

IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

THESIS

**Proposed as a requirement for obtaining
Sarjana degree at
Business Information Systems
Master Track (Macquarie) – Information Systems Management
Education Level Strata-1 (Sarjana/Bachelor)**

by

Jason Alexander Tan 2440042310



**BINUS INTERNATIONAL
BINUS UNIVERSITY
JAKARTA
2024**

IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO & CLOUD

THESIS

Prepared by:

**Jason Alexander Tan
2440042310**

Approved by:

Supervisor

**Samuel Mahatmaputra T, S.Kom., M.Info.Tech
Lecture Code : D2131**

**BINUS UNIVERSITY
Jakarta
2024**

**STATEMENT FROM BOARD
OF EXAMINERS
GOES HERE**

**STATEMENT FROM BOARD
OF EXAMINERS
GOES HERE**

**STATEMENT FROM BOARD
OF EXAMINERS
GOES HERE**

**STATEMENT FROM BOARD
OF EXAMINERS
GOES HERE**

PERNYATAAN
STATEMENT

Dengan ini, saya/kami,

With this, I/We,

Nama (Name): JASON ALEXANDER TAN

NIM (Student ID): 2440042310

Judul Tesis (Thesis Title): IOT ENABLED HYDROPONIC FARM
MONITORING USING ARDUINO & CLOUD

Memberikan kepada Universitas Bina Nusantara hak non-eksklusif untuk menyimpan, memperbanyak, dan menyebarluaskan tesis saya/kami, secara keseluruhan atau hanya sebagian atau hanya ringkasannya saja, dalam bentuk format tercetak atau elektronik.

Hereby grant to my/our school, Bina Nusantara University, the non-exclusive right to archive, reproduce, and distribute my/our thesis, in whole or in part, whether in the form of a printed or electronic format.

Menyatakan bahwa saya/kami, akan mempertahankan hak exclusive saya/kami, untuk menggunakan seluruh atau sebagian isi tesis saya/kami, guna mengembangkan karya di masa depan, misalnya dalam bentuk artikel, buku, perangkat lunak, ataupun sistem informasi.

I/We acknowledge that I/we retain exclusive rights of my/our thesis by using all or part of it in a future work or output, such as an article, a book, software, or information system.

Catatan: Pernyataan ini dibuat dalam 2 (dua) bahasa, Indonesia dan Inggris, dan apabila terdapat perbedaan penafsiran, maka yang berlaku adalah versi Bahasa Indonesia.

Note: This Statement is made in 2 (two) languages, Indonesian and English, and in the case of a different interpretation, the Indonesian version shall prevail.

Jakarta, 11/04/2023

Jason Alexander Tan
2440042310

BINUS INTERNATIONAL
BINUS UNIVERSITY

Business Information Systems

Master Track (Macquarie) – Information Systems Management

Sarjana Komputer Thesis

Odd Semester 2023

**IOT ENABLED HYDROPONIC FARM MONITORING USING ARDUINO &
CLOUD**

Jason Alexander Tan

2440042310

Abstract

This case study focuses on the development of an Arduino and PHP based integrated hydroponic farm monitoring system by leveraging IoT and cloud technologies. The system's objective is to deliver relevant environmental parameter data, such as parts per million (PPM), pH levels, CO₂ levels, humidity, and temperature, to greatly optimize the routine hydroponic monitoring activity performed by JUST HYDROPONICS.

Preliminary information collection is done qualitatively, which is used in the system's conception process. The Arduino is used as the sensor. The detailed specifications of the Arduino's software and hardware are discussed in detail, including the specific models of the components and subcomponents used in the creation of the Arduino prototype, which are specifically compatible with Arduino. The web application provides the users with an interface to visualize the collected data. The web API, which is built into the web application serves as a receiver for data from the Arduino. The design of the web application and API are also discussed in detail. The cloud platform provides application hosting, data storage, and remote access to the system.

Primary evaluation of the system's performance is done by studying the system's accuracy and reliability. A secondary evaluation is done qualitatively by directly interviewing JUST HYDROPONICS's owners & management about the system's impact and effectiveness.

The findings of this case study contribute to the progress of research on IoT and precision agriculture, which are highly important fields in addressing the sustainability and security of food in the world. The findings of this case study should be easily adaptable to a variety of hydroponic farm types.

Key Words

IOT, Hydroponic, Farm, Arduino, Cloud

Acknowledgements

This case study is dedicated to a few people, without whom I would have to endure unspeakable difficulties to get to where I am today. Words alone cannot express how grateful I am to have their unyielding support and company.

