Overview of IoT development in Agriculture and Applications in Vietnam

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Applying Internet of Things (IoT) in agriculture can be identified as the process of digitalizing agricultural production including processing and consumption through sensor system, data management and automatic farming. Intelligent agriculture has helped some developed country provide enough not only for their people but also for exportation. For example, in Israel, with 2.5% of the population do the farming, the productivity of one person can provide enough for 15 people in average in 1995. But in 2014, each farmer can provide for up to 100 people and they can export more than 3 billion USD agriculture products each year [1]. In Japan, with only 1.5% population do farming, they do not need to import rice. More than that, they can export beef and some kind of fruits. In Korea, with only 5% population do farming, they can provide enough for their people [1]. The IoT applications have provided agriculture a big move. The report is as the followings. Section I will investigate the detail of the IoT hardware and platforms which have been used in agriculture. Section II is the applications of IoT in agriculture. Section III provides an overview and development of IoT in Vietnam's agriculture.

I. IoT hardware and platforms in agriculture

In the intelligent agriculture, sensors and intelligent devices are connected and automatically controlled to face with climate changing and to improve the microclimate in greenhouses.

1. Low-power wireless sensor networks

In the recent literature, a large number of embedded programmable devices have been used. It can be custom-built, or commercial programmable boards. Custom-built programmable devices give developers the flexibility to have full control over the behavior of the nodes. It is easy to add or remove nodes depending on the necessity [2] [3] [4]. Commercial sensing solutions provide a number of features out of the box, which allows researchers focus on other aspect of IoT deployment, such as meta-processing, smart algorithm for monitoring and control, cloud interoperability [5] [6].

For the potential applications of IoT in agriculture, researchers divided them into networks of scalar sensors (sensing and control of infrastructure), multimedia sensor networks (remote image capturing and processing for the detection of insects and plant diseases) and tag-based networks (RFID, NFC) [7]. For the wireless sensor networks to be applicable to agriculture, the specific characteristics of the situation and the environment in which the nodes will be deployed should be considered. Crops, or other obstacles in the farm, may cause interference in the communication among nodes. The movement of the obstacles may affect the quality of links, the deployment, routing, then lead to failure diagnosis. In [8], the environment factors such as temperature, humidity, rainfall and high solar radiation, the effect of shading by the plant leaves, etc… have been proposed to greatly affect the links and communications among nodes. Therefore, the choice of correct IoT platform to build a deployment could affect the overall success of the project. A summary of some popular programmable boards and embedded platforms used in recent deployment is presented in Table 1 [9]

Table 1 – Summary table of WSN/IoT embedded platforms.

Platform name	Microcontroller	Transceiver	Program, Data Memory	Flash, EEPROM, Ext. Memory	Programming
IMote 2.0	Marvell PXA271 ARM 11–400 MHz	TI CC2420 IEEE 802.15.4/ZigBee compliant radio	32 MB SRAM	32 MB	C,.Net, NesC
Iris Mote	ATmega 1281	Atmel AT86RF230 802.15.4/ZigBee compliant radio	8 KB RAM	128 KB	NesC, C
TelosB/T-Mote Sky	Texas Instruments MSP430 microcontroller	250 kbit/s 2.4 GHz IEEE 802.15.4 Chipcon Wireless Transceiver	8 KB RAM	48 KB	NesC, C
Zolertia Remote	CC2538 ARM Cortex-M3	Dual Radio: 802.15.4/CC1200 868/915 MHz	32 KB RAM	512 KB	C, NesC
Zolertia Z1	Texas Instruments MSP430 microcontroller	Chipcon Wireless Transceiver 2.4 GHz IEEE 802.15.4	8 KB RAM	92 KB	C, NesC
WiSMote	Texas Instruments MSP430	TI CC2520 2.4 GHz IEEE 802.15.4	16 KB	1–8 MB, 128, 192 or 256 KB	C
Waspmote	Atmel ATmega 1281	ZigBee/IEEE 802.15.4/DigiMesh/RF, 2.4 GHz/868 MHz/915 MHz	8 KB SRAM	128 KB, 4 KB EEPROM, 2 GB SD card	C, Processing
Arduino Uno/ Mega/Nano	ATmega328P/ATmega168/ ATmega328P	External modules	2 KB SRAM/8 KB SRAM/2 KB SRAM	32 KB, 1 KB/256 KB, 4 KB/32 KB, 1 KB	C, Processing
Arduino Yun (2 processors)	ATmega32U4/Atheros AR9331	Ethernet, Wifi	2.5 KB, 64 MB DDR2	1 KB/16 MB	C, Processing, Linux
Raspberry Pi (various versions)	ARMv6 (1-core, 700 MHz)/ARMv7 (4-cores, 900 MHz)/ARMv8 (4-cores, 1.2 GHz)	Onboard LAN, *Wifi/Bluetooth (*RPi 3 only)	256 MB–1 GB SDRAM (@400 MHz)	SD card	Linux
LoPy (2 processors)	Xtensa (2-cores, 160 MHz)	Onboard Wifi, SX1272 LoRa, Bluetooth (BLE)	256 KB	1 MB (internal) 4 MB (external)	MicroPython
NodeMCU	ESP8266/LX106	Onboard Wifi	20 KB RAM	4 MB Flash	Lua, C, Processing, Python
Arietta G25	ARMv9 (4-cores, 400 MHz)	External Wifi adapter	128–256 MB RAM	SD card	Linux
WIOT Board	ATmega32U4 ESP8266 (for Wifi)	Wifi	2.5 KB SRAM	32 KB, 1 KB	C, Processing
Intel Galileo/Edison	Intel Quark X1000/Intel Atom	External modules/Wifi/Bluetooth LE	256 MB RAM/1 GB RAM	8 MB, SD card/4 GB, SD card	C, Processing/Linux

