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Smart Agriculture Solutions for Vietnamese Farmers

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Abstract

Agriculture is the back bone of Vietnam and more than 70% of people in Vietnam depend on agriculture. Nowadays, agriculture crops are affected due to many environmental changes. To overcome this problem, I design and prototype a wireless sensor and actuator network for smart agriculture application. The aim of this work is to be able to capture useful data to start predicting measurements and events that could help farmers and specialists to save time and money. I propose two solutions for smart agriculture. In the first solution, wireless sensor and actuator nodes monitor multiple environmental parameters and transmit the sensor data to a server via the internet. Users can monitor these environmental parameters from anywhere via the internet. In the second solution, wireless sensor and actuator nodes send data to a local computer. This computer is deployed in a technical room. The experiments show that both solutions operate well in real conditions.

Keywords: smart agriculture; internet of things in agriculture; wireless sensor and actuator networks; greenhouse.

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1. Introduction

In agriculture, information-based systems that were unimaginable a generation ago are improving crop and farm management today. Smart Agriculture, for instance, is one area where sensor technology brings new capabilities that solve age-old problems.

Wireless sensor network [1] is the most standardized technology playing an active role in smart agriculture. Many countries like China, India, Korea, Brazil, Australia, several European countries, and different American states, are introducing agricultural technologies to strengthen their economy by using information and communication technologies for the improvement in agricultural and rural development [2].

Hybrid architecture for localized agricultural information dissemination is the client-server architecture, in conjunction with the mobile applications on smartphones, which can be used to deliver precise agricultural information to the farmers.

Considering these facts, the greenhouses are increasing in their popularity, every day. According to recent trends and technological development in Wireless Sensor Networks (WSN), it has been made possible to use WSN in the monitoring and control of the greenhouse parameters, in precision agriculture [2, 3]. Wireless Sensor and Actuator Nodes (WSANs) are being deployed for the management of greenhouses. Using wireless sensor networks will reduce the chances of human errors that can occur while investigating the facts, about the ideal method of irrigation suitable for all weather conditions, types of soils, and different crop cultures.

Smart agriculture is composed of many different technological implementations. These applications are replacing the tough, unreliable, and time-consuming traditional farming techniques with efficient, reliable, and sustainable smart agriculture. Water irrigation context-aware farming, pesticide control, remote monitoring, environmental monitoring, etc. are a few examples.

In [4], the authors proposed a novel approach for precision agriculture using wireless sensor network. A wireless sensor network model is presented to monitor the

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crops found on the agriculture lands. Sensor nodes are used to measure the water level, temperature, humidity, pesticides and so on.

In [5], an Intelligent Greenhouse Monitoring System (IGMS) based on WSN is presented. Environmental parameters such as humidity, soil moisture and temperature are measured using IGMS. Sensors data monitored using software which activates the control system to irrigate and fertile the crops according to a preset threshold.

In [6], a wireless sensor network is designed for irrigation management. Six sensors are developed, deployed, and used to gather soil properties and sensor data is transmitted to a base station. A programmable logic controller is used to control the irrigation system and locate the position of sprinklers using Global Positioning System (GPS).

An IoT based intelligent system for agriculture is proposed in [7] which discusses the implementation of machine learning in ThingSpeak cloud platform. Integrating IoT into agriculture improves crop quality and productivity. In [7], only irrigation is considered.

In this paper, I propose two smart agriculture solutions for Vietnamese farmers. The first solution (smart agriculture using the Internet of Things technology), farmers can monitor multiple environmental parameters via the Internet. In the second solution (autonomous smart agriculture model), farmers can only monitor environmental parameters by a local computer.

2. Smart agriculture using internet of things technology

2.1. Descriptions

Figure 1 shows a model for smart agriculture using internet of things technology. WSANs are deployed in large farms. These nodes are used to monitor a wide range of environmental issues that affect directly agriculture, such as light, air temperature, air humidity, and soil humidity, etc. These nodes can communicate to each other in the maximum range of 1,000 meters by IEEE 802.15.4 radio links [10]. Therefore, this solution is suitable for large farms. Users can use PC, laptops, tablets, smartphones to monitor these environmental parameters from anywhere via the Internet.

