HyLo: Development of a Smart Hydroponics System using Long Range Wide Area Network (LoRaWAN)-based Wireless Sensor Network (WSN)

Lean Karlo S. Tolentino, Rachelle B. Delos Santos, Nikka Marie V. Ebbay, Wendel G. Mendez, Kim Rafael Q. San Andres, Rem Raymond M. Tamayo, Gilfred Allen M. Madrigal, Romeo Jr. L. Jorda,Jay Fel Quijano, Cherry G. Pascion,

Department of Electronics Engineering, Technological University of the Philippines

Abstract

Climate change is one of the significant challenges that needs to be overcome by modern farming. One of the aspects of climate change is the global warming. The effects of global warming make it harder to plant in an uncontrolled environment. In a traditional farming method, the growers require good quality of soil and a large amount of space and water. On the other hand, the yield does not match or satisfy the customers' needs. For these reasons, it is necessary to use a farming technique that requires lower cost factor demands and to retain and regulate significant parameters such as light, water level temperature and humidity. This paper presents a smart vertical hydroponics farming; the plant growing technique without using of soil. In this technique, instead of subterranean soil, the crops are cultivated with their roots exposed to the combination of solutions with water in a vertical form of nutrient film technique (NFT) pipes. The vertical farming provides a great factor in terms of space and arrangement of growing plants which is also effective with hydroponics technique. Through the development of technology in terms of automation and transmission of data, the smart hydroponics evolved since detection, correction and monitoring of the significant parameters are present. Also, it was collaborated with the technology of LoRaWAN which gives a long range, low powered transmission of data through a wide area network (WAN). The number of leaves and circumference of the lettuce which were grown in the proposed hydroponics setup and the conventional setup were compared. Results showed that the number of leaves and circumference of the lettuce were greater in the proposed hydroponics setup than in the conventional setup.

Keywords: climate change, smart farming, vertical farming, hydroponics, nutrient film technique, LoRaWAN

Introduction

Hydroponics is a plant cultivation that uses water containing the nutrients needed pumped to the roots of the plants. The technology of the agricultural development has reached the useful benefits of the wireless technology and mobile devices to make use of energy and consumption of electricity by the machines that is useful and gives more profits to the farmers. The Internet of Things connects people and things by the use of internet and storing data to the cloud for evaluation, this arising of Internet of Things (IoT) allows the farmers to automated hydroponics. Many researches have been employing the technology of IoT for monitoring and maintaining their hydroponics water level, pH level, temperature, flow, and light intensity in its optimum value. And with the use of IoT the critical parameters can be controlled and regulate automatically.

Previous studies were conducted in the mechanization of hydroponics setups. An IoT-based aquaponics setup was developed by Peuchpanngarm, Srinitiworawong, Samerjai, & Sunetnanta (2016) which has automated control Android/iOS mobile application with variety of sensors such as water level sensor, temperature sensor, light and humidity sensor connected to the Arduino. Raspberry Pi3 controlled the environment of the hydroponic based from the data gathered from the sensors. It also functions as interface between the microcontroller and the cloud. The mobile application provided remote monitoring, record of the harvest, and provided plan for future hydroponic farming.

The proposed IoT based smart greenhouse system of Namgyel et al. (2018) has networks of sensors and control system. It consisted of master control and varieties of sensors using procedures for Zigbee technology and the control system of the hardware are connected via serial network interface. The main component affecting the growth of the plant is the light. Hence, in the studies of JSM & Sridevi (2014) and Amado, Valenzuela, & Orillo (2016), light and solution parameters were varied to obtain the optimal parameters and nutrients in the hydroponics setup. Wireless sensor nodes were implemented in the Intelligent Greenhouse Environment Monitoring System of Qiu, Dong, Wang, & Yan (2014) where the parameters used to maintain irrigation in the greenhouse, ventilation, and the lightning were monitored.

