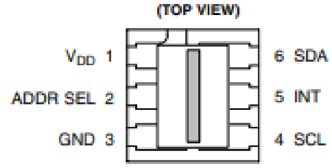
PACKAGE CS
6-LEAD CHIPSCALE
(TOP VIEW)



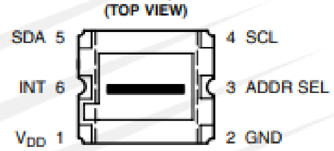
PACKAGE T
6-LEAD TMB
(TOP VIEW)



PACKAGE FN
DUAL FLAT NO-LEAD
(TOP VIEW)



PACKAGE CL
6-LEAD ChipLED
(TOP VIEW)



Package Drawings are Not to Scale

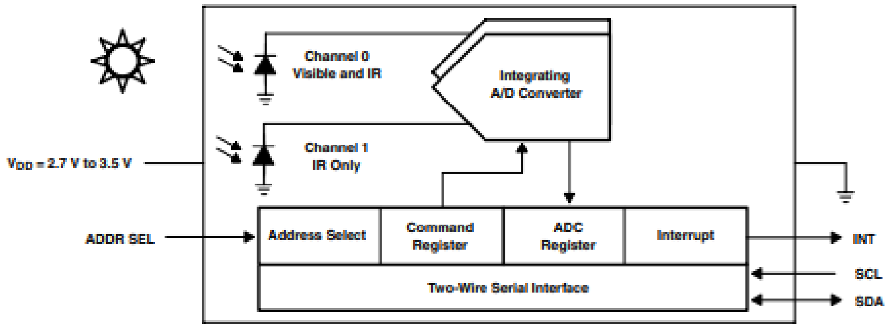
Description

The TSL2560 and TSL2561 are light-to-digital converters that transform light intensity to a digital signal output capable of direct I²C (TSL2561) or SMBus (TSL2560) interface. Each device combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit capable of providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photodiode currents to a digital output that represents the irradiance measured on each channel. This digital output can be input to a microprocessor where illuminance (ambient light level) in lux is derived using an empirical formula to approximate the human eye response. The TSL2560 device permits an SMB-Alert style interrupt, and the TSL2561 device supports a traditional level style interrupt that remains asserted until the firmware clears it.

While useful for general purpose light sensing applications, the TSL2560/61 devices are designed particularly for display panels (LCD, OLED, etc.) with the purpose of extending battery life and providing optimum viewing in diverse lighting conditions. Display panel backlighting, which can account for up to 30 to 40 percent of total platform power, can be automatically managed. Both devices are also ideal for controlling keyboard illumination based upon ambient lighting conditions. Illuminance information can further be used to manage exposure control in digital cameras. The TSL2560/61 devices are ideal in notebook/tablet PCs, LCD monitors, flat-panel televisions, cell phones, and digital cameras. In addition, other applications include street light control, security lighting, sunlight harvesting, machine vision, and automotive instrumentation clusters.

Texas Advanced Optoelectronic Solutions Inc.
1001 Klein Road • Suite 300 • Plano, TX 75074 • (972) 673-0759
www.taosinc.com

Functional Block Diagram



Detailed Description

The TSL2560 and TSL2561 are second-generation ambient light sensor devices. Each contains two integrating analog-to-digital converters (ADC) that integrate currents from two photodiodes. Integration of both channels occurs simultaneously. Upon completion of the conversion cycle, the conversion result is transferred to the Channel 0 and Channel 1 data registers, respectively. The transfers are double-buffered to ensure that the integrity of the data is maintained. After the transfer, the device automatically begins the next integration cycle.

Communication to the device is accomplished through a standard, two-wire SMBus or I^2C serial bus. Consequently, the TSL256x device can be easily connected to a microcontroller or embedded controller. No external circuitry is required for signal conditioning, thereby saving PCB real estate as well. Since the output of the TSL256x device is digital, the output is effectively immune to noise when compared to an analog signal.

The TSL256x devices also support an interrupt feature that simplifies and improves system efficiency by eliminating the need to poll a sensor for a light intensity value. The primary purpose of the interrupt function is to detect a meaningful change in light intensity. The concept of a *meaningful change* can be defined by the user both in terms of light intensity and time, or persistence, of that change in intensity. The TSL256x devices have the ability to define a threshold above and below the current light level. An interrupt is generated when the value of a conversion exceeds either of these limits.

Available Options

DEVICE	INTERFACE	PACKAGE – LEADS	PACKAGE DESIGNATOR	ORDERING NUMBER
TSL2560	SMBus	Chipscale	CS	TSL2560CS
TSL2560	SMBus	TMB-6	T	TSL2560T
TSL2560	SMBus	Dual Flat No-Lead – 6	FN	TSL2560FN
TSL2560	SMBus	ChipLED-6	CL	TSL2560CL
TSL2561	I^2C	Chipscale	CS	TSL2561CS
TSL2561	I^2C	TMB-6	T	TSL2561T
TSL2561	I^2C	Dual Flat No-Lead – 6	FN	TSL2561FN
TSL2561	I^2C	ChipLED-6	CL	TSL2561CL

Terminal Functions

TERMINAL NAME	CS, T, FN PKG NO.	CL PKG NO.	TYPE	DESCRIPTION
ADDR SEL	2	3	I	SMBus device select — three-state
GND	3	2		Power supply ground. All voltages are referenced to GND.
INT	5	6	O	Level or SMB Alert interrupt — open drain.
SCL	4	4	I	SMBus serial clock input terminal — clock signal for SMBus serial data.
SDA	6	5	I/O	SMBus serial data I/O terminal — serial data I/O for SMBus.
V_{DD}	1	1		Supply voltage.

Absolute Maximum Ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{DD} (see Note 1) . . . . . 3.8 V
Digital output voltage range, V_O . . . . . −0.5 V to 3.8 V
Digital output current, I_O . . . . . −1 mA to 20 mA
Storage temperature range, T_{stg} . . . . . −40°C to 85°C
ESD tolerance, human body model . . . . . 2000 V

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

NOTE 1: All voltages are with respect to GND.

Recommended Operating Conditions

	MIN	NOM	MAX	UNIT
Supply voltage, V_{DD}	2.7	3	3.6	V
Operating free-air temperature, T_A	−30		70	°C
SCL, SDA input low voltage, V_{IL}	−0.5		0.8	V
SCL, SDA input high voltage, V_{IH}	2.1		3.6	V

Electrical Characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{DD}	Supply current	Active		0.24	0.6	mA
		Power down		3.2	15	μA
V_{OL}	INT, SDA output low voltage	3 mA sink current	0		0.4	V
		6 mA sink current	0		0.6	V
I_{LEAK}	Leakage current		−5		5	μA

Operating Characteristics, High Gain (16×), V_{DD} = 3 V, T_A = 25°C, (unless otherwise noted) (see Notes 2, 3, 4, 5)

	PARAMETER	TEST CONDITIONS	CHANNEL	TSL2560T, FN, & CL TSL2561T, FN & CL			TSL2560CS, TSL2561CS			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
f_{osc}	Oscillator frequency			690	735	780	690	735	780	kHz
	Dark ADC count value	E_e = 0, T_{int} = 402 ms	Ch0	0		4	0		4	counts
			Ch1	0		4	0		4	
	Full scale ADC count value (Note 6)	T_{int} > 178 ms	Ch0			65535			65535	counts
			Ch1			65535			65535	
		T_{int} = 101 ms	Ch0			37177			37177	
			Ch1			37177			37177	
		T_{int} = 13.7 ms	Ch0			5047			5047	
			Ch1			5047			5047	
	ADC count value	λ_p = 640 nm, T_{int} = 101 ms E_e = 36.3 µW/cm²	Ch0	750	1000	1250				counts
			Ch1		200					
		λ_p = 940 nm, T_{int} = 101 ms E_e = 119 µW/cm²	Ch0	700	1000	1300				
			Ch1		820					
		λ_p = 640 nm, T_{int} = 101 ms E_e = 41 µW/cm²	Ch0				750	1000	1250	counts
			Ch1					190		
		λ_p = 940 nm, T_{int} = 101 ms E_e = 135 µW/cm²	Ch0				700	1000	1300	
			Ch1					850		
	ADC count value ratio: Ch1/Ch0	λ_p = 640 nm, T_{int} = 101 ms		0.15	0.20	0.25	0.14	0.19	0.24	
		λ_p = 940 nm, T_{int} = 101 ms		0.69	0.82	0.95	0.70	0.85	1	
R_e	Irradiance responsivity	λ_p = 640 nm, T_{int} = 101 ms	Ch0		27.5			24.4		counts/ (µW/ cm²)
			Ch1		5.5			4.6		
		λ_p = 940 nm, T_{int} = 101 ms	Ch0		8.4			7.4		
			Ch1		6.9			6.3		
R_v	Illuminance responsivity	Fluorescent light source: T_{int} = 402 ms	Ch0		36			35		counts/ lux
			Ch1		4			3.8		
		Incandescent light source: T_{int} = 402 ms	Ch0		144			129		
			Ch1		72			67		
	ADC count value ratio: Ch1/Ch0	Fluorescent light source: T_{int} = 402 ms			0.11			0.11		
		Incandescent light source: T_{int} = 402 ms			0.5			0.52		
R_v	Illuminance responsivity, low gain mode (Note 7)	Fluorescent light source: T_{int} = 402 ms	Ch0		2.3			2.2		counts/ lux
			Ch1		0.25			0.24		
		Incandescent light source: T_{int} = 402 ms	Ch0		9			8.1		
			Ch1		4.5			4.2		
	(Sensor Lux) / (actual Lux), high gain mode (Note 8)	Fluorescent light source: T_{int} = 402 ms		0.65	1	1.35	0.65	1	1.35	
		Incandescent light source: T_{int} = 402 ms		0.60	1	1.40	0.60	1	1.40	

https://cdn-shop.adafruit.com/datasheets/TSL2561.pdf

1. General Description

The SX1276/77/78/79 incorporates the LoRa™ spread spectrum modem which is capable of achieving significantly longer range than existing systems based on FSK or OOK modulation. At maximum data rates of LoRa™ the sensitivity is 8dB better than FSK, but using a low cost bill of materials with a 20ppm XTAL LoRa™ can improve receiver sensitivity by more than 20dB compared to FSK. LoRa™ also provides significant advances in selectivity and blocking performance, further improving communication reliability. For maximum flexibility the user may decide on the spread spectrum modulation bandwidth (BW), spreading factor (SF) and error correction rate (CR). Another benefit of the spread modulation is that each spreading factor is orthogonal - thus multiple transmitted signals can occupy the same channel without interfering. This also permits simple coexistence with existing FSK based systems. Standard GFSK, FSK, OOK, and GMSK modulation is also provided to allow compatibility with existing systems or standards such as wireless MBUS and IEEE 802.15.4g.