1. To my core family, especially my mother, to whom I owe everything.
2. To my extended family, which have been so kind and supportive as to allow me to use their business as the object of this case study and put up with my annoyingly large number of questions.
3. To my girlfriend, for her unwavering support, for her words of encouragement, and for her extraordinary ability to calm me down when times are difficult.
4. To my closest friends, for their invaluable friendship, their company, and the laughs we shared, which has opened many doors to me, be it physical, mental, or emotional.
5. To my thesis supervisor, Samuel Mahatmaputra T, S.Kom., M.Info.Tech., for providing me with invaluable guidance and inspiration during my thesis period and throughout the years since I started studying in Binus International, for being the lecturer who taught me the very lessons that are quintessential to my ability to perform this case study, for being the anchor of stability in my efforts of navigating Binus's bureaucratic nightmare for Master Track, all of which were crucial in enabling me to finish this case study.

Table of Contents

Statement From Board of Examiners.....	iii
Personal Statement.....	iv
Abstract.....	v
Acknowledgements.....	vi
Table of Contents.....	vii
List of Tables.....	xi
List of Figures.....	xii
Chapter 1 – Introduction.....	1
1.1 Introduction.....	1
1.2 Background.....	1
1.3 Object of Study.....	3
1.4 Case Study Objectives.....	4
1.5 Research Questions.....	5
1.6 Hypothesis.....	5
1.7 Scope & Limitations.....	8
1.8 Case Study Outline.....	9
1.8.1 Chapter 1 - Introduction.....	9
1.8.2 Chapter 2 – Theoretical Foundation.....	10
1.8.3 Chapter 3 – Problem.....	10
1.8.4 Chapter 4 – Solution Design.....	10
1.8.5 Chapter 5 – Solution Implementation.....	11
1.8.6 Chapter 6 – Evaluation & Discussion.....	11
1.8.7 Chapter 7 – Conclusion & Recommendation.....	11
Chapter 2 – Theoretical Foundation.....	12
2.1 Theoretical Foundation of the Hydroponic Sensor.....	12
2.1.1 Arduino Uno.....	12
2.1.2 Wi-Fi Module.....	15
2.1.3 Water Temperature Sensor.....	23
2.1.4 Humidity Sensor.....	27
2.1.5 CO2 Sensor.....	30
2.1.6 pH Sensor.....	36
2.1.7 PPM Sensor.....	39

2.1.8 Possible Alternatives.....	44
2.2 Theoretical Foundation of the Web Application.....	46
2.2.1 PHP.....	46
2.2.2 HTML & CSS.....	48
2.2.3 JavaScript.....	49
2.2.4 XAMPP.....	50
2.2.5 Amazon Web Services (AWS).....	52
2.3 Literature Review.....	54
2.3.1 “DIY Hydroponic Garden w/ Arduino and IoT”	55
2.3.2 “ESP8266 + Arduino + Database”	56
2.3.3 “Sending Data to Thingspeak Website Using ESP8266”	57
Chapter 3 – Problem Analysis.....	59
3.1 Current Processes.....	59
3.1.1 Data Measurement & Collection.....	59
3.1.2 Data Storage.....	60
3.2 Problem Analysis.....	60
3.2.1 Data Vulnerability.....	60
3.2.2 Arduous Data Management.....	61
3.2.3 Labor Intensive.....	61
3.2.4 Reduces Accuracy & Inconsistency.....	62
3.2.5 Delayed Response.....	62
3.2.6 Inefficient Allocation of Financial Resources.....	63
3.3 Empathy Map.....	64
3.4 Value Proposition Canvas.....	64
Chapter 4 – Solution Design.....	66
4.1 Arduino.....	66
4.1.1 Architecture Overview.....	66
4.1.2 Loop Cycle.....	67
4.1.3 Data Collection Frequency.....	67
4.1.4 Unit Cost.....	67
4.2 Web Application.....	68
4.2.1 Architecture Overview.....	68
4.2.2 Class Diagram.....	69

4.2.3 Design Pattern.....	70
4.2.4 Use Case.....	72
4.2.5 User Interface.....	74
4.2.6 Database.....	76
4.2.7 Arduino API.....	76
4.3 Cloud Deployment.....	77
4.4 Testing Plan.....	78
Chapter 5 – System Implementation.....	80
5.1 Arduino.....	80
5.1.1 Architecture.....	80
5.1.2 Code Structure.....	82
5.1.3 The Code.....	84
5.2 Web Application.....	95
5.2.1 Application Code Structure.....	95
5.2.2 Database & API.....	99
5.2.3 Cloud Deployment.....	101
Chapter 6 – Evaluation & Discussion.....	115
6.1 Evaluation.....	115
6.1.1 Methodology.....	115
6.1.2 Arduino.....	115
6.1.3 Web Application.....	121
6.1.4 End-to-End.....	124
6.1.5 Research Questions & Hypothesis Evaluation.....	130
6.2 Discussion.....	132
6.2.1 Not Ready for Commercialization.....	133
6.2.2 Range Extension.....	133
6.2.3 Wi-Fi Reliability.....	134
6.2.4 Data Collection Frequency.....	134
6.2.5 Documentation Scarcity.....	135
6.2.6 UI Design Simplicity.....	135
Chapter 7 – Conclusion & Recommendation.....	136
7.1 Conclusion.....	136