2.2. Hardware solutions

Figures 2, 3 show the block diagram of the wireless sensor and actuator nodes, internet gateway node. In this design, I use MSP430G2553, EK-TM4C1294XL which are devices of Texas Instruments, and DRF1605h (with a CC2530 core of Texas Instruments [10]).

The Texas Instruments MSP430 family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16 bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 µs. With the requirements of a wireless sensor and actuator node, such as low power consumption, low cost, handling both digital and analog signals, MSP430G2553 [8] is completely suitable for all the above requirements. Therefore I choose MSP430G2553 in this design.

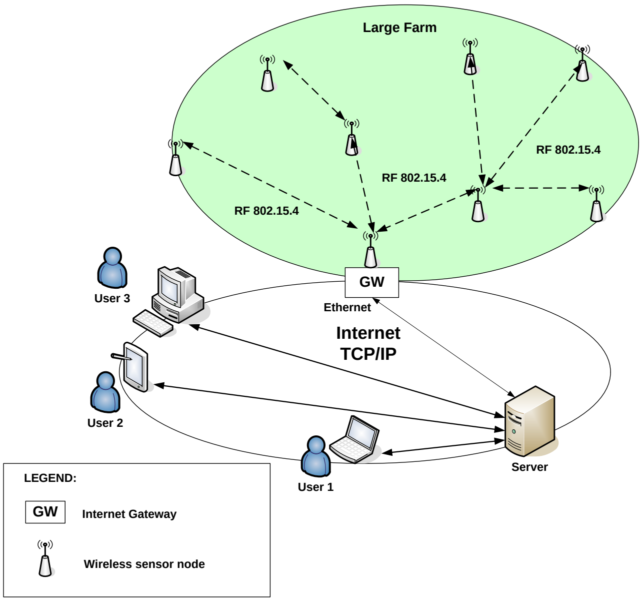

Figure 1. A model for smart agriculture using internet of things technology

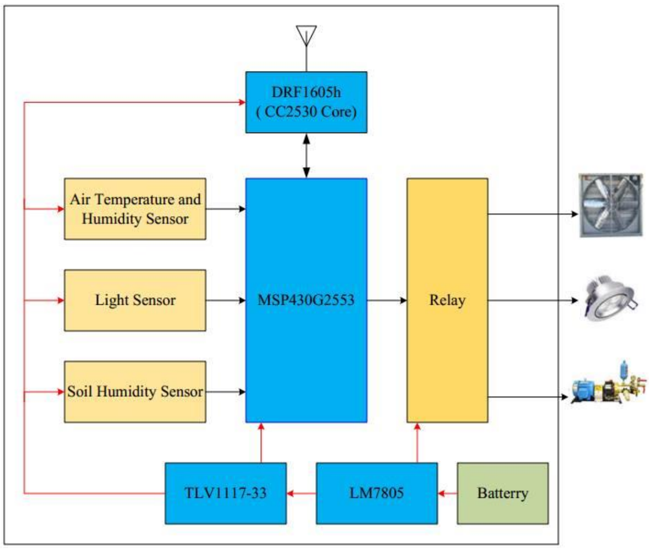

Figure 2. Functional block diagram of wireless sensor and actuator nodes

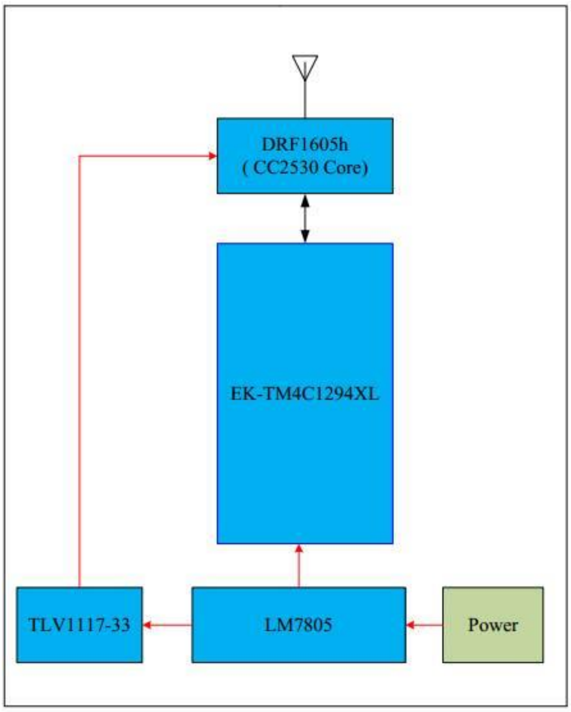

Figure 3. Functional block diagram of the internet gateway node

The TM4C1294 Connected LaunchPad Evaluation Kit [9] is a low-cost development platform for ARM® Cortex-M4F-based microcontrollers. The Connected LaunchPad design highlights the TM4C1294NCPDT MCU with its on-chip 10/100 Ethernet MAC and PHY. TM4C1294 has low cost, low power consumption, large memory, which combines with ethernet interface on board. Therefore I choose TM4C1294 in the design of the internet gateway node.

The WSAN and Internet gateway node use DRF1605H modules for wireless communication. The operation approach of nodes depends on the Zigbee 2007 protocol and their wireless modules are operated by using CC2530 Zigbee chips of Texas instruments. These wireless modules interact with the microcontrollers through the UART interface. The communication distance is able to come to 1,000 meters in suitable environmental conditions.

The wireless sensor and actuator nodes are integrated with air temperature & humidity sensors, light sensors, soil humidity sensors, and expansion connections with other sensors. These nodes can control the fan, light, pump by using relay modules.

2.3. Embedded software solutions

Figures 4, 5 illustrate the embedded software algorithm for the internet gateway node, wireless sensor and actuator nodes.