The SX1276 and SX1279 offer bandwidth options ranging from 7.8 kHz to 500 kHz with spreading factors ranging from 6 to 12, and covering all available frequency bands. The SX1277 offers the same bandwidth and frequency band options with spreading factors from 6 to 9. The SX1278 offers bandwidths and spreading factor options, but only covers the lower UHF bands.

1.1. Simplified Block Diagram

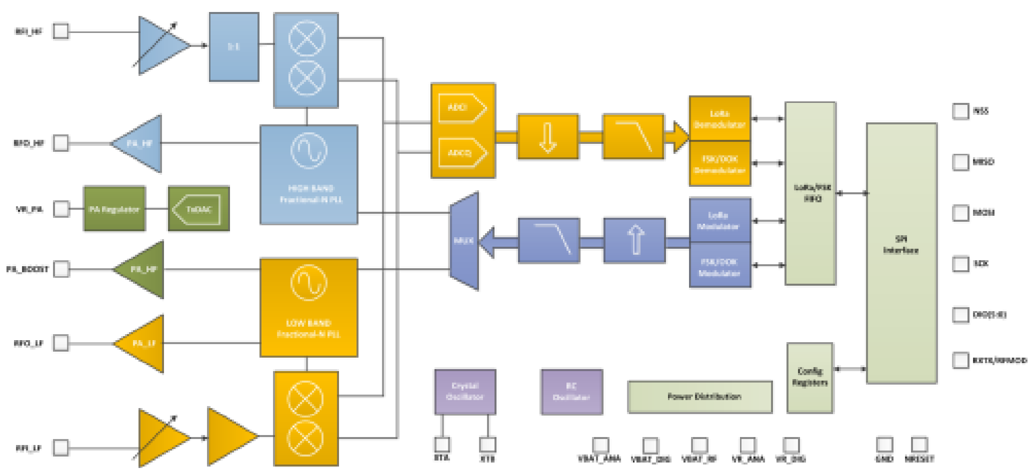


Figure 1. Block Diagram

1.2. Product Versions

The features of the four product variants are detailed in the following table.

Table 1 SX1276/77/78/79 Device Variants and Key Parameters

Part Number	Frequency Range	Spreading Factor	Bandwidth	Effective Bitrate	Est. Sensitivity
SX1276	137 - 1020 MHz	6 - 12	7.8 - 500 kHz	.018 - 37.5 kbps	-111 to -148 dBm
SX1277	137 - 1020 MHz	6 - 9	7.8 - 500 kHz	0.11 - 37.5 kbps	-111 to -139 dBm
SX1278	137 - 525 MHz	6- 12	7.8 - 500 kHz	.018 - 37.5 kbps	-111 to -148 dBm
SX1279	137 - 960MHz	6- 12	7.8 - 500 kHz	.018 - 37.5 kbps	-111 to -148 dBm

1.3. Pin Diagram

The following diagram shows the pin arrangement of the QFN package, top view.

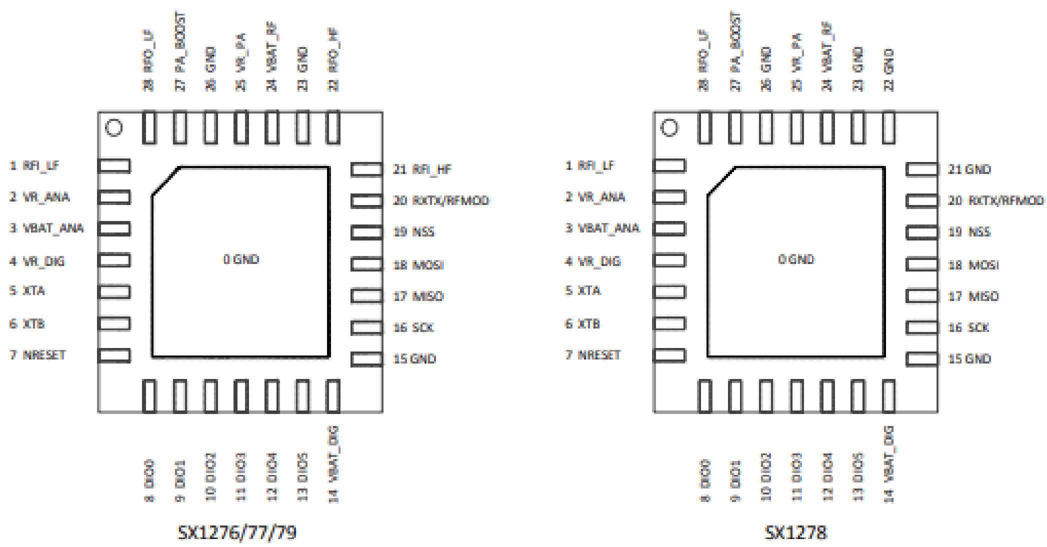


Figure 2. Pin Diagrams

1.4. Pin Description

Table 2 Pin Description

Number	Name	Type	Description
	SX1276/77/79/(78)	SX1276/77/79/(78)	SX1276/77/79/(78)
0	GROUND	-	Exposed ground pad
1	RFI_LF	I	RF input for bands 2&3
2	VR_ANA	-	Regulated supply voltage for analogue circuitry
3	VBAT_ANA	-	Supply voltage for analogue circuitry
4	VR_DIG	-	Regulated supply voltage for digital blocks
5	XTA	I/O	XTAL connection or TCXO input
6	XTB	I/O	XTAL connection
7	NRESET	I/O	Reset trigger input
8	DIO0	I/O	Digital I/O, software configured
9	DIO1/DCLK	I/O	Digital I/O, software configured
10	DIO2/DATA	I/O	Digital I/O, software configured
11	DIO3	I/O	Digital I/O, software configured
12	DIO4	I/O	Digital I/O, software configured
13	DIO5	I/O	Digital I/O, software configured
14	VBAT_DIG	-	Supply voltage for digital blocks
15	GND	-	Ground
16	SCK	I	SPI Clock input
17	MISO	O	SPI Data output
18	MOSI	I	SPI Data input
19	NSS	I	SPI Chip select input
20	RXTX/RF_MOD	O	Rx/Tx switch control: high in Tx
21	RFI_HF (GND)	I (-)	RF input for band 1 (Ground)
22	RFO_HF (GND)	O (-)	RF output for band 1 (Ground)
23	GND	-	Ground
24	VBAT_RF	-	Supply voltage for RF blocks
25	VR_PA	-	Regulated supply for the PA
26	GND	-	Ground
27	PA_BOOST	O	Optional high-power PA output, all frequency bands
28	RFO_LF	O	RF output for bands 2&3

2. Electrical Characteristics

2.1. ESD Notice

The SX1276/77/78/79 is a high performance radio frequency device. It satisfies:

- Class 2 of the JEDEC standard JESD22-A114 (Human Body Model) on all pins.
- Class III of the JEDEC standard JESD22-C101 (Charged Device Model) on all pins

It should thus be handled with all the necessary ESD precautions to avoid any permanent damage.

2.2. Absolute Maximum Ratings

Stresses above the values listed below may cause permanent device failure. Exposure to absolute maximum ratings for extended periods may affect device reliability.

Table 3 Absolute Maximum Ratings

Symbol	Description	Min	Max	Unit
VDDmr	Supply Voltage	-0.5	3.9	V
Tmr	Temperature	-55	+115	° C
Tj	Junction temperature	-	+125	° C
Pmr	RF Input Level	-	+10	dBm

Note Specific ratings apply to +20 dBm operation (see Section 5.4.3).

2.3. Operating Range

Table 4 Operating Range

Symbol	Description	Min	Max	Unit
VDDop	Supply voltage	1.8	3.7	V
Top	Operational temperature range	-40	+85	°C
Clop	Load capacitance on digital ports	-	25	pF
ML	RF Input Level	-	+10	dBm

Note A specific supply voltage range applies to +20 dBm operation (see Section 5.4.3).

