IoT Applications in Smart Agriculture: Issues and Challenges

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Abstract-The rapid development of Internet of Things (IoT) technologies created tsunamis almost in every industry across the world and particularly in agriculture. This massive changes are shaking the existing agriculture methods and creating new wave of opportunities. Due to the increase of world population by 30%, agriculture products will have a very high demand by 2050. Human resources for agriculture development is becoming less due to migration of young people to big cities and land use for agriculture cultivation is being used for rapid development. As a result, most of the agriculture activities need to be automated to fulfill the food demand. IoT and related technologies will be the potential solution to solve the above agricultural and food demand issues. This paper will explore the latest trends in IoT agriculture applications and highlight the issues and challenges particularly in network and open source software for smart agriculture.

Keywords - IoT, smart farming, agriculture, network, architecture, wireless sensors and open systems.

I. INTRODUCTION

Internet of Things (IoT) technologies have created tsunamis almost in every industry across the world. IoT technologies and devices will sense, collect, store and communicate data to various components in an application such as smart agriculture. The smart agriculture revolution refers to the use, integration and deployment of the latest technologies such as Internet of Things (IoT) in agriculture, with the aim of improving and increasing the quantity and quality of crop harvest.

The adoption of smart agriculture can be further improved among farmers in many ways. The government may consider to give subsidy to farmers accordingly to the rate of their technology adoption [1]. However, it is very crucial for farmers to be given comprehensive knowledge and know-how advice on the use of smart agriculture techniques before the proposed system is widely introduced.

Agriculture will continue to be an important source of economy for many countries and in near future smart agriculture will change the country's agricultural landscape. IoT technologies will enable farmers to view and manage their farms remotely and at the same time big scale agriculture farms could easily be implemented and monitored precisely.

Section 2 will discuss about the related works and IoT applications in the agriculture industry. Section 3 and 4 will elaborate the potential IoT applications in agriculture. Section 5 will elaborate open source software for agricultural (farm) management. Section 6 will address the issues and callenges. Finally, Section 7 will discuss on the conclusions.

II. RELATED WORKS

There are many successful IoT applications in agriculture sector implemented throughout the world including China, Taiwan, Thailand, Malaysia and other countries. In the next sub-sections, some of the applications will be discussed in detail.

In the area of environment monitoring, China has developed a low cost and low power environment monitoring system in a greenhouse. Practical implementation of the system shows that the system is reliable which reduces the cost of manpower by sending the instructions remotely and timely. As a result of the IoT implementation, fertilization rate was reduced about 60% whereas pesticides up to 80% and labour cost by 60% [2].

Taiwan have produced a low cost IoT platform for precision farming to monitor the soil conditions [3]. The platform has been implemented to monitor the turmeric cultivation. By

implementing the IoT system, amount of chlorophyll in the Turmeric plants was increased from 40~60% which is more than existing traditional methods whereas 70% of water also saved

In Thailand, IoT water control system has been designed to monitor the water consumption. The result indicates that humidity level should be 70-80% for lemons growth whereas for the high productivity of vegetables and lemons temperature was 29 °C and 32 °C [4].

In Malaysia, IoT system was developed for fruit tracebility. Ministry of Science, Technology, and Innovation of Malaysia (MOSTI) developed an IoT-based solutions called *Mi-Trace*. The developed system is a tracking platform to trace any agricultural products especially *musang king* fruit which is advantageous for sellers and exporters to ensure the origin and quality of the fruit [5].

In general, IoT agriculture applications can be divided into precision agriculture (outdoor) and greenhouse monitoring (indoor).

III. IoT APPLICATIONS IN PRECISION AGRICULTURE

Precision agriculture helps to improve the livelihood of the farmers by automating and optimizing all feasible agricultural parameters in order to enhance the agricultural cultivation and productivity. IoT sensors help to measure soil quality, weather conditions, moisture level, and finally optimize these parameters to increase the yield.

