UNIVERSITY OF SCIENCE AND TECHNOLOGY OF HANOI
**MASTER**

Research and Development
# MASTER THESIS

by

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M22.ICT.003

Information and Communication Technology

Title:

## IOT data collection and preprocess method for Smart Farm prototype

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Lab name: ICT Lab

**Hanoi, September 2023**

# Declaration

I declare that the thesis is entirely my own under the guidance of Dr Nghiem Thi Phuong. I certify that the work and result are not copied/plagiarized from any sources. In addition, all assessments, comments, and statistics from other authors and organizations are indicated and have been cited accordingly. In case of plagiarism in my report, I know the consequences, and I understand that my report will not be evaluated. In this case, my master's thesis will be noted as "failed."

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Hanoi, September 2023

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(Nguyen Thi Ly Linh)

Hanoi, September 2023

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# Abstract

Smart agriculture integrates advanced technologies like IOT, Artificial Intelligence (AI), and remote monitoring to optimize farming practices. The importance of researching and applying these technologies to real-life scenarios has grown significantly in recent years. In this thesis, we study IOT data collection and preprocess method on Smart Farm Control Technology of Hanback Electronics. The works focus on SOA-based architecture, gathering data from sensors in the area to visualize those data in graphs, monitor actuators for elaborate.

**Keywords:** *Smart agriculture, IOT,SOA-based architecture, Sensors, Actuators, Monitor, Visualize*

## Chapter 1

# Introduction

## 1.1 Overview

### 1.1.1 Smart agriculture

Smart agriculture is known as precision agriculture or precision farming. It represents a contemporary farming methodology harnessing technology and data-driven solutions to optimize multiple facets of agricultural production. Its primary objective is to elevate the efficiency, sustainability, and productivity of farming practices. Some main aspects of smart agriculture in the modern day are as follows.

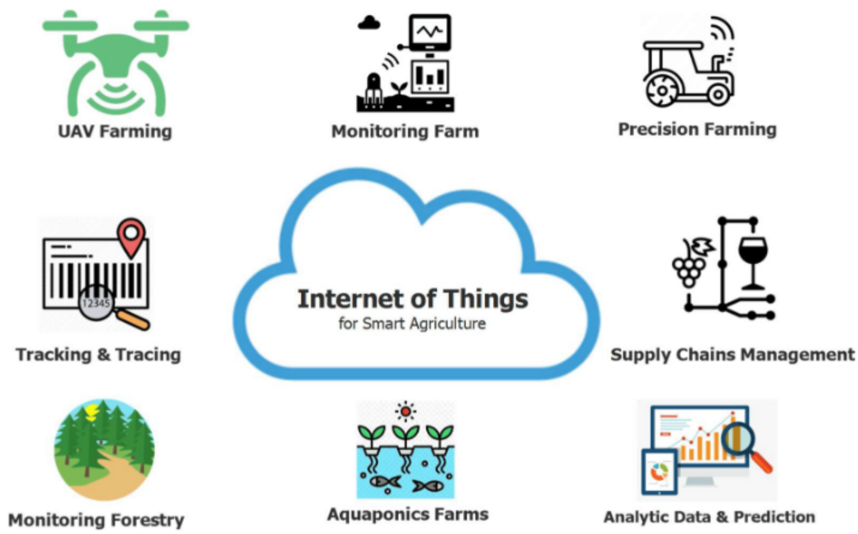


**Figure 1.1** – Smart agriculture aspects

[5]

- **IOT:** IOT devices and networks are used extensively in smart agriculture. They enable real-time communication between actuators, sensors, and farm management systems, allowing for seamless coordination and data exchange.

- **Precision Farming:** Precision agriculture techniques are at the core of smart agriculture. Farmers use Global Positioning System (GPS) technology and variable rate application systems to precisely control the distribution of inputs like water, fertilizers, and pesticides. This reduces waste and optimizes resource usage.

- **Monitoring Farm:** IOT sensors and GPS tracking are used to monitor the health, behavior, and location of livestock. This helps in early disease detection and efficient management.

- **Unmanned aerial vehicles (UAV) Farming:** UAV and drones are used for aerial imaging and data collection. They provide insights into crop health, pest infestations, and irrigation needs.

- **Tracking and Tracing:** Blockchain technology is used for supply chain transparency and traceability, allowing consumers to track the origin and quality of agricultural products.

- **Monitoring Forestry:** Monitoring helps minimize deforestation, promotes sustainable logging, and protects biodiversity.

- **Aquaponics Farms:** They often integrate sensors and IOT devices to monitor water quality, temperature, pH levels, and oxygen levels. This data ensures optimal conditions for both fish and plants.

- **Analytic Data and Prediction:** Advanced data analytics and AI are used to process and analyze the vast amounts of data collected. This includes predictive analytics for weather and crop yield forecasting, disease detection, and resource optimization.

- **Supply Chains Management:** It encompasses various stages, from farm to market, and leverages technology and data-driven solutions for improved efficiency, transparency, and sustainability.

### 1.1.2 IOT solution architectures for smart agriculture

The IOT plays a central role in modern smart agriculture, which contributes a range of benefits such as the efficiency, sustainability, and productivity of farming practices. IOT sensors and devices are placed throughout farms to gather real-time data such as soil moisture, temperature, humidity, weather conditions, and livestock behavior. This continuous monitoring provides farmers with a comprehensive understanding of their farm's conditions, enabling them to make data-driven decisions promptly. Therefore, smart agriculture systems must guarantee the operations of IOT, which connects the physical and the virtual worlds.

IOT solution architectures refer to the structure and design of an IOT system, including the various components and their interactions, to enable the collection, processing, and management of data from connected devices. There are three most common IOT solution architectures: 3-Layer Architecture, SOA-based Architecture, Middleware-based Architecture.