2.4. Thermal Properties

Table 5 Thermal Properties

Symbol	Description	Min	Typ	Max	Unit
THETA_JA	Package θ_{ja} (Junction to ambient)	-	22.185	-	°C/W
THETA_JC	Package θ_{jc} (Junction to case ground paddle)	-	0.757	-	°C/W

https://cdn-shop.adafruit.com/product-files/3179/sx1276_77_78_79.pdf

Internet of Things

NodeMCU ESP8266 ESP-12E WiFi Development Board

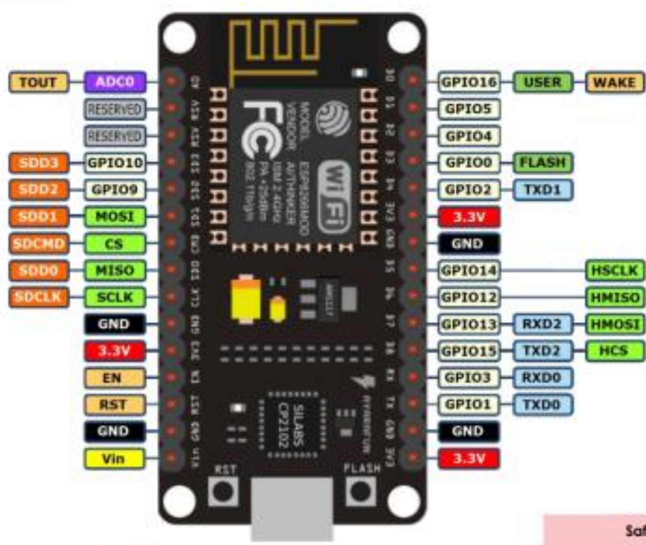
NodeMCU is an open source IoT platform. It includes firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module. The term "NodeMCU" by default refers to the firmware rather than the DevKit. The firmware uses the Lua scripting language. It is based on the eLua project, and built on the Espressif Non-OS SDK for ESP8266. It uses many open source projects, such as lua-cjson, and spiffs.

Features

- Version : DevKit v1.0
- Breadboard Friendly
- Light Weight and small size.
- 3.3V operated, can be USB powered.
- Uses wireless protocol 802.11b/g/n.
- Built-in wireless connectivity capabilities.
- Built-in PCB antenna on the ESP-12E chip.
- Capable of PWM, I2C, SPI, UART, 1-wire, 1 analog pin.
- Uses CP2102 USB Serial Communication interface module.
- Arduino IDE compatible (extension board manager required).
- Supports Lua (alike node.js) and Arduino C programming language.

PINOUT DIAGRAM

NodeMCU ESP8266 v1.0



Safety Precaution
All GPIO runs at 3.3V !!

Source
https://iotbytes.wordpress.com/nodemcu-pinout/

1

NodeMCU ESP8266

Front View

Front View

Specifications of ESP-12E WiFi Module

Wireless Standard	IEEE 802.11 b/g/n
Frequency Range	2.412 - 2.484 GHz
Power Transmission	802.11b : +16 ± 2 dBm (at 11 Mbps) 802.11g : +14 ± 2 dBm (at 54 Mbps) 802.11n : +13 ± 2 dBM (at HT20, MCS7)
Receiving Sensitivity	802.11b : -93 dBm (at 11 Mbps, CCK) 802.11g : -85 dBm (at 54 Mbps, OFDM) 802.11n : -82 dBm (at HT20, MCS7)
Wireless Form	On-board PCB Antenna
IO Capability	UART, I2C, PWM, GPIO, 1 ADC
Electrical Characteristic	3.3 V Operated 15 mA output current per GPIO pin 12 - 200 mA working current Less than 200 uA standby current
Operating Temperature	-40 to +125 ºC
Serial Transmission	110 - 921600 bps, TCP Client 5
Wireless Network Type	STA / AP / STA + AP
Security Type	WEP / WPA-PSK / WPA2-PSK
Encryption Type	WEP64 / WEP128 / TKIP / AES
Firmware Upgrade	Local Serial Port, OTA Remote Upgrade
Network Protocol	IPv4, TCP / UDP / FTP / HTTP
User Configuration	AT + Order Set, Web Android / iOS, Smart Link APP

https://ardustore.dk/error/Manuel%20-%20NodeMCU%20Lua.pdf

Polulu Step Up Converter

Pololu
Robotics & Electronics

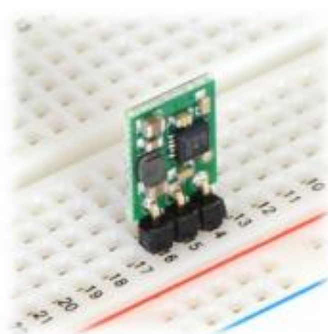
Pololu 3.3V Step-Up Voltage Regulator U1V10F3

Overview

This 3.3 V boost (step-up) voltage regulator generates higher output voltages from input voltages as low as 0.5 V, and it also automatically switches to a linear down-regulation mode when the input voltage exceeds the output. This makes it great for powering 3.3 V electronics projects from 1 to 3 NiMH, NiCd, or alkaline cells or from a single lithium-ion cell.

When boosting, this module acts as a switching regulator (also called switched-mode power supplies (SMPS) or DC-to-DC converters) and has a typical efficiency between 65% to 85%. The available output current is a function of the input voltage, output voltage, and efficiency (see Typical Efficiency and Output Current section below), but the input current can typically be as high as 1.2 A. This regulator is also available with a fixed 5 V output, and very similar 3.3V, 5V, and adjustable-output versions are available with a true shutdown option that turns off power to the load.

The regulator's thermal shutdown engages at around 140°C and helps prevent damage from overheating, but it does not have short-circuit or reverse-voltage protection.



Features

- **Input voltage: 0.5 V to 5.5 V**
- **Fixed 3.3 V output with 4% accuracy**
- **Automatic linear down-regulation when the input voltage is greater than the output voltage**
- **1.2 A switch allows for input currents up to 1.2 A**

- **Good efficiency at light load: <1 mA typical no-load quiescent current, though it can exceed 1 mA for very low input voltages**
- **Integrated over-temperature shutoff**
- **Small size: 0.35" × 0.45"; × 0.1" (9 × 11.5 × 2.5 mm)**

Using the Regulator Connections
The boost regulator has three connections: input voltage (VIN), ground (GND), and output voltage (VOUT).

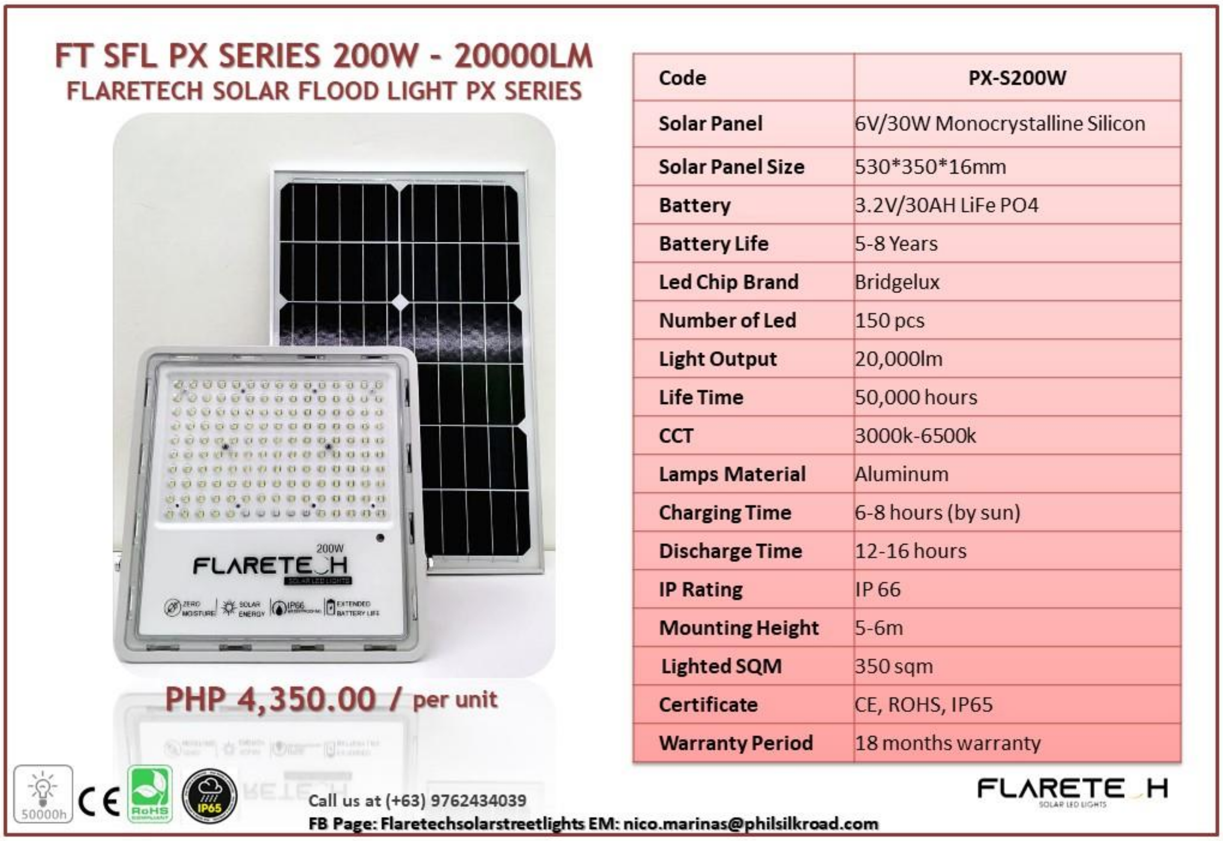
The input voltage, VIN, must be at least 0.5 V for the regulator to turn on. However, once the regulator is on, the input voltage can drop as low as 0.3 V and the 3.3 V output voltage will be maintained on VOUT. Unlike standard boost regulators, this regulator has an additional linear down-regulation mode that allows it to convert input voltages as high as 5.5 V down to 3.3 V for small to moderate sized loads. When the input voltage exceeds 3.3 V, the regulator automatically switches to this down-regulation mode. The input voltage should not exceed 5.5 V. Please be wary of destructive LC spikes that might cause the input voltage to surpass 5.5 V (see below for more information).

