



**Internet of Things Technology for Greenhouse
Monitoring and Management System Based on
Wireless Sensor Network**

by

AHMAD ASHRAF BIN ABDUL HALIM

1530211732

A thesis submitted in fulfillment of the requirements for the degree of
Master of Science in Computer Engineering

**School of Computer and Communication Engineering
UNIVERSITI MALAYSIA PERLIS**

2017

UNIVERSITI MALAYSIA PERLIS

DECLARATION OF THESIS

Author's Full Name : Ahmad Ashraf Bin Abdul Halim
Date of Birth : 06/02/1991
Title : Internet of Things Technology for Greenhouse Monitoring and
Management System Based on Wireless Sensor Network
Academic Session : 2015-2017

I hereby declare that this thesis becomes the property of Universiti Malaysia Perlis (UniMAP) and to be placed at the library of UniMAP. This thesis is classified as:

- CONFIDENTIAL** (Contains confidential information under the Official Secret Act 1997)*
- RESTRICTED** (Contains restricted information as specified by the organization where research was done)*
- OPEN ACCESS** I agree that my thesis to be published as online open access (Full Text)

I, the author, give permission to reproduce this thesis in whole or in part for the purpose of research or academic exchange only (except during the period of _____ years, if so requested above)

Certified by:

SIGNATURE

SIGNATURE OF SUPERVISOR

910206-14-5575

ASSOC. PROF. DR. MOHD
NAJMUDDIN BIN MOHD HASSAN

(NEW IC NO. /PASSPORT NO.)

NAME OF SUPERVISOR

Date:

Date:

ACKNOWLEDGMENT

First and foremost, all praise and gratitude due to ALLAH, the most gracious and the most merciful for giving me the continuous strength and guidance in completing this master study.

I would like to convey my sincere gratitude and respect to my supervisor Associate Professor Dr. Mohd Najmuddin Mohd Hassan and my co-supervisor Dr. Ammar Zakaria for their conscientious guidance, motivating support and encouragement to accomplish this master thesis. Thank you very much indeed, for their suggestions, critics and guidance.

I extended my warmest gratitude to all my friends who directly or indirectly helped me to complete this project. I would like to thank Mohd Aliff and Malik for their thoughts and guidance in programming, useful feedback and comments that helped me to improve this project. To all my friends in CEAStech and Mechatronic Postgraduate Lab, your help and encouragement are greatly appreciated.

I would like to thank my family and my in-law for their constant moral support and encouragement during the period of my study and throughout my life. Special thanks to my beloved wife, Fatinnabila for her unconditional love and never ending support. I would not be the person who I am now without their continuous support.

Special thanks to my sponsors, Universiti Malaysia Perlis (UniMAP) and Ministry of Higher Education (MOHE) for their support. I would like to acknowledge with much appreciation to CEASTech that gave me the permission to use the required equipment and materials to complete my task.

Last but not least, I would like to take this opportunity to express my sincere thanks for those who have involved and supported me towards the successful completion of my master thesis.

TABLE OF CONTENT

DECLARATION OF THESIS	I
ACKNOWLEDGMENT	II
TABLE OF CONTENT	III
LIST OF FIGURES	VIII
LIST OF TABLES	XI
LIST OF ABBREVIATIONS	XII
LIST OF SYMBOL	XIV
ABSTRAK	XV
ABSTRACT	XVI
CHAPTER 1 INTRODUCTION	1
1.1 Problem Statement and Proposed Solution	2
1.2 Objectives	4
1.3 Scope of Study	4
1.4 Thesis Organization	5
CHAPTER 2 LITERATURE REVIEW	6
2.1 Introduction	6
2.2 Plant Physiology	6
2.2.1 Plant Development vs. Plant Growth	7
2.2.2 Environmental Factor Affecting Plant Growth Phases	10
2.2.3 Effect of Temperature	11