The focus of study of Ruengittinun, Phongsamsuan, & Sureeratanakorn (2017) is to assist ranchers in manufacturing a hydroponic homestead but do not have room scheduled for monitoring and planting the parameters that the test measures are stickiness, air temperature, electrical conductivity and pH level. For their future work, analysts suggested symmetrical planting to check the accuracy of the setup they manufactured and effectively confirm the control by using works. The study is based in Thailand where horticulture is the living conditions. It used IoT for machine-to-machine collaboration that estimated the hydroponic setup's mugginess, temperature, pH level and electrical conductivity. Creating and cautioning clients when the parameters are in unevenness to dismiss manual checking using an Android application

A diligent review of the studies manifests that there are few researches about a long-range wide area network use for transmitting data from the sensor node to the cloud services that is also employing low power, low data rate technology. Among those wireless sensor network and researches, LoRaWAN or Long-Range Wide Area Network is the most effective Wireless Sensor Network platform. This research focused in automating the monitoring the environment such as maintaining the pH level and electrical conductivity in a greenhouse. It also developed a mobile application for users to monitor the current status of the greenhouse via internet, so it can make the monitoring and maintenance easier (Sarawathi et al., 2018). LoRaWAN was also employed in the measurement of meteorological and hydrological parameters through an ocean buoy (Arago et al., 2020) and the measurement of biomedical parameters and vital signs in far remote areas (Cruz et al., 2019; Tolentino et al., 2019). It was also successfully implemented as transmission and reception modes for water quality parameter monitoring in the aquaculture setups of Tolentino et al. (2020a), Tolentino et al. (2020b), and Tolentino et al. (2020c).

The general objective of this study is to develop a LoRaWAN-based Wireless Sensor Network for a vertical hydroponics setup that is capable of intelligently monitoring parameters affecting production and quality of planvts using Long Range Wide Area Network (LoRaWAN). Specifically, this research work aims: (1) to design an in vdoor vertical farming setup hydroponics system, (2) to design a circuit that monitors light intensity, pH level, electrical conductivity (EC) and air temperature, and automatically corrects illumination for plants using grow lights and the temperature through an air cooling and ventilation system of the chamber respectively, (3) to develop a wireless sensor network using Long Range Wide Area Network (LoRaWAN) that transmit different parameters subsequently, and (4) to evaluate the effectivity and accuracy of the system developed.

The study aims to improve the production and yield of the plant lettuce concerning the vertical hydroponics farming setup. The farmer will be able to monitor the growth of the lettuce and its parameters. The study is fully self-sustainable and automatically control the nutrients, water, light, and air needed of the plants, there is no need for human intervention.

With this automated setup, it can help the interested new farmers or growers who wants to have their own hydroponics farm and grow their own plants but have no time to monitor and provide the requirements of the plants. The automated correction of light and air parameters can lead to optimized crop production and yield of a hydroponic system. Using the technology of Long-Range Wide Area Network (LoRaWAN) that transmit the significant parameters of lettuce subsequently through internet to the Application device, the farmer/grower will be able to obtain accurate data in real time and will be able to help in improving the decision-making. This Wireless Sensor Network technology will make it easier for the growers to monitor the parameters no matter how near or far they are from their farm. The farmer can rest assure that the plants meet the required nutrients for its growth.

This study was implemented at an experimental scale at Sta. Ana, Manila with lettuce as crops. Production and quality of the plants in vertical setup would lead to more earnings of the farm owner. The proposed system focused on monitoring, correction of grow lights and air temperature in vertical setup chamber, maintaining the nutrients required of the lettuce, and transmission of the significant parameters of the lettuce via the Internet. The significant parameters mentioned are pH Level, air humidity and temperature, water level, and light intensity.

