INTERNET OF THINGS SYSTEM THROUGH MESSAGE QUEUE TELEMETRY TRACKING PROTOCOL FOR MODERNIZING RED CHILI AGRICULTURE

NIK MOHD SYAHIRRUDDIN BIN JUSOH

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical Power)

School of Electrical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

JULY 2021

DEDICATION

Syukur Alhamdulillah for the blessings of Allah s.w.t. gave me the strength and enthusiasm for me to prepare this thesis. This thesis is dedicated to both my parents, Jusoh bin Mahmod and Engku Kamariah binti Engku Teh, who gave me a lot of encouragement mentally and physically. Not to be forgotten for the beloved wife Sabaratun Azila binti Uda Abu Bakar who was very patient and fully supported me and gave help and encouragement to continue and complete this thesis as well as the beloved children Nik Nur Arissa Sofia, Nik Nur Aleesya Maryam and Nik Muhammad Mu ‘az Affan who was a loyal companion throughout the period of completing this thesis.

ACKNOWLEDGEMENT

In preparing this thesis, I was in contact with many people, and practitioners. They have contributed towards my understanding and thoughts. In particular, I wish to express my sincere appreciation to my main thesis supervisor, Associate Professor Ts. Dr. Dalila binti Mat Said, for encouragement, guidance, critics and friendship. Without her continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to the Government of Malaysia through the Department of Manpower for giving me permission and clearance to further my studies and Institut Latihan Perindustrian Kota Bharu also deserve special thanks for their assistance and gave me permission to use the resources available.

My fellow postgraduate student especially Ir. Wan Yusrizal, Ir. Ahmad Fauzi, Mohd Razani and Norhaisam should also be recognized for their support. My sincere appreciation also extends to all my colleagues especially Mohd Ruzlan and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family member. I love u all to be at my side during this time.

ABSTRACT

The rate of food imports of the country continues to show an increase from year to year especially red chilies. Malaysians still spend most of their income on food. At the same time, domestic food production for certain foods continues to decline. This situation in turn will lead to the problem of low-income ability and the country should continue to import food from foreign countries. A study in 2018 showed that the import dependency (IDR) rate of the Malaysian population for red chili is 73.1%. Although specific planning has been made through the National Agricultural Policy, but food imports continue to increase. In the era of technological development of the 4.0 industrial revolution, the country's agricultural sector needs to follow this revolution to maximize production and meet the demands of society in Malaysia currently. Cultivation areas that are far from facilities, especially electricity, make it difficult for crop farms to operate more modern in accordance with the current development era. The use of renewable energy, namely solar energy as the main source of energy is needed to make plantations equipped with modern equipment that requires a source of electricity to operate. This research proposed smart farming method studies the growth rate of plant roots based on soil factors namely pH and moisture. Data obtained from pH sensors and moisture sensors will be transmitted to cloud using MQTT protocol. The data will be analysed by Raspberry Pi and the system will determined the appropriate irrigation and fertilization to increase the growth rate of roots. This system will continuously monitor the environment crops include sources of electricity supply using photovoltaic system (PV) systems. The planting site is divided into two (2) zones to facilitate monitoring and control operations. From the results of the study conducted, the system will ensure that the soil pH rate is suitable for chili cultivation which is between 5.5 - 6.5 while the suitable soil moisture is between 55% - 70%. If that value is not reached, the system will turn on the necessary pump automatically. Manual control mode is also provided to give convenience to users. Users can also observe the system operating by using web access or android applications.