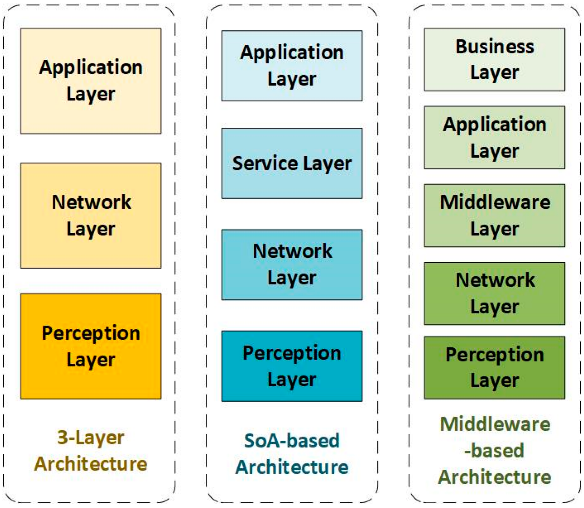


**Figure 1.2** – Most common IOT architectures [3]

Each of above architecture offers distinct advantages and is better suited to certain use cases and goals. In order to select the most suitable IOT solution architecture, we need to have a clear understanding of the business objectives. When the role of IOT in addressing those goals is defined, businesses can methodically evaluate and choose the IOT technology or platform that aligns best with our requirements.

The SOA-based architecture can simplify complex systems by breaking them down into discrete, reusable objects or subsystems. This modular approach allows for individual maintenance and upgrades of these components, enhancing the efficiency of both software and hardware within IOT systems. Therefore, the architecture has gained widespread adoption as a prominent architectural framework. For all mentioned above, we propose the SOA-based architecture[1] for the Smart Farm prototype in this project. This architecture presents four layers, considering the main components of an IOT solution: devices, network, services and application.

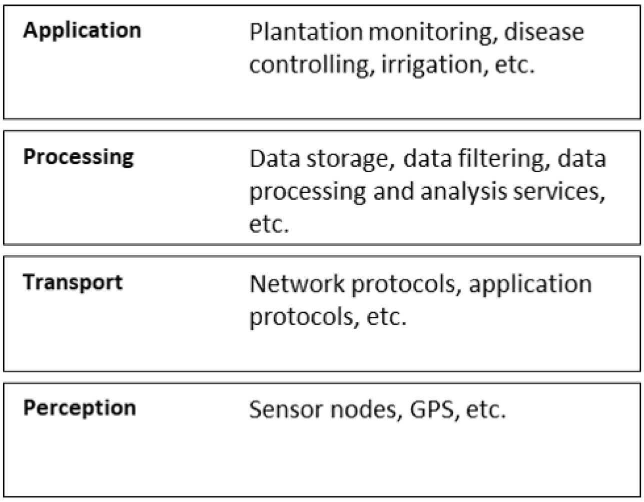


**Figure 1.3** – SOA-based architecture [4]

- **Perception layer:** The perception layer plays a crucial role in orchestrating the physical devices (sensor nodes, GPS, etc) within the IOT solution and orchestrating their interactions, both among themselves and with the transport layer. The primary purpose of the perception layer is to collect information from various sensors and devices, process this data at the edge, and then transmit relevant data to higher layers of the IOT architecture for further analysis and decision-making. For examples, sensor nodes are small, autonomous devices equipped with various sensors and communication capabilities, and they are strategically deployed throughout the farm to monitor and manage various aspects of agricultural operations. Those nodes are responsible for gathering a wide range of data related to the farm's environment and activities. This data can include temperature, humidity, soil moisture, water levels, and more. They may also include specialized sensors for monitoring specific parameters like soil moisture, pH, CO2 or nutrient levels.

- **Transport layer:** It facilitates the reliable and efficient exchange of data between devices, sensors, and other components within the IOT ecosystem. This layer is responsible for managing data transmission, ensuring data integrity, and addressing issues related to connectivity, scalability, and interoperability. Data's transmission between devices can be conducted over various communication networks such as Wi-Fi, cellular, Zigbee or Bluetooth depending on the business requirements. These IOT devices often use different communication protocols, and the transport layer must support a variety of these protocols. Examples of common IOT protocols include Message Queuing Telemetry Transport, HTTP/HTTPS and others.

- **Processing layer:** It manages data through a combination of data storage, visualization, and processing resources. In this context, big data technologies are useful to facilitate distributed storage and parallel data processing which enables the rapid extraction of valuable insights and information. Besides, machine learning plays as a helpful data processing technique that is capable of discovering intricate patterns and correlations within complex and disparate datasets.

- **Application layer:** The application layer in IOT architecture serves as the interface through which IOT applications, deliver vital management information to farmers. These IOT applications give farmers abilities to oversee and arrange the entire production process within their farms. They collect the data and process within the perception and transport layers, so they provide valuable insights and control, support farmers to make informed decisions, optimize resource , enhance crop yields, and arrange their agricultural operations with precision and efficiency.

## 1.2 Problems

### 1.2.1 Challenges in Vietnam

Smart agriculture holds the promise of transforming traditional farming methods in Vietnam, which makes efficient and sustainable agricultural practices. However, the adoption of smart agriculture technologies in Vietnam faces various challenges and problems that range from weather and environment, limited access to necessary equipment and the high initial costs associated with implementing these innovations to concerns about technical skills.