System Architecture

A. Block Diagram

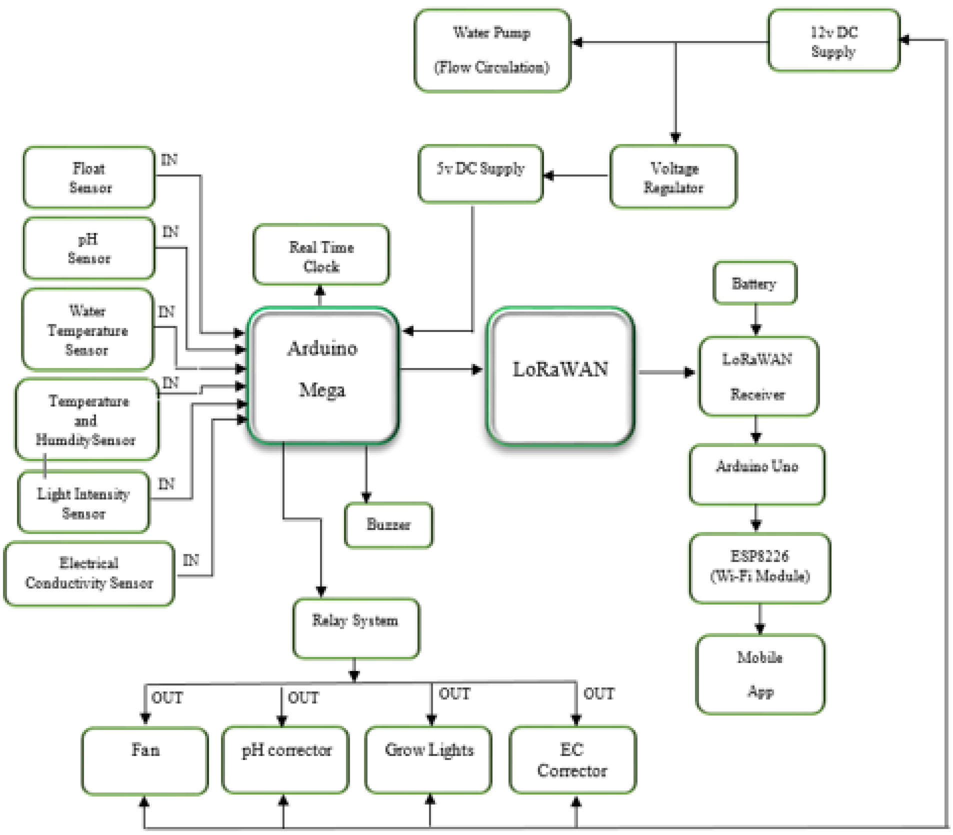


Figure 49. Block Diagram of the system

The system has three major parts: input, process and output. Input for the system is a variety of sensors that will occasionally be monitored using Arduino for data processing. It consists of different nodes and base station that is used to monitor environmental and physical conditions such as temperature, humidity, pH, EC, etc. In the development of model and system design, data acquisition through sensors, control and task management, collection and analysis of data were considered. The parameters were feed to the Arduino microcontroller to monitor and automatically control the desired optimum value whenever there is imbalance in the said parameters. On the process of the system, the data gathered from the parameters were transmitted through the LoRaWAN Gateway into LoRaWAN Network Server and then transferred to LoRaWAN Application Server.

General Flow of the System

The left phase of process in Figure 50 illustrates the flowchart of controlling the air temperature and humidity in this system. This is done by indicating the temperature value from the DHT22. The temperature value is important hence it is vital to the growth of plants. Afterwards, values acquired from the sensor will be verified if it is within the threshold value. Supposing that values didn't reach or excessive within the threshold, automatically system will switch off the fan to adjust the temperature inside the system. From the time that the value attains the range of the threshold, switching off the fan in the system is done. Temperature threshold of the system can be manipulated that makes the system adapt the current season. The data acquired from the system will be displayed in the LoRaWAN Application Server. The scale of temperature is fixed to a certain degree Celsius (¬°C) and can be manipulated via mobile phone.