7.2 Recommendation.....	137
References.....	139
Curriculum Vitae.....	143
Appendices.....	144

List of Tables

Table 2.1 – MH-Z19B Technical Specifications.....	30
Table 2.2 – MH-Z19B Recommended Software Settings.....	31
Table 2.3 – Specifications of the TDS Signal Transmitter Board (DFRobot, n.d.)...	40
Table 2.4 – Specifications of the TDS Probe (DFRobot, n.d.)... ..	40
Table 4.1 – Unit Cost.....	67

List of Figures

Figure 1.1 – Just Hydroponics 1.....	3
Figure 1.2 – Just Hydroponics 2.....	3
Figure 2.1 – Arduino Uno R3 16U2.....	12
Figure 2.2 – Arduino Schematic (freeCodeCamp.org, 2021)...	13
Figure 2.3 – The ESP-01 Module.....	15
Figure 2.4 – A Schematic of the ESP-01 Module (Electronoobs, 2019).....	16
Figure 2.5 – ESP-01 in Bypass Mode.....	18
Figure 2.6 – Empty Arduino Code.....	19
Figure 2.7 – The Arduino IDE Serial Monitor.....	20
Figure 2.8 – ESP-01 in SoftwareSerial Mode.....	21
Figure 2.9 – Garbled Response From ESP-01.....	23
Figure 2.10 – Two Models of the DS18B20 Sensor.....	23
Figure 2.11 – The DS18B20 Operating in External Power Mode (Maxim, 2019)...	24
Figure 2.12 – The DS18B20 Operating in Normal Mode (Santos, 2016).....	24
Figure 2.13 – The DS18B20 Operating in Parasite Power Mode (Maxim, 2019).....	25
Figure 2.14 – The DS18B20 Operating in Parasitic Power Mode (Santos, 2016).....	25
Figure 2.15 – The OneWire Library.....	26
Figure 2.16 – The DallasTemperature Library.....	26
Figure 2.17 – The DHT11 Sensor (Mouser, n.d.)...	27
Figure 2.18 – Typical Application of the DHT11 Sensor (Mouse, n.d.)...	28
Figure 2.19 – Basic Schematic of a DHT11 Sensor in Use (Campbell, 2015).....	29
Figure 2.20 – MH-Z19B Sensor (Winsen, 2016)....	30
Figure 2.21 – MH-Z19B Diagram (Winsen, 2016)	30
Figure 2.22 – The MH-Z19B Library.....	32
Figure 2.23 – MH-Z19B Schematic, Digital Mode (Fahad, 2022)...	32
Figure 2.24 – MH-Z19B, Digital Mode.....	34
Figure 2.25 – MH-Z19B Schematic, PWM Mode (IoTSpace, 2011)...	35
Figure 2.26 – PH-4502C Module (CimpleO, 2020).....	36
Figure 2.27 – The pH Probe.....	37
Figure 2.28 – A Schematic of the PH-4502C with Arduino.....	37
Figure 2.29 – PH-4502C Probe Offset Calibration.....	38