ABSTRAK

Kadar import makanan negara terus menunjukkan peningkatan dari tahun ke tahun terutamanya cili merah. Rakyat Malaysia membelanjakan sebahagian besar pendapatan mereka untuk makanan. Pada masa yang sama, pengeluaran makanan domestik untuk makanan tertentu terus menurun. Keadaan ini seterusnya akan menimbulkan masalah dan negara harus terus mengimport makanan dari negara asing. Kajian pada tahun 2018 menunjukkan bahawa kadar kebergantungan import (IDR) penduduk Malaysia bagi cili merah adalah 73.1%. Walaupun perancangan khusus telah dibuat melalui Dasar Pertanian Negara, tetapi kadar import makanan terus meningkat. Pada era perkembangan teknologi revolusi industri 4.0, sektor pertanian negara perlu seiring dengan revolusi ini untuk memaksimumkan pengeluaran dan memenuhi tuntutan masyarakat di Malaysia ketika ini. Kawasan penanaman yang jauh dari kemudahan, terutamanya bekalan elektrik, menyukarkan ladang tanaman untuk beroperasi lebih moden sesuai dengan era pembangunan sekarang. Penggunaan tenaga boleh diperbaharui, iaitu tenaga suria sebagai sumber tenaga utama diperlukan untuk ladang beroperasi dengan peralatan elektrik/elektronik moden. Kajian ini mencadangkan kaedah pertanian pintar dengan mengkaji kadar pertumbuhan akar tanaman berdasarkan faktor tanah iaitu pH dan kelembapan. Data yang diperoleh dari sensor pH dan sensor kelembapan akan dihantar ke awan menggunakan protokol MQTT. Data akan dianalisis oleh Raspberry Pi dan sistem akan menentukan pengairan dan pembajaan yang sesuai untuk meningkatkan kadar pertumbuhan akar. Sistem ini akan terus memantau tanaman persekitaran merangkumi sumber bekalan elektrik menggunakan sistem fotovoltaik (PV). Tapak penanaman dibahagikan kepada dua (2) zon untuk memudahkan operasi pemantauan dan kawalan. Dari hasil kajian yang dilakukan, sistem akan memastikan bahawa kadar pH tanah diantara 5,5 - 6,5 sementara kelembapan tanah yang sesuai adalah antara 55% - 70%. Sekiranya nilai tersebut tidak tercapai, sistem akan menghidupkan pam yang diperlukan secara automatik. Mod kawalan manual juga disediakan untuk memberi kemudahan kepada pengguna. Pengguna juga dapat memerhatikan sistem beroperasi dengan menggunakan akses web atau aplikasi android.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FAO	-	Food and Agriculture Organization of the United Nations
SSR	-	Subsistence Rate
IDR	-	Import Dependency Rate
IoT	-	Internet of Things
M2M	-	Machine to Machine
MQTT	-	Message Queuing Telemetry Transport Protocol
LPWAN	-	Low-Power Wide Area Network
LoRa	-	Long Range
LoraWAN	-	Long Range Wireless Area Network
PV	-	Photovoltaic
WSN	-	Wireless Sensor Networks
SMP	-	Soil matric potential sensors
VWC	-	Volumetric soil water content sensors
UAV	-	Unmanned Aerial Vehichle
EC	-	Electrical Conductivity
PID	-	proportional–integral–derivative
ILP	-	integer linear programming
HGA	-	hybrid genetic algorithm
CCN	-	convolutionary neural network
YOLO	-	You Only Look Once
EI	-	embedded intelligence
SEH-WSN	-	solar energy harvesting wireless sensor network
FDR	-	Frequency Domain Reflectometry
TDR	-	Time Domain Reflectometer
CSS	-	chirp spread spectrum
DoD	-	depth of discharge
GUI	-	Graphical User Interface

CHAPTER 1

INTRODUCTION

1.1 Background

Increasing food security is one of the main goals of the national agricultural policy that was first established in 1984. Food security means that every person, according to the Food and Agriculture Organization of the United Nations (FAO), can physically and economically obtain adequate, safe and nutritious food resources at all times to meet their dietary needs and food choices for active and healthy lives. There are four components of food security referred to by the FAO, namely food availability, food access, consumption and stability.

The subsistence rate (SSR) is an indicator used to explain the extent to which a country's agricultural commodity supply can meet domestic demand. SSRs that reach 100% or more show that production is sufficient to meet domestic needs and if SSRs do not reach 100%, the country needs to import the food supply to meet the demand and tastes of domestic consumers. Import dependency can be measured using the import dependency rate (IDR) indicator.