2.2.4	Effects of Humidity	13
2.2.5	Effects of Soil Moisture	14
2.2.6	Effects of Light	16
2.2.7	Effects of Carbon Dioxide	18
2.3	Internet of Things (IoT)	19
2.3.1	The Fundamental Characteristics of The IoT	21
2.3.2	IoT Components	22
2.3.3	IoT Application in Agriculture	22
2.4	Technologies of Wireless	23
2.4.1	IEEE 802.11	24
2.4.2	IEEE 802.15.1	25
2.4.3	IEEE 802.15.4 (ZigBee)	26
2.4.3.1	ZigBee Architecture	27
2.4.3.2	ZigBee Protocol Stack	29
2.4.3.3	ZigBee Topology	31
2.4.4	Comparison between Wi-Fi, Bluetooth and ZigBee	33
2.4.5	Applications of WSN	34
2.4.6	Related Work	36
2.5	Research Gap and Proposed Solution	42
2.6	Summary	43
CHAPTER 3 METHODOLOGY		45
3.1	Introduction	45
3.2	Research Design	45
3.3	System Development Design	46

3.3.1	Sensor Base	48
3.3.2	Main Base	48
3.3.3	Actuator Base	49
3.3.4	Client Base	50
3.4	System Architecture	52
3.4.1	Sensor Device	52
3.4.1.1	LDR	53
3.4.1.2	LM35	53
3.4.1.3	DHT22	54
3.4.1.4	SN-Moisture-Mod	55
3.4.1.5	CDM 4161A	55
3.4.2	Transceiver Device	56
3.4.3	Processing Device	57
3.4.4	Analog Digital Conversion	58
3.4.5	Development Platform (programming)	59
3.5	Hardware System Design Prototype	60
3.5.1	Sensor Base Hardware Design	60
3.5.2	Main Base Hardware Design	63
3.5.3	Actuator Base Hardware Design	64
3.5.4	Client Base Hardware Design	65
3.6	Software System Design	66
3.6.1	Sensor Base Software Design	66
3.6.2	Main Base Software Design	69
3.6.3	Actuator Base Software Design	70
3.6.4	Client Base Software Design	71

3.7	ZigBee Wireless Module	75
	3.7.1 ZigBee Configuration	76
3.8	Method of System Analysis	78
3.9	Experimental Method	78
	3.9.1 WSN Performance	79
	3.9.1.1 RSSI, Displacement and Packet Loss Test	79
	3.9.1.2 Zigbee Load Test	82
	3.9.2 Scheduler System Verification	84
	3.9.2.1 Light Ambiance Test Steps	84
	3.9.2.2 Temperature Test Steps	86
	3.9.2.3 Humidity Test Steps	87
	3.9.2.4 Soil Moisture Test Steps	89
	3.9.2.5 Carbon Dioxide Test Steps	90
3.10	Summary	92
CHAPTER 4 RESULTS AND DISCUSSIONS		94
4.1	Introduction	94
4.2	WSN Performance	94
	4.2.1 RSSI, Displacement and Packet Loss Test	94
	4.2.2 Zigbee Load Test	96
4.3	Scheduler System Verification	98
	4.3.1 Light Control	98
	4.3.2 Temperature Control	100
	4.3.3 Humidity Control	102
	4.3.4 Soil Moisture Control	104

4.3.5	Carbon Dioxide Control	105
4.4	GUI Final Design	107
4.4.1	Server-Client Application	107
4.4.1.1	Login Section	108
4.4.1.2	Scheduler Section	109
4.4.2	IoT Platform Application	111
4.5	Summary	113
CHAPTER 5 CONCLUSION AND RECOMMENDATIONS		116
5.1	Introduction	116
5.2	Conclusion	116
5.3	Future Recommendation	118
REFERENCES		120
APPENDIXES		126
LIST OF PUBLICATIONS		133
LIST OF AWARDS		135

