Design and development of an IoT-based smart hydroponic system

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***Abstract*— One of the main issues of human civilization is how to fulfill the food needs. Food and Agriculture Organization (FAO) of the United Nations predicted that in 2050 the world population will grow to 9.1 billion people. It means that food production needs to be raised by 70% between 2005 and 2050 in order to feed a world population of 9.1 billion people. UN also predicts that 60% of the global population will live in urban areas by 2030. This will lead to the expansion of the metropolitan area of the city and conversely the reduction of agricultural land. On the other hand, the development of technology in the area of IT leads to the appearance of technology called the Internet of Things (IoT). In this paper, we present the design, development, and implementation of our preliminary research about the smart hydroponic system using the IoT concept to connect it to the cloud server.**

Keywords—internet of things; smart farming; hydroponics;

I. Introduction

One of the main issues of human civilization is how to fulfill the food needs. Food and Agriculture Organization (FAO) of the United Nations predicted that in 2050 the world population will grow to 9.1 billion people. It means that food production needs to be raised by 70% between 2005 and 2050 in order to feed a world population of 9.1 billion people [1].

UN also predicts that 60% of the global population will live in urban areas by 2030 [2]. This will lead to the expansion of the metropolitan area of the city and conversely the reduction of agricultural land. Hydroponic farming arises to address this problem. This urban agriculture model allows people to use their space of land or building for agriculture purpose, even if they only have small areas.

On the other hand, the development of technology in the area of IT leads to the appearance of technology called the Internet of Things (IoT). This technology enables other existing technology to be used in a much broader area. IoT enables the communication between machines, both in the local area or in the remote places by using the internet as the medium. The user can also monitor their sensors remotely using this technology. With all this advantages and opportunities created by this technology, IoT received a lot of attention both from industry and academia. Researchers and engineers begin to apply this technology, along with Wireless Sensor Network (WSN) technology [26-28], to diverse field area such as health care [3-5], transportation [6-8], surveillance [29-30], smart home [9-11], smart city [12-14], and agriculture [15-17].

This paper describes an application prototype for smart hydroponic using an IoT cloud platform. The first section describes the introduction of the study. Section two will describe the related works conducted by other researchers. Section three will be describing the design of the system. Implementation and result will be covered in section four. Then the conclusion will be presented in section five.

II. Related Works

Although the IoT technology is still immature in the agriculture field, there are several studies conducted in the application of IoT in the agriculture field. Karim et. al. proposes a prototype of precision agriculture using a wireless sensor network, using ubidots [18] as the IoT cloud platform. Popovic et. al. [19] proposed an architecture of IoT platform for agriculture and ecological monitoring and has been tested to use with a heterogeneous type of hardware (Arduino, Raspberry Pi, PC) as the IoT nodes.

There is a fewer paper published in the hydroponic-specific field. Wu, et. al. [20] use various sensors and actuators along with IoT in their Intelligent Plant Care Hydroponic Box (IPCH-Box). Triawan et. al. [21] use publish-subscribe method as their middleware architecture in their Nutrient Film Technique (NFT) hydroponic IoT system. They use MQTT as the protocol of communication between the nodes, middleware, and application. They also use the information from the sensors to control electrical conductivity and pH in their hydroponic system using fuzzy logic as the method [22].

Several studies on challenges on the application of IoT in smart farming has been published. One biggest challenge is to find a suitable architecture of the IoT, especially the middleware technologies [23]. The heterogeneous and the quantity of data collected by the sensors become another challenge, as the collected data will become a big data. Wolfert et. al. [17] conducted a review on this challenge, providing an overview of the challenges and the key issues in this matter. Finding a suitable database for IoT data storage can also be tricky, as stated by Ahn Mai et. al. in their study of database comparison for IoT data storage [24]. Another challenge is how to get the benefit of these big data, the challenges can be in form analytics method, or how to reduce the data dimensionality of the big data produced from smart farming [25].

III. METHODOLOGY

This research focuses on designing and developing the IoT-based smart hydroponic system. The global steps of this research can be seen in the following list:

- System Development
- Integration

For the system development methodology, we use the Agile method [26]. Agile method was chosen in order to develop a working prototype as soon as possible by minimizing the planning process and focusing on the iterative process of development. Agile model can be seen in fig. 1.

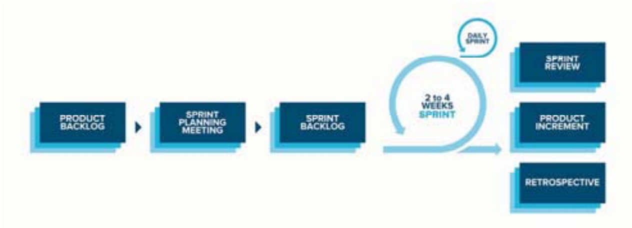

Fig. 1. Agile Scrum model

IV. SYSTEM DESIGN

A. System Architecture

In our system, there are three main blocks that build the system. The first one is the node. The node is the bundle of sensors and actuator which planted in and interacts with the hydroponic system. The second block is the API and backend server. This block acts as the gateway for both node and the next block which is front-end application. Front-end application is used as the interface between the system and users, either via computer or smartphone. The block diagram of the system architecture can be seen in Fig.2.