The three connections are labeled on the back side of the PCB, and they are arranged with a 0.1" spacing along the edge of the board for compatibility with solderless breadboards, connectors, and other prototyping arrangements that use a 0.1" grid. You can solder wires directly to the board or solder in either the 3×1 straight male header strip or the 3×1 right-angle male header strip that is included.

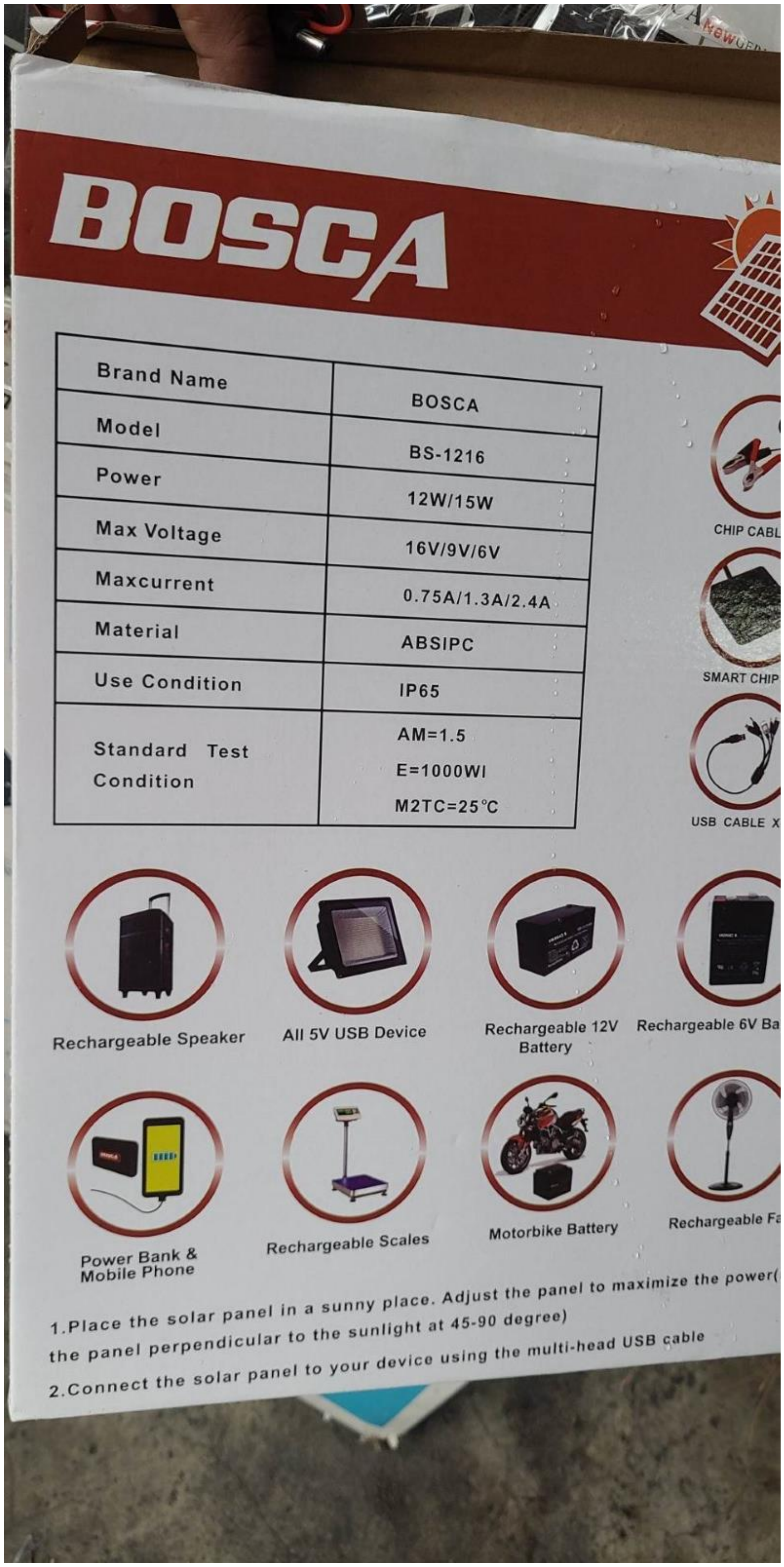
Typical Efficiency and Output Current
The efficiency of a voltage regulator, defined as (Power out)/(Power in), is an important measure of its performance, especially when battery life or heat are concerns. As shown in the graphs below, this switching regulator typically has an efficiency of 65 to 85%.

https://www.tme.eu/Document/672d4628011eda6b5165b6147ad8d875/POLOLU-2563.pdf

Solar Floodlight



Bosca Solar Panel



1. Scope

This specification describes the technological parameters and testing standard for the lithium ion rechargeable cell manufactured and supplied by EEMB Co. Ltd.

2. Products specified

2.1 Name Cylindrical Lithium Ion Rechargeable Cell
2.2 Type LIR18650-2600mAh

3. References

In this specification reference is made to: GB/T182847-2000, UL1642 and IEC61960-1:2000.

4. Caution:

4.1. Please read these specifications carefully before testing or using the cell as improper handling of a Li-ion cell may result in lose of efficiency, heating, ignition, electrolyte leakage or even explosion.

4.2 While testing the cell by charging and discharging, please use test-equipment especially designed for Li-ion cell. Do not use ordinary constant current and constant voltage (CC/CV) power supplies. These do not protect the cell from being overcharged and over-discharged, resulting in possible loss of functionality or danger.

4.3 When charging and discharging cells or packing them into equipment, reversing the positive and negative terminals will result in overcharging and over-discharging of the cell(s). This could lead to serious loss of efficiency and even explosions.

4.4 Do not solder directly on the cell. Do not resolve the cell.

4.5 Do not put cell(s) in pockets or bags together with metal products such as necklaces, hairpins, coins, screws, etc. Neither stores them together without proper isolation. Do not connect the positive and negative electrode directly with each other through conductive materials. This can result in a short circuit of the cell.

4.6 Do not beat, throw or trample the cell, do not put the cell into washing machines or high-pressure containers.

4.7 Keep the cell away from heat sources such as fires, heaters, etc. Do not use or store cell(s) at locations where the temperature can exceed 60℃， such as in direct sunlight. This may lead to the generation of excessive heat, ignition and lose of efficiency.

4.8 Do not get cells wet or throw them into water. When not in use, place the cells in a dry environment at low temperatures.

4.9 While during use, testing or storing cells, cells become hot, distribute a smell, change color, deform or show any other abnormalities, please stop using or testing immediately. Attempt to isolate the cell and keep it away from other cells.

4.10 Should electrolyte get into the eyes, do not rub the eyes, rinse the eyes with clean water and seek medical attention if problems remain. If electrolyte gets onto the skin or clothing, wash with clean water immediately.

5. BASIC CHARACTERISTICS

5.1 Capacity（25±5℃）	Nominal Capacity：2600mAh (0.52A Discharge，2.75V) Typical Capacity：2550mAh（0.52A Discharge，2.75V） Minimum Capacity：2500mAh (0.52A Discharge，2.75V)
5.2 Nominal Voltage	3.7V
5.3 Internal Impedance	≤ 70mΩ
5.4 Discharge Cut-off Voltage	3.0V
5.5 Max Charge Voltage	4.20±0.05V
5.6 Standard Charge Current	0.52A
5.7 Rapid Charge Current	1.3A
5.8 Standard Discharge Current	0.52A
5.9 Rapid Discharge Current	1.3A
5.10 Max Pulse Discharge Current	2.6A
5.11 Weight	46.5±1g
5.12 Max. Dimension	Diameter(Ø): 18.4mm Height (H): 65.2mm
5.13 Operating Temperature	Charge: 0 ~ 45℃ Discharge: -20 ~ 60℃
5.14 Storage Temperature	During 1 month: -5 ~ 35℃ During 6 months: 0 ~ 35℃

6. Standard conditions for test

All the tests need to be done within one month after the delivery date under the following conditions : Ambient Temperature:25±5℃; Relative Huimdity:65±20%

Standard Charge	Constant Current and Constant Voltage (CC/CV) Current = 0.52A Final charge voltage = 4.2V Final charge Current = 0.052A
Standard Discharge	Constant Current (CC) Current = 0.52A End Voltage = 3.0V

7. Appearance

All surfaces must be clean, without damages, leakage and corrosion. Each product will have a product label identifying the model.

8. Characteristics

In this section, the Standard Conditions of Tests are used as described in part 6.