LIST OF FIGURES

NO.	PAGE
Figure 2.1: Harumanis plant growth phase	8
Figure 2.2: Environmental factor which affect plant growth	11
Figure 2.3: Growth response for broccoli and maize crop vs. temperature	12
Figure 2.4: Soil at diffeent moisture levels	15
Figure 2.5: Graph for human eye sensitivity and plant sensitivity	16
Figure 2.6: IoT environment	19
Figure 2.7: Tree of IoT overview	20
Figure 2.8: ZigBee network	28
Figure 2.9: ZigBee protocol stack	29
Figure 2.10: ZigBee topology	31
Figure 2.11: Network architecture	37
Figure 2.12: Topology WSN	38
Figure 2.13: Ladder logic	39
Figure 2.14: Development process of greenhouse monitoring	40
Figure 2.15: System architecture	41
Figure 2.16: Summary of Chapter 2	44
Figure 3.1: Research methodology flowchart	46
Figure 3.2: Overall system design architecture	47
Figure 3.3: Server-client model	50
Figure 3.4: Overall system design flowchart	51
Figure 3.5: LDR sensor	53
Figure 3.6: (a) LM35 sensor; (b) LM35 characteristic	54
Figure 3.7: (a) DHT22 sensor; (b) Humidity Sensing Components	54
Figure 3.8: SN-moisture-mod sensor	55
Figure 3.9: CDM4161A Sensor	56
Figure 3.10: XBee module	57
Figure 3.11: Arduino genuino uno microcontroller	57
Figure 3.12: Analog to digital conversion process	58
Figure 3.13: System block diagram	60
Figure 3.14: Automated system (a) Greenhouse box setup; (b) Sensor circuit design	61
Figure 3.15: Pin connection between arduino genuino uno and Xbee S1	62

Figure 3.16: Layout of main base	63
Figure 3.17: Pin connection between arduino genuino uno and NodeMcu	65
Figure 3.18: Sensor and actuator initialization	67
Figure 3.19: Environmental sensor data initialization	67
Figure 3.20: IDE serial monitor	68
Figure 3.21: Data printed in IDE serial monitor	68
Figure 3.22: Arduino data acquisition	69
Figure 3.23: Data manipulation with treshold limit	70
Figure 3.24: Output or actuator initialization	70
Figure 3.25: Actuator switching initialization	71
Figure 3.26: Server-Client coding	71
Figure 3.27: Programming in NodeMcu for arduino connection to ThingSpeak	72
Figure 3.28: Channel setting in ThingSpeak	73
Figure 3.29: API key in ThingSpeak	74
Figure 3.30: Designer for the build apps	75
Figure 3.31: Command blocks for build apps application	75
Figure 3.32: X-CTU dashboard (PC Settings)	76
Figure 3.33: X-CTU dashboard (Terminal)	77
Figure 3.34: Method of analysis	78
Figure 3.35: RSSI, displacement and packet loss test setup	81
Figure 3.36: RSSI, displacement and packet loss setup steps	82
Figure 3.37: Zigbee load test setup	83
Figure 3.38: Zigbee load test setup steps	83
Figure 3.39: Light ambiance test steps	85
Figure 3.40: Temperature test steps	86
Figure 3.41: Humidity test steps	88
Figure 3.42: Soil moisture test steps	89
Figure 3.43: Carbon dioxide test steps	91
Figure 3.44: Summary of Chapter 3	93
Figure 4.1: Graph of RSSI, displacement and packet loss experiment	95
Figure 4.2: Zigbee load test graph	97
Figure 4.3: Graph of light test result	99
Figure 4.4: Graph of temperature test result	101
Figure 4.5: Graph of humidity test result	103

Figure 4.6: Graph of soil moisture test result	104
Figure 4.7: Graph of carbon dioxide test result	106
Figure 4.8: GUI design flowchart	108
Figure 4.9: Login section	109
Figure 4.10: Crop detail section	110
Figure 4.11: The Tree apps in phone application	111
Figure 4.12: GUI in mobile apps	112
Figure 4.13: IoT platform design flowchart	113
Figure 4.14: Summary of Chapter 4	115