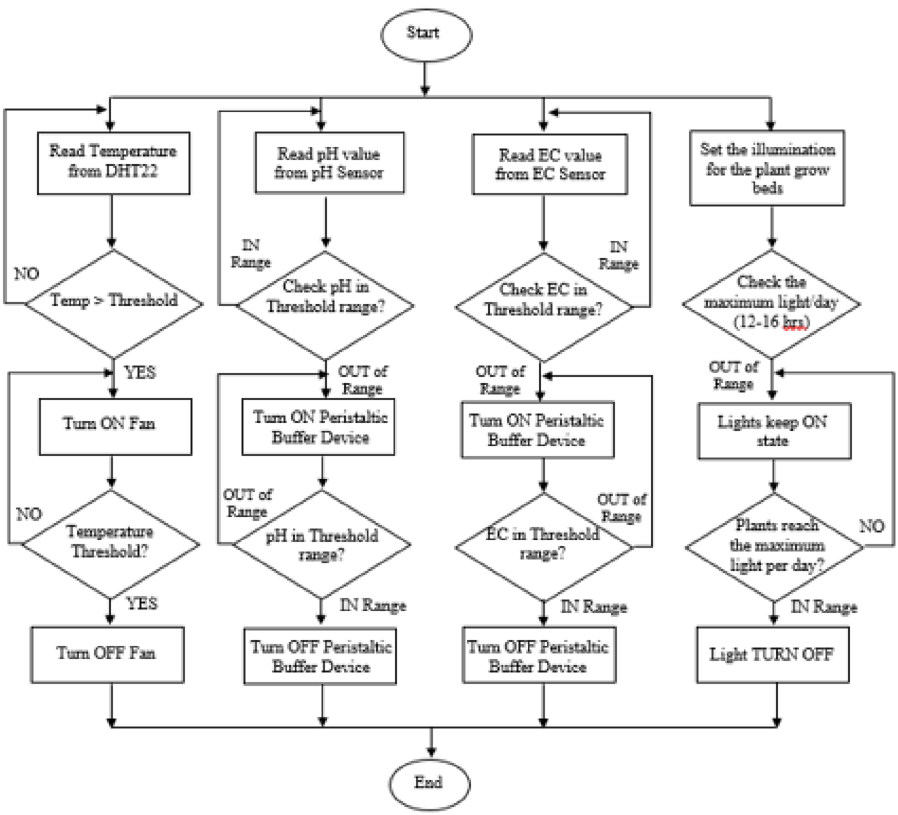


Figure 50. Process Flow of the System

The next phase of process in flowchart shows the pH value correction which is done by reviewing of data from the pH sensor. If the value is not within range, the Peristaltic Buffer Device will be turned on to release a substance, reducing the nutrient solution's basicity / alkalinity and vice versa.

The third phase shows how the EC values are managed. It has a similar mechanism to the PH process, but the difference is that the EC Sensor will read the value and release various substances. If the value goes out of the threshold range, the EC mechanism will add water and release nutrients if the value is too low. The EC will be measured per centimeter (µS / cm) in milli - siemens.

The last phase shows the Illumination of the grow-lights required by the plants per day. After setting the number of hours, the system will check the required maximum light per day. If the set parameters not in range, the lights will keep turn on until the plants reach the maximum required illumination per day. In order to improve the quality of agricultural sites and increase the production of plants, the study presented a monitoring system using Android-based smart phone for smart farming agriculture.