The import rate of red chillies to meet the needs of Malaysians is increasing every year as shown in Figure 1.1. As a challenge in bringing the current of modernization in red chilli cultivation, the use of the Internet of Things in cultivation management is in line with the industrial revolution 4.0. Based on a study in 2019, red chilli is an agricultural commodity item with the lowest SSR of

26.4% and this means that the country needs to import a total of 73.6% from foreign countries to meet the needs of the local market. Along with the era of technological revolution 4.0 industry development, the country's agricultural sector also needs to adapt this technology in order to maximize production and meet the current demand of the population in Malaysia.

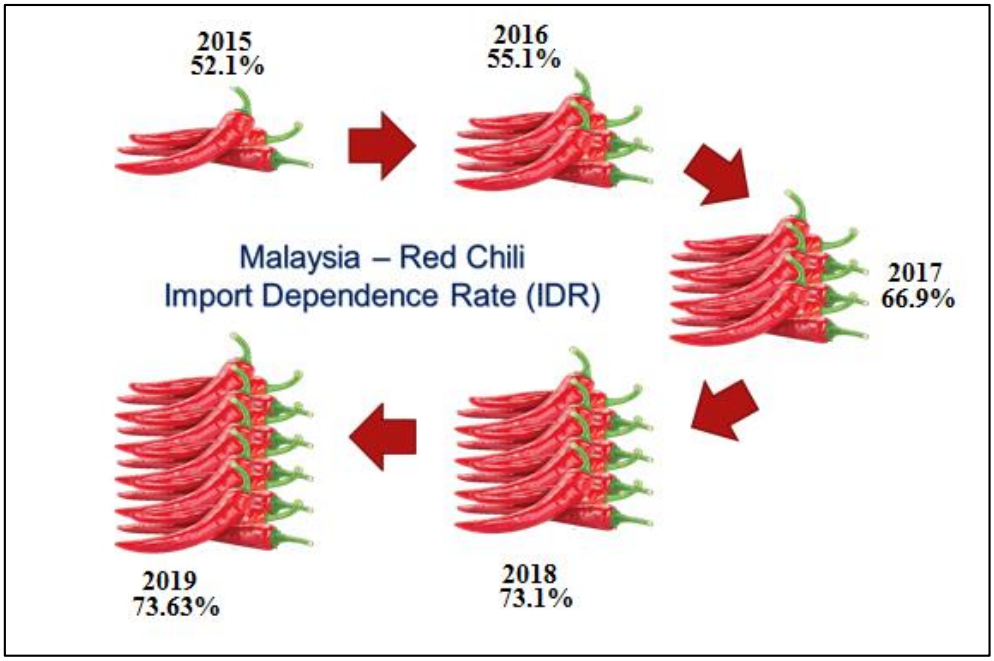

Figure 1.1 Red Chili – Malaysian Import Dependence Rate

This study will take into account the need for cultivation in rural areas with limited power supply resources and requires remote monitoring and control using cloud computing facilities. The plantation farm will be equipped with detection and control devices that will help increase fertility levels and root growth further increase red chilli production. Soil factors such as pH level and soil moisture will be measured, processed and sent to control devices to determine the level of fertilization, level of irrigation and level of pesticides required by soil and crops.

The main framework of the study will use the Raspberry Pi as the primary processor and supported by the use of low-power wide area networks for remote data transmission and reception. To ensure a stable and durable power supply source, this system will use a power source from solar energy and batteries. All of these systems will be remotely monitored and controlled by users with attractive and simple but multi-functional display settings.

A common concept now-a-days, the Internet of Things (IoT), describes a framework with the help of different kinds of sensors where the environment is connected to the Internet. It allows objects to be sensed or managed remotely via existing network infrastructure, creating possibilities for a more direct integration of the physical environment into computer-based systems and improving performance, accuracy and economic gain, in addition to decreasing human interference.

The agricultural IoT uses various sensor devices and sensing technologies to collect information on agricultural growth through wireless sensor networks, mobile wireless communications networks and the Internet. Cleaning, incorporation and processing of the vast knowledge gathered from agriculture. Crop treatment will be ensured by intelligent operating terminals, process control, scientific decision-making and real-time service in the whole industrial chain for the production of agricultural products. It is a major technical support for modern agriculture with a high degree of quality, accuracy and environmental protection, and is also essential for agricultural knowledge and intelligence.