©This item is protected by original copyright

LIST OF TABLES

NO.	PAGE
Table 2.1: Plant development vs. plant growth	8
Table 2.2: Type of light and characteristic	17
Table 2.3: Comparison of different wireless standard	25
Table 2.4: Advantage and disadvantage between star, mesh and tree topology	32
Table 2.5: Wi-Fi, Bluetooth and ZigBee characteristic	33
Table 2.6: Summary of related work	41
Table 3.1: Hardware and software	52
Table 3.2: List of sensors used in this project	52
Table 3.3: Comparison between C, C++ and C#	59
Table 3.4: Sensor Base Hardware	62
Table 3.5: Main Base Hardware	63
Table 3.6: Actuator Base Hardware	64
Table 3.7: Client Base Hardware	65
Table 3.8: Rule condition for light ambiance test	85
Table 3.9: Rule condition for temperature test	87
Table 3.10: Rule condition for humidity test	88
Table 3.11: Rule condition for soil moisture test	90
Table 3.12: Rule condition for CO ₂ test	91
Table 4.1: Rule condition for light test	99
Table 4.2: Rule condition for temperature test	100
Table 4.3: Rule condition for humidity test	102
Table 4.4: Rule condition for soil moisture test	104
Table 4.5: Rule condition for CO ₂ test	105

LIST OF ABBREVIATIONS

ADC	Analog Digital Conversion
AFH	Adaptive Frequency Hoping
AP	Access Point
API	Application Program Interface
CPU	Central Processing Unit
DAN	Desk Area Network
DVD	Digital Video Disk
dBm	Decibels
ES	Electromagnetic Spectrum
EDR	Enhanced Data Rate
FHSS	Frequency Hopping Spread Spectrum
GSM	Global System for Mobile communication
GUI	Graphical User Interface
HCL	Human Computer Interaction
HS	High Speed
IC	Integrated Circuit
IDE	Integrated Development
IoT	Internet of Things
IP	Internet Protocol
ISM	Industrial, Scientific and Medical
IT	Information Technology
LAN	Local Area Network
LCD	Liquid Crystal Display
LDR	Light Dependent Resistor
LED	Light Emitting Diode
LTE	Long-Term Evolution
MAC	Media Access Protocol
MQTT	Message Queue Telemetry Transport
OSI	Open System Interconnection
PAN	Personal Area Network
PAR	Photo-synthetically Active Radiation

PC	Personal Computer
PIC	Peripheral Interface Controller
PLC	Programmable Logic Control
PLR	Packet Loss Rate
RX	Receiver
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SMS	Short Message Services
TX	Transmitter
USB	Universal Serial Bus
UV	Ultra Violet
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network
6LoWPAN	IPv6 over low-power Wireless Personal Area Network

©This item is protected by original copyright

LIST OF SYMBOL

CO_2	Carbon Dioxide
H_2O	Water
CH_2O	Carbohydrate
O_2	Oxygen

©This item is protected by original copyright

Teknologi Internet Benda bagi Pemantauan dan Pengurusan Rumah Hijau Berdasarkan Rangkaian Penderia Tanpa Wayar