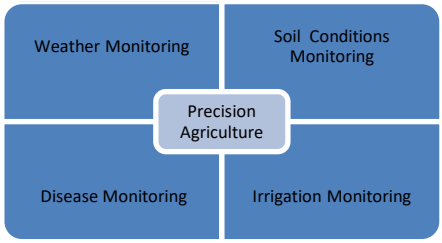

Figure 1. IoT in Agriculture Applications

Figure 1 shows the major components of IoT applications in Precision Agriculture. In general, the IoT precision agriculture consist of four components; weather monitoring, soil conditions monitoring, plant disease monitoring and irrigation monitoring.

a. Weather Monitoring

Critical weather parameters that impact the growth of agriculture includes temperature, humidity, wind and air pressure etc. These data are collected using sensors (wired or wireless) and transmitted to the cloud servers. The collected data will be mapped with climate conditions, and analytic tools are used to determine the next course of actions to improve the agricultural growth.

b. Soil Contents Monitoring

Soil monitoring has become one of the most demanding practices in agriculture field. Soil patterns which are critical for agriculture cultivation includes soil humidity, pH, moisture and temperature.

c. Diseases Monitoring

Several IoT agricultural applications such as diseases monitoring and identification have been digitized which helps the farmer to make informed decisions much faster. Image processing and machine learning techniques are used to determine the healthiness of the plants. An IoT-based wheat diseases and pest monitoring system has been developed [6].

d. Irrigation Monitoring

IoT helps to improve the traditional irrigation system in a more innovative way by taking into consideration the current (in real time) weather and soil conditions. Irrigation is only done when its necessary based on the above parameters. This will help the farmers to reduce irrigation cost and optimize water resources [7-8].

IV. IoT APPLICATIONS IN GREENHOUSE

IoT technologies in a greenhouse provides benefits to growing plants using “anytime and anywhere” concept. Monitoring, controlling and tracking in a greenhouse requires high precision since the cultivation taking place in a controlled environment. Deployment of IoT technologies in greenhouses have minimized the human resources, optimize resources (e.g. water, fertilizer etc.), increase yield and provides direct link between farmers to customers [9-10].

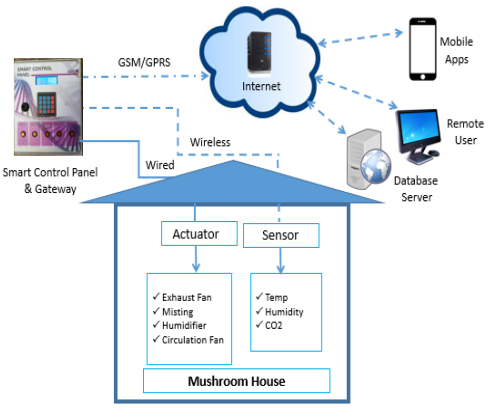

Figure 2. A WSN for Greenhouse Monitoring [11]

Figure 2 shows a Wireless Sensor Network (WSN) to monitor a Smart Mushroom House (SMH), an example of a greenhouse environment. The wireless sensors will send data collected in real-time from the greenhouse to the Smart Control Panel (SCP). The SCP will use the analytic tools plus the sensor data to make strategic decisions such as on/off the irrigation systems at the right time through the actuators. Different monitoring devices and sensors will be used in a greenhouse and this is based on the crop and environment requirements.

V. OPEN SOURCE AGRICULTURAL MANAGEMENT SOFTWARE

In general, smart agriculture software is a web-based tool that enables farmers to monitor environmental parameters, manage and maximize yields while preserving and optimizing resources. An advanced version even allow farmers to use AI tools to forecast expected yield and revenues.

There are not many open source smart agriculture software available in the market compared to the commercial software. In the following sections commonly available open source smart agriculture software will be explained.

Tambero is a web-based farm management software that allows farmers to manage the crops effectively. Besides that, *Tambero* also includes the weather forecast system and supports the agriculture management, cattle management and livestock management features [12].

FarmOS is another web-based farm management application using Drupal web application framework and completely open source. Drupal is used worldwide, and it provides infrastructure to translate *FarmOS* into many languages. It can be used for agricultural management, planning, and record keeping [13].

Trimble is a web-based farm management platform and the basic plan is free for farmers. Farmers can access their farm data from anywhere from the world since they are connected to the Internet. It includes features such as weather forecast, creates a client, farm and yield records [14].

The *Farmathand* is another agricultural multiuser software and provides features such as farm management, farm equipment management, sales and inventory management [15].

Tania is an open source farm management software based on Go, Vue.JS, and SQLite. *Tania* is licensed under Apache 2.0. It allows to connect various sensors and manage it while we are on-the-go. This software is built using *Go* programming language and it will generate an executable binary to run on your computer [16].

FarmRexx is an online agricultural farming recording and management software that can be used anywhere that you have Internet access. The features include keep track of the farm equipment records, livestock records, livestock movement, farm chemicals and weather records [17].