Cloud Computing provides on-demand network access to a common pool of configurable computer resources. IoT systems generate massive quantities of data, and Cloud Storage paves the way for that data to reach its destination. Clouds and IoT have a relationship that is complementary, and our daily tasks can be more efficient. Different communication protocols for transmitting data exist in IoT and machine to machine (M2M) systems. As an abbreviation for Message Queuing

Telemetry Transport Protocol (MQTT), OASIS implemented MQTT in 2013. Now, this open standard is a commonly used communication protocol across a number of industries.

The consistency of the soil can be calculated in terms of plantations by calculating various soil parameters. Measurements of soil parameters are needed continuously to obtain information about the condition of the soil environment that has approached the real condition. Suitable crops are recommended to farmers on the basis of soil analysis, in order to improve crop productivity.

It is a challenge to cover a wide area that uses IoT, as typically required in agriculture and agriculture. To achieve efficient communication, Low-Power Wide Area Network (LPWAN) protocols such as LoRa are a perfect solution. A new agricultural information technology, called smart farming, has appeared in recent years, suggesting a service focusing on the wireless sensor network and LoRa.

1.2 Statement of the Problem

Major problem is monitoring and controlling the irrigation, fertilization and pesticide of the plantation located at rural areas as they are requires a long and stable power supply source and high efficiency data received and trasmitted for the operation of sensor and control devices. To overcome this problem, designing a project combined with all the three element and the efficiency of data transfer between the receiver and transmitter are much higher, further and stable power supply.

From the technical perspective, major research gaps are how to improve the power supply souces including the selection of battery, selection of low power consumption devices and the efficiency of data received and transmitted and controlling irrigation, fertilization and pesticide for better crop productivity.

1.3 Objectives of the Study

Followings are the objectives proposed for this study:

i. To study and design Agriculture IoT framework using Raspberry Pi through MQTT Protocol
ii. To analyse the system performance using Node Red
iii. To test and validate the improve Agriculture IoT with the experimental work

1.4 Scopes

The determination of the scope of the study was identified based on the research gap of past studies as well as improvements in terms of the use of better sensors and at an affordable price. The chilli crop is the choice because the rate of dependence on the import of the material is increasing every year. The indentified scope of the project are listed as below:

i. Design IoT framework using Raspberry Pi, MQTT Protocol, LoRa and PV

ii. PV system using 200watt PV panel and 18Ah Sealed Lead Acid as power bank for powering sensors and LoRa devices
iii. Hanging planting because of the original soil site contains unknown compounds and can cause disease to plants
iv. Irrigation system using surface drip because it is much more efficient and save water resources
v. Fertilization system using surface drip because more efficient and save fertilizer resources
vi. Pesticide system using surface mist because of more practicable

1.5 Thesis Outline

Chapter 1 describes the background of the study which is related to the rate of importation of red chillies in the country which is increasing every year. The main factor of this increase is due to limited supply sources. The selection of the main topic of the study was based on observations against this background. Next in this chapter describes a statement of problems faced in increasing the production level of red chilli crops in the country. The use of high-tech devices is one of the ways in helping to increase crop yields. The objectives and scope of the study are also stated in this chapter.

Chapter 2 contains past studies related to the title of the study. The past studies mentioned in this chapter are divided into three sub-studies namely studies related to Agriculture IoT, Wireless Sensor Network and MQTT Protocol. Research in the field of smart agriculture has started since 2008 and is growing with current technology. Studies in Iot agriculture focus on the selection and comparison of the use of sensors, methods of monitoring and controlling resource requirements as well as the transmission of data directly to users. The study in the Wireless Sensor Network, on the other hand, leads to a smaller scope, which is to connect all the

sensing devices used wirelessly and without affecting the quality of the data sent to the receiver. A study of the MQTT protocol to obtain information related to the suitability of the use of this protocol in the transmission of data without errors in the delivery of information to the recipient

Chapter 3 describes in detail the methods in conducting the study. In this chapter will describe the framework of study and development of each node within the framework. There are 3 nodes developed in this study, namely sensor node, processing node and controlling node. In addition, this chapter also states the device selection factors as well as the advantages of the device.