2. Widely used sensors and platform characteristics for agriculture IoT deployments

Although many theoretical aspects of WSN have been extensively studied in literature, when applied into agriculture, realistic IoT wireless sensor network deployment is quite demanding and challenging. Sensor modules need to be accurate enough as there will be environment factor (temperature, wind, rain…), which can either create fall readings or even destroy the sensor permanently. High temperature and humidity are two very common phenomena as we need to take care of. The authors in [10] [11] have observed that temperature has a significant effect on the received signal strength (RSS). Furthermore, humidity can also be very high in agriculture deployments and it has been shown to strongly affect to radio wave propagation [12] [13]. Therefore, when choosing a wireless transceiver for an agriculture deployment, the number of nodes, the distance between nodes, the height of the antenna, and the operating frequency based on the desired size of messages are serious matters to be taken into consideration.

II. Applications in agriculture

The structure of IoT is based on three layers; namely, the perception layer (sensing), the network layer (data transfer), and the application layer (data storage and manipulation). Despite great improvements, IoT is still evolving and trying to obtain its final shape [14] [15] [16]. The internet as we know today is mostly an internet of human end-users, while the IoT will be an internet of non-human entities, therefore a lot of machine-to-machine (M2) communication will take place. Thanks to the IoT hardware, platforms and sensors in agriculture, the traditional agriculture has evolved logically to precision and micro-precision agriculture [17]. Climate sensors, radiation sensors, weather stations emphasize that it is all about sensors and sensor data flows, which are stored and used for monitoring and control. Moreover, in recent years, there is an increasing demand for high quality and safe agriculture products, which requires for interoperable, distributed, robust and accurate logistics traceability systems. The IoT techniques provides all the appropriate tools for building and maintaining such systems

1. Agricultural monitoring and control

In [18], a chlorophyll fluorescence imaging robot is built to monitor the health conditions of tomato crops in semi-commercial greenhouse. Sensing the environment in which production occurs and the response of the plant is crucial for taking the precise decision. The tomato fruit color change at different maturity stages after storage was estimated using a multiple regression, using three independent variables: chromaticity of tomato before storage, storage temperature and storage duration. It is suggested the tomato fruit color estimation technique can be used to control the tomato color with storage.

The authors in [19] proposes a methodological approach to the development of Decision Support Systems (DSS) to build a quantitative approach for pest prevention in greenhouse. By monitoring the climatic conditions inside the greenhouse and establishing proper alert, it is able to control actions for preventing the spread of pests and diseases. The monitoring system installed in the greenhouse is a WSN constituted by Adruino based temperature sensors (MLX90614 from Melexis) communicating with central station through a zigbee network..