ABSTRAK

Perkembangan dalam teknologi pertanian memainkan peranan yang amat penting dalam pengeluaran hasil tanaman dari rumah hijau khusus bagi penanaman buah-buahan, bunga-bunga atau sayur-sayuran yang mempunyai nilai komersial yang tinggi. Memantau dan memastikan tumbuhan mendapat nutrien yang secukupnya pada setiap fasa dalam kitaran pertumbuhan tanaman adalah amat penting untuk mengekalkan hasil dan kualiti pengeluaran yang terbaik. Walaubagaimanapun, pemantauan secara konvensional terhadap tanaman rumah hijau berskala besar adalah tidak efisien, melibatkan kos yang tinggi dan penggunaan tenaga buruh yang ramai. Projek ini memperkenalkan konsep penjadualan mengikut keperluan tanaman di setiap fasa pertumbuhan untuk meningkatkan keberkesanan penghasilan dan pengeluaran yang optimum. Konsep penjadualan ini juga merupakan satu sumbangan bagi projek penyelidikan yang dilaksanakan dan dipercayai tiada lagi kajian khusus berkaitan sistem automasi dalam konsep penjadualan mengikut kitaran dan fasa-fasa tertentu dalam tanaman. Beberapa pengukuran keadaan persekitaran rumah hijau perlu di cerap bagi melaksanakan sistem automasi pengurusan rumah hijau di dalam projek ini. Penggunaan rangkaian kabel di persekitaran rumah hijau berskala besar yang terdedah kepada faktor luar akan meningkatkan kos pemasangan dan ianya lebih berisiko selain daripada pemasangan yang lebih rumit dan kesukaran dalam penyelenggaraan. Oleh itu, rangkaian penderia tanpa wayar (WSN) yang terdiri daripada nod sensor tanpa wayar yang bersaiz kecil menggunakan teknologi ZigBee merupakan pilihan yang terbaik dan menjimatkan kos untuk membina sistem yang dicadangkan. WSN digunakan bagi mengesan dan memantau suhu, kelembapan, cahaya, kelembapan tanah dan karbon dioksida. Parameter ini dipilih kerana ianya adalah komponen penting di dalam proses fotosintesis tumbuhan. Jadual bagi sistem automasi ini dibangunkan menggunakan bahasa pengaturcaraan Visual Basic C# untuk melakukan penganalisan maklumat dan memaparkannya dalam masa nyata (real-time). Apabila WSN mengesan keadaan persekitaran tumbuhan di luar kondisi optimum yang diperlukan mengikut fasa-fasa yang telah ditetapkan, maka sistem ini akan mengaktifkan penggerak (actuator) untuk menstabilkan kembali keadaan persekitaran agar tumbuhan kekal berada di tahap optimum. Projek ini juga mengkaji prestasi WSN dengan melaksanakan ujian kedudukan dengan jarak yang bersesuaian antara nod dan ujian keboleharapan data. Sistem automasi pengurusan rumah hijau ini memperkasakan Internet Benda (IoT) dengan penggabungan teknologi deria elektronik, rangkaian tanpa wayar serta pengaturcaraan komputer. Sistem yang dibangunkan ini dijangka akan dapat meningkatkan pengeluaran hasil tanaman dari rumah hijau, memaksimumkan keuntungan dan seterusnya menjadi pemangkin kearah pengurusan perladangan yang cekap (precision farming).

Internet of Things Technology for Greenhouse Monitoring and Management System Based on Wireless Sensor Network

ABSTRACT

The rapid development of agrotechnology is playing an important role in the production of greenhouse plantation for cultivating high value fruits, flowers or vegetables. It is imperative to constantly monitor these high value crops optimal requirements at every phase of the plant growth cycle to maintain the best quality production. However, traditional manual inspection, data collection and control method for large-scale greenhouse plantation deemed inefficient with high costs, time consuming and laborious. This project introduces a scheduler to enhance greenhouse management by taking into considerations the different phases of plant growth. The scheduling concept is also a contribution to this research projects implemented and it is believed there is no specific study on scheduling concepts in the automation system according to specific cycles and phases in the crop. Measuring several points in a greenhouse are required to trace down the local climate parameters to ensure the automation system works properly. Cabling would make the measurement system expensive and vulnerable in a large greenhouse plantation. Moreover, the cabled measurement points are complicated and difficult to maintain and relocate once they are installed. Thus, a Wireless Sensor Network (WSN) consisting of small-size wireless sensor nodes based on ZigBee technology is an attractive and cost-efficient option to build the required system. The system is used to sense and monitor the temperature, humidity, light, soil moisture and carbon dioxide which are essential in the photosynthesis process. The scheduler is build using Visual Basic C# to analyse, display and control the actuators in real-time. The system through the scheduler will sense the climate conditions, analyse it and trigger the actuator should the measurement is not within the specified region. These tasks are performed to ensure optimal conditions at different phases of plant growth are achieved. The system performance is also measured to confirm efficient deployment and data reliability in this project. The convergence of embedded electronic sensing, wireless networking and computer science promotes Internet of Things (IoT) in the system. It is expected that the developed system will increase greenhouse production efficiency, profitability and concurrently realising precision greenhouse management.