8.1 Electrical Performances

Items	Test procedure	Requirements
8.1.1 Nominal Voltage	The average value of the working voltage during the whole discharge process.	3.7V
8.1.2 Discharge Performance	The discharge capacity of the cell, measured with 1.3 A down to 3.0V within 1 hour after a completed charge.	≥114min
8.1.3 Capacity Retention	After 28 days storage at 25±5℃, after having been completely charged and discharged at 0.52A, discharge to 3.0V, the residual capacity is above 80%	Capacity≥2080mAh
8.1.4 Cycle Life	After 299 cycles at 100% DOD. Charge and discharge at 1.3A, and plus 1 day, measured under 0.52A charge and discharge, the residual discharge capacity is above 80% of initial capacity (Cycle life may be determined by conditions of charging, discharging, operating temperature and/or storage.)	300 cycles the residual capacity ≥2050mAh
8.1.5 Storage	(Within 3 months after manufactured) The cells is charged with 1.3A to 40-50% capacity and stored at ambient temperature 25±5℃, 65±20%RH for 12 months. After the 12 months storage period the cell is fully charged and discharged to 3.0V with 0.52A	Discharge time≥4h

https://www.ineltro.ch/media/downloads/SAAItem/45/45958/36e3e7f3-2049-4adb-a2a7-79c654d92915.pdf

APPENDIX E

PROJECT MANUAL

MANUAL FOR DUPLICATION

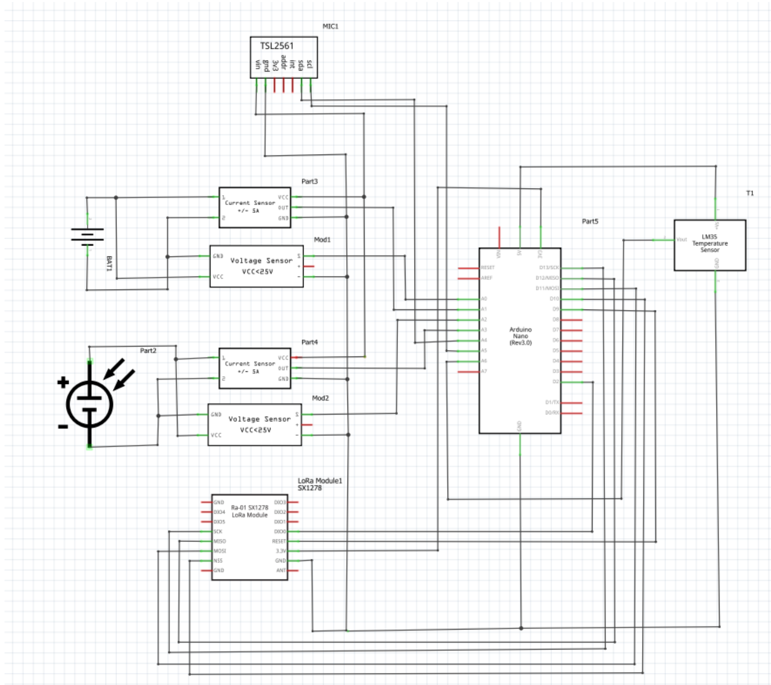
1. Buy materials needed for the monitoring system.

   List of Material to buy.

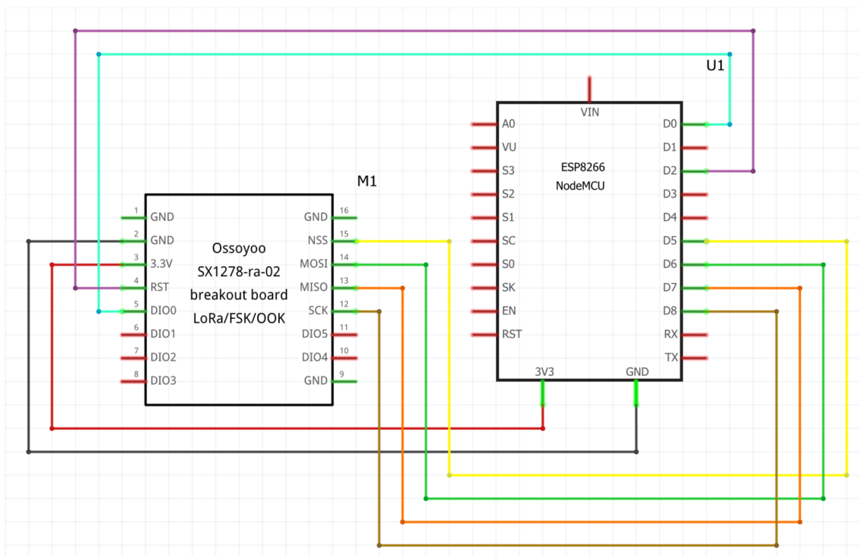
- Sensors
  - 2pcs. Voltage Sensor (you can do your own, it is just voltage divider circuit)
  - 2pcs. Current Sensor (ACS712 is used in this system)
  - 1pc. Temperature Sensor (LM35 is used in this system)
  - 1pc. Luminosity Sensor (TSL2651 is used in this system)
- Breadboard
  - Used for testing.
- Microcontroller
  - Arduino Nano is used on the transmitter side of this system. You can use another microcontroller of your choice.
  - ESP8266 NodeMCU is used on the receiver side of this system. You can use another microcontroller of your choice.
- LoRa Module
  - Ai Thinker SX1278 Ra-02 LoRa Module is used in this system. You can use another LoRa Module of your choice.
  - 2pcs. 1 as transmitter, 1 as receiver.

2. Create Schematic Design for transmitter and receiver.

- Schematic Design
  - Transmitter



- Receiver



3. Connect all the hardware. Connect each transmitter node and receiver node based on the schematic design.
4. Program transmitter and the receiver. Program the sensors and LoRa in the Arduino for the transmitter. Program the LoRa for the receiver side.

   - **Transmitter Codes (see in appendix)**
   - **Receiver Codes (see in appendix)**

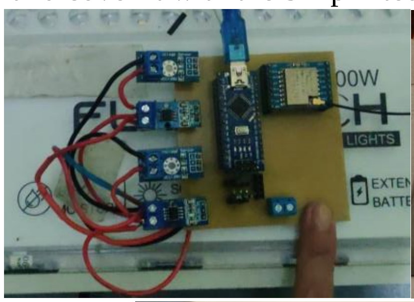
5. Test and calibrate the hardware and program.

6. Setup your database. Create your front and back end for your website. Connect your microcontroller to your database and backend.

USER MANUAL

HARDWARE INSTALLATION

1. Install the transmitter nodes to the streetlight. Connect each wire needed for the sensors and cover it with the 3D printed casing.

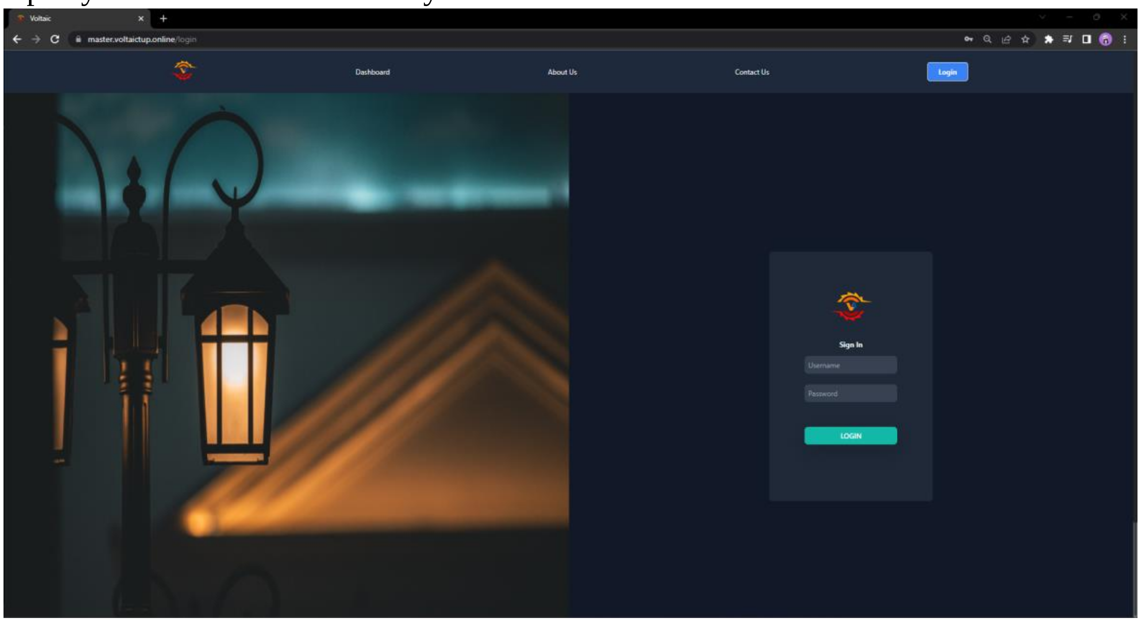



2. Install each Streetlight into the community.

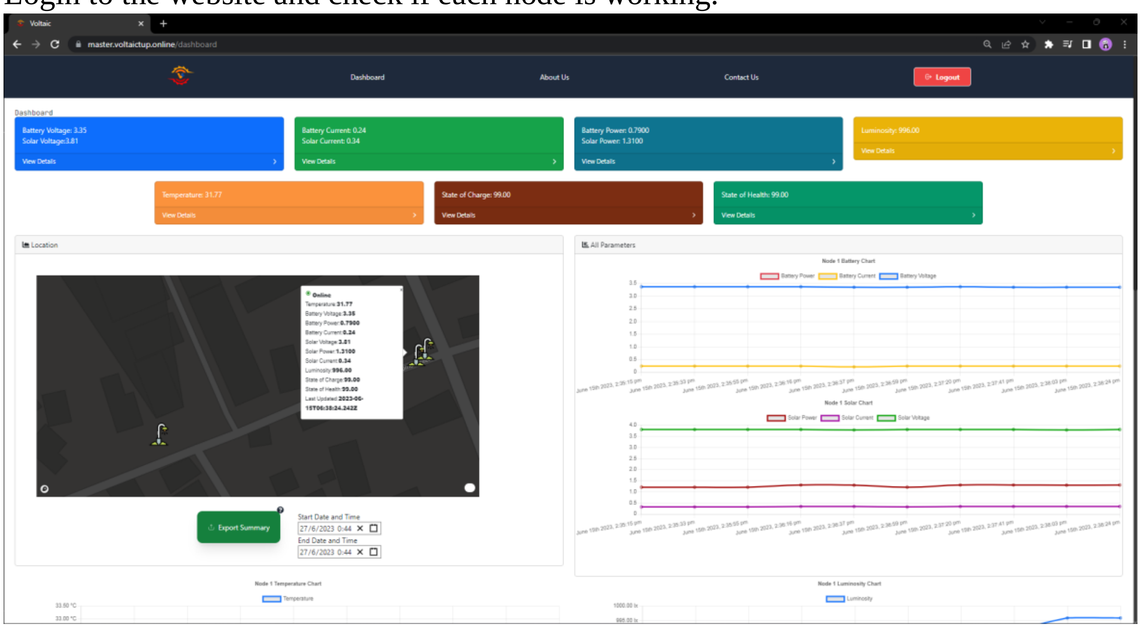
3. Turn on the switch of the receiver. Connect the receiver to your Wi-Fi connection.