Figure 2.30 – DFRobot Analog TDS Sensor Illustration (DFRobot, n.d.)...	40
Figure 2.31 – Signal Transmitter Board (DFRobot, n.d.).....	41
Figure 2.32 – Example Use of the Analog TDS Sensor Kit (DFRobot, n.d.).....	42
Figure 2.33 – The Raspberry Pi.....	44
Figure 2.32 – NodeMCU Lolin.....	45
Figure 2.33 – XAMPP Control Panel.....	51
Figure 2.34 – The DIY Hydroponic Concept Sketch.....	55
Figure 3.1 – The HI98301 TDS Meter.....	59
Figure 3.2 – A Whiteboard Used for Storing Data.....	60
Figure 3.3 – Arduous Data Management.....	61
Figure 3.4 – Empathy Map.....	64
Figure 3.5 – Value Proposition Canvas.....	64
Figure 4.1 – Arduino System Architecture.....	66
Figure 4.2 – Process Cycle.....	67
Figure 4.3 – Web Application System Architecture.....	68
Figure 4.4 – Class Diagram.....	69
Figure 4.5 – Use Case Diagram.....	72
Figure 4.6 – User Interface, Dashboard.....	74
Figure 4.7 – User Interface, Login Page.....	75
Figure 4.8 – The Database Structure.....	76
Figure 4.9 – Superglobal URL Pattern.....	76
Figure 4.10 – AWS Cloud Architecture..	77
Figure 5.1 – Schematic of the Arduino Prototype.....	80
Figure 5.2 – The Arduino Prototype.....	81
Figure 5.3 – The File Structure.....	82
Figure 5.4 – The Web Application’s File Structure.....	95
Figure 5.5 – The Index File.....	96
Figure 5.6 – Router, Check Function.....	97
Figure 5.7 – Router, Load Function.....	97
Figure 5.8 – Controllers Abstraction Layer.....	98
Figure 5.9 – The DashboardController’s run() Function.....	98
Figure 5.10 – Database Master Table.....	99

Figure 5.11 – Database Sensors Table.....	99
Figure 5.12 – The API Code.....	100
Figure 5.13 – Deployment S1/A.....	101
Figure 5.14 – Deployment S1/B.....	102
Figure 5.15 – Deployment S2/A.....	102
Figure 5.16 – Deployment S2/B.....	103
Figure 5.17 – Deployment S2/C.....	104
Figure 5.18 – Deployment S2/D.....	105
Figure 5.19 – Deployment S2/E.....	106
Figure 5.20 – Deployment S2/F.....	106
Figure 5.21 – Deployment S3/A.....	107
Figure 5.22 – Deployment S3/B.....	108
Figure 5.23 – Deployment S3/C.....	108
Figure 5.24 – Deployment S3/D.....	108
Figure 5.25 – Deployment S3/E.....	109
Figure 5.26 – Deployment S4/A.....	109
Figure 5.27 – Deployment S4/B.....	110
Figure 5.28 – Deployment S4/C.....	110
Figure 5.29 – Deployment S4/D.....	110
Figure 5.30 – EC2 Deployment S2/A.....	111
Figure 5.31 – EC2 Deployment S2/B.....	112
Figure 5.32 – EC2 Deployment S2/C.....	112
Figure 5.33 – EC2 Deployment S2/D.....	113
Figure 6.1 – Wi-Fi Module Unit Test Setup (Serial Monitor)..	116
Figure 6.2 – Wi-Fi Module Unit Test Results (Serial Monitor)...	116
Figure 6.3 – Wi-Fi Module Unit Test Results (Database)...	116
Figure 6.4 – Water Temperature Sensor Unit Test Results.....	117
Figure 6.5 – Humidity Sensor Unit Test Results.....	118
Figure 6.6 – CO ₂ Sensor Unit Test Results.....	118
Figure 6.7 – pH Sensor Unit Test Results.....	119
Figure 6.8 – TDS Sensor Unit Test Results.....	119
Figure 6.9 – Integration Test Results (Serial Monitor)...	120

Figure 6.10 – Integration Test Results (Database)...	120
Figure 6.11 – Dashboard Display.....	121
Figure 6.12 – Sensor Selection.....	121
Figure 6.13 – Column Sorting.....	122
Figure 6.14 – Login Box.....	122
Figure 6.15 – Time Filters.....	122
Figure 6.16 – Remember Functionality.....	122
Figure 6.17 – DB Inserted.....	123
Figure 6.18 – DB Insertion Instructions.....	123
Figure 6.19 – Null Insert Test.....	123
Figure 6.20 – Partial Null Insert Test.....	123
Figure 6.21 – Partial Null Insert Instructions.....	123
Figure 6.22 – Dashboard Displaying Inserted Test Data.....	124
Figure 6.23 – Evaluation Point 1A.....	125
Figure 6.24 - Evaluation Point 1B.....	125
Figure 6.25 - Evaluation Point 2.....	125
Figure 6.26 - Evaluation Point 3.....	125
Figure 6.27 – Visualization of the Reliability Testing Results.....	126
Figure 6.28 – The Visualized Gap.....	126
Figure 6.29 – Visualization of the Reliability Testing Results (Cloud).....	127
Figure 6.30 – The Visualized Gap (Cloud).....	128
Figure 6.31 – The Main Prototype & Emulator.....	129
Figure 6.32 – Database Results for MDT.....	129
Figure A1.1 – UI Suggestion 1.....	144
Figure A1.2 – UI Suggestion 2.....	144
Figure A1.3 – UI Suggestion 3.....	145
Figure A1.4 – UI Suggestion 4.....	145