VI. ISSUES AND CHALLENGES

There are few open issues and challenges which are needed to address immediately in smart agriculture [18]. These issues include hardware and devices, networking, infrastructure, signal interference, data security and organizational challenges. There are many challenges which are link to smart agriculture technology and applications deployment. The issues and challenges will be explained in detail in the next sections.

a. Power Consumption

The coverage area in smart farming make wireless devices indispensable, and solutions to reduce their power consumption or extend their battery life are required. These solutions can include energy harvesting such as solar cells, low power consumption sensors and communication

technologies or incorporating intelligent power efficient management algorithms [19].

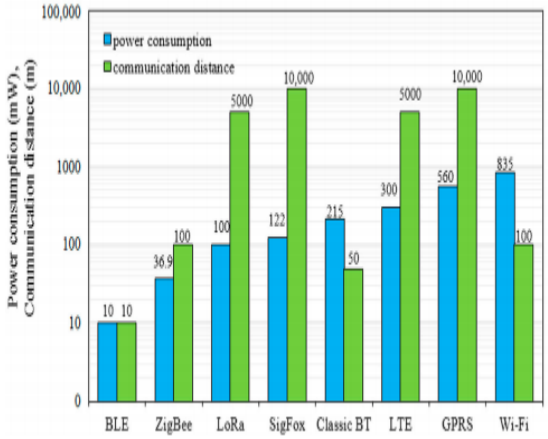

Table 1: Wireless technologies, power consumption and distance [19]

Power consumption also depends on the communication protocols utilized in the Smart Farming applications. Table 1 shows the communication protocols and the power consumption for each of them. ZigBee and LoRa wireless protocols have been identified as the most suitable wireless protocols for agricultural applications because of their low power consumption and communication range.

b. Hardware

IoT hardware and equipments which are directly expose to harsh environmental conditions such as, rain, high level temperature and extreme humidity may destroy the equipments (e.g. electronic parts). The design of the IoT devices are very crucial and also the compliance to standards such as IP67 especially for devices which are deployed in open field [20].

c. Networking

Due to high wiring cost and maintenance issue, wireless communication is widely used for the deployment of smart agriculture. Communication signals from IoT devices become weak when they reached the transceivers due to many physical obstacles in the agriculture field. As such, the most reliable and robust networking technologies should be used to transfer data in agricultural environment [21].

d. Infrastructure

IoT infrastructure for agricultural environment is more complicated as compared to other applications. This is simply because agricultural environment requires continuous real time monitoring and support stringent environmental conditions. A service oriented approach (SOA) can be considered as a more suitable software platform. Besides that, frameworks and open source tools should be made available to agricultural developers to build sustainable and affordable applications [22].

e. Communication Signal

In many remote rural areas, particularly in the developing countries, strong, reliable Internet connectivity is not available yet. Unless the network performances and bandwidth speeds are significantly improved, implementation of smart agriculture will remain as an issue. In many farmlands that have tall and dense trees reception of communication signals becomes a big issue [23].

f. Reliability and Scalability

In smart agriculture, the IoT devices are deployed in open field with stringent environmental conditions. As such, the external impacts may cause the IoT devices fail to communicate and unable to send the collected data to the server or cloud on time. A large number of gateways are needed to support ever increasing IoT devices and applications. Furthermore, IoT agricultural databases and networks should be reliable and scalable to support complex applications.

g. Awareness and Knowledge

In general, majority of farmers are uneducated and lives in rural areas. They are lack of IoT knowledge and applications. This is one of the main obstacle for deploying IoT in rural areas. Farmers need to be educated on IoT technologies and how it can help them to run their farms more efficiently and at the same time increase the productivity and revenue.

h. Data Security

There are a wide variety of smart devices deployed in IoT applications. Most of these devices are not primarily designed with security

and privacy issues in mind. Therefore, new security and privacy problems arise such as data integrity, authentication, access control, etc. [24]

The IoT-based agricultural applications transmit millions of data every day and the security of the data is very important. The IoT devices need to make sure that sensitive data or information are encrypted before there are transmitted. There is a need to provide a mechanism that guarantees data security throughout IoT network layers [25].

i. Business Process

The entire value chain in food organizations and agricultural sectors need to be reengineered since there will be a major change in the business process of agriculture products from the farmers to the retailers and customers. Farmers and agricultural orgnizations should be equipped with knowledge (e.g. e-commerce platforms) and resources to manage the new challenges.

VII. CONCLUSIONS

This paper present a survey on IoT applications in agriculture. IoT-based agricultural applications, open source agricultural software, issues and challenges are discussed in detail. Furthermore, this paper provides an overview of how IoT technologies are going to change the agricultural sector and help the farmers to manage their farms more effectively and at the same time increase their revenues. Finally, it is expected that IoT technologies will help the agricultural sector and farmers to meet the food demand by 2050.

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