The findings from the study are described in Chapter 4. This chapter will show the reading values received from digital type sensors installed on the crop medium as well as a comparison of those values with analogue type sensor readings. Apart from that, tests on the level of performance of the use of the MQTT protocol as a data transmission medium were also conducted. Display for users is also featured in this chapter.

The focus in chapter 5 is related to the discussion of the results of the study conducted as well as suggestions for improvement to the study in the future. The recommendations focus on the use of more high -tech devices as well as the addition of several new applications that can help improve the efficiency of IoT agriculture.

REFERENCES

1. Sebastian Sadowski, Petros Spachos. “Wireless Technologies For Smart Agricultural Monitoring Using Internet Of Things Devices With Energy Harvesting Capabilities”. Computers And Electronics In Agriculture 172 (2020) 105338

2. Na Lin, Xuping Wang, Yihao Zhang, Xiangpei Hu, Junhu Ruan. “Fertigation Management For Sustainable Precision Agriculture Based On Internet Of Things”. Journal Of Cleaner Production 277 (2020) 124119

3. Emmanuel Abiodun Abioyea,b, Mohammad Shukri Zainal Abidina,⁎, Mohd Saiful Azimi Mahmuda,Salinda Buyamina, Mohamad Hafis Izran Ishaka, Muhammad Khairie Idham Abd Rahmana, Abdulrahaman Okino Otuozec, Patrick Onotub, Muhammad Shahrul Azwan Ramli “A Review On Monitoring And Advanced Control Strategies For Precision Irrigation”. Computers And Electronics In Agriculture 173 (2020) 105441

4. Ching-ju Chen, Ya-yu Huang, Yuan-shuo Li, Chuan-yu Chang, And Yueh-min Huang. “An Aiot Based Smart Agricultural System For Pests Detection”. IEEE Access 180750, Volume 8 2020

5. Achilles D. Boursianis, Maria S. Papadopoulou, Panagiotis Diamantoulakis, Aglaia Liopa-tsakalidi, Pantelis Barouchas, George Salahas, George Karagiannidis, Shaohua Wan, Sotirios K. Goudos. “Internet Of Things (Iot) And Agricultural Unmanned Aerial Vehicles (Uavs) In Smart Farming: A Comprehensive Review”. Https://Doi. Org/10.1016/J.Iot.2020.100187

6. Zhaoyu Zhai, José Fernán Martínez, Victoria Beltran, Néstor Lucas Martínez. “Decision support systems for agriculture 4.0: Survey and challenges”. Computers and Electronics in Agriculture 170 (2020) 105256

7. Biswajeeban Mishra And Attila Kertesz. “The Use Of MQTT In M2M And Iot Systems: A Survey”. IEEE Access 201071, Volume 8 2020

8. Himanshu Sharma, Ahteshamul Haque, Zainul Abdin Jaffery. “Maximization Of Wireless Sensor Network Lifetime Using Solar Energy Harvesting For Smart Agriculture Monitoring”. Ad Hoc Networks 94 (2019) 101966

9. Fachrul Kurniawan, Hani Nurhayati, Yunifa Miftachul Arif, Sri Harini, Supeno Mardi Susiki Nugroho, Mochamad Hariadi. “Smart Monitoring Agriculture Based on Internet of Things” The 2nd East Indonesia Conference on Computer and Information Technology (EIConCIT) 2018

10. Ramya Venkatesan and Anandhi Tamilvanan. ”A Sustainable Agricultural System Using IoT”. International Conference on Communication and Signal Processing, April 6-8, 2017, India

11. Lekjaroen, Ponganantoayotin, Charoenrat, Funilkul, Supasitthimethee, Triyason. IoT Planting: Watering system using mobile application for the elderly. Computer Science and Engineering Conference (ICSEC). 2016.

12. Keynes, JK, Punithavathani, D. Clustering methodology to prolong lifetime in wireless sensor networks. Paper presented Information Communication and Embedded Systems (ICICES). International Conference on. 2017.