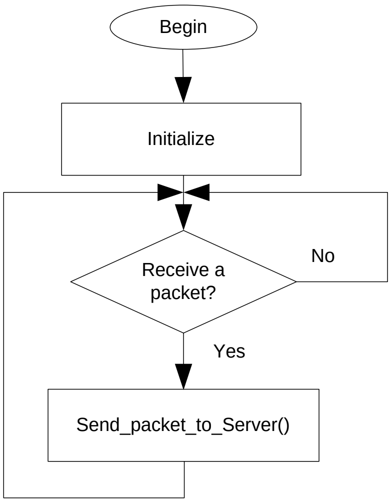

Figure 4. Embedded software algorithm for the internet gateway node

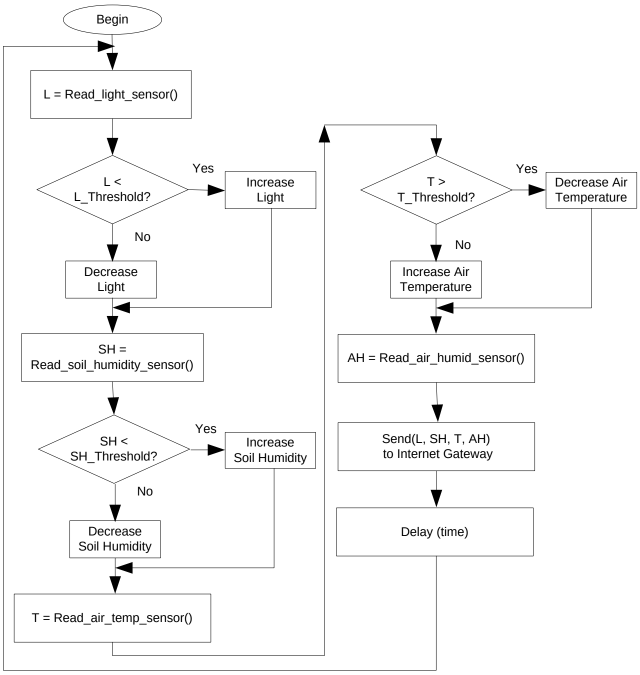

Figure 5. Embedded software algorithm for wireless sensor and actuator nodes

2.4. Web server software

Web server software allows users to monitor the environmental parameters of the greenhouse in real time. These parameters are also stored in a database. Therefore, users can adjust the environmental parameters of the greenhouse according to crops. Figure 6 shows the user interface of the website.