4. Turn on the switch of each transmitter node.

5. Open your browser and brose to your website.



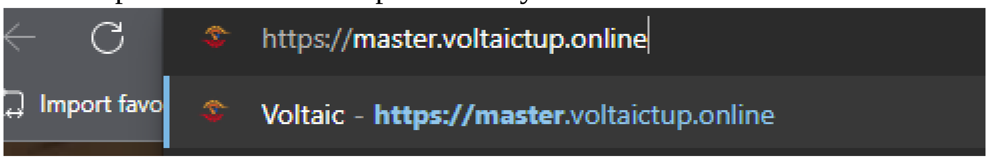
6. Login to the website and check if each node is working.



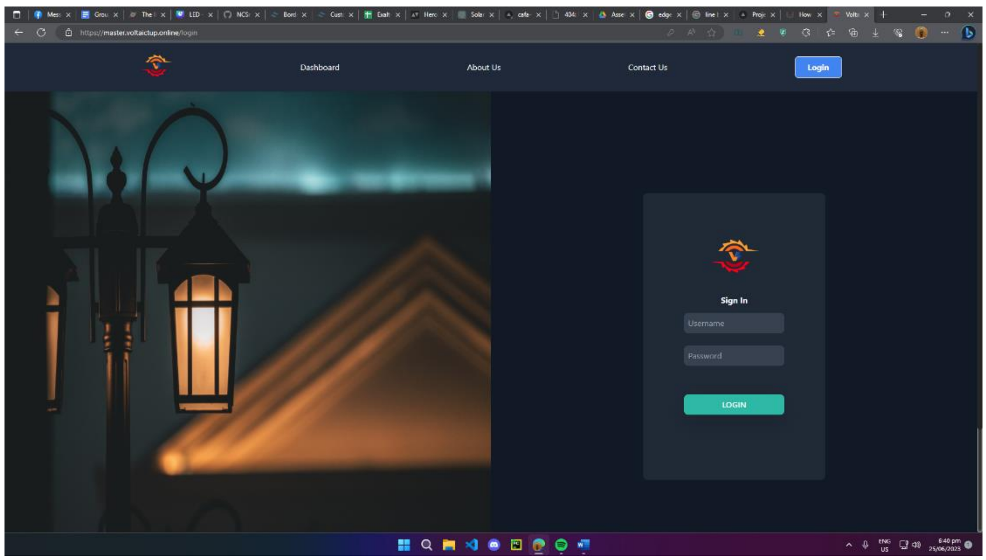
HOW TO USE THE WEBSITE

PC/Desktop Instructions (Steps)

1. Open any browser from your local computer. Chrome = Firefox =, or Microsoft Edg))
2. Enter https://master.voltaictup.online in your search URL:

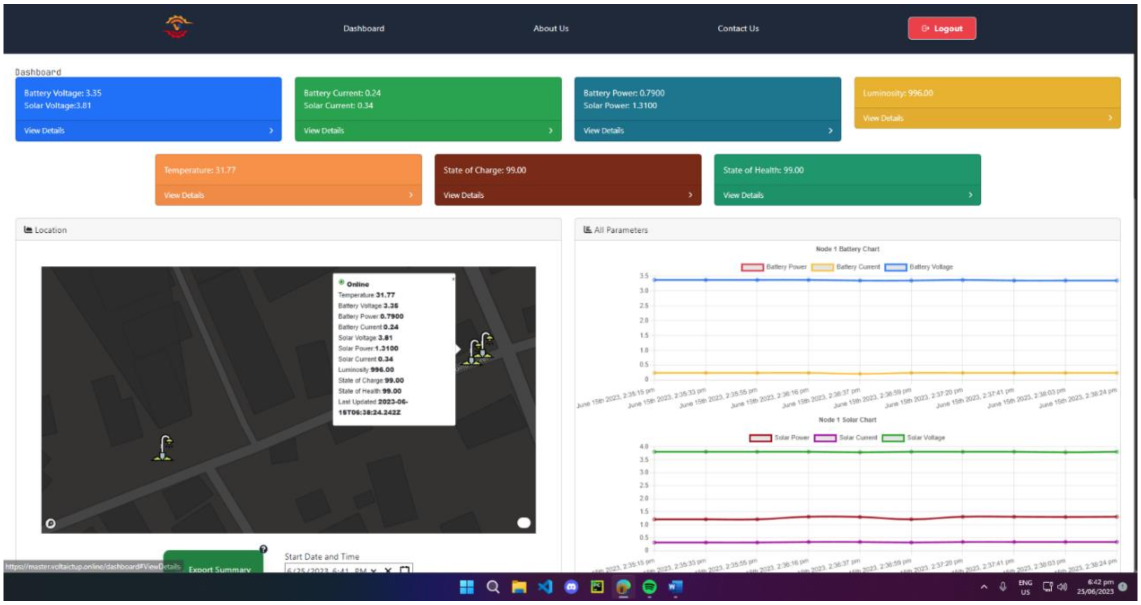


3. You will be prompted to the login screen and password is given through email for added security (Admin access only)



4. If the login credentials are correct, click dashboard: 

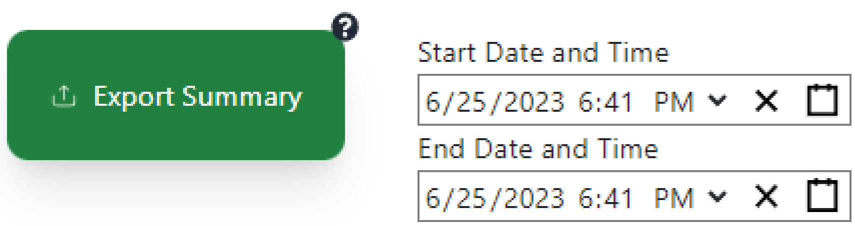
5. You will be prompted to the dashboard details:



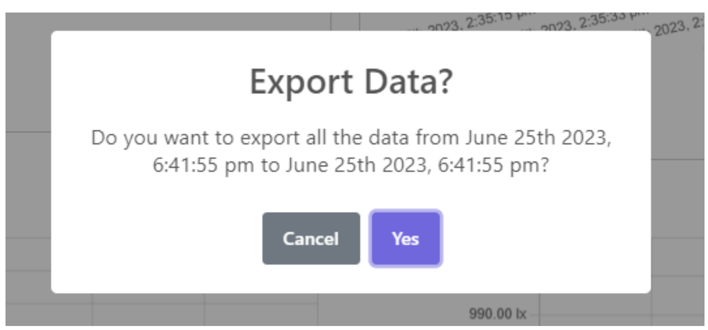
You will then see 3 lamp posts; you can click it to view details and all the graphs will show its full content.

EXPORTING:

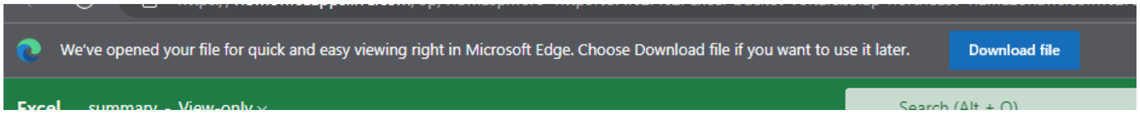
6. If you want to export the data, click EXPORT SUMMARY and you will be asked to which date you want to export:



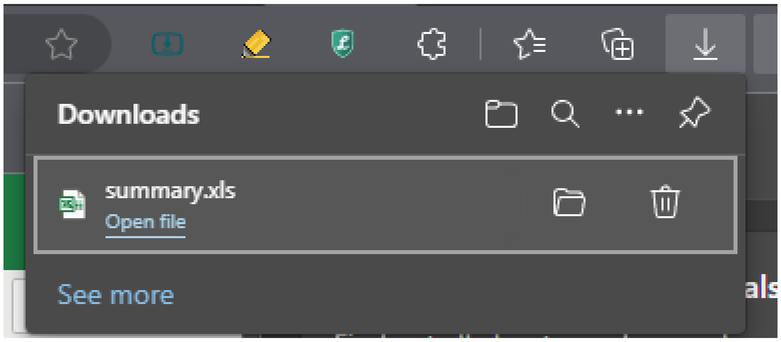
7. You will be asked to download it and there will be a message to confirm:



8. If you clicked yes, you will be directed to this site: Just click the DOWNLOAD FILE:

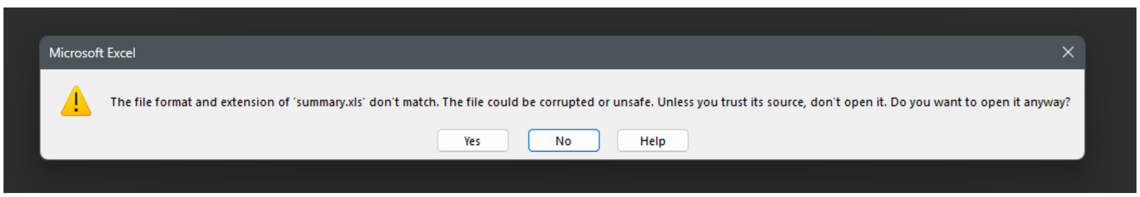


9. Click the download button in your browser, and click the downloaded file



"summary.xls"