13. M Kaushik, R Ratan, Development of a Novel Approach to Enhance the performance of real time intelligent Telemetry based Irrigation System. 2018 5th International Conference on Signal Processing and Integrated Networks (SPIN), Noida. 2018: 316-321.

14. S Vaishali, S Suraj, G Vignesh, S Dhivya, S Udhayakumar. Mobile integrated smart irrigation management and monitoring system using IoT. 2017 International Conference on Communication and Signal Processing (ICCSP), Chennai. 2017: 2164-2167.

15. D Mishra, A Khan, R Tiwari, S Upadhay. Automated Irrigation System-IoT Based Approach. 2018 3rd International Conference on Internet of Things: Smart Innovation and Usages (IoT-SIU), Bhimtal. 2018: 1-4.

16. SB Saraf, DH Gawali. IoT based smart irrigation monitoring and controlling system, 2017 2nd IEEE International Conference on Recent Trends in Electronics. Information & Communication Technology (RTEICT), Bangalore. 2017: 815-819.

17. MN Rajkumar, S Abinaya, VV Kumar. Intelligent irrigation system-An IoT based approach. 2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT), Coimbatore. 2017: 1-5.

18. HJ Lad, VG Joshi. Irrigation control system using distributed embedded system. 2014 International Conference on Contemporary Computing and Informatics (IC3I), Mysore. 2014: 1336-1339.

19. Sridevi Navulur, ASCS Sastry, MN Giri Prasad. Agricultural Management through Wireless Sensors and Internet of Things. IAES International Journal of Electrical and Computer Engineering (IJECE). 2017; 7(6): 3492-3499.

20. M Mahalakshmi, S Priyanka, SP Rajaram, R Rajapriya. Distant Monitoring and Controlling of Solar Driven Irrigation System through IoT. 2018 National Power Engineering Conference (NPEC), Madurai. 2018: 1-5.

21. A Diyana Rosli et al. Intelligence irrigation system employing the use of solar PV. 2012 IEEE International Conference on Control System, Computing and Engineering, Penang. 2012: 458-461.

22. G. Alex and M. Janakiranimathi. Solar based plant irrigation system. 2016 2nd International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB), Chennai. 2016: 425-428

23. SatyaPrasanthYalla, KV RajeshKumar, B Ramesh, Energy management in an automated solar powered irrigation system, 2013 International Conference on Information Communication and Embedded Systems

(ICICES), Chennai. 2013, pp. 1136-1140.doi: 10.1109/ICICES.2013.6508260

24. G Eragamreddy, KR Sree. Solar powered auto watering system for irrigation using embedded controller. 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai. 2017: 2424-2428.

25. Liu Xiaochu, Ling Jingpeng, Yao Li, Wu Hualong and Tao Jianhua. Engineering quality control of solar-powered intelligent water-saving irrigation, 2010 2nd International Asia Conference on Informatics in Control, Automation and Robotics (CAR 2010), Wuhan. 2010: 254-257.

26. RN Rao, B Sridhar, IoT based smart crop-field monitoring and automation irrigation system. 2018 2nd International Conference on Inventive Systems and Control (ICISC), Coimbatore 2018: 478-483. doi: 10.1109/ICISC.2018.8399118

27. G Chen, L Yue. Research of irrigation control system based on fuzzy neural network. 2011 International Conference on Mechatronic Science, Electric Engineering and Computer (MEC), Jilin. 2011: 209-212.

28. Shibo Zhang, Zhihong Qie, Xinmiao Wu, Zhiyu Zhang and Xingjun Tian. Irrigation system optimization under non-sufficient irrigation based on Elitist Non-dominated Sorting Genetic Algorithm, 2008 Chinese Control and Decision Conference, Yantai, Shandong. 2008: 4299-4302.

29. SN Ishak, NNNA Malik, NMA Latiff, NE Ghazali, MA Baharudin. Smart home garden irrigation system using Raspberry Pi. 2017 IEEE 13th Malaysia International Conference on Communications (MICC), Johor Bahru. 2017: 101-106.