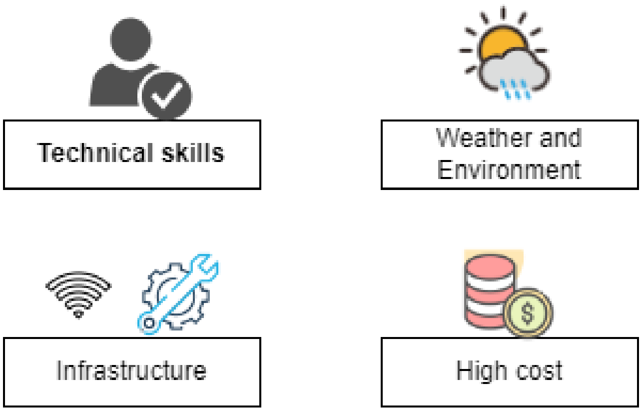


**Figure 1.4** – Difficulties of IOT smart agriculture in Vietnam

- **Weather and Environment:** Vietnam is prone to extreme weather events such as typhoons and floods. These natural phenomena pose substantial risks to the adoption and sustainability of smart agriculture practices. Typhoons, with their strong winds and heavy rains, can damage on the infrastructure essential for smart farming, including sensors, drones, and communication systems. Moreover, the inundation caused by floods can lead to soil erosion and crop loss, further complicating the application of precision agriculture.

- **Infrastructure:** Rural areas of Vietnam like Lao Cai, Yen Bai, Ha Giang, Tuyen Quang frequently grapple with insufficient infrastructure for both internet connectivity and a stable electricity supply. Farmers set up fields in the mountains. Without reliable power sources, sensors, and other devices essential for smart farming cannot function optimally, hindering data collection and management. Additionally, the lack of internet access restricts farmers' ability to access crucial information and real-time data, which are fundamental to informed decision-making in modern agriculture.

- **High cost:** The adoption of smart agriculture technologies represents a promising avenue for advancing farming practices, it brings with it substantial financial demands. The successful implementation of these innovations typically entails significant upfront investments in a range of cutting-edge equipment, including sensors, drones, and data management systems. In the context of Vietnam, this financial hurdle can be particularly daunting, especially for farmers with limited land holdings and modest resources. For these small-scale farmers, the initial costs associated with smart agriculture technologies can be prohibitive, potentially limiting their access to the benefits of these advancements.

- **Technical skills:** To harness the full potential of the smart agriculture technologies, farmers must possess a certain level of expertise in their operation. This implies a need for comprehensive training and ongoing support to ensure that farmers can adeptly utilize these technologies. However, a pressing challenge in Vietnam, as in many other regions, is the potential shortage of experts or trainers with the requisite knowledge to facilitate this learning process. Bridging this knowledge gap is pivotal in enabling farmers to make informed decisions, optimize resource use, and maximize the benefits of smart agriculture.

A significant challenge within the realm of smart agriculture in Vietnam lies in **the limited adoption of modern technology**, particularly among smallholder farmers. This deficiency in technological uptake has adverse implications for both productivity and sustainability within the agricultural sector. The primary culprits include **a lack of knowledge about these technologies and the absence of prototypes for experiential learning**. By promoting technology education and providing tangible learning opportunities, we can address these barriers and help smallholder farmers to harness the benefits of smart farming practices.

### 1.2.2 Research and Development in IOT smart agriculture

Many universities are trying to spearhead research and innovation in the realm of smart agriculture technologies, with the goal of addressing the sector's multifaceted challenges. However, one persistent obstacle that researchers frequently encounter pertains to the realm of IOT research. This challenge arises from the scarcity of comprehensive models capable of seamlessly integrating the diverse array of devices and components essential for smart agriculture. Despite progress, there remains a notable gap in developing holistic systems that can efficiently connect, monitor, and alert users in real-time.

- Firstly, in these universities, educational initiatives often involve providing students with separate components such as Arduino, Raspberry Pi, various sensors, and Zigbee devices as essential learning materials. While these components offer valuable insights and hands-on experience, they can also pose challenges when it comes to integrating them into a cohesive and functional IOT smart farm model. The fragmented nature of these components can make it difficult to effectively cooperate and define an appropriate, holistic research model for smart agriculture. Consequently, there is a growing need for collaborative efforts and interdisciplinary approaches to seamlessly bring together these components into comprehensive systems that can drive meaningful innovation in the field of agricultural technology. By fostering such cooperation and integration, universities can empower their students to tackle the complex challenges of modern agriculture more effectively.

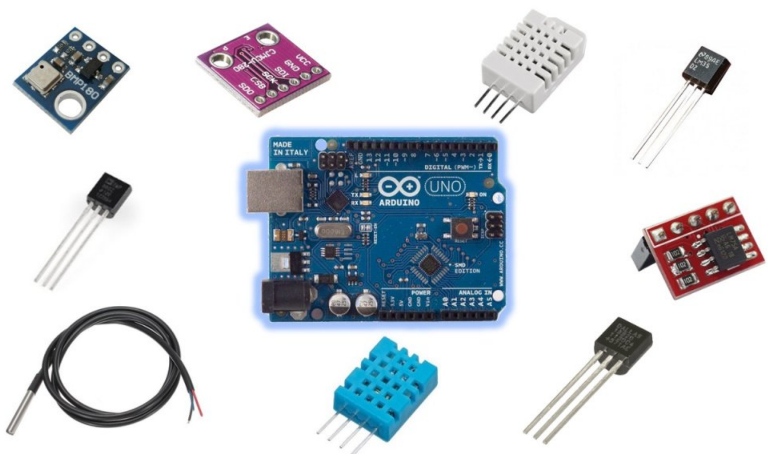

**Figure 1.5** – IOT devices

- Secondly, the absence of suitable models for smart agriculture involves tasks such as setting up sensors, gathering data, and implementing their applications within the real agricultural environment. While hands-on experience is invaluable for learning, it can be logistically complex, time-consuming, and resource-intensive. It also exposes students to the unpredictability of real-world agricultural conditions, which can present additional challenges. Developing more sophisticated and controlled experimental environments, possibly through simulation could alleviate some of these challenges and provide students with a more conducive platform to explore and refine their skills in the realm of smart agriculture.