CHAPTER 1

INTRODUCTION

In the future, the climate change, population growth, increasing of food prices, and environmental stressors will have significant impacts on food security. Food security, as defined by the United Nations Committee on World Food Security, is the condition in which all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2006).

In order to ensure and sustain food security that able to feed around 9.1 billion world population by 2050 (FAO, 2009), agrotechnology will play an important role in maximizing the production and quality of high value crops and sensitive plants. Conventional method of agriculture in open field is susceptible to extreme sunlight (solar radiation), high or low rainfall, weed competition, pest and disease. Greenhouse has been widely used in precision agriculture to acquire the best quality for production of fruits or vegetables (Rezuwan, 2008; Smith et al., 2010; UKCES, 2011). However, a fully automated system taking into considerations the different phases of plants growth and the optimal requirement by the plants during these growth period and cycle is not fully designed and available. The optimal plant growth depends on several parameters which are temperature, soil moisture, humidity, radiation of light and carbon dioxide (D.D.Chaudhary et al., 2011).

In the last decade there have been tremendous advancements using WSN (WSN) technology for agriculture (D.D.Chaudhary et al., 2011). WSN enabling technology for efficient and inexpensive precision agriculture includes collecting, storing and sharing

sense data. In general it consists of a large number of low-cost and low-power multifunctional sensor nodes that are deployed in the area of interest. In WSN, the nodes communicate wirelessly over short distance and are capable of organizing themselves in an autonomous multi-hop mesh network. Thus, WSN is proposed as part of the technology to be deployed in this system. The sensor nodes collect information about the greenhouse parameter and communicate over a network to a computer system which is called a base station or sink (Kodali et al., 2014). Then the system will respond according to the threshold limit set by the scheduler that has been designed.

This research project proposed a scheduling method for monitoring and management of greenhouse crops in real-time. The system ensures the crops maintains its optimum condition by introducing interventions based on the selected parameters of the growth phases. This concept of scheduling realizes a fully integrated and automated greenhouse monitoring and management system. This system is also flexible to suits to many types of plants in the greenhouse.

1.1 Problem Statement and Proposed Solution

Three (3) main problems identified in the current greenhouse monitoring and management system are:

- a) Engaging in large scale greenhouse requires many labor to work at the fields by way of traditional approach of agriculture. Rigorous automated scheduling according to each phase of the plant growth cycle is still not designed and available, in order to ensure the plant receive optimal requirement. By promoting automated scheduling, any problems, irregular conditions or

unwanted scenarios within the greenhouse environment can be monitored and managed effectively. Human intervention only occur when it is required, hence improving labor productivity and resource utilization.

- b) Deploying wired network in outdoor environment and in large scale greenhouse ground is complicated and requires cables to be laid around the fields which can create trip hazards and exposure to moisture and severe weather conditions. These risks may lead to sensing and actuator unreliability issue. Wireless networks have much less cabling which leads to better field working environment and simple to deploy with conscientious network planning.
- c) Information and data collection to measure against farm yield in the traditional way is troublesome as it is done manually. Manual keying in the data may lead to human error. Loosing datasheets, analyzing and plotting the data can be a lengthy process. Limitations to access latest update from the greenhouse in real-time will lead to early action cannot be taken if there is unreliability issues occurred. Automation with efficient data storage and real-time visualization in Internet of Things (IoT) environment can highly assist in supporting new formula in precision farming. Moreover with real-time data and control, enable the user to realize a true remote monitoring system.