During the growing period of produce, in order to control the farming condition, using the polyhouses. It helps in control of various factors affecting the produce. Soil pH and moisture can be measured using pH and moisture potentiometer at various points in the polyhouse and sent to the central server over Bluetooth or Wifi [20]

2. Controlled environment agriculture

Greenhouses have been shown to present significant climate variability, which affects the productivity [21]. Greenhouse cultivation is more intense; hence, it requires higher precision in monitoring and control. Several studies focus only on localized and remote monitoring. In most cases, data are stored and represented in graphical ways [22] [6]

[23]. Cloud IoT has been applied to agriculture as well. End-nodes collect various data which are uploaded to the cloud. Then data is analyzed at a faster way, lower cost, reliability and efficiently [24] [25]

In [22], a knowledge-based system was built for online precise irrigation scheduling (OpIRIS). Microclimate sensors in the greenhouse are connected to device-to-web data loggers that feed a sensor data database. The algorithm calculates the crop transpiration rate based on solar radiation, air temperature, humidity, measurement of substrate water content, nutrient supplied, weather forecast, then states when to irrigate and how much nutrient solution to apply. The system was tested in two farms in Greece and proved to be successful in predicting crop water need in advance and increase the fertilizer-use efficiency. Similar attempts to automate irrigation have been based on an agriculture information cloud and a hardware combination of IoT and RFID [26]. The results showed high efficiency of resource use and significant improvement in water quality.

3. Open-field agriculture

In open-field agriculture, researchers often measure climate and soil conditions. In many cases, more than one sensor has been used at different depths. Optical sensors have been also used for additional information on remote temperature sensing and mapping of the situation in the field [27] [28]. Integration of IoT and Geographical Information System (GIS) has been used in cases where precision of mapping of the sensed data is important [29] [30].

4. Food supply chain tracking

RFID is the most common IoT technology found in Food Supply Chain (FSC). RFID tags, acting as enhanced barcodes, enable the tracking of agriculture products. Recent research has combined more than one sensor to enrich the information of product when it is recorded through RFID [31] [32]. The realization of IoT-based infrastructure leads to the virtualization of the supply chain, as the physical proximity is no longer required [33] [34]. The robustness and maturity of technologies in IoT have given researchers the opportunity to develop complete systems, which offer automated services, intelligent schemes and automatic reasoning [35] [36]

III. Applications of IoT in Vietnam’s algriculture

Regarding the IoT infrastructure in Vietnam, there are about 10 official IoT suppliers. To name a few: Viettel, IoT Group, FPT, DTT Company, Microsoft Vietnam, Konexy, Hachi, Rynan Smart Fetilizer. Besides, here are some enterprises that have applied IoT into their agriculture process: Hanoi University of Agriculture, Nguyen Tat Thanh University, Ho Chi Minh University of Science and Technology, TH True Milk, Dalat

Hasfarm, Vingroup in Hai Phong, Quang Ninh, Lam Dong. Among them, TH True Milk (dairy cow) and Vingroup (fresh vegetables) have a quite complete IoT system.

Microsoft Vietnam provided the SmartChick software, which provides a safety and scientifically chicken raising process. SmartChick is a automatic or semi-automatic through IoT, for users can take care of their chickens at any time and any place through the Internet [1]

In Vietnam, the application of IoT in agriculture has been more and more concentrated. A day-to-day increasing population leads to the rising demand for high-quality products, which create the need for the modernization and intensification of agriculture practice. Currently, Vietnam has 3 high-tech agriculture zones in Hau Giang, Phu Yen and Bac Lieu [37]. The State Bank of Vietnam (SBV) along with commercial banks also offered a financial package of VND 100 trillion (US$4.37 billion) to support enterprises applying high-tech farming [37].

There are several softwares that has been developed and applied for the Vietnam agriculture. For example, iQShrimp [38]- a digital software developed by Cargill. Using this software, data from shrimp ponds, which are shrimp size, water quality, feeding patterns, health and weather conditions, can be captured through mobile devices, sensors. The software uses these captured data to provide insights and recommendations, such as feeding management strategies and optimal harvest dates. The iQShrimp has been installed and developed in Technology Application Center in Bac Lieu and Tien Giang. The center is designed to help farmers access the lastest innovations and apply the best possible solutions to their seafood products and increase their profits.

Another software is Smart Agri [39]- by Global CyberSoft, which has been applied in Vietnam since 2015. By using remote real-time data collection, users can monitor the status of production, adjust environment and control production devices [37].

Here are some interesting results after applying software into agriculture. Ms. Nguyen Thi Hue in Da Lat City, Lam Dong Province already invested US$50,000 into her 7-hectare farm that integrates technologies that can monitor and decide on factors such as amount of irrigation, fertilizer, temperature, to ensure the product's high quality. This integrated technology allows the farm to cut labor cost, stop using harmful chemical pesticides, reduce risk of diseases and maintain consistent output, bringing in a profit of US$250,000 every year. In 2015, FPT - Vietnam’s leading technology corporation - collaborated with Japan’s Fujitsu to open Fujitsu-FPT Akisai Farm in Hanoi to implement Fujitsu’s Akisai Food and Agriculture Cloud and transfer the technology to its Vietnamese counterparts. [40]

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