**Figure 1.6** – Students of the Vietnam Academy of Agricultural Sciences collect information in the fields

At University of science and technology of Hanoi, several innovative models for smart agriculture have been developed, marking significant strides in agricultural technology. However, these models currently pose challenges in terms of manual monitoring and user notification systems. This highlights the imperative need for persistent innovation and collaborative efforts to address these technological gaps. By enhancing and refining these existing models, and by focusing on user-friendliness and seamless automation, we can play a pivotal role in creating advanced solutions that have the potential to revolutionize and elevate the agricultural landscape.

## 1.3 Internship Objectives

Given the challenges outlined above, it becomes imperative to explore avenues for enhancing manual monitoring in smart agriculture through the utilization of modern frameworks and technology. In this context, the focus should be on devising innovative solutions that streamline data collection, monitoring, and notification processes, making them more efficient and user-friendly. In this internship, we create a Smart Farm prototype based on Hanback Electronics's Smart Farm Control Technology to collect, monitor and visualize IOT data in real-time.

## 1.4 Thesis Structures

In this section, we will summarize the content of each chapter thoroughly:

- Chapter 1 presents background knowledge of smart agriculture, IOT solution architectures and their challenges.
- Chapter 2 gives the information on the proposal system and how its components interact in detail.
- Chapter 3 gives the results.
- Chapter 4 summarises findings and proposes future research directions.

# Chapter 2

# Materials and methods

## 2.1 Smart Farm Control Technology

The focus of our project centers on exploring the capabilities of Hanback Electronics' Smart Farm, which serves as a sophisticated smart greenhouse simulator. Within this simulator, a list of sensors, including those for monitoring temperature, humidity, and illuminance, closely mirrors the conditions found within real smart greenhouses. Moreover, it offers the functionality to automate crucial greenhouse operations such as window opening and closing and precise water supply management.

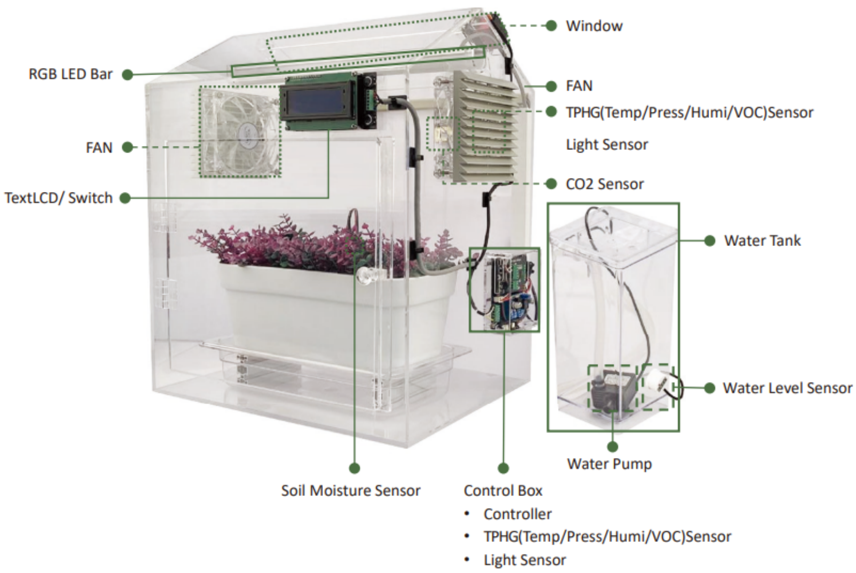


**Figure 2.1** – Smart Farm Control Technology

The Smart Farm simulator by Hanback Electronics proves to be an ideal tool for educational purposes within university settings due to its unique capacity to offer students practical, hands-on experience. It serves as a dynamic platform where students can acquire essential skills in setting up sensors, gathering data, conducting data analysis, and ultimately, making informed decisions. Here are the Smart Farm components:

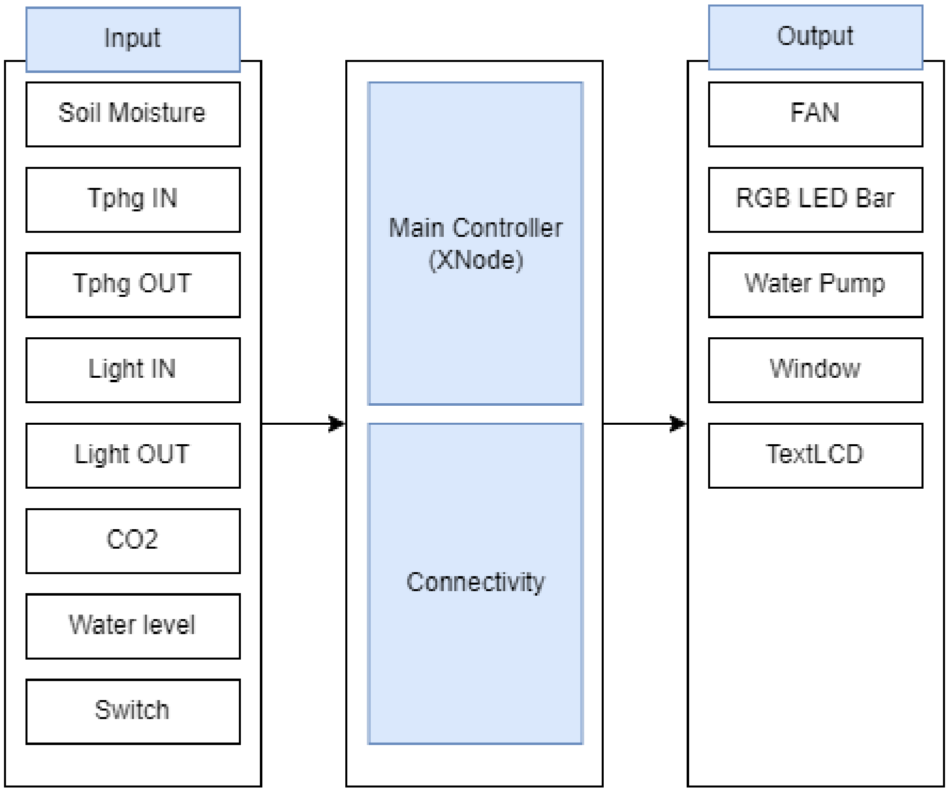


**Figure 2.2** – Smart Farm components

1. Input

   The responsibility of input devices is to monitor specific environmental parameters and conditions. They continuously gather data from the Smart Farm.There are Tphg (Temp, Humi, Press, GAS ) IN and Tphg(Temp, Humi, Press, GAS) OUT sensors to monitor the temperature and humidity inside and outside the Smart Farm, and Light IN and Light OUT sensors to monitor the illuminance inside and outside the Smart Farm, a Soil Moisture sensor to monitor the humidity of the soil, a CO2 sensor to measure the indoor CO2 concentration, a water level in the Water Tank, and 2 switches. The input devices specifications are as follows.

| **Devices** | **Specifications** |
|---|---|
| Soil Moisture Sensor | Analog Output<br>MainController: P15/GPIO038/ADC1-2 |
| Temperature / Humidity Sensor | Humidity Resolution: 12bit(0.04%RH), 8bit(0.7%RH)<br>Humidity Accuracy: +-3%RH<br>Temperature Resolution: 14bit(0.01C), 12bit(0.04C) |

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| Devices | Specifications |
|---|---|
| | Temperature Accuracy: +-4°C<br>Interface: I2C (address 0x77, 0x76)<br>MainController: P9/GPIO12/SDA, P10/GPIO13/SCL |
| Light Sensor | Illuminance: 1 - 65535(lx)<br>Interface: I2C (address 0x5C, 0x23)<br>MainController: P9/GPIO12/SDA, P10/GPIO13/SCL |
| Carbon Dioxide(CO2) | Measuring Range : 0 - 10000 ppm<br>Accuracy : ±7% ±50ppm<br>Response Time : 18 - 30 sec<br>Interface: I2C (address 0x62)<br>MainController: P9/GPIO12/SDA, P10/GPIO13/SCL |
| Water Level Sensor | Output Voltage: (Low(0V), High(5V)<br>Response Time: 500ms<br>Sensitivity: 0 - 13mm<br>Waterproof Performance: IP67<br>MainController: P18/GPIO34 |
| Switch | MainController: P8/GPIO2 (up), P23/GPIO14(down) |

**Table 2.1** – Smart Farm - Input specifications.

2. Ouput

   The output devices are used to display information and take physical actions based on collected data and commands from the main controller. For example, we can continuously gather CO2 information and display them on Smart Farm's TextLCD. In addition, when the mount CO2 in the greenhouse is too high, we can control to open the window.

   In the Smart Farm, FANs place on both sides of the device for air injection and exhaust, an RGB LED bar as a light source for growth, a water pump to supply soil moisture, a window for room temperature control, and a text LCD at the top of the front. The output devices specifications are as follows.

| Devices | Specifications |
|---|---|
| FANs | MainController: P3/GPIO4 |
| Relay: 3ch | DC: 7A/28VDC<br>AC: 7A/240VAC |
| Motor Driver | Dual Full-Bridge Driver(4A/46V) |
| Ventilation | Vinyl Curtain: Step Motor Driver |

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| Devices | Specifications |
|---|---|
| | FAN 2EA: Relay Control<br>Light Control: RGB LED Strip<br>Power: 12V/3A Adaptor (DC Jack) |
| Water Pump | Flow Rate: 3.5L/Minute<br>12V/3W(Relay Control)<br>Mini Sprinkler 2EA<br>MainController: P22/GPIO26 |
| Display | Character LCD<br>Format Size: 16x2<br>Interface: I2C (address ) |

**Table 2.2** – Smart Farm - Output specifications.

3. Main Controller
   The main controller (Xnode) serves as the brain of the Smart Farm. Its responsibilities are processing the collected data, performing computations or data analysis locally. We can connect our personal computer and the main controller via Micro USB. The controller specifications are as follows.

| Specifications |
|---|
| Xtensa Dual–Core 32–Bit LX6 Microprocessor(s), Up to 600 DMIPS |
| RAM: 4MB |
| Flash Memory: 8MB |
| Interface: UART, SPI, I2C, I2 |
| Indicator: RGB LED |

**Table 2.3** – Smart Farm - Main Controller specifications.

4. Connectivity

There are three connection methods in the Smart Farm, which are Wi-Fi, Bluetooth and LoRa. Farmers can control the actuators or monitor the sensors through their applications. Besides, they can also use LoRa to transfer data between two Smart Farm systems. The connectivity specifications are as follows.

| Devices | Specifications |
|---|---|
| Wi-Fi | 802.11b |

Continue on the next page

| Devices | Specifications |
|---|---|
| | Data Rate: 1Mbps to 72Mbps<br>Transmit Power: Up to +16dBm<br>Receiver Sensitivity: -93 to -71 dBm |
| Bluetooth | Bluetooth 4.2 BR/EDR BLE<br>Range: 30M<br>Data Rate: 1Mbps<br>Sensitivity: -97dBm<br>Output Power: 12dBm |
| LoRa | Frequency: 868MHz<br>Range: 10km<br>Data Rate: 300kbps<br>Sensitivity: -148dBm<br>Output Power: 20dBm |

**Table 2.4** – Smart Farm - Connectivity specifications.

## 2.2 SodaIDE

The Smart Farm model relies on the utilization of SodaIDE, which stands as an integral component of our integrated development environment. The SodaIDE plays an indispensable role in bridging the gap between users and the intricate workings of the Smart Farm. We can engage directly with the Smart Farm Main Controller, enabling us to both write and execute software programs tailored to the specific needs through the IDE. Especially, Hanback Electronics has thoughtfully provided this SodaIDE in a Windows environment, enhancing its accessibility and user-friendliness, particularly for students.

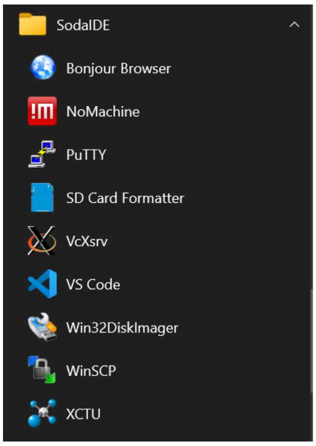


**Figure 2.3** – SodaIDE components

The IDE has the following integrated components:

- VS Code: Preconfigured VS Code for Smart Farm MainController
- PuTTY: Serial emulator
- Tools for edge servers WinScp: Remote file explorer
  NoMachine: Remote desktop
  VcXsrv: X-Server for Windows
  SD Card Formatter: MicroSD card formatting tool
  Win32DiskImager: Installs image for edge server (Soda OS) to microSD card
  Bonjour Browser: Dynamic server browsing

## 2.3 Architecture

Within the context of this project, we propose a comprehensive architectural framework that leverages the principles of SOA. This proposal architecture aims to provide a structured and adaptable framework to support the integration and interaction of diverse smart agriculture components and services.

The architecture comprises four key components: sensor node, gateway, server, and user, interconnected through wired and wireless technologies. Sensor nodes collect data, gateways facilitate data transfer, cloud servers process and store data, and users access and act upon insights, enabling efficient IOT integration.

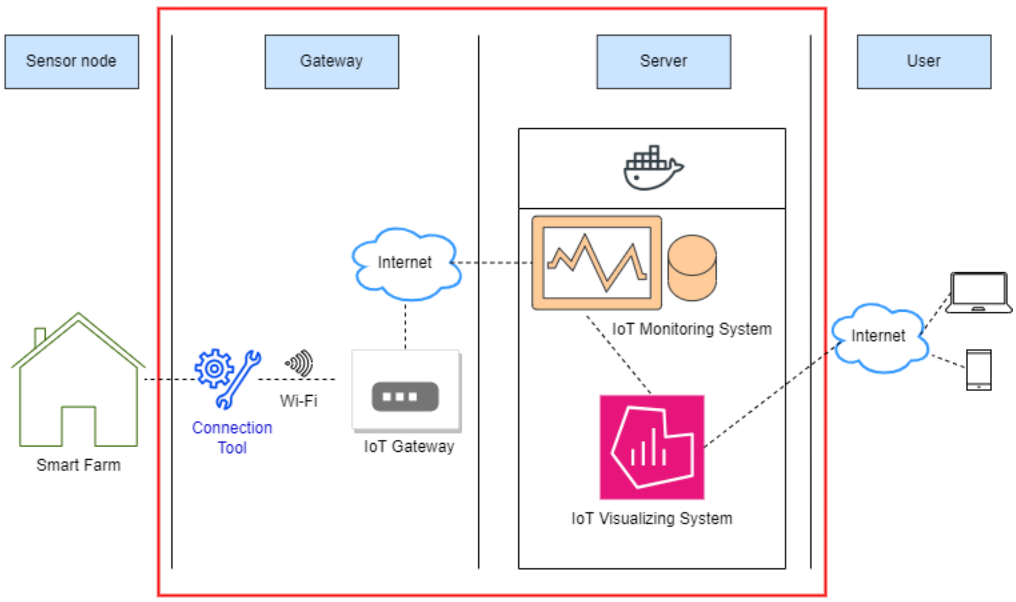


**Figure 2.4** – The proposal Smart Farm architecture

### 2.3.1 Sensor Node

The Smart Farm, also known as a sensor node which contains various physical components like sensors, main controller (Xnode), connectivity and actuators. These components work together to collect data and facilitate communication between devices.

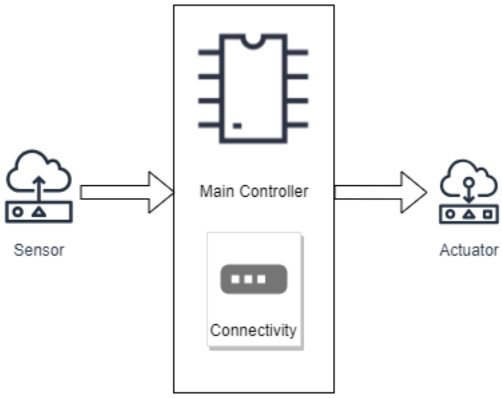


**Figure 2.5** – Sensor node

### 2.3.2 Gateway

The Smart Farm has limitations in terms of data storage and accessibility. With its limited 8MB flash memory, local data storage becomes impractical. We cannot save sensor information within the device itself for a long time. To address this, the system utilizes an IOT framework called Blynk, which helps us retrieve data from the Smart Farm and storage on the Blynk server. However, there are cost considerations, as each datastream comes with associated fees. Additionally, the visualization and analysis of the data are restricted and limited, so we are not able to explore and gain insights from the collected information in diverse ways.

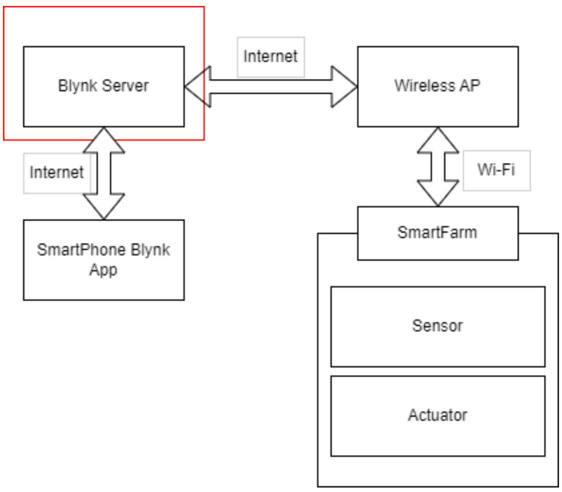


**Figure 2.6** – The Blynk framework for the Smart Farm

To overcome the limitations of the Smart Farm's flash memory capacity and the cost constraints of third-party cloud services, we have developed a specialized plugin or gateway. This gateway establishes periodic connections with the Smart Farm, efficiently extracting valuable sensor data. Instead of relying on external cloud storage (Blynk), this data is securely stored on our dedicated server. Therefore, we can optimize costs, ensure data privacy, and provide flexibility in data analysis and visualization.

To achieve reliable communication, we propose the implementation of **a client-server architecture utilizing sockets and the TCP** as the underlying communication framework for the tool's design. This approach ensures the efficient and robust exchange of sensor data, supporting real-time updates.

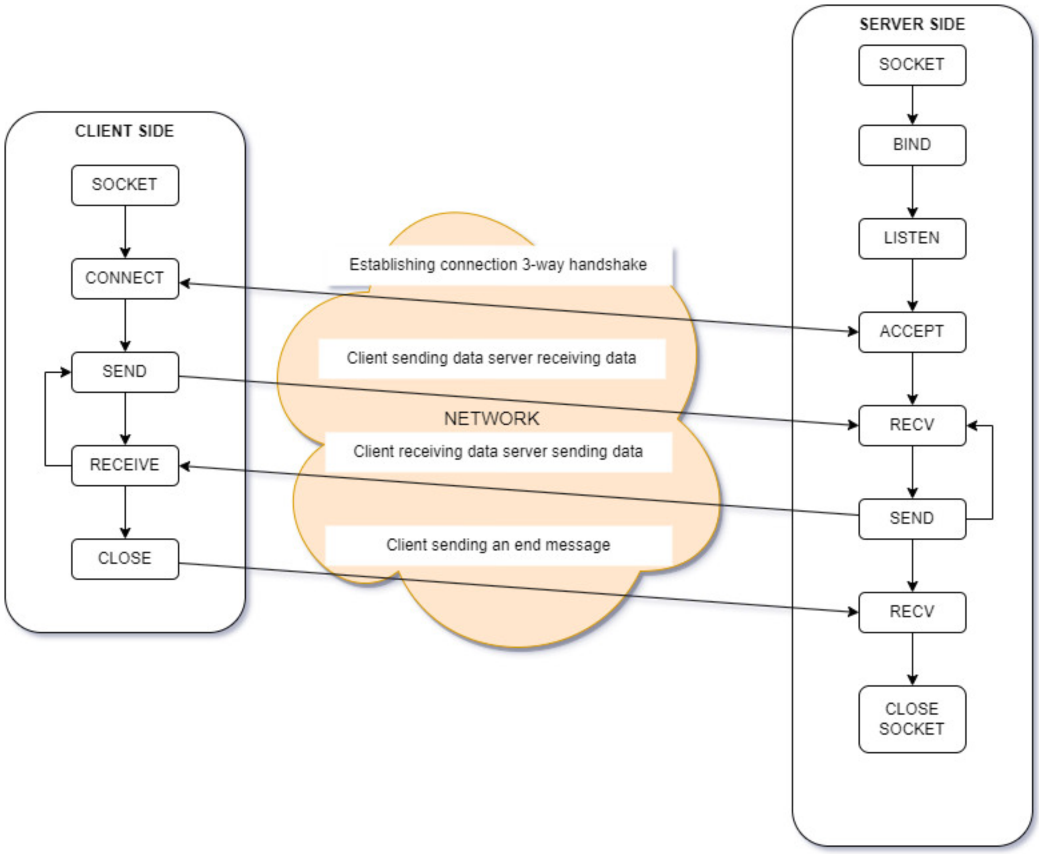


**Figure 2.7** – TCP client - server

[2]

In the proposed architecture, a personal computer can play a pivotal role as an IOT gateway. This gateway transfers data collected from the sensors within the Smart Farm to our designated servers. The implementation of the connection tool and IOT gateway is defined by Python program.

### 2.3.3 Server

We propose an integrated server that hosts both **an IOT Monitoring System and an IOT Visualizing System**, both encapsulated within **Docker** containers.

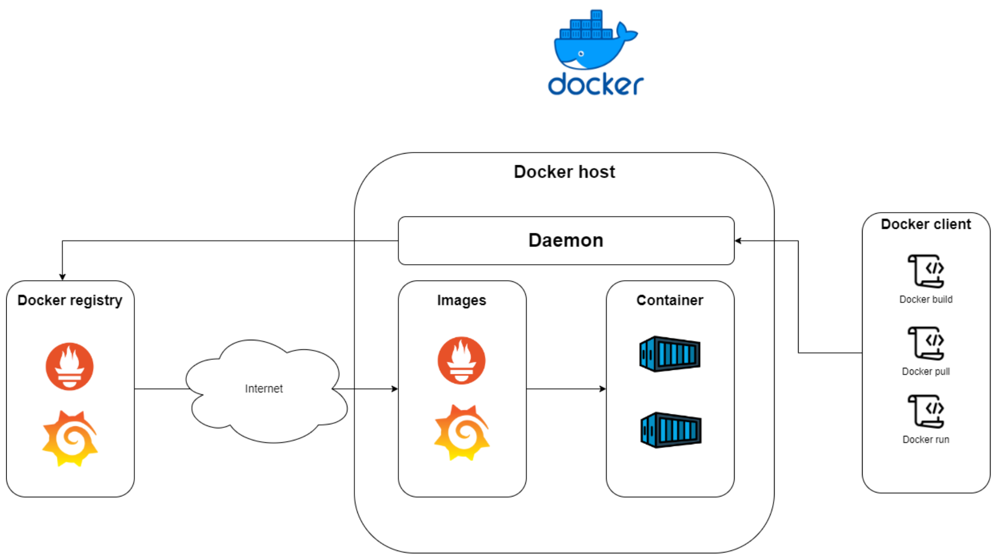


**Figure 2.8** – Server

Firstly, the IOT Monitoring System is built upon Prometheus which is an open-source software application renowned for its prowess in event monitoring and alerting. Prometheus can easily collect and archive metrics in the form of time series data. In this paradigm, metrics are associated with timestamps, marking the precise moment of their capture. Moreover, Prometheus employs an labeling system which allows optional key-value pairs to be associated with each metric, and provides an invaluable level of context and granularity to the collected data. Within Prometheus, the IOT Monitoring System can make comprehensive data analysis, precise alerting, and informed decision-making in diverse operational scenarios.

Secondly, the IOT Visualizing System is crafted with Grafana which is a dynamic and multi-platform open-source analytics and interactive visualization web application. Grafana offers a spectrum of capabilities, including the creation of compelling charts, graphs, and timely alerts when connected to compatible data sources. Grafana is particularly powerful because of its ability to seamlessly bridge the gap between disparate data sources, enabling a unified visualization and analysis experience. By leveraging Grafana, we have potential opportunities to visualize, alert on, and gain insightful comprehension of our data, regardless of where it resides.

On the other hand, Docker plays an important role in this layer. It allows us to package Prometheus, Grafana and all their dependencies into a standardized container format.

They have been containerized, providing a straightforward installation method via Docker images. This containerization simplifies deployment, allowing us to set up a monitoring and visualization system effortlessly. Prometheus handles data collection and storage, while Grafana offers a user-friendly interface for dashboard creation. By packaging these tools as Docker images, the installation process becomes highly accessible and consistent, benefiting users across various skill levels and ensuring a streamlined monitoring experience.

### 2.3.4 User

Users can access to the server via Grafana which allows them to effortlessly access and view the sensor data that has been meticulously collected. This data is thoughtfully presented through graph charts, enabling users to glean valuable insights into the prevailing environmental conditions. Users can readily understand their farm's environment, and make informed decision-making.The clarity and accessibility of the data visualization in graph charts via Grafana empower users to optimize watering schedules, implement precise fertilization plans, or arrange other crucial tasks.


**Figure 2.9** – User's dashboard

# Chapter 3

# Results

In this study, we applied IOT SOA-based architecture and preprocess method to build the Smart Farm prototype that gathers, monitors and visualizes the sensor data.

Firstly, different types of data such as humidity, temperature, CO2, water level, etc have been transmitted from the sensor node layer to the server by the proposal connection tool.

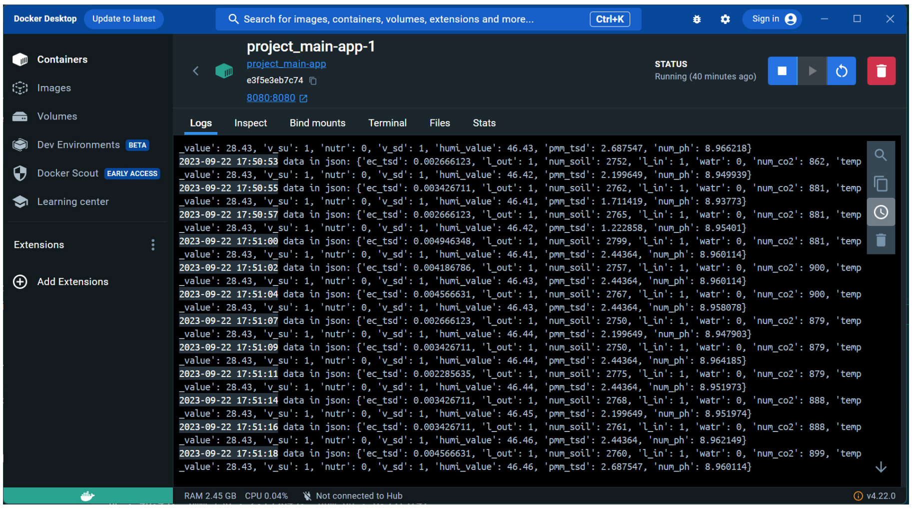


**Figure 3.1** – Connection tool - Data transmission

Second, these data have been stored and observed by IOT monitoring system - Prometheus.


Figure 3.2 – Prometheus - Data storage

Finally, users access and view the sensor data that has been meticulously collected in IOT visualizing system - Grafana.


**Figure 3.3** – Grafana - Data visualization

# Chapter 4

# Conclusion

This study of the Smart Farm is suitable for broking a lack of knowledge about IoT technologies and the absence of prototypes for experiential learning.

- Constructed a Smart Farm prototype by IoT SOA-based architecture.
- Implemented data collection, monitoring, and visualization successfully.

However, many adaptations, tests, and experiments have been left for the future due to lack of time. These are the ideas that we may experiment with in the future.

- Try to apply alternative IoT architectures to the prototype, facilitating comparison and evaluation.
- Try to incorporate process methodologies to delve deeper into aspects like extrapolating unmeasured information from sensors and predicting trends in the Smart Farm environment.

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