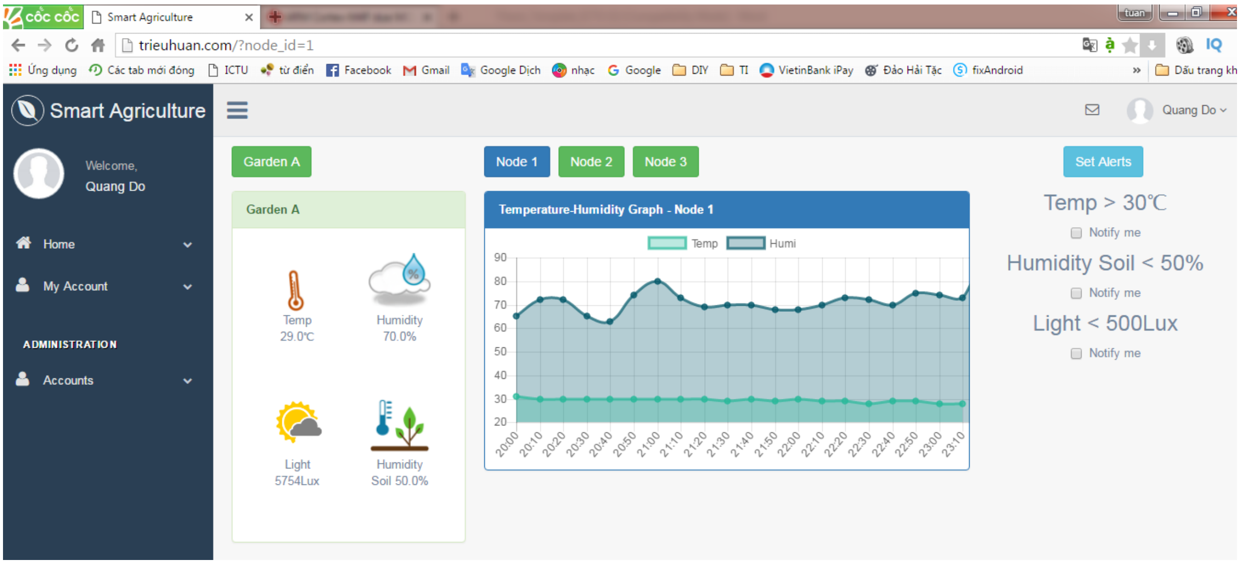

Figure 6. The user interface of the website

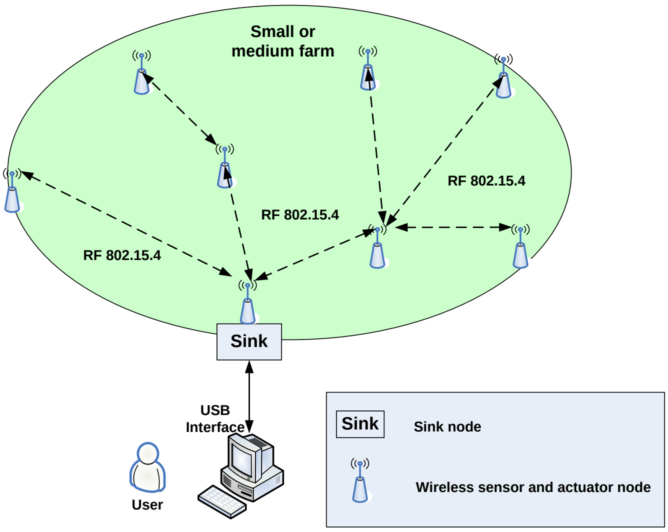

Figure 7. Autonomous smart agriculture model

3. Autonomous smart agriculture model

3.1. Descriptions

Figure 7 illustrates the autonomous smart agriculture model. Wireless sensor and actuator nodes are deployed in small or medium farms. These nodes are used to monitor a wide range of environmental issues that affect directly agriculture, such as light, air temperature, air humidity, and soil humidity etc. These nodes can communicate to each other in the range of 80 meters by IEEE 802.15.4 radio links [12]. Therefore this solution is suitable for small/medium farms.

A local computer is deployed in a technical room. The user can only monitor environmental parameters by this local computer.