Various Components of the System

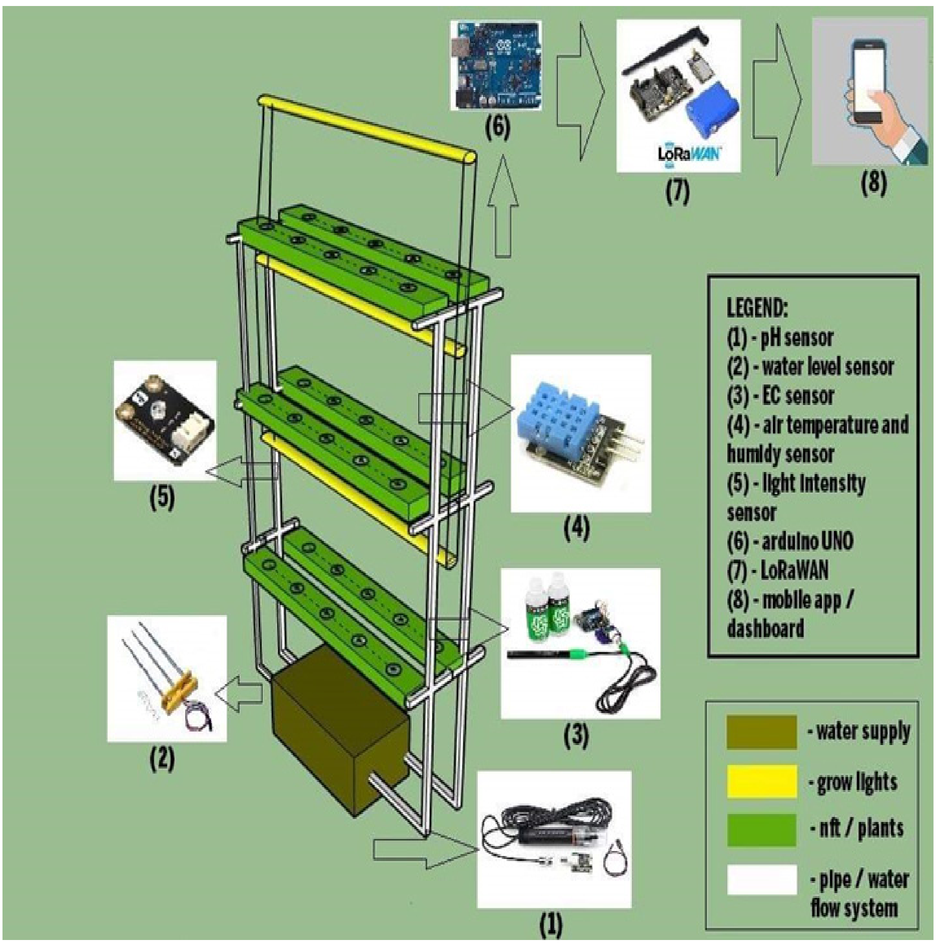


Figure 51. Experimental Set-up

Figure 51 shows the experimental setup of the proposed hydroponics system. It also shows the location of the components. Table 23 shows the descriptions and functions in the hydroponics automation. Figure 52 shows the connection of Arduino Mega to different sensors while Figure 53 shows the interface of the LoRa module to the Arduino Mega. Figure 54 illustrates the connection of the Relay System for correction.

Table23

Hydroponics Components and their functions

No.	Components	Description
01	PH Sensor	this is an industrial grade analog pH sensor that can be submerged under water for a relatively long time before re-calibration.
02	Water Level Sensor	is a kind of level sensor which is a device used for detecting the level of liquid within a system.
03	EC Sensor	this Atlas Scientific Electrical Conductivity Kit includes the K1.0 conductivity probe and the EZOTM Conductivity Circuit, which is best used in brackish water.
04	Air Temperature & Humidity Sensor	It utilizes a capacitive moisture sensor and a thermistor to assess the surrounding air and sends a digital signal to the information pin.
05	Light Intensity Sensor	this light sensor for Arduino or Raspberry Pi enables you detect the light density and reflect the analog voltage signal back to the computer for Arduino.
06	Arduino	is a microcontroller board based on the ATmega2560.
07	LoRa/LoRaWAN	A star-of-star topology deploys LoRaWAN network architecture in which gateways relay messages between end devices and a central network server.
08	Mobile Application	visualized the data monitoring of specific critical parameter needed to be maintained and the real-time data logs.