30. Al-Ali, AR, Qasaimeh, Al-Mardini, Radder, & Zualkernan I. A. (2015). ZigBee-based irrigation system for home gardens. Communications, Signal Processing, and their Applications (ICCSPA). 2015.

31. Abbas, Mohammed, Gehad Mostafa Ahmed, Eman Adel Ahmed, & Seoud. Smart watering system for gardens using wireless sensor networks (WSN). Engineering and Technology (ICET). 2014.

32. Divani, Patil, & Punjabi. Automated plant watering system. Computation of Power, Energy Information and Commuincation (ICCPEIC). 2016.

33. Chawla, Kapoor, Sharma, Shukla, Gupta, Kaushik, & Pushkar. App based Garden Bot for Regulation of Water Level in plants. International Research Journal of Engineering and Technology (IRJET). 2016; 3(10): 1208-1212.

34. Shenoy, Pingle. IoT in agriculture. Computing for Sustainable Global Development (INDIACom), 2016 3rd International Conference on. 2016.

35. X Aktham Hasan Ali, Raad Farhood Chisab, Mohannad Jabbar Mnati, A smart monitoring and controlling for agricultural pumps using LoRa IoT technology. Indonesian Journal of Electrical Engineering and Computer Science. 2019; 13(1): 286-292.

36. Abd, S., Zainal, H., & Ibrahim, S. N. (2015). Web-based Monitoring of an Automated Fertigation System : An IoT Application. 2015 IEEE 12th Malaysia International Conference on Communications (MICC), 1–5 https://doi.org/10.1109/MICC.2015.7725397

37. Barradas, J. M. M., Matula, S., & Dolezal, F. (2012). A Decision Support System-Fertigation Simulator (DSS-FS) for design and optimization of sprinkler and drip irrigation systems. Computers and Electronics in Agriculture, 86, 111–119. https://doi.org/10.1016/j.compag.2012.02.015

38. José, A., Neto, S., Zolnier, S., & Carvalho, D. De. (2014). Development and evaluation of an automated system for fertigation control in soilless tomato production, 103, 17–25. https://doi.org/10.1016/j.compag.2014.02.001

39. Joseph, C., Thirunavuakkarasu, I., Bhaskar, A., & Penujuru, A. (2017). Automated fertigation system for efficient utilization of fertilizer and water

40. Mohamed, O., & Ahmed, E. (2018). A Design of an Automated Fertigation System Using IoT. 2018 International Conference on Computer, Control, Electrical, and Electronics Engineering (ICCCEEE), 1–5

41. Samsuri, S. F. M., Ahmad, R., & Hussein, M. (2010). Development of nutrient solution mixing process on time-based drip fertigation system. Asia Modelling Symposium 2010 -4th International Conference on Mathematical Modelling and Computer Simulation

42. S. A. H. Z. Abidin and S. N. Ibrahim, "Web-based monitoring of an automated fertigation system: An IoT application," 2015 IEEE 12th Malaysia International Conference on Communications (MICC), Kuching, 2015, pp. 1-5doi: 10.1109/MICC.2015.7725397

43. Hazilah Mad Kaidi et al., International Journalof Integrated Engineering Vol. 12 No. 6 (2020) p. 55-61

44. Zhang, Peng & Liang, Jun & Zhang, Feng. (2017). An Overview of Different Approaches for Battery Lifetime Prediction. IOP Conference Series: Materials Science and Engineering. 199. 012134. 10.1088/1757-899X/199/1/012134.

45. J. Toldinas, B. Lozinskis, E. Baranauskas and A. Dobrovolskis, "MQTT Quality of Service versus Energy Consumption," 2019 23rd International Conference Electronics, 2019, pp. 1-4, doi: 10.1109/ELECTRONICS.2019.8765692.

46. A. Khan, S. Aziz, M. Bashir and M. U. Khan, "IoT and Wireless Sensor Network based Autonomous Farming Robot," 2020 International Conference on Emerging Trends in Smart Technologies (ICETST), 2020, pp. 1-5, doi: 10.1109/ICETST49965.2020.9080736.