10. There might be compatibility issues upon opening it: Just click "Yes."



APPENDIX F

LETTERS

Republic of the Philippines
Technological University of the Philippines
Technology Licensing Office
INNOVATION AND TECHNOLOGY SUPPORT OFFICE
Manila
Tel. No.: 5301-3001 local 622 Fax: 8521-4063
www.itso@tup.edu.ph

NON-DISCLOSURE AGREEMENT

THIS AGREEMENT by and between the **SALUYSOY BARANGAY OFFICE** a local government organization under the Municipality of Meycauayan, Bulacan. whose address is at Brgy. Saluysoy, Meycauayan Bulacan, herein referred to this agreement as the **"RECIPIENT,"** and the **TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES,** a government state university, whose address is at Ayala Blvd., corner San Marcelino St., Ermita, Manila, herein referred to this agreement as the **"OWNER"**

The parties agree as follows:

1. "Confidential Information" shall be defined as that proprietary information, other intellectual property, and/or any and all information, know-how and data, technical or non-technical, concerning software, data and/or other technologies owned or controlled by either party that is transmitted or otherwise disclosed by one party (DISCLOSING PARTY) to the other party to this Agreement (RECIPIENT) orally, in writing, electronically, or in any other tangible form that has or could have commercial value or other utility to a party to this agreement, or to any other person or party. Confidential Information also includes all information which the unauthorized disclosure of such information could be detrimental to the interests of the party which owns or controls said information, whether or not such information is identified as Confidential Information.

2. The parties agree that the disclosure hereunder is for the sole purpose of evaluating a possible collaborative research arrangement between the parties in accordance with or using in whole or in part such Confidential Information.

3. The disclosure of the Confidential Information shall be in writing and clearly marked "CONFIDENTIAL," or if orally disclosed, shall be described as "CONFIDENTIAL" when disclosed and shall be reduced to writing by the party making the disclosure within thirty days of its disclosure.

RESPONSIBILITY OF THE RECIPIENT

4. The Recipient shall not use any Confidential Information received from the Owner as hereby agreed to this agreement for the purpose and , especially for the purpose of developing a commercial application using any part of the Confidential

Information, other than for assessment, except as provided in this paragraph. Without the prior, written consent of the duly authorized representative of the party making the disclosure, the Recipient shall not disclose such Confidential Information to any third party other than to employees under similar obligations of non-use and non-disclosure and who have a strict need for access to such Confidential Information in order to assist in doing the aforementioned assessment.

5. In consideration, of such disclosure, for a period of five (5) years after the disclosure of the Confidential Information, the Recipient agrees not to disclose the Confidential Information to any third party of affiliated with the parties to this agreement by common ownership and then only under similar conditions or confidentiality or use it for any purpose, other than as described in this Agreement, unless the party disclosing the Confidential Information agrees otherwise in writing prior to the disclosure of the Information.

6. If a party to this Agreement or anyone to whom the party transmits the Confidential Information is requested to disclose the Confidential Information in connection with a legal or administrative proceeding, that party agrees to give the other party prompt notice of the request. The other party to this Agreement may, at its own expense, seek a protective order or other remedy and/or waive compliance with the provisions of this Agreement. If one of the parties to the Agreement seeks a protective order or other remedy, the other party to the Agreement will cooperate in protecting the confidentiality of the information. In the event that such protective order or other remedy is not obtained, the party obliged to disclose the information shall disclose only that portion of the Confidential Information which is legally required to be disclosed.

7. The party receiving the Confidential Information will disclose it only to those employees, individuals or entities who have a need to know of it as a part of the party's evaluation of the information and those receiving the Confidential Information shall hold such information in confidence pursuant to the terms of this Agreement.

8. The party receiving the information will make its evaluation as promptly as possible and upon completion of its evaluation, shall return the Confidential Information to the other party, or certify in writing that it has destroyed all Confidential Information together with all the copies thereof except for a single copy of which the party may keep for archival purposes only.

9. If a party receiving Confidential Information shall have knowledge of any breach of confidentiality or the misappropriation of any Confidential Information, that party shall promptly give notice thereof to the other party. In the event of any violation of this agreement by any party, without limitation to any of the other remedies to which it may be entitled by law, the aggrieved party may be entitled to injunctive relief

and to repayment of court costs and attorney's fees that it incurs in protecting its intellectual property rights, and/or the confidentiality of any information.

JOINT RESPONSIBILITIES

10. The obligations of confidentiality shall not apply to information transmitted by one party to the other party that:

    a. Was known to the receiving party prior to its disclosure by the other party;
    b. Is or becomes publicly known through no fault or omission attributable to the party receiving the information;
    c. Is given to a party by a third party under no obligation of confidentiality to the party receiving the information from the third party; or,
    d. Is independently developed by a party without the aid, application or use of such Confidential Information, as established by a preponderance of documentary evidence.

11. The parties further agree that during the period of time that such information is to be treated as confidential under this Agreement, no party will make any commercial use, in whole or in part of the other party's Confidential Information, without the party's prior written consent.

12. No rights or obligations to the Confidential Information other than those expressly recited herein are to be implied from this Agreement. No license is hereby granted, either directly or indirectly, in or under any trade secret, know-how, copyright and/or patents or portion thereof were not contained herein.

13. The validity and interpretation of this Agreement shall be governed by the laws of the Republic of the Philippines. If any provision or any portion of a provision of this Agreement is determined to be invalid or unenforceable, the remaining provisions shall be binding upon the parties hereto and enforceable as though the invalid or unenforceable provisions or portion thereof were not contained herein.

14. A waiver by any party of any provision or portion thereof in any one instance shall not be deemed or construed to be a waiver of such provision thereof for any similar, subsequent instance.

15. Any notice required or permitted under this Agreement shall be deemed to have been duly delivered when mailed by government post office with postage prepaid and return receipt requested to the intended at the address set forth for that party herein above.

16. This Agreement may be modified only in writing and shall be binding upon the parties hereto and upon their successors in the business, but shall not otherwise be assignable.

IN WITNESS WHEREOF, the parties have executed this Agreement, the effective date of which is the date of the last signature below.

Researchers:

IOT Centralized Monitoring System for Solar Streetlight Application using microcontroller with LoRa

Balicoco, Oniel C.
Ilagan, Ma. Elaiza D.
Lacap, Kae Adriana A.
Santos, Neil Carlos C.
Tipalan, Jhasset B.

For TUP:

ENGR. MARK P. MELEGRITO
Project Adviser
TUP
Date: ____________________

For Barangay Saluysoy:

HON. CRISPIN M. LUNARIA
Barangay Captain
Barangay Saluysoy
Date: ____________________

DR. EMMANUEL L. FERRER
VP for Research and Extension

ENGR. NILO M. ARAGO
Dean, COE

ENGR. JONEL R. MACALISANG
Director, TLO-ITSO

Witnesses:

MS. ANGELICA D. FALCIS
Barangay Secretary

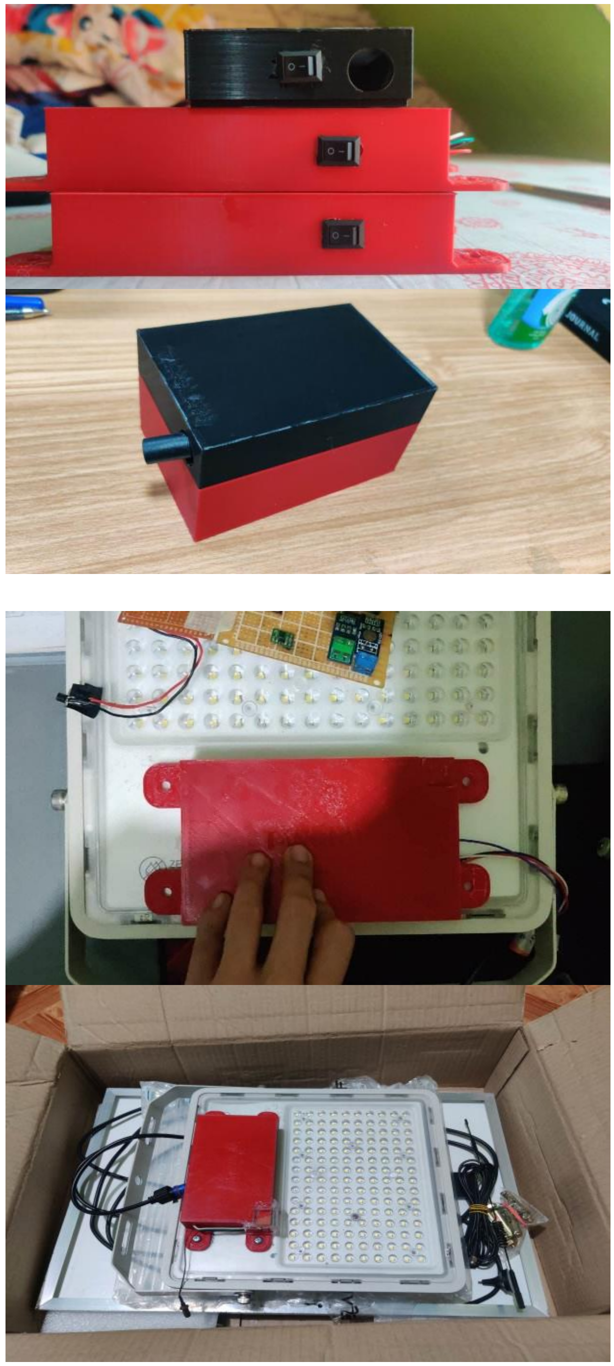
MR. BEEJAY M. JIMENEZ
Sk Chairman

APPENDIX G

PROJECT DOCUMENTATION

Project Presentation with the Barangay Saluyloy Officials

Needs Assessment Interview with The Residents of Brgy. Saluysoy



Making of the Monitoring Syst

Project Deployment at Requino St. Saluysoy, Meycauayan, Bulacsn

PROGRESS PRESENTATION

PRE-FINAL DEFENSE

FINAL DEFENSE

APPRECIATE 2023

APPENDIX H

STUDENT'S PROFILE

ONIEL C. BALICOCO

+639760047226 / +639215320866

obalicoco@gmail.com / obalicoco@outlook.com

Hernandez St. Catmon, Malabon City

PERSONAL INFORMATION

Date of Birth: April 14, 2001
Civil Status: Single
Citizenship: Filipino

EDUCATION

2019 - PRESENT — **TERTIARY**
TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES MANILA
Ayala Blvd. cor. San Marcelino St. Ermita, Manila, Metro Manila

