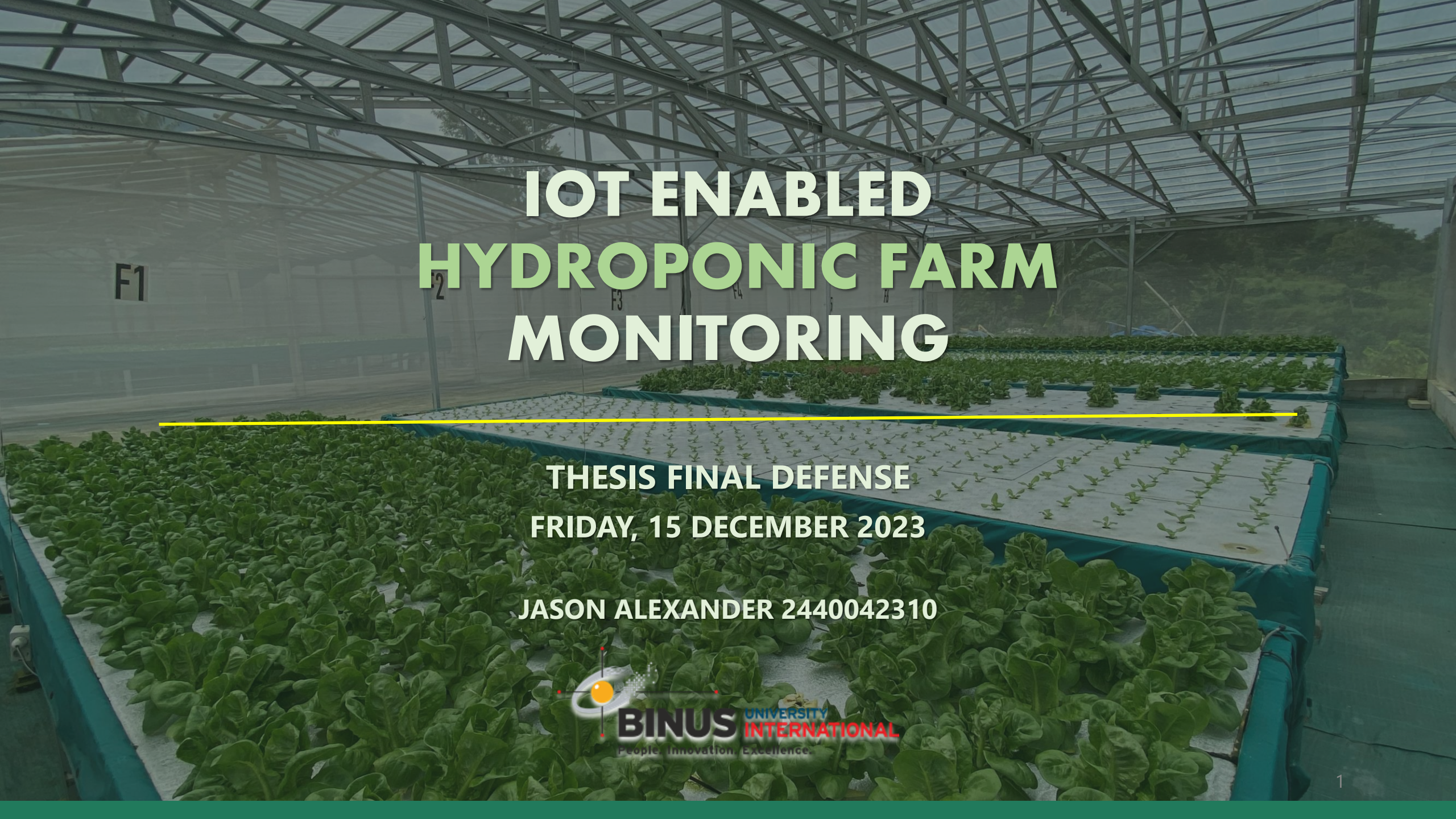

IOT ENABLED HYDROPONIC FARM MONITORING

THESIS FINAL DEFENSE

FRIDAY, 15 DECEMBER 2023

JASON ALEXANDER 2440042310

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Table of Contents

General Summary of the chapters on this presentation.

01 Introduction

Background | Analysis | Objectives

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Background

Company Profile, Just Hydroponics

Just Hydroponics is a family-owned company located in the outskirts of Bogor.

They are a medium-sized farm with around a dozen hydroponic greenhouses with plans for expansion soon.

They employ a small number of mostly local blue-collar staff with little to no educational background.

Background

Company Profile, Just Hydroponics

Analysis

Current Method of Data Collection

Just Hydroponics currently collects only nutrient data. The collection is done manually using hand-held tools. They have a few of them with different brands/manufacturers.

- (+) Practical, pragmatic, simple, and easy to use.

- (-) **Low scalability**.
- (-) Laborious and Inefficient.
- (-) Slow reaction time.
- (-) Inconsistent Data

Analysis

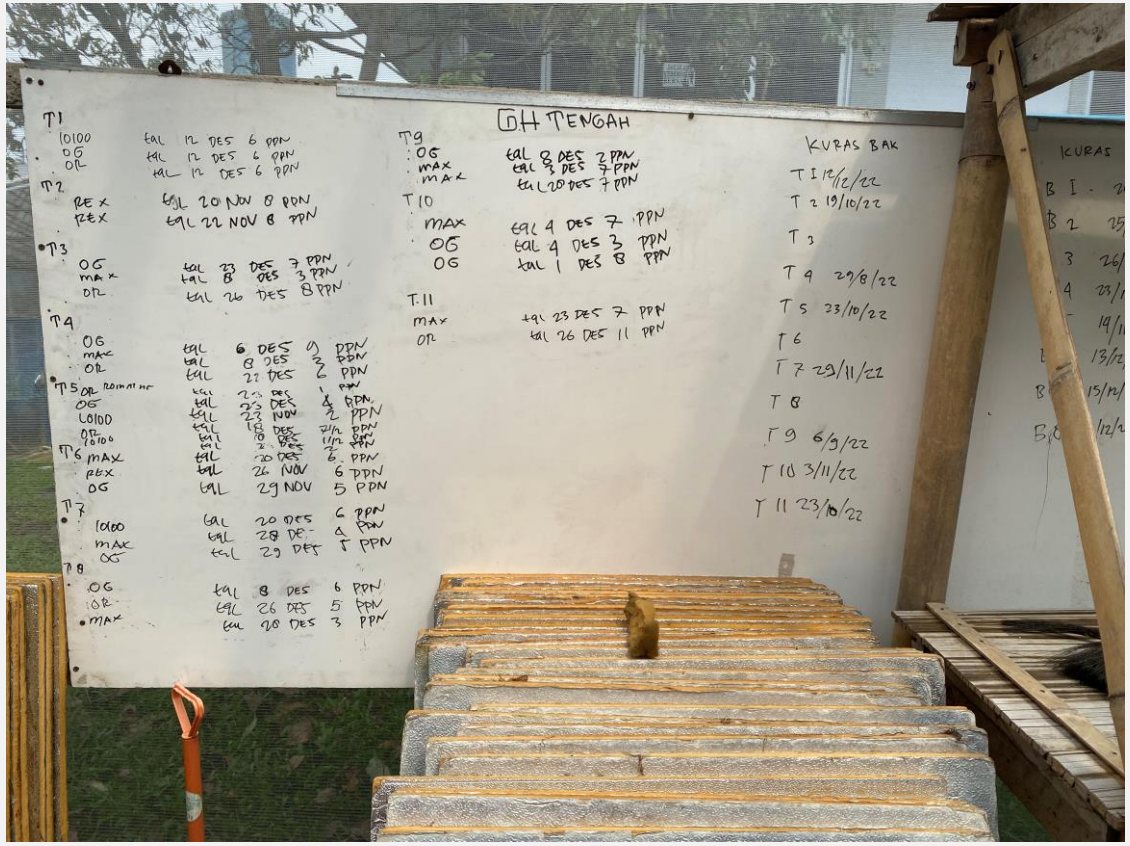
Current Method of Data Storage

Just Hydroponics currently stores their collected nutrient data on whiteboards.

There are whiteboards on each greenhouse.

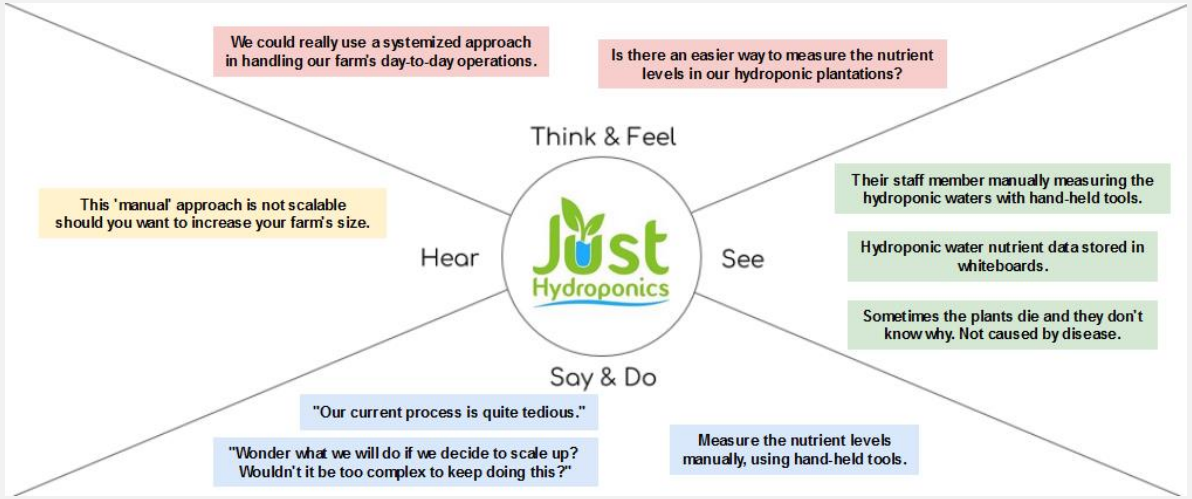
- (+) Practical, pragmatic, simple, and easy to use.

- (-) Low data capacity.
- (-) Very low data integrity. Impossible to recover if accidentally wiped.
- (-) Subject to human error.



Analysis

Understanding The “Client”

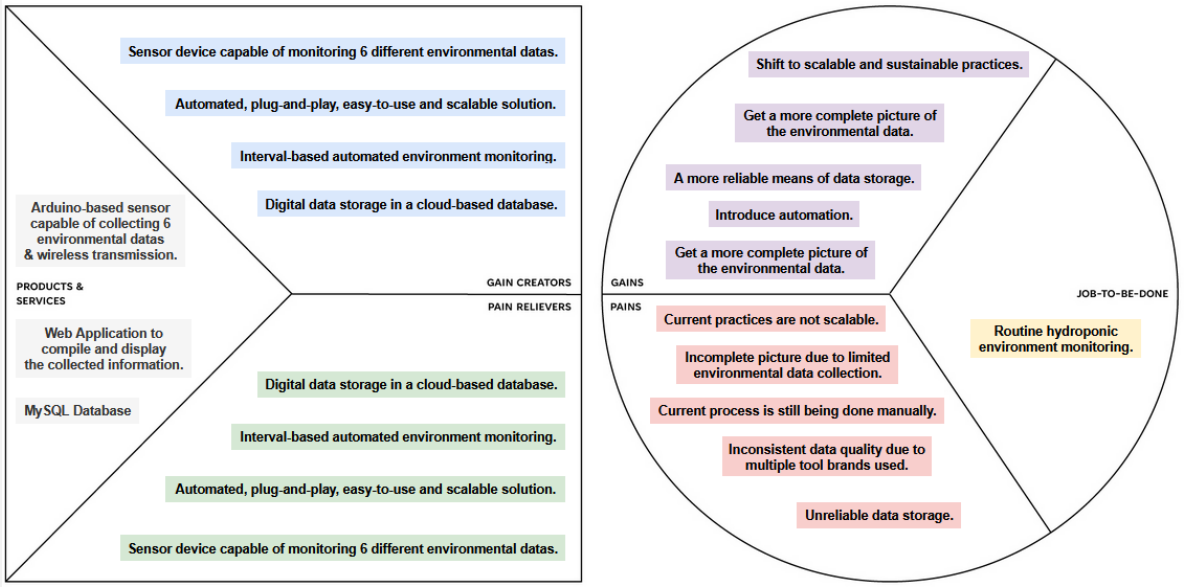


Empathy Map

To gain a better understanding of the client and know what they want, I used an **Empathy Map**.

After understanding what the client’s profile, I used a **Value Proposition Canvas** to summarize and solidify the product/service that my solution needed to provide.

Value Proposition Canvas



Analysis

Conclusion

In short: **Lack of scalability**.

- *Just Hydroponics* has expressed interest in further expansion, but a brief analysis of their processes reveals potential problems, which haven't surfaced yet because their operations are still relatively small.
- An expansion would expose these problems and cause issues for *Just Hydroponics*.
- A solution needs to be devised. That solution needs to solve the problems which we have just discussed.
- I decided on an Arduino-based sensor device, which transmits environmental sensor data to a web application, where it would be readily available on demand and constantly and automatically updated.

Objectives

Case Study Objective

The creation of a **systemized hydroponic farm monitoring** solution with:

- A physical **Arduino-based sensor**.
- A **web application powered by PHP**.
- A **database** for data storage.

The Solution's primary purpose is to **serve as a proof-of-concept** and **technical demonstrator**.

Due to constraints in time and resources, the resulting solution will likely not be commercially viable, **yet**.

02 Solution Design

Technology | Design | Limitations

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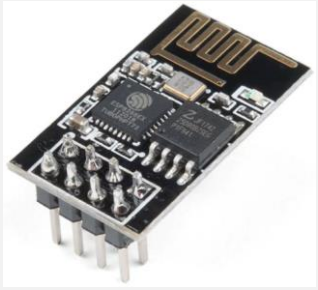
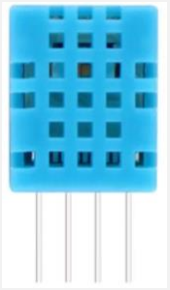
Technology

Arduino - Hydroponic Sensor

Arduino Uno R3
Motherboard



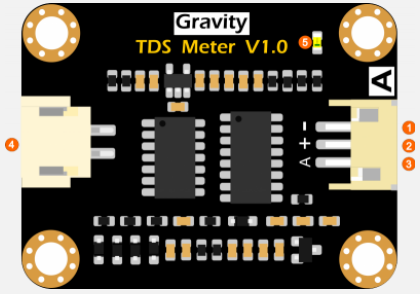
ESP-01
Wi-Fi



DHT11
Air Temperature & Humidity

MH-Z19B
CO_2

PH-4502C
CO_2



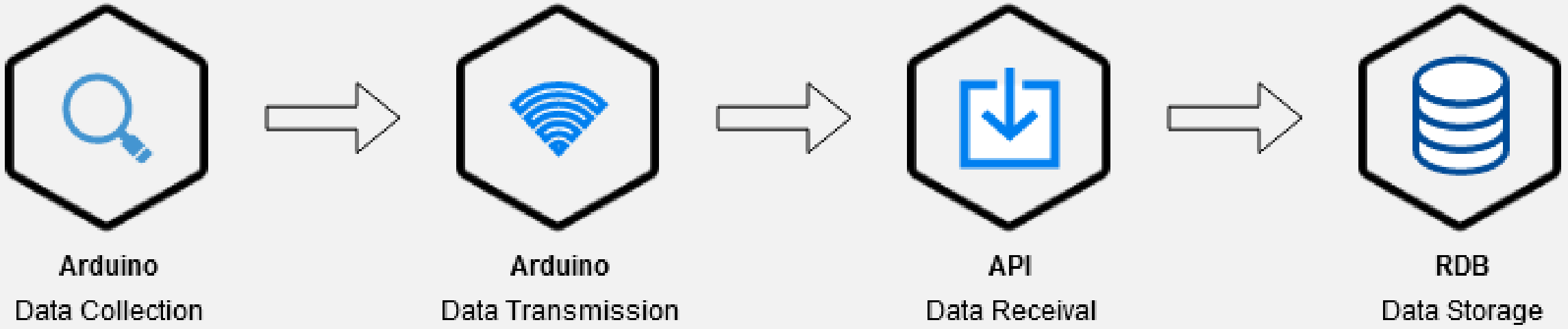
TDS Meter
Nutrient Levels

Technology

Website, Database & API

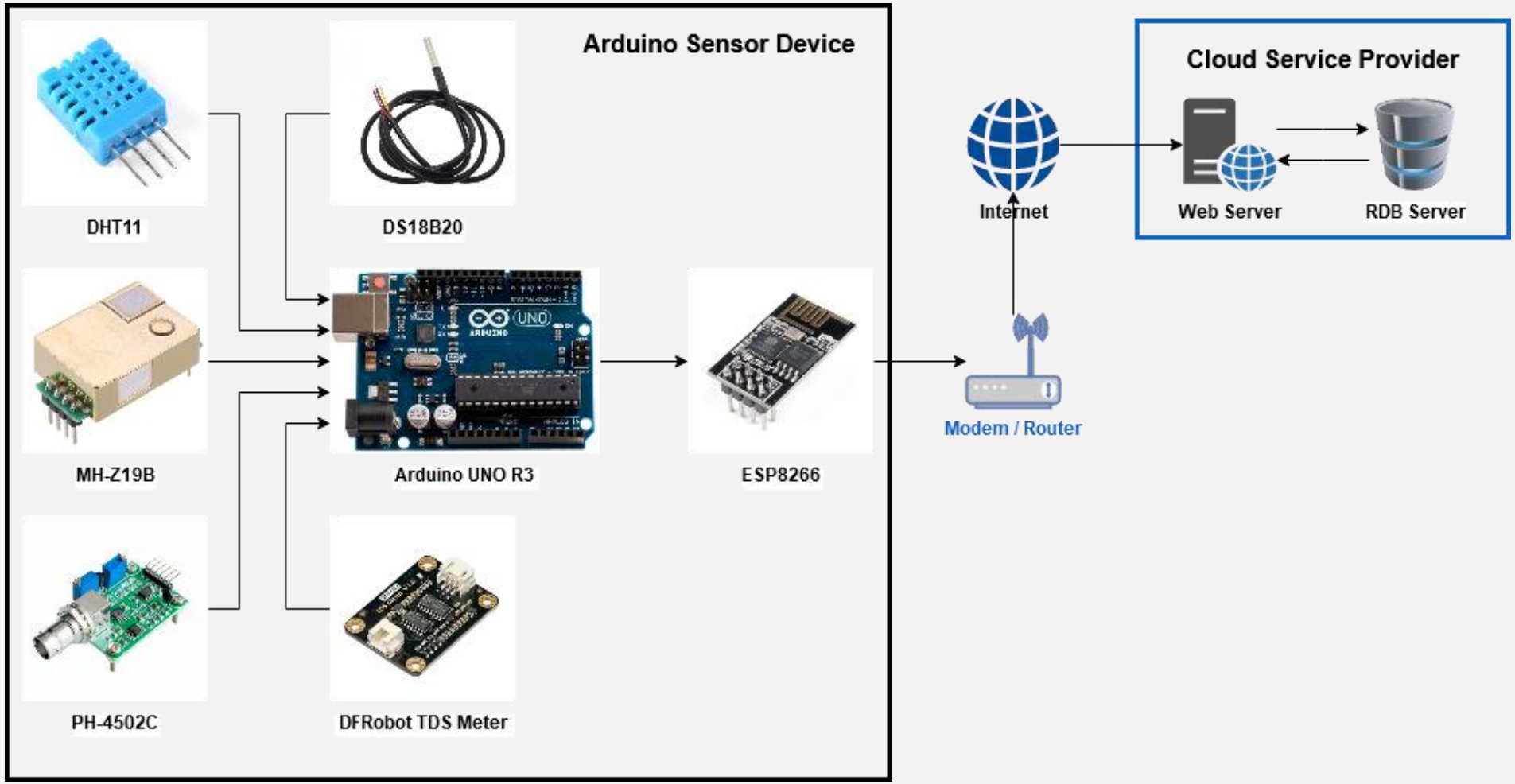
Design

Process Cycle



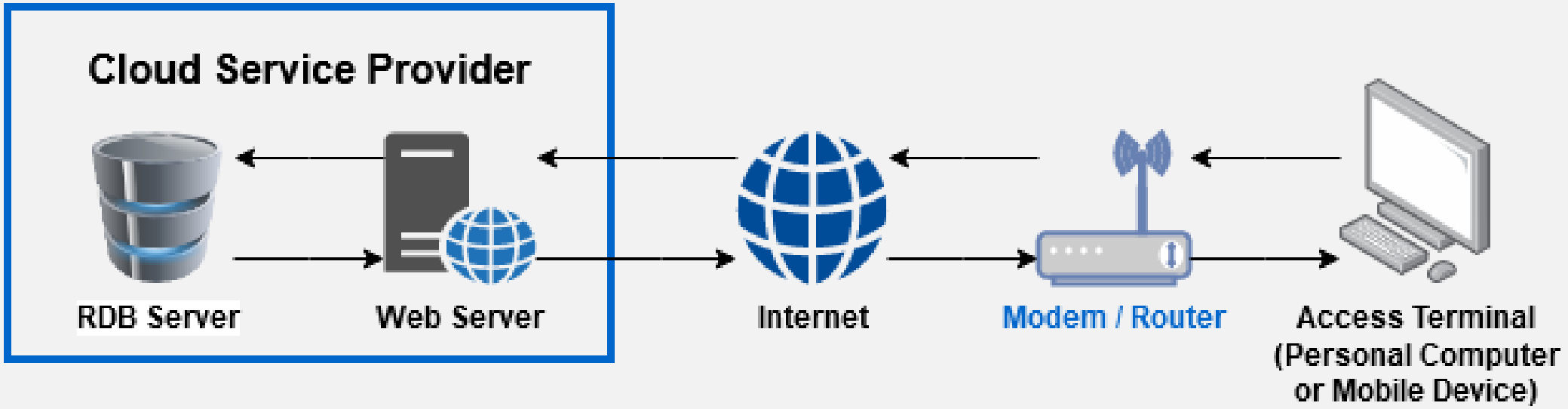
Design

Hydroponic Sensor Schematic



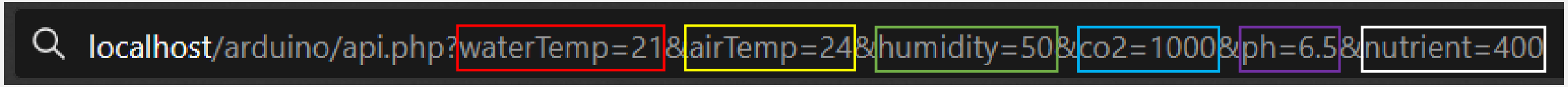
Design

Web Application & Database Architecture



Design

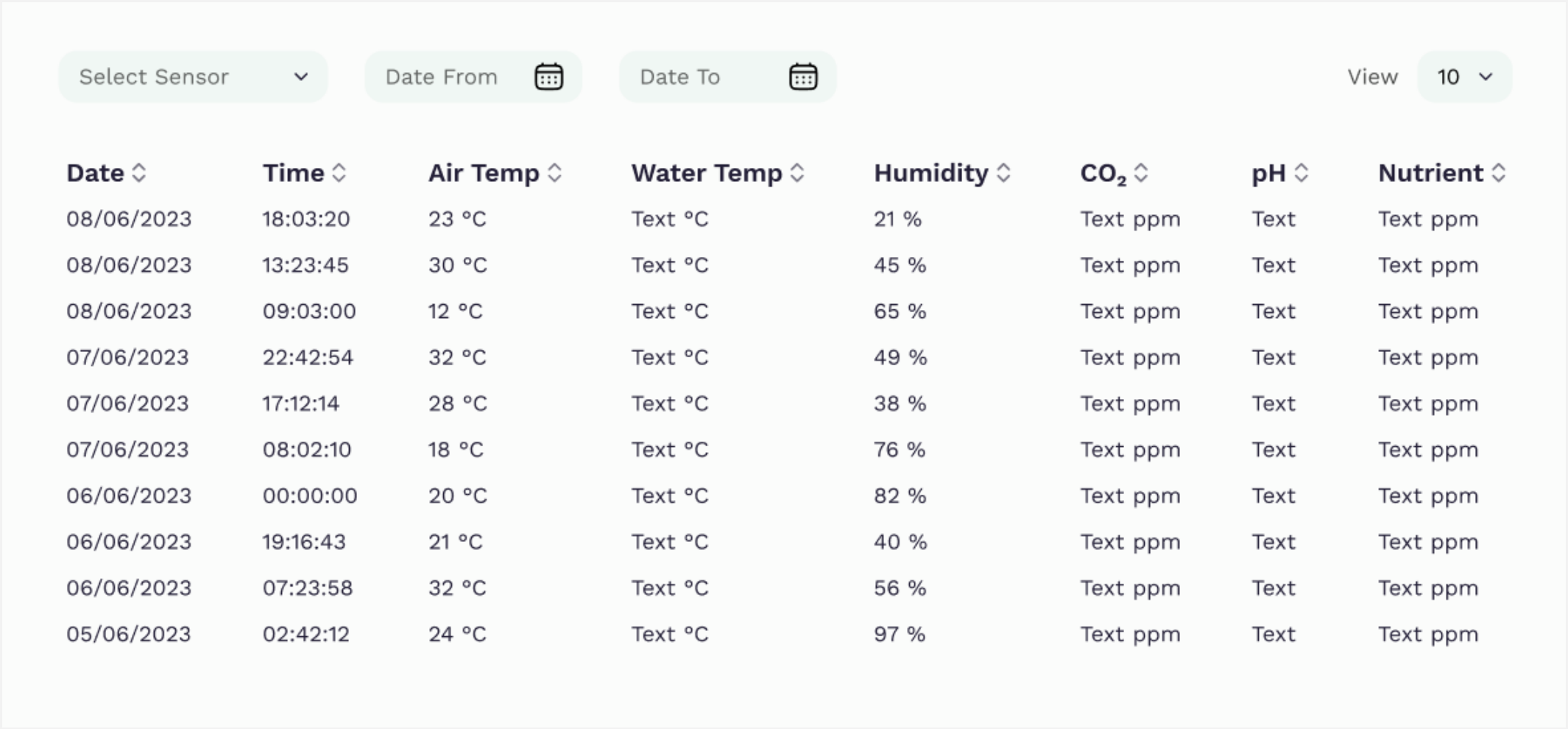
Web Application, API Format



- The *String* above illustrates how the sensor data will be transmitted into the API.
- Because the web application and the API uses PHP, the data *String* is formatted to be compliant with PHP's $_GET superglobal variables.

Design

Web Application, Early UI Design



Limitations

Scope, Arduino

- The sensor device will be **limited to monitoring**. No capability to actively ‘influence’ the hydroponic farm.
- **Six environmental variables**: water temperature, air temperature, humidity, CO_2 levels, pH levels, and nutrient density.
- The device should be able to **operate wirelessly** with only a power source and an access to Wi-Fi.
- The device will be only an early prototype. It will not have a casing design *yet*.

Limitations

Scope, Web Application

- **The user-facing side**: a prototype with limited capabilities.
  - Can display data from a user selected criteria / filter.
  - No ability to modify data.
- A database will be used to store the data collected by the Arduino device.
- The website will have an “API” feature that acts as a middleman to receive data from the Arduino and store it into the database.
- It will be developed using base PHP 8.

03 Solution Implementation

Arduino | Database | API | Web Application | Test Plan

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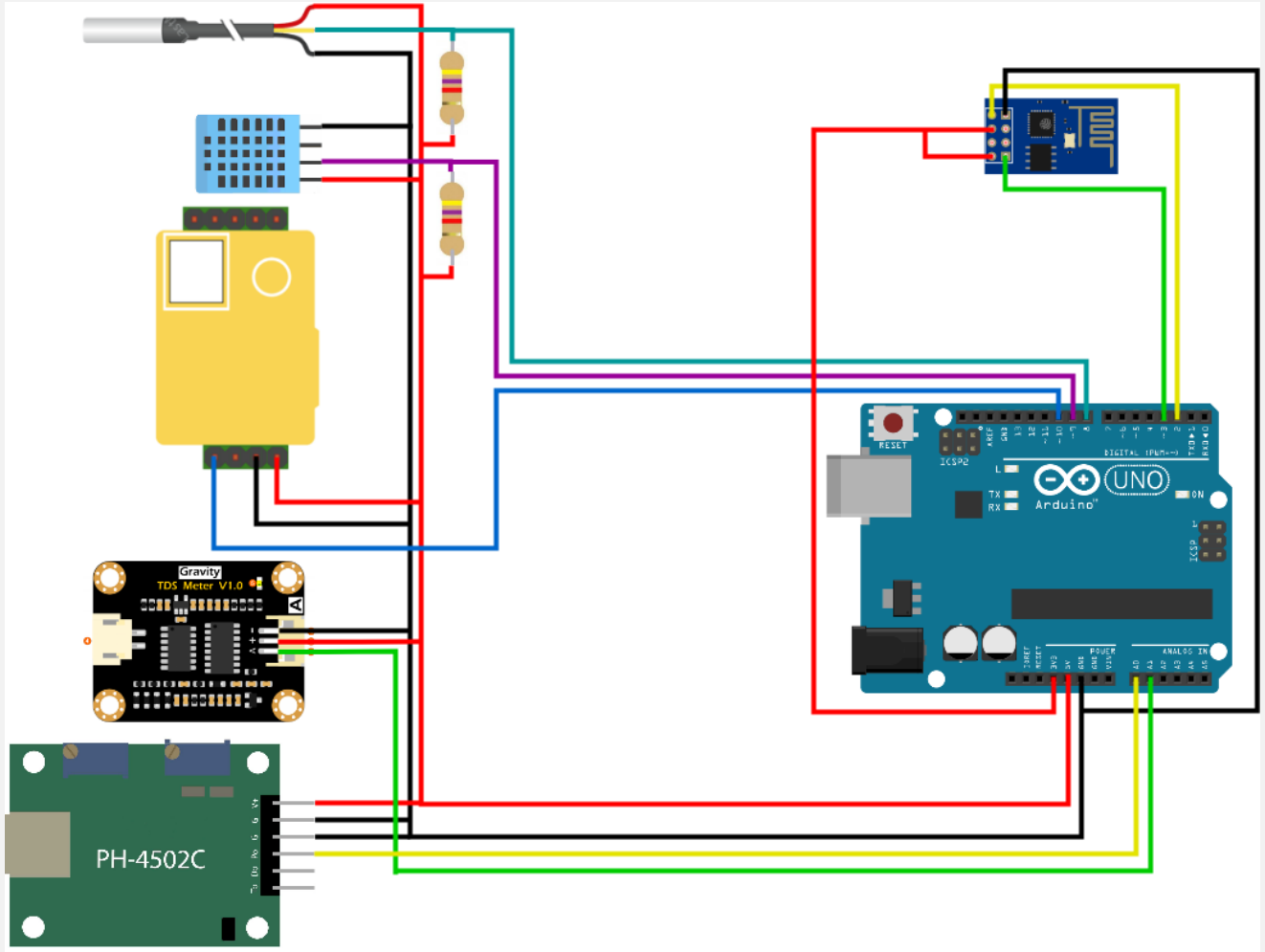
Arduino

Hydroponic Sensor



This is a schematic

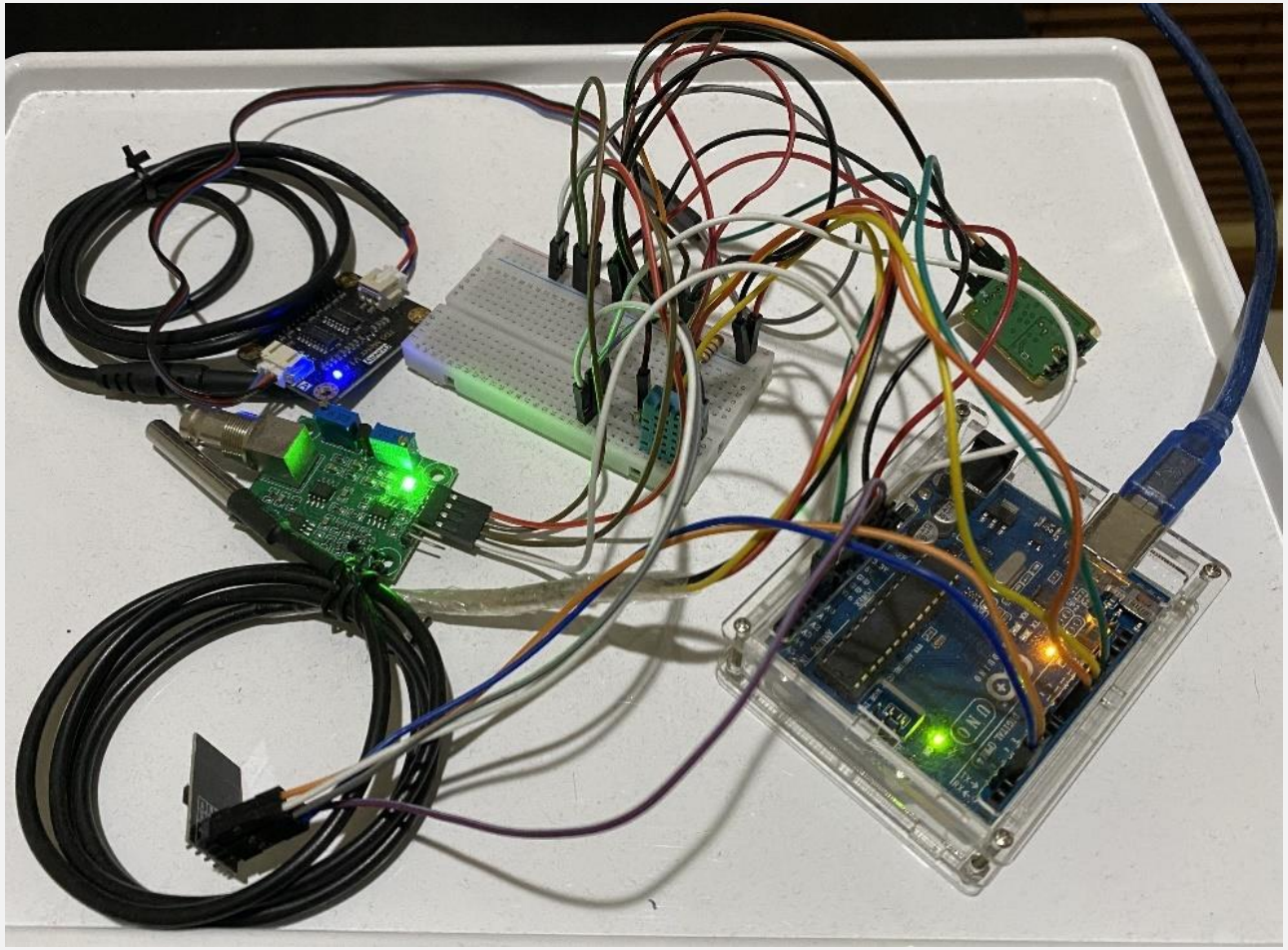
of the sensor prototype.

Arduino

Hydroponic Sensor

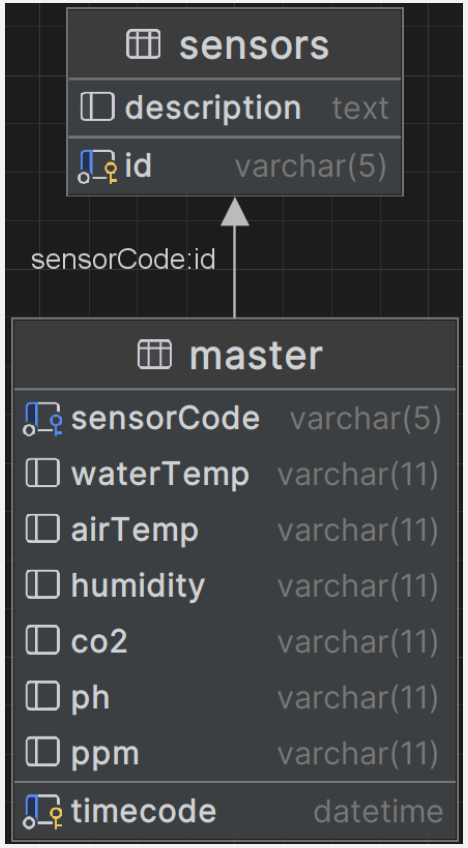
This is the sensor prototype,

the first of two.



Web Application

Database Implementation



	id	description
1	SAMPL	Placeholder sensor.
2	SE001	Sensor 1
3	SE002	Sensor 2

- Two tables, containing sensor information and the master data.
- Six master variables on the master table.

	timecode	sensorCode	waterTemp	airTemp	humidity	co2	ph	ppm
8	2023-09-12 19:02:52	SE001	26.81	26.70	64.00	941.24	-5.71	21.87
9	2023-09-12 19:03:50	SE001	27.00	26.70	64.00	946.22	-5.84	17.88
10	2023-09-12 19:04:48	SE001	26.94	27.10	63.00	966.14	-6.29	8.01
11	2023-09-12 19:05:46	SE001	27.00	27.10	63.00	986.06	-6.02	13.95
12	2023-09-12 19:06:10	SE002	69.42	69.42	69.42	69.42	69.42	69.42
13	2023-09-12 19:06:43	SE001	27.00	27.10	63.00	971.12	-6.41	8.00
14	2023-09-12 19:07:06	SE002	69.42	69.42	69.42	69.42	69.42	69.42
15	2023-09-12 19:07:41	SE001	27.13	27.10	62.00	971.12	-6.52	7.99
16	2023-09-12 19:08:02	SE002	69.42	69.42	69.42	69.42	69.42	69.42
17	2023-09-12 19:08:39	SE001	27.19	27.10	62.00	951.20	-6.33	11.93
18	2023-09-12 19:09:37	SE001	27.25	27.10	62.00	971.12	-6.42	11.92
19	2023-09-12 19:09:41	SE002	69.42	69.42	69.42	69.42	69.42	69.42
20	2023-09-12 19:10:34	SE001	27.25	27.10	62.00	991.04	-5.84	63.19

Web Application

API Implementation

1

```php
# Attempt to retrieve $_GET data from the arduino.
$sensorCode = $_GET['sensorCode'] ?? null;
$waterTemp = $_GET['waterTemp'] ?? null;
$airTemp = $_GET['airTemp'] ?? null;
$humidity = $_GET['humidity'] ?? null;
$co2 = $_GET['co2'] ?? null;
$ph = $_GET['ph'] ?? null;
$nutrient = $_GET['nutrient'] ??  null;
```

2

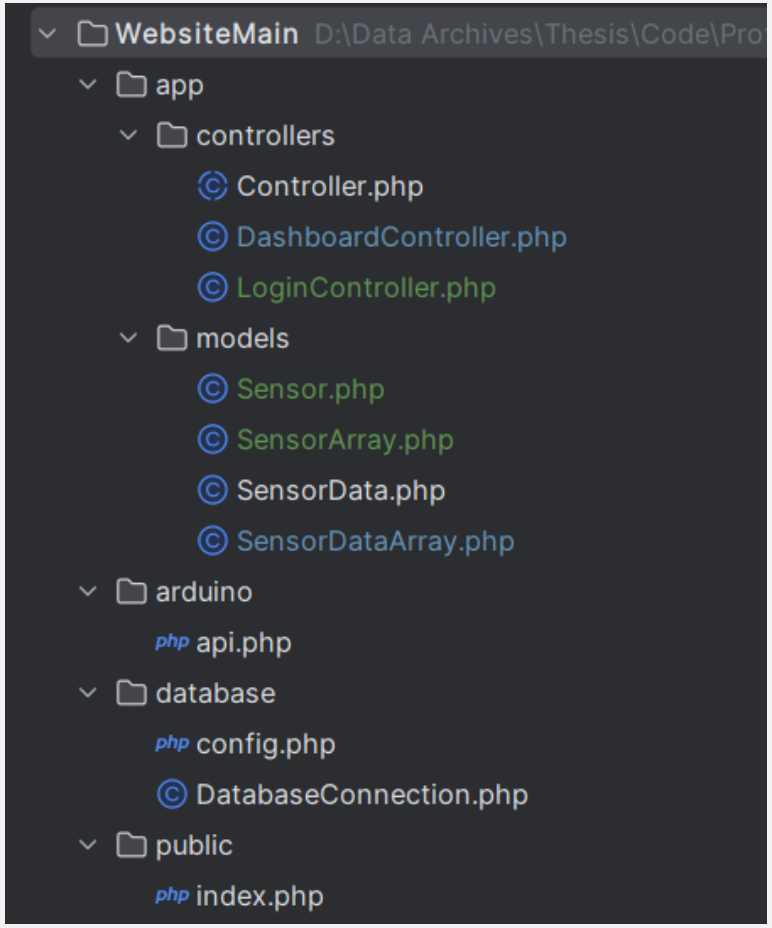
```php
# Checker. If ALL data is null, then do not insert.
if(is_null($waterTemp) and is_null($airTemp) and is_null($humidity) and is_null($co2) and is_null($ph) and is_null($nutrient)) {
    die("WARNING - No data inserted!");
}
```

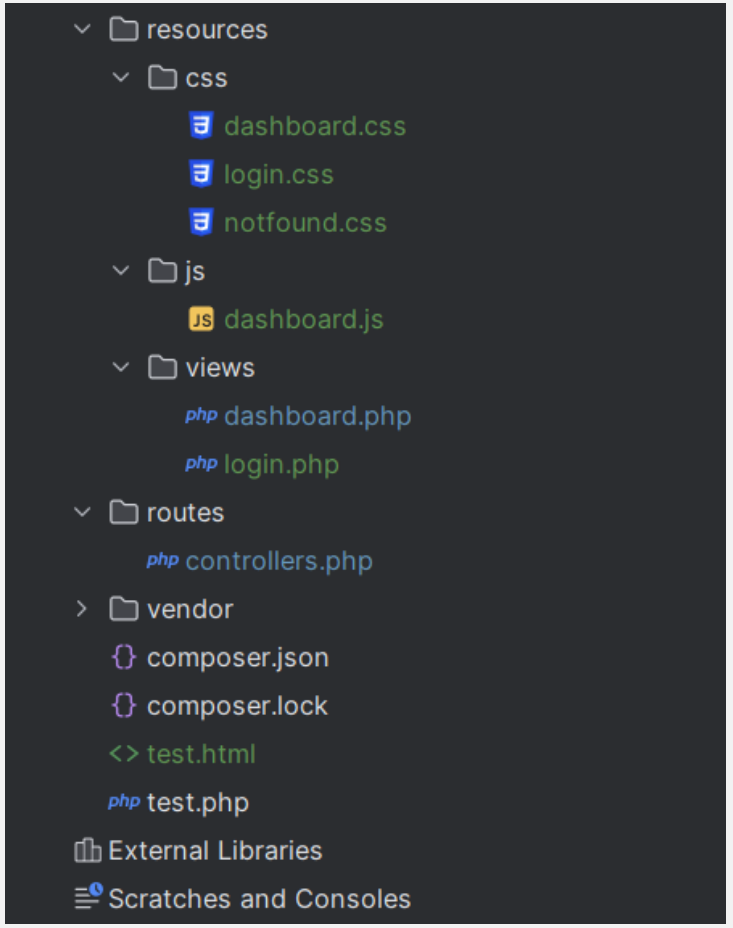
3

```php
$query = "
    INSERT INTO master
    VALUES(
            CURTIME(),
            ".$sensorCode.",
            ".$waterTemp.",
            ".$airTemp.",
            ".$humidity.",
            ".$co2.",
            ".$ph.",
            ".$nutrient."
    );
";
```

Web Application

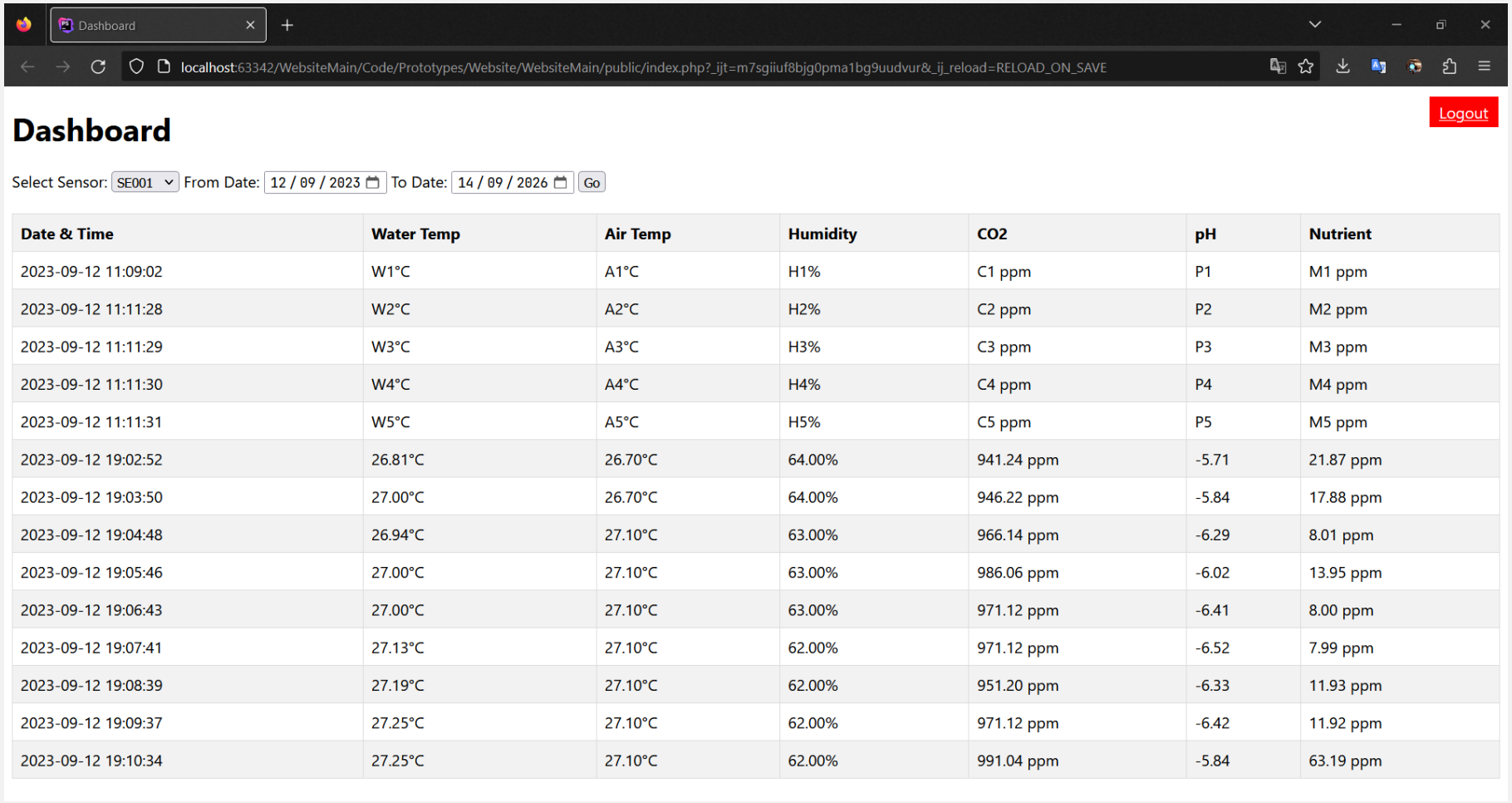
Web Application, Structure





Web Application

Web Application, Dashboard



Date & Time	Water Temp	Air Temp	Humidity	CO2	pH	Nutrient
2023-09-12 11:09:02	W1°C	A1°C	H1%	C1 ppm	P1	M1 ppm
2023-09-12 11:11:28	W2°C	A2°C	H2%	C2 ppm	P2	M2 ppm
2023-09-12 11:11:29	W3°C	A3°C	H3%	C3 ppm	P3	M3 ppm
2023-09-12 11:11:30	W4°C	A4°C	H4%	C4 ppm	P4	M4 ppm
2023-09-12 11:11:31	W5°C	A5°C	H5%	C5 ppm	P5	M5 ppm
2023-09-12 19:02:52	26.81°C	26.70°C	64.00%	941.24 ppm	-5.71	21.87 ppm
2023-09-12 19:03:50	27.00°C	26.70°C	64.00%	946.22 ppm	-5.84	17.88 ppm
2023-09-12 19:04:48	26.94°C	27.10°C	63.00%	966.14 ppm	-6.29	8.01 ppm
2023-09-12 19:05:46	27.00°C	27.10°C	63.00%	986.06 ppm	-6.02	13.95 ppm
2023-09-12 19:06:43	27.00°C	27.10°C	63.00%	971.12 ppm	-6.41	8.00 ppm
2023-09-12 19:07:41	27.13°C	27.10°C	62.00%	971.12 ppm	-6.52	7.99 ppm
2023-09-12 19:08:39	27.19°C	27.10°C	62.00%	951.20 ppm	-6.33	11.93 ppm
2023-09-12 19:09:37	27.25°C	27.10°C	62.00%	971.12 ppm	-6.42	11.92 ppm
2023-09-12 19:10:34	27.25°C	27.10°C	62.00%	991.04 ppm	-5.84	63.19 ppm

04 Evaluation & Discussion

Evaluation | Discussion

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Evaluation

Test Plan

Unit Test

Tests each individual module. See if each module works as specified.

Integration Test

Tests inter-module synergy. See if each module works as expected when operated as a part of a larger system.

End-to-End Test

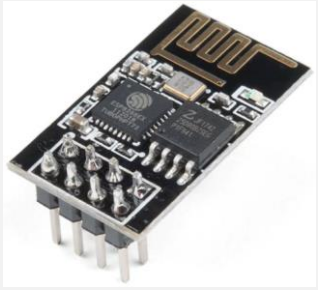
Simulates actual use, system is tested from start to end of the process cycle.

Further divided into: Basic Acceptance Test, Reliability Test, and Multi-Device Test.

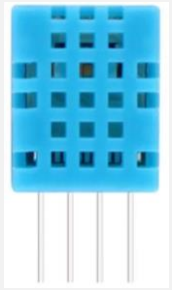
Evaluation

Unit Test

Arduino Uno R3
Motherboard



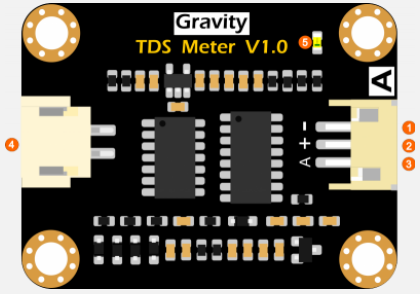
ESP-01
Wi-Fi



DHT11
Air Temperature & Humidity

MH-Z19B
CO_2

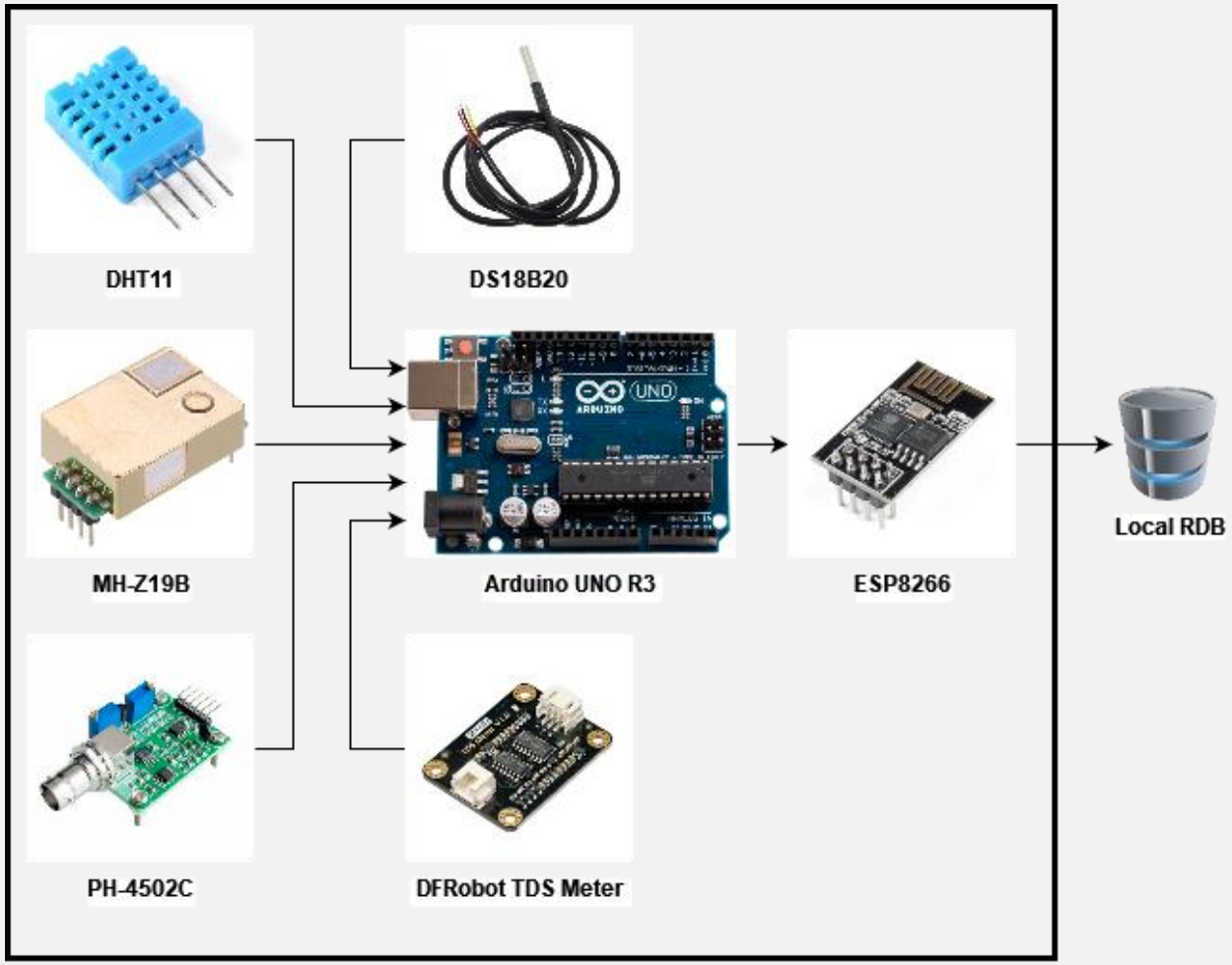
PH-4502C
CO_2



TDS Meter
Nutrient Levels

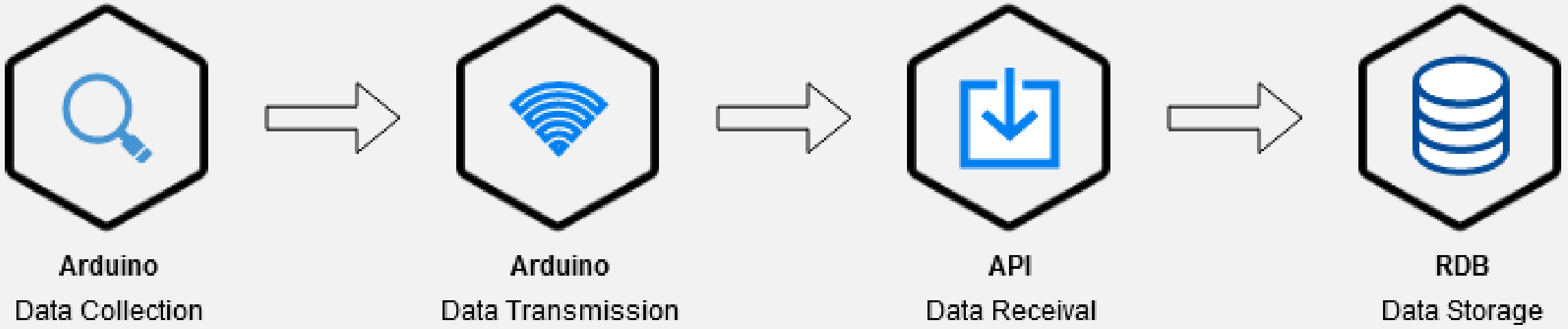
Evaluation

Integration Test



Evaluation

End-to-End Test



Evaluation

Test Results Summary

Unit Test

- Arduino (**PASS**)
- Web Application (**PASS**)

Integration Test

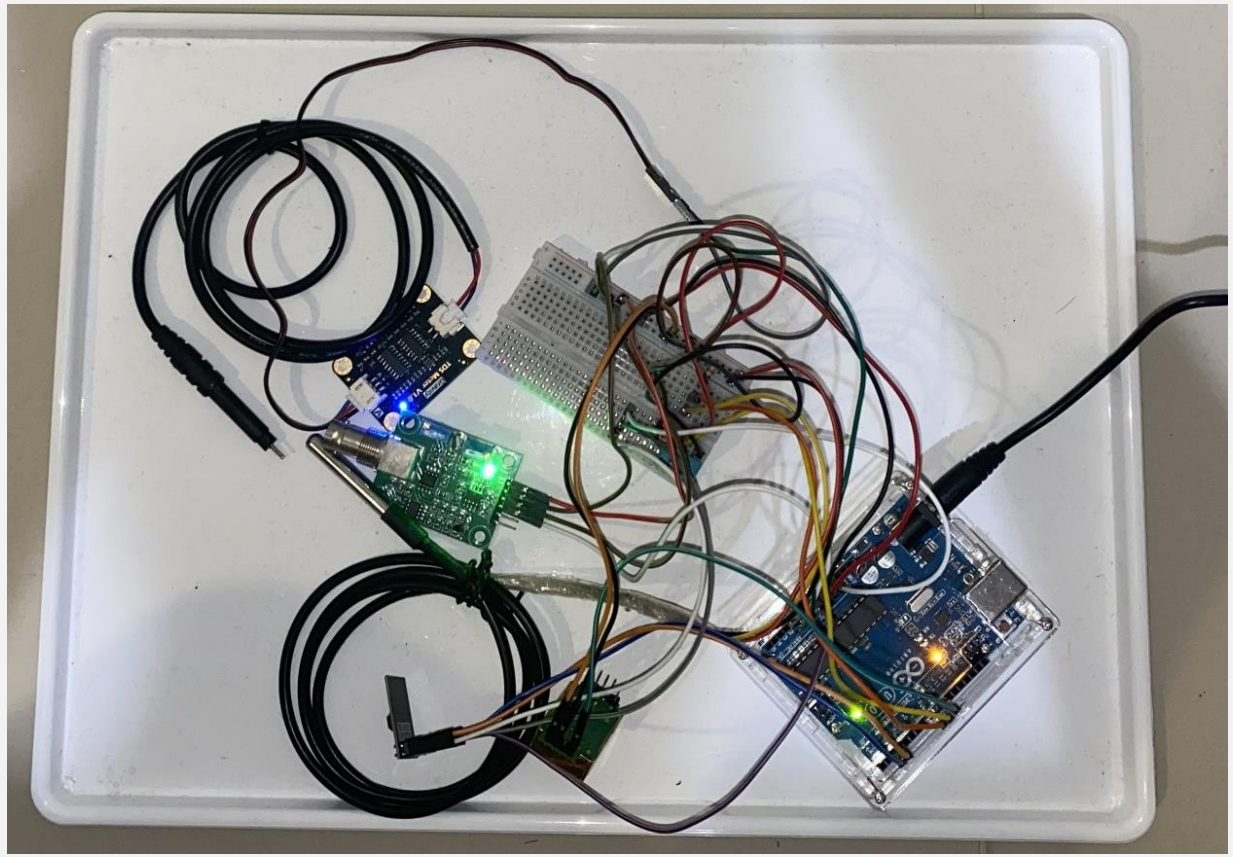
- Arduino (**PASS**)
- Web Application (**PASS**)

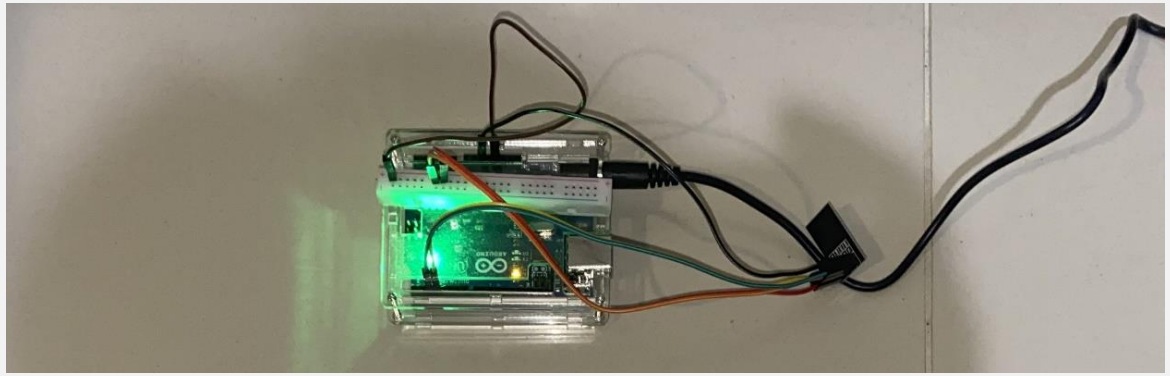
End-to-End Test

- Basic Acceptance Test (**PASS**)
- Reliability Test (**Requires Attention**)
- Multi-Device Test (**PASS**)

Evaluation

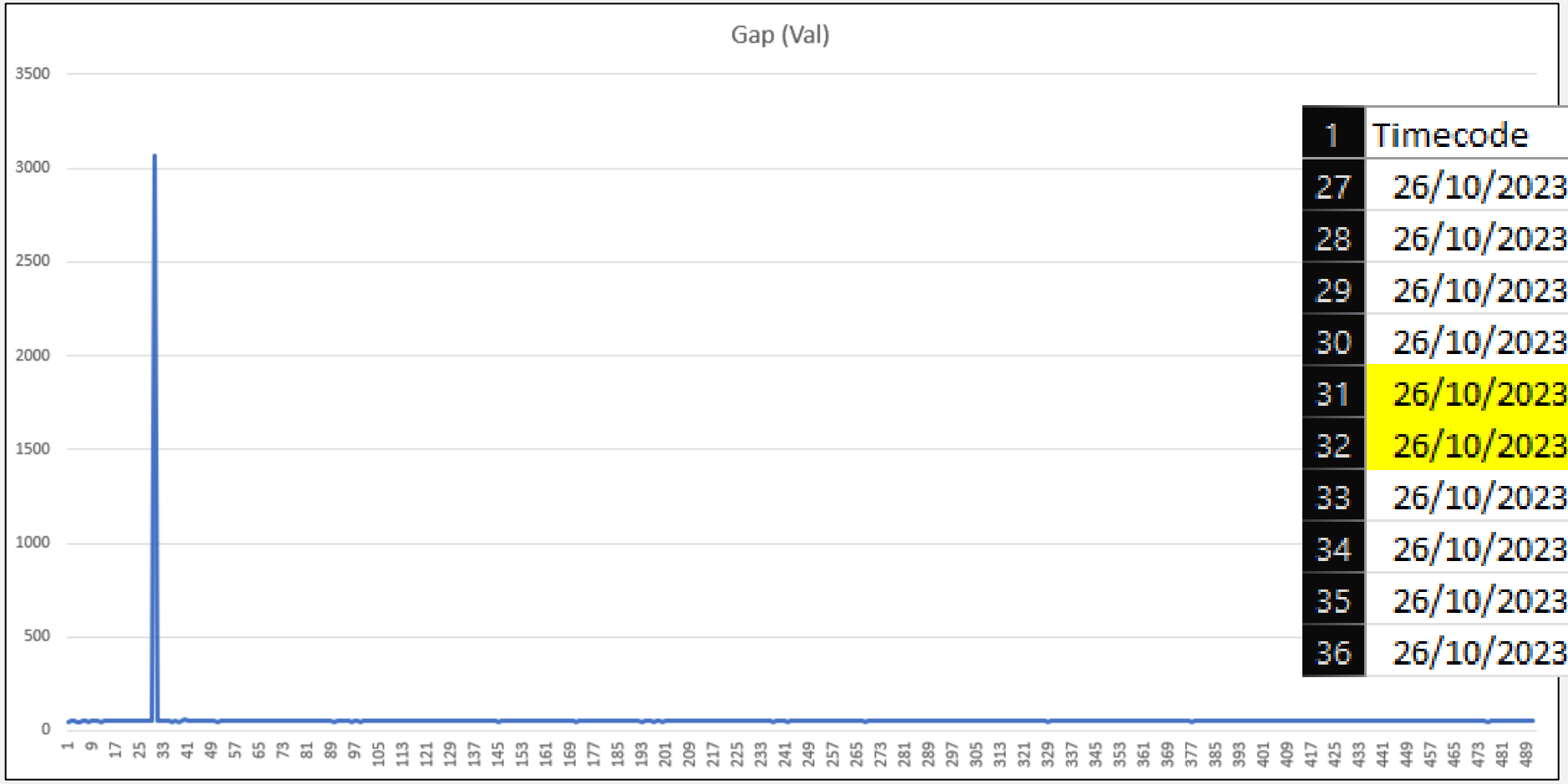
Multi-Device Test





Evaluation

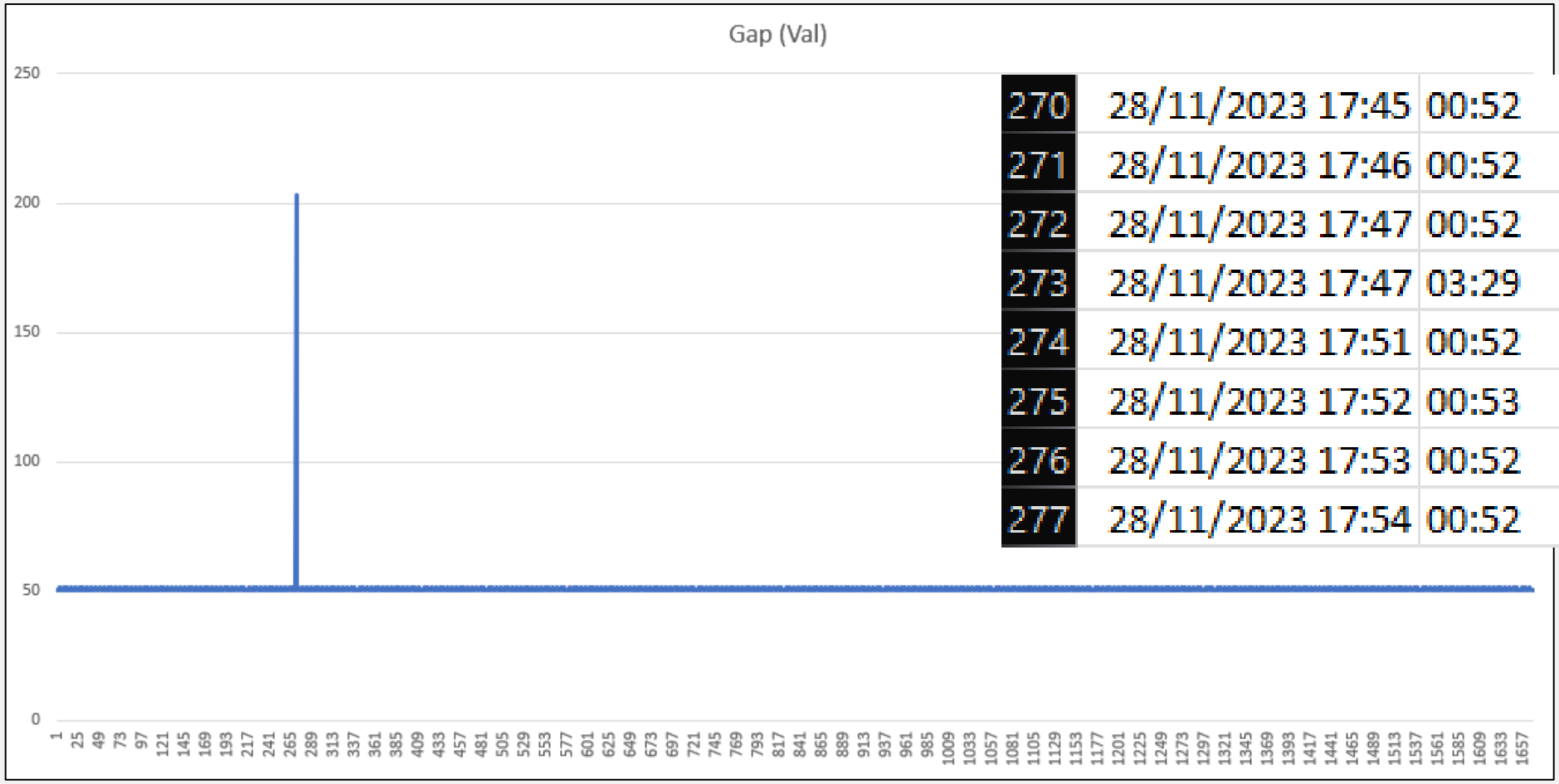
Reliability Test, 8-hour Local Test



1	Timecode	Gap	Gap (Val)
27	26/10/2023 22:42	00:56	54.44444
28	26/10/2023 22:43	00:56	54.44444
29	26/10/2023 22:44	00:57	55.41667
30	26/10/2023 22:45	00:56	54.44444
31	26/10/2023 22:46	52:33	3065.417
32	26/10/2023 23:38	00:57	55.41667
33	26/10/2023 23:39	00:57	55.41667
34	26/10/2023 23:40	00:56	54.44444
35	26/10/2023 23:41	00:57	55.41667
36	26/10/2023 23:42	00:56	54.44444

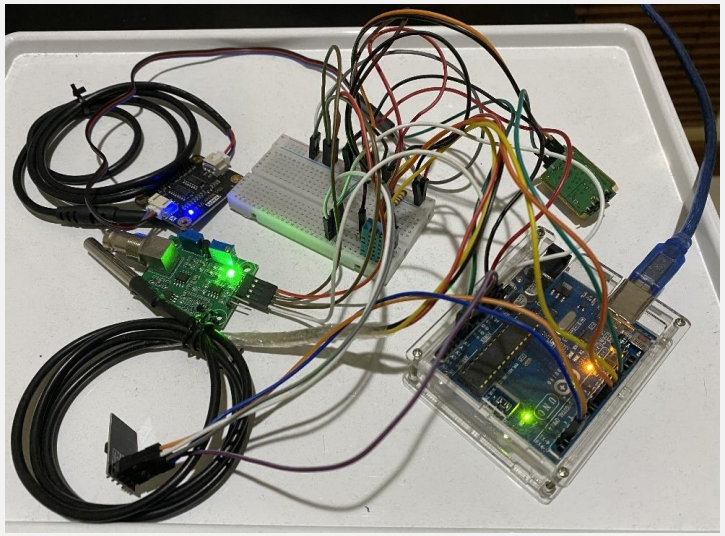
Evaluation

Reliability Test, 24-hour Cloud-based Test



270	28/11/2023 17:45	00:52	50.55556
271	28/11/2023 17:46	00:52	50.55556
272	28/11/2023 17:47	00:52	50.55556
273	28/11/2023 17:47	03:29	203.1944
274	28/11/2023 17:51	00:52	50.55556
275	28/11/2023 17:52	00:53	51.52778
276	28/11/2023 17:53	00:52	50.55556
277	28/11/2023 17:54	00:52	50.55556

Discussion



Not Ready for Commercialization

The current prototype is extremely unfriendly to end users.

It requires knowledge on how to modify Arduino programming, database management, and server troubleshooting.

Wi-Fi Reliability

The current prototype depends heavily on the stability of the Wi-Fi connection that it is connected to.

It has no “backups” or any ability to self-troubleshoot should anything go wrong with the Wi-Fi.

Discussion

Range Extension

- Dr. Michael expressed interest in expanding the device's range by having them communicate with one another.
- This approach is not possible due to the Arduino Uno's limitations. It can't provide enough power on 3.3V and it's memory can't bear the increased code complexity.
- Utilizing a commercial solution to extend the Wi-Fi network's coverage is a more practical solution.

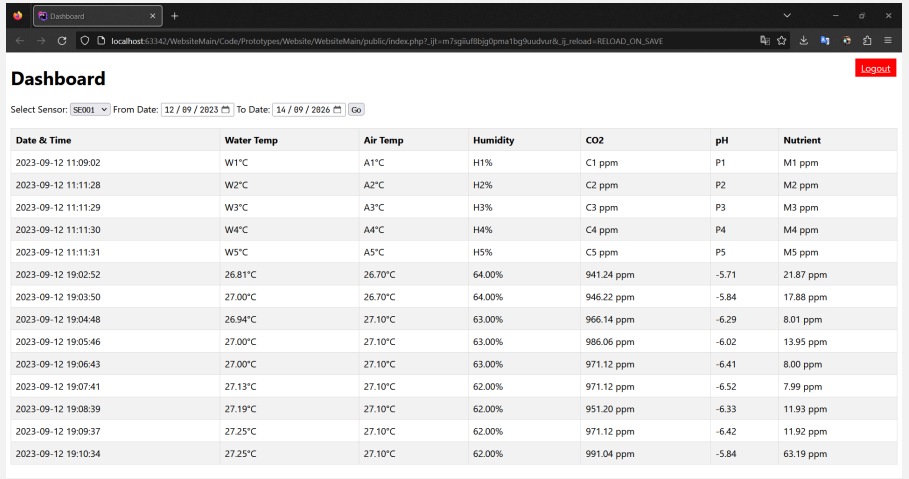
Discussion

Data Collection Frequency

- Everything is up to the customer.
- Currently a client/customer is only able to decide data collection frequency. But with a little development, they will be able to decide things like periodic data deletions (to conserve space).

UI Design Simplicity

- The UI design is very simple.
- The UI can be further developed on a client/customer's request.
- I think simplicity is a positive point because the day-to-day users will be low-education blue collar workers.



Date & Time	Water Temp	Air Temp	Humidity	CO2	pH	Nutrient
2023-09-12 11:09:02	W1°C	A1°C	H1%	C1 ppm	P1	M1 ppm
2023-09-12 11:11:28	W2°C	A2°C	H2%	C2 ppm	P2	M2 ppm
2023-09-12 11:11:29	W3°C	A3°C	H3%	C3 ppm	P3	M3 ppm
2023-09-12 11:11:30	W4°C	A4°C	H4%	C4 ppm	P4	M4 ppm
2023-09-12 11:11:31	W5°C	A5°C	H5%	C5 ppm	P5	M5 ppm
2023-09-12 19:02:52	26.81°C	26.70°C	64.00%	941.24 ppm	-5.71	21.87 ppm
2023-09-12 19:03:50	27.00°C	26.70°C	64.00%	946.22 ppm	-5.84	17.88 ppm
2023-09-12 19:04:48	26.94°C	27.10°C	63.00%	966.14 ppm	-6.29	8.01 ppm
2023-09-12 19:05:46	27.00°C	27.10°C	63.00%	986.06 ppm	-6.02	13.95 ppm
2023-09-12 19:06:43	27.00°C	27.10°C	63.00%	971.12 ppm	-6.41	8.00 ppm
2023-09-12 19:07:41	27.13°C	27.10°C	62.00%	971.12 ppm	-6.52	7.99 ppm
2023-09-12 19:08:39	27.19°C	27.10°C	62.00%	951.20 ppm	-6.33	11.93 ppm
2023-09-12 19:09:37	27.25°C	27.10°C	62.00%	971.12 ppm	-6.42	11.92 ppm
2023-09-12 19:10:34	27.25°C	27.10°C	62.00%	991.04 ppm	-5.84	63.19 ppm

05 Conclusion

Conclusion | Recommendation

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Conclusion

Conclusion & Recommendation

Conclusion

1. Current method of data collection is manual, infrequent, and lack standards.
2. Use of whiteboards to store data compromises data integrity.
3. Current processes are laborious, inefficient, time-consuming, prone to errors, and **are not scalable**.
4. An automated system based on Arduino, PHP, and MySQL was created to address these problems.
5. This case study successfully produced a working proof-of-concept prototype.
6. Lacks studies for commercialization due to project *constraints*.

Recommendation

1. **Casing design study.**
   Needs a casing. Current design is just a prototype of jumper cables.
2. **Independent 3.3V power supply for the ESP-01**.
   Current power supply is insufficient for the ESP-01.
3. **Economic viability study**.
   Such as economies of scale and cheaper module alternatives.
4. **Parallel local and offsite databases**.
   To increase data integrity should one of them suffer failure.
5. **Improvements on UI/UX, possibly a dedicated app for setup.**
   Current processes are not user friendly and requires direct code modification. Something like a mobile app to configure the sensor device would tremendously increase user-friendliness.

THANK YOU