1.2 Objectives

This research propose a precision agriculture system and scheduler management in greenhouse by applying IoT and WSN. In order to design a Graphical User Interface (GUI) system, Visual Studio C# is used. Based on the problem statement, four (4) main objectives have been identified:

1. To deploy WSN for local data and control signal transmission.
2. To develop and manage a scheduling method of plant monitoring in real-time for every phases of its growth cycle.
3. To develop a cloud based remote monitoring system using IoT technology and design a user experience dashboard for greenhouse monitoring and management system.

1.3 Scope of Study

The goal of this research is to develop an automated system that can monitor the plant growth from a selected parameter to ensure the plant received optimum requirement for higher quality production. This system consists of; sensor base, main base, actuator base and client base to display output. This study is bounded for greenhouse crops in a control environment and Harumanis Mango plant has chosen as a subject. This project involve input from agricultural practitioners and the farmers to obtain the best agricultural practices such as the threshold limit for each parameter and information on crop requirements for each phase of the plant growth.

1.4 Thesis Organization

This thesis is organised as follows; *Chapter 2* presents the literature review on agrotechnology and similar project carried out by other researchers. This chapter explains the plant physiology focussed on environmental factors and plant growth development. It provides the fundamental characteristic, components, and possible application of IoT. This chapter then discusses on various technologies of wireless information, comparison and applications.

Chapter 3 describes about the methodology of the research and the design on the experimental setup. This chapter also provides methods of analysis used to evaluate the collected data obtain through experimental study.

Chapter 4 presents the experimental test for the scheduler conducted under different conditions. This chapter also presents the results and discussion for test conducted from the WSN and system performance test. In this chapter, the utilisation of IoT and GUI final design are discussed in detail.

Finally *Chapter 5* presents the conclusion of this thesis. Research limitation and recommendations for future research directions.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

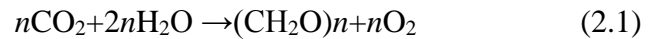
This chapter provides information about the plant physiology in detail, specifically on the plant development, plant growth, and environmental factors affecting each phases of the plant growth. Section 2.3 in this chapter present related research work and also the fundamental characteristic, components and application in IoT. Apart from that, existing wireless technologies, comparison, and application of WSN are introduced in detail under Section 2.4; wireless technologies.

2.2 Plant Physiology

A plant that grow on soil and on water, or on other plants, usually has a stem, leaves, roots, and flowers and produces seeds. Plant provide human and animal with food, oxygen, fibre, shelter or habitats, medicine and fuel. The basic food for all organism in this world is produced by green plants. Green plants are the primary producers of food for the rest of the biological world, food that is subsequently converted to growth energy nutrients from the soil and carbon dioxide from the atmosphere in a process called photosynthesis process.

Photosynthesis is defined as the process by which light energy is absorbed by green plants and produced carbohydrate are synthesized from carbon dioxide (CO₂) and

water (H₂O). It is essentially an energy transfer reaction and this process is occur in the chloroplast of leaves. This process nourishes almost all entire living world directly or indirectly. To show the overall process of photosynthesis, the simplified equation is use (Campbell et al., 2014):



Where n is the number of molecules of CO₂ carbon dioxide that combine with H₂O water to form carbohydrate (CH₂O) _{n} , releasing n molecules of oxygen (O₂) to the surrounding.

2.2.1 Plant Development vs. Plant Growth

Growth is the manifestation of life for all living things. Plant growth refers to a quantitative increase in size of volume of a cell, tissue, or organism. It occurs because of metabolic energy and cell division is accompanied by an increase in cell size. While development is a summation of all activities leading to change in a cell, tissue, and organism (Parker, 2009). The differentiation between plant development and plant growth explained in Table 2.1 (Bareja, 2015).

All type of plant has its own cycle according to a specific time period divided into certain phases according to the respective parameters requirements. UniMAP is the pioneer university for Harumanis projects to improve the quality and quantity of products through greenhouse technology and research development (Saari, 2015). Therefore, the review of the crop in this research project is mostly related to the cultivation of Harumanis based on the cycle and parameter requirements according to certain phases.