2017 - 2019 — **SENIOR HIGH SCHOOL**
TECHNOLOGICAL INSTITUTE OF THE PHILIPPINES
P. Casal St. Quiapo, Manila, Metro Manila

2013 - 2017 — **JUNIOR HIGH SCHOOL**
MALABON NATIONAL HIGH SCHOOL
M.Naval St. Hulong Duhat, Malabon, Metro Manila

AFFILIATIONS

2022 - PRESENT — **ECE QUIZZER'S SOCIETY**
Member

2019 - PRESENT — **INSTITUTE OF ELECTRONICS ENGINEERS OF THE PHILIPPINES (IECEP)**
Member

2019 - PRESENT — **ORGANIZATION OF ELECTRONICS ENGINEERING STUDENTS (OECES)**
4th Yr. Class Representative

WORK EXPERIENCE

AUG 2022 - SEP 2022 — **MITSUBISHI HEAVY INDUSTRIES**
INTERN (ON-THE-JOB-TRANIEE) - ENGINEERING DEPARTMENT
27th Floor Robinson Cybergate Center Tower 3, Pioneer St, Mandaluyong, 1550 Metro Manila

SKILLS SUMMARY

- Proficient in using various schematic editor, layout editor, and simulation application.
  Schematic Editors: Proteus, Multisim, Cadence Virtuoso, KiCAD, EasyEDA
  Layout Editors: Cadence Virtuoso, KiCAD, EasyEDA
  Simulation Applications: Proteus, Multisim, Cadence Virtuoso
- Proficient in basic programming
  Programming Languages: Assembly Language, C, C++, JavaScript, Php, Python
- Proficient on basic photo and video editing
- Proficient in using MS Office Suite such as Word, PowerPoint, Excel, and Publisher.

MA. ELAIZA D. ILAGAN

09456642518

maelaiza.ilagan@tup.edu.ph

Saluysoy,Meycauayan, Bulacan

PERSONAL INFORMATION

Date of Birth: Oct 27, 2000
Civil Status: Single
Citizenship: Filipino

EDUCATION

2019 - PRESENT

TERTIARY
TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES MANILA
Ayala Blvd. cor. San Marcelino St. Ermita, Manila

2017 - 2019

SENIOR HIGH SCHOOL
POLYTECHNIC UNIVERSITY OF THE PHILIPPINES
Sta. Mesa, Manila

AFFILIATIONS

2020- 2021

GOOGLE DEVELOPER STUDENT CLUB TUP-MANILA
executive secretary

2020- 2021

INSTITUTE OF ELECTRONICS ENGINEERS OF THE PHILIPPINES- STUDENT CHAPTER TUP MANILA DIVISION
board of Director - Membership and Documentation Officer

WORK EXPERIENCE

AUG 2022 - OCT2022

ADVANCED WORLD SYSTEMS INC.
INTERN (ON-THE-JOB-TRANIEE) - ENGINEERING DEPARTMENT
ATC, AYALA ALABANG MUNTINLUPA CITY.

SKILLS SUMMARY

- Proficient in NI Multism
- Basic Knowledge in in programming - Python, MATLAB, OCTAVE, R, C#, C++
- Literate in Microsoft Offices
- Knowledgeable in basic APP DEVELOPMENT

KAE ADRIANA A. LACAP

09054217848

kaelacap321@gmail.com

Sampaloc, Manila

PERSONAL INFORMATION

Date of Birth: April 11, 2001
Civil Status: Single
Citizenship: Filipino

EDUCATION

2019 - PRESENT

TERTIARY
TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES MANILA
Ayala Blvd. cor. San Marcelino St. Ermita, Manila

2017 - 2019

SENIOR HIGH SCHOOL
POLYTECHNIC UNIVERSITY OF THE PHILIPPINES
Anonas, Sta. Mesa, Maynila

2013 - 2017

JUNIOR HIGH SCHOOL
ESTEBAN ABADA HIGH SCHOOL
Andrade, Sampaloc, Manila

AFFILIATIONS

2019 - PRESENT

ORGANIZATION OF ELECTRONICS ENGINEERING STUDENTS (OECES)
Member

WORK EXPERIENCE

AUG 2022 - SEP 2022

PHILLIPINE CLINICAL CHEMISTRY & DIAGNOSIC CORP.
INTERN (ON-THE-JOB-TRANIEE) - ENGINEERING DEPARTMENT
9/F, FEMS Tower Building, Zobel Roxas Street corner Osmena Highway, Sta. Ana, City of Manila, Metro Manila

SKILLS SUMMARY

- Have experience and knowledge in using Proteus, Multisim, and Matlab
- Have basic skills in Frontend
- Basic Programming Skills in specific programming language (HTML, CSS, MySQL, and Python)
- Computer Literate (MS Office)

NEIL CARLOS C. SANTOS

+639214601309 / +639613141053

santoscneil@gmail.com

2154 Granite St. Cor. RD4, San Andres, Manila

PERSONAL INFORMATION

Date of Birth: September 30, 2000

Civil Status: Single

Citizenship: Filipino

EDUCATION

2019 - PRESENT

TERTIARY

TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES MANILA

Ayala Blvd. cor. San Marcelino St. Ermita, Manila, Metro Manila

2017 - 2019

SENIOR HIGH SCHOOL

PASAY CITY NATIONAL SCIENCE HIGH SCHOOL

2888 Vergel St., Pasay, Metro Manila

2013 - 2017

JUNIOR HIGH SCHOOL

PASAY CITY NATIONAL SCIENCE HIGH SCHOOL

2888 Vergel St., Pasay, Metro Manila

AFFILIATIONS

2022 - PRESENT

GOOGLE DEVELOPER STUDENT CLUB TUP-MANILA

Member

2022 - PRESENT

UX SOCIETY TUP - MANILA

Member

2019 - PRESENT

INSTITUTE OF ELECTRONICS ENGINEERS OF THE PHILIPPINES (IECEP)

Member

2019 - PRESENT

ORGANIZATION OF ELECTRONICS ENGINEERING STUDENTS (OECES)

Member and ***Technical & Productions Manager - 2022-2023***

WORK EXPERIENCE

AUG 2022 - SEP 2022

STELSEN INTEGRATED SYSTEMS, INC.

INTERN (ON-THE-JOB-TRANIEE) - ENGINEERING DEPARTMENT

7514 Bagtikan Street, Makati, Kalakhang Maynila

SKILLS SUMMARY

- Proficient in using various schematic editor, layout editor, and simulation application. Schematic Editors: Proteus, DesignSpark, Multisim, and LTSpice
- Proficient in using basic programming languages such as: Assembly, C#, C++, TypeScript, and SQL
- Proficient in HTML, CSS, and JavaScript for Front-End Development.
- Has advanced knowledge to Python Programming and Development
- Proficient in MS Office Applications
- Proficient in Basic Photo and Video Editing
- Proficient in using basic knowledge in Figma, Canva, and AdobeXD for UX/UI Design

JHASSET B. TIPALAN

090526379700

jhasset.tipalan@tup.edu.ph

Tinajeros, Malabon City

PERSONAL INFORMATION

Date of Birth: April 2, 2001
Civil Status: Single
Citizenship: Filipino

EDUCATION

2019 - PRESENT

TERTIARY
TECHNOLOGICAL UNIVERSITY OF THE PHILIPPINES MANILA
Ayala Blvd. cor. San Marcelino St. Ermita, Manila

2017 - 2019

SENIOR HIGH SCHOOL
MANUEL G. ARAULLO HIGH SCHOOL
Taft Ave. cor. U.N. Ave. Ermita, Manila

2013 - 2017

JUNIOR HIGH SCHOOL
MANUEL G. ARAULLO HIGH SCHOOL
Taft Ave. cor. U.N Ave. Ermita Manila

AFFILIATIONS

2019 - PRESENT

ORGANIZATION OF ELECTRONICS ENGINEERING STUDENTS (OECES)
Member

WORK EXPERIENCE

AUG 2022 - SEP 2022

PHILLIPINE CLINICAL CHEMISTRY & DIAGNOSIC CORP.
INTERN (ON-THE-JOB-TRANIEE) - ENGINEERING DEPARTMENT
9/F, FEMS Tower Building, Zobel Roxas Street corner Osmena Highway, Sta. Ana, City of Manila, Metro Manila

SKILLS SUMMARY

- Proficient in NI Multism
- Basic Knowledge in in programming - Python, MATLAB, OCTAVE
- Literate in Microsoft Offices
- Knowledgeable in basic web design