3.2. Hardware solutions

Figure 8 shows the block diagram of the wireless sensor and actuator nodes and figure 9 shows the block diagram of the sink node. In this design, I use MSP430F1611, CC2420 which are devices of Texas Instruments.

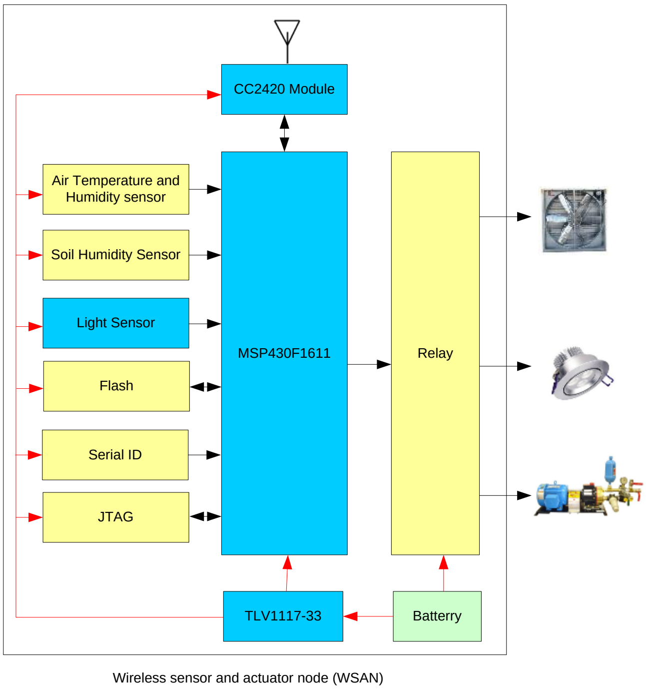

Figure 8. Functional block diagram of wireless sensor and actuator nodes

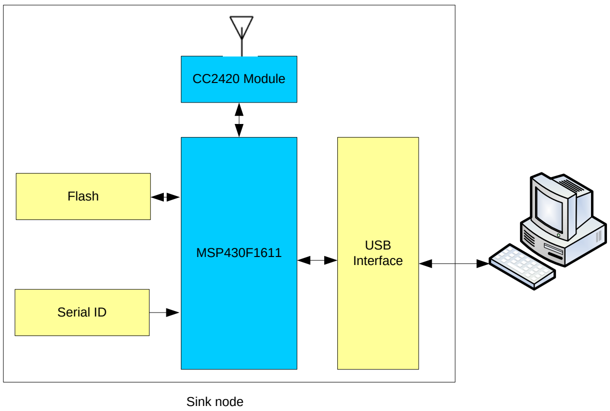

Figure 9. Functional block diagram of the sink node

The low power operation of the WSAN is due to the ultra-low power Texas Instruments MSP430 F1611 microcontroller featuring 10kB of RAM, 48kB of flash, and 128B of information storage. The features of the MSP430 F1611 are presented in detail in the Texas Instruments MSP430x1xx Family User's