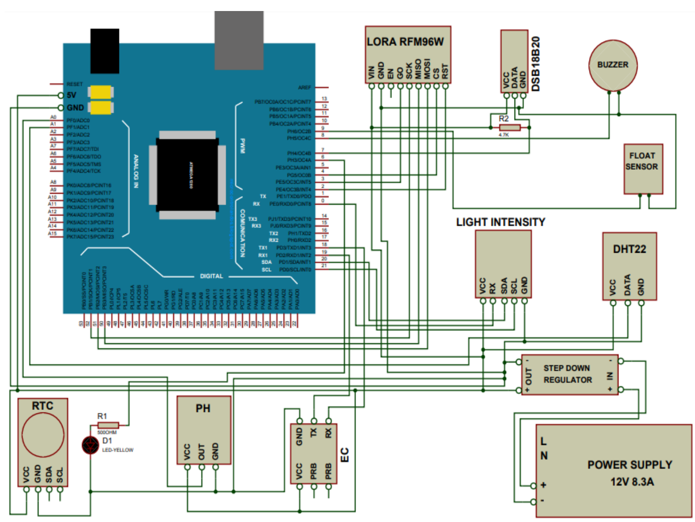


Figure 52. Schematic Diagram of Arduino Mega for Different Sensors

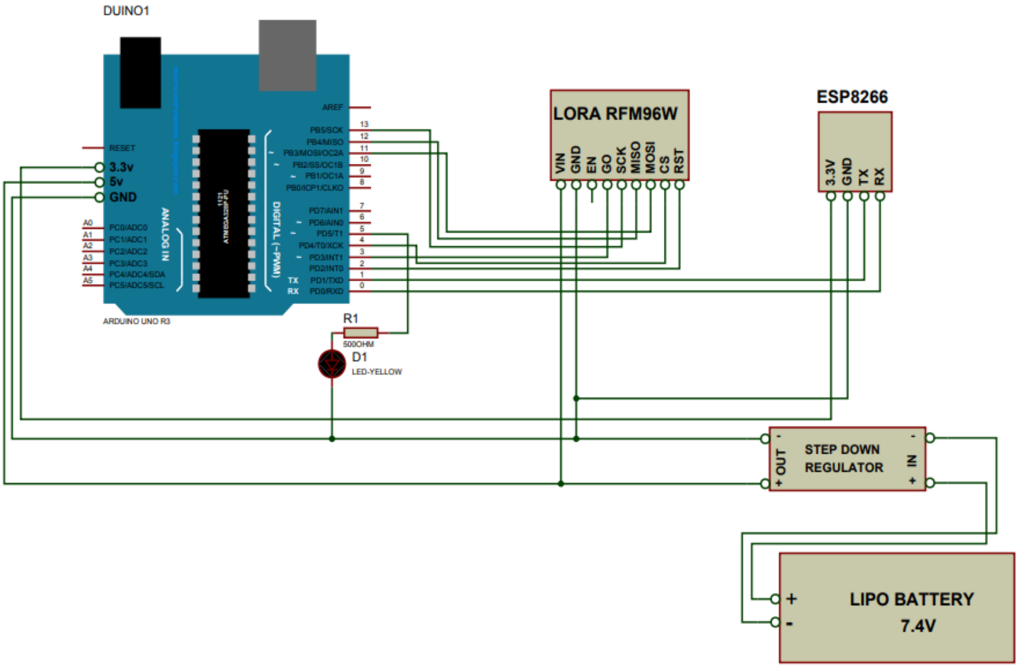


Figure 53. Schematic Diagram of Arduino to LoRa connection for Receiver

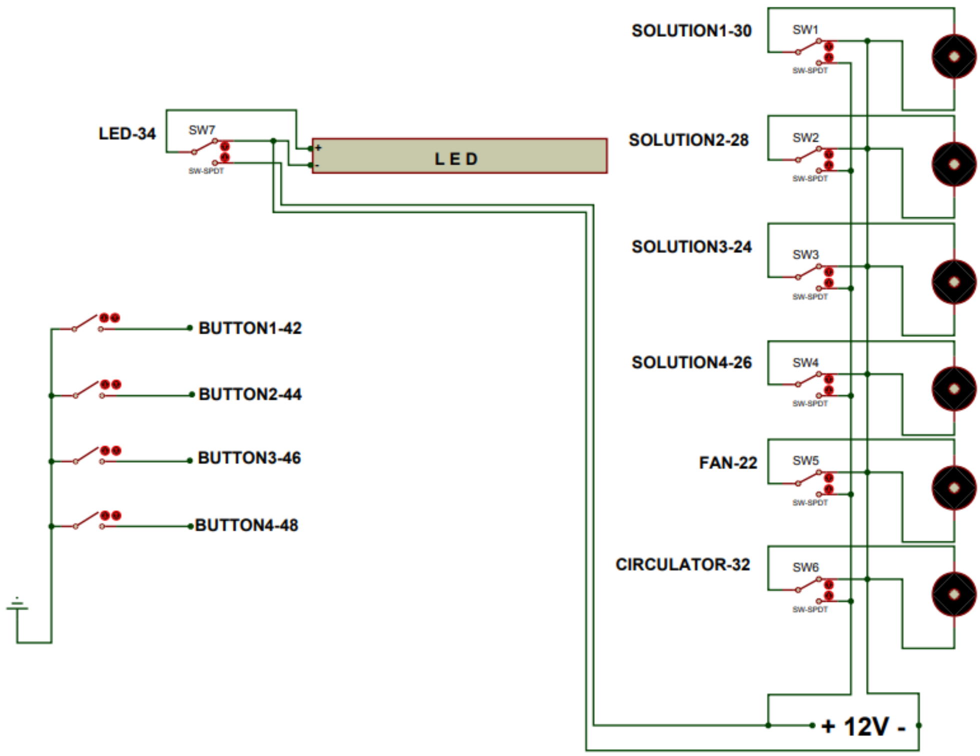


Figure 54. Schematic Diagram of Relay System for correcting device

General Flow of the System

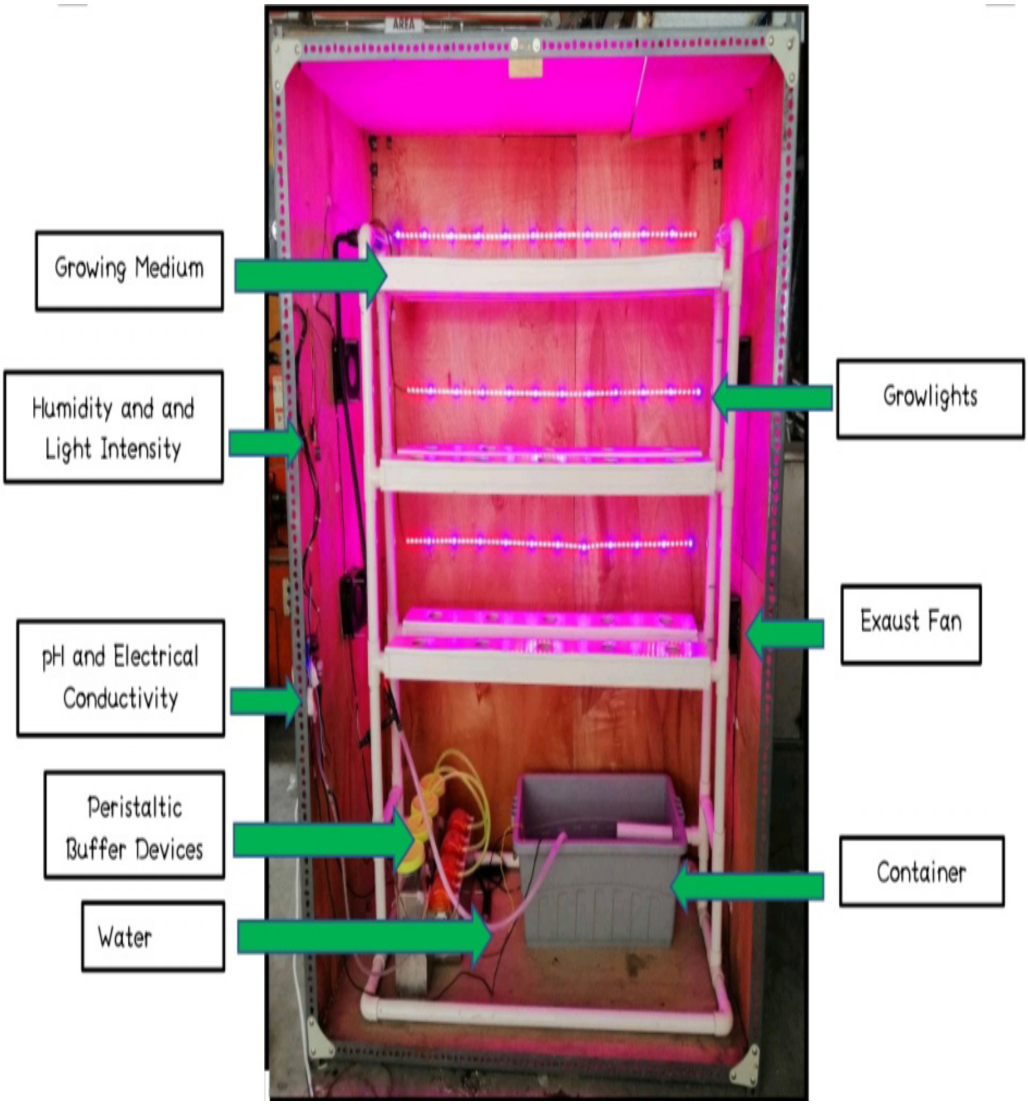


Figure 55. Actual Chamber and the Hydroponics Set-up

Figure 55 shows the parts of the single set-up of hydroponics is. Attached are the inlet fans at the side of the chamber. The sump tank contained the pH sensor, water level sensor and the temperature sensor. The peristaltic buffer device was connected with the sump tank through a hose where the $CaCO_3$ was being released.

Web Application

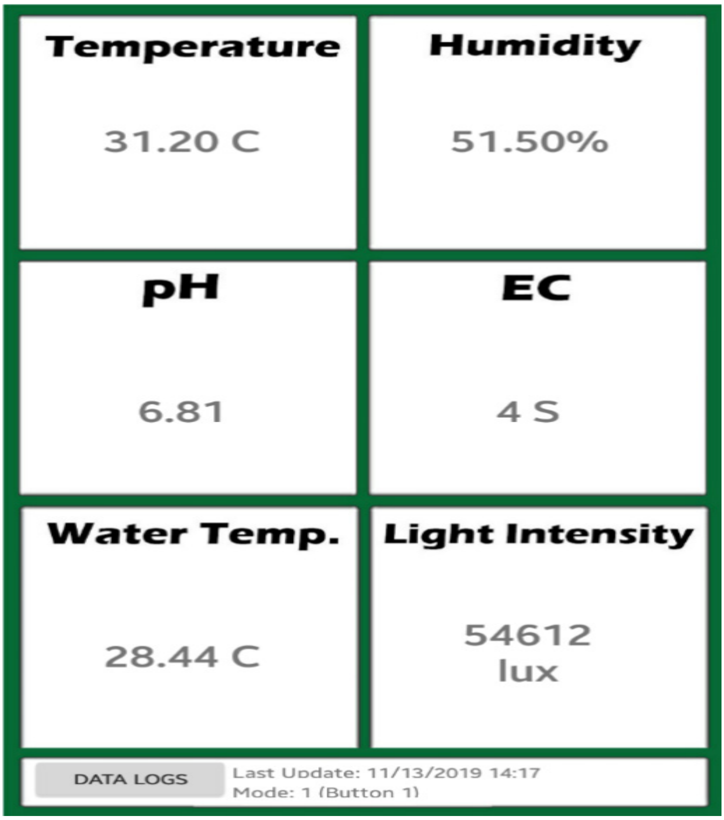


Figure 56. Application Interface

Figure 56 shows the initial application interface of the project. This page visualized the data monitoring of specific critical parameter needed to be maintained and the real-time data logs.

Results and Discussion

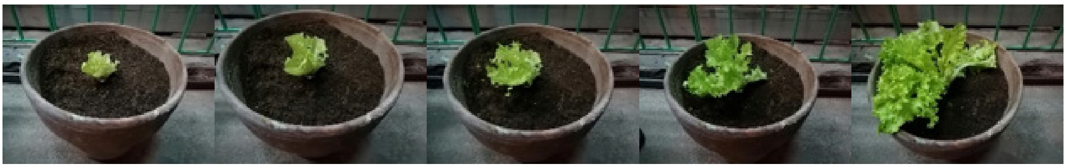
Comparison of the Proposed System with the Conventional Setup

The mean circumference and the average number of leaves of the lettuce which were planted in the proposed hydroponics system and the conventional setup were presented in Table 24. As shown in the table, the circumference and the number of leaves of lettuce were greater in those planted in the proposed hydroponics setup than in the conventional approach. Figures 57 and 58 shows the lettuce which were planted in two different setups.

Table 24

Comparison of the proposed hydroponics system with the conventional setup for five weeks.

Week	Conventional Setup		Proposed Hydroponics System	
	Mean Circumference (in.)	Average Number of Leaves	Mean Circumference (in.)	Average Number of Leaves
1	3.1415	3	6.283	3
2	5.026	3	11.309	4
3	11.308	4	17.582	5
4	18.849	4	21.991	6
5	25.132	5	26.389	6



[a] [b] [c] [d] [e]

Figure 57. Growth of lettuce in the conventional setup. (a) Week 1, (b) Week 2, (c) Week 3, (d) Week 4, and (e)Week 5

Figure 58. Growth of lettuce in the proposed hydroponics system.

Project Limitations and Capabilities

The project has the capability to correct the critical parameters needed by plants for its growth. The system has 4 buttons that has different range of Electrical Conductivity and pH level for different kinds of plant. The grow lights are capable of meeting the required no. of hours per day needed by setting a specific time to turn on and off. The project was limited in comparing the plant growth of the smart hydroponics from the conventional soil-based farming, and limited in related studies in comparison of the data transmission using Long Range Wide Area Network and other wireless transmission devices such as Zigbee, etc.

The limitations of the project were as follows:

1. The system can correct the critical parameters such as light intensity, air temperature, pH level and Electrical Conductivity.
2. The system was limited to only growing leafy vegetables ranging from 0.8 to 2.5 electrical conductivity and from 5.0 to 7.0 for pH level.

Conclusion

A vertical farming smart hydroponics system with the use of LoRaWAN-based WSN for transmission of data monitoring was proposed in this study. This project sought to respond alternative way of farming in urban areas while attaining solution towards environment impact in the Philippines. In line with these, the study focused on correcting pH level and EC other than the remaining parameters needed for the system. Successful implementation of the vertical hydroponics monitoring system was made through web database and user-friendly Android application. This system is applicable for IoT applications such that monitoring and automatically providing the requirements of the plants to grow. Thus, giving the user ease of access in monitoring the smart hydroponics in any place and time with IoT gateway.

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