We use Open Garden as our data acquisition module. Then we serialized the data from Open Garden and transfer it to WiFi module to be sent to the Cloud Server. ESP 8266 is used as the WiFi module of our system.

B. Application Programming Interface (API)

The API acts as a gateway of communication between nodes, front-end app, and mobile app. We use Representational State Transfer (REST) as an architectural style for the API. In general, the API of this system can be categorized as follows:

- Sensors
  - Sensor node
  - Single sensor data
- Actuators
  - Actuator node
- Single actuator
- Application
  - Generic application data

The backend of the API is built on top of the PHP-CodeIgniter stack. MySQL is used as the database management system. According to [24] MySQL performance is only falling behind to MongoDB in write performance. But MySQL is better in size required to store the data, which required a smaller amount of disk space. Javascript Object Notation (JSON) is used as the format of data exchange between the API and nodes/app. To get the sensors information of certain node, we use GET method with following URL: */iot_api/sensor?sd_id=*[*node id*]. The JSON format of sensor node API can be seen in the following code:

```
[
    {
        "ss_id": "xxxxxx1",
        "ss_name": "sensor 1",
        "ss_description": "Sensor 1 description",
        "ss_unit": "point",
        "ss_creation_date": "YYYY-MM-DD HH:MM:ss",
        "ss_last_activity":
             " YYYY-MM-DD HH:MM:ss ",
        "sd_id": " xxxxxxa1"
    },
     …
     {
        "ss_id": " xxxxxxn",
        "ss_nama": " Sensor n",
        "ss_description": " Sensor n description ",
        "ss_unit": "&deg;C",
        "ss_creation_date": " YYYY-MM-DD HH:MM:ss ",
        "ss_last_activity":
             " YYYY-MM-DD HH:MM:ss ",
        "sd_id": " xxxxxxan"
     },
]
```

As we can see, the API returns the information of sensors in the form of an array. The array contains the object of sensors in the selected node. To get the data of selected sensor, we use GET method with following URL: */iot_api/sensordata?ss_id=*[*sensor id*]. The JSON format of sensor data API can be seen in the following code:

```
{
    "name":"pH",
    "unit":"point",
    "status":"success",
    "category": ["YYYY-MM-DD HH:MM:ss", "YYYY-MM-DD
         HH:MM:ss", "YYYY-MM-DD HH:MM:ss", "YYYY-MM-DD
         HH:MM:ss", " YYYY-MM-DD HH:MM:ss",
    "data": [(float) x, x, x, x, x],
    "last_data ": {
         "datetime": "DD MM YYYY - HH:MM:ss ",
         "value": (float) x
    }
}
```

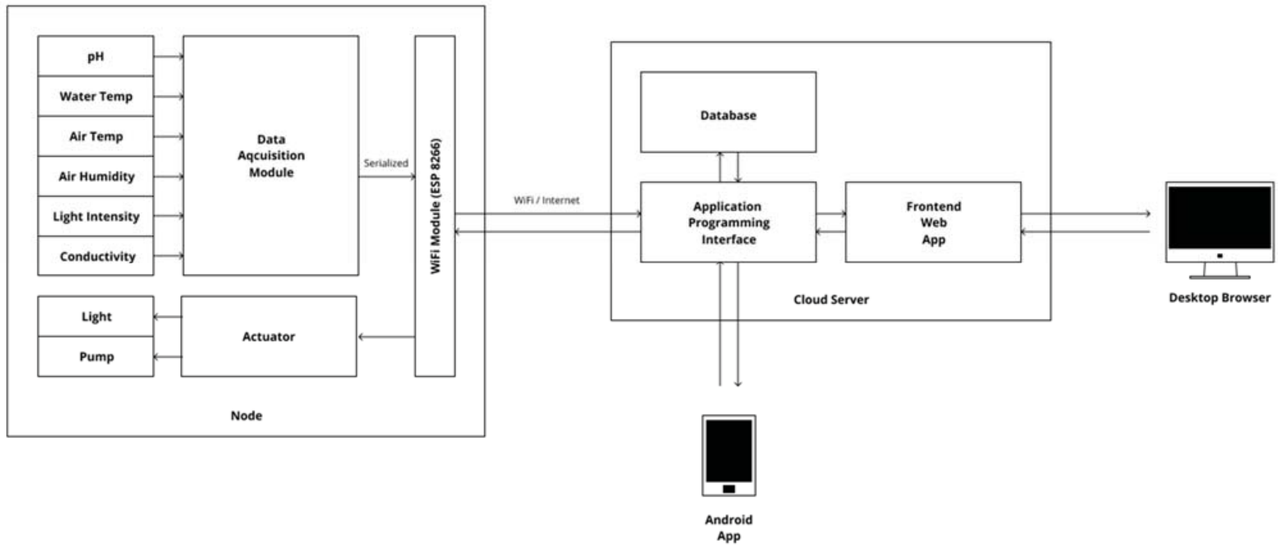

Fig. 2. System Architecture

C. *Front-end Applications*

There are two kinds of front-end application we built for this system. The first one is the front-end web application. This web app basically extends the system of the API with the addition of the views module. This app relies heavily on Javascript to display the data to the user. The other one is the mobile application. The app is developed for the Android smartphone platform, allowing the user to monitor and control the hydroponic from their smartphone. The app is developed using MIT app inventor, a tool for developing an android app without having to actually code the program, but instead using a block-like visual object as the logic program. This tool allows us to prototype the android app quickly.

V. Implementation and Results

The design then developed into a working prototype of the system. Fig. 3 shows the physical view of the developed prototype. Fig. 4 shows the prototype of the node hardware which contains sensors and data acquisition module.

The screenshot of the frontend web app can be seen in fig. 5 below. The app dashboard shows the chart of each sensors data at a certain interval. The number of data displayed can be set by selecting the desired length of data in the combo box provided. Fig. 6 and fig. 7 shows the chart from the pH and light intensity sensors.

The dashboard of the Android mobile app is shown in Fig. 8, containing a chart for sensors data, including pH, water temperature, air temperature, air humidity, light intensity, and conductivity. The red bar in the chart shows that the current level of condition measured by the sensor is not optimal. So a certain action of control in the actuator needs to be made in order to make the condition is optimal for the plants (shown by the green bar).

Fig. 3. Hydroponic system prototype

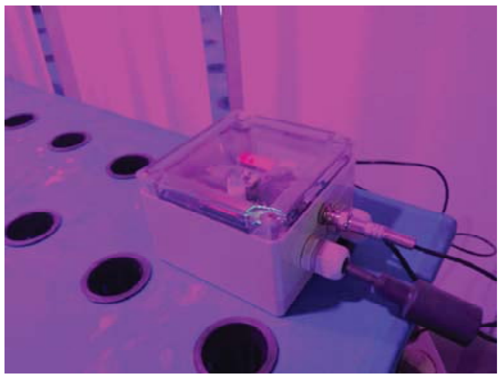

Fig. 4. Node hardware prototype

Fig. 5. Front-end web app dashboard

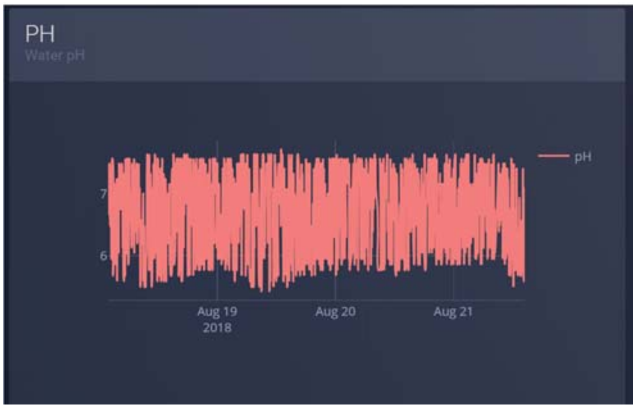

Fig. 6. pH data chart on front-end web app

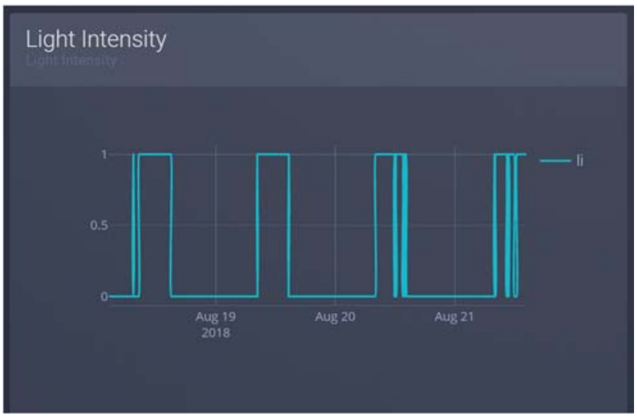

Figure 7 Light intensity data chart on front-end web app

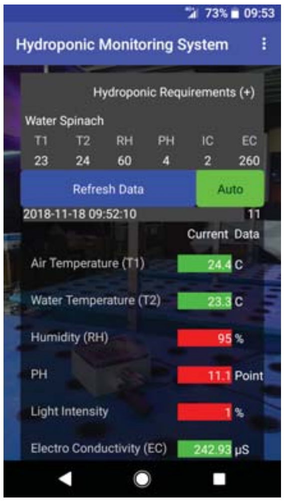

Fig. 8. Dashboard screen on android mobile app

VI. Conclusion

In this paper, we presented design, development, and implementation of our preliminary research about a smart hydroponic system using the IoT concept to connect it to the cloud server. Open Garden is used as our data acquisition module. The data from Open Garden is serialized and then transferred to WiFi module to be sent to the Cloud Server. From there the data can be displayed in the web using front-end web app or in the smartphone using the android app. After testing, the system is work as intended and ready to use. As future work, we plan to develop a smart model based on the data obtained from this system. This model could be used as the decision for controlling the actuator or as the insight for the user by providing some trends or large scale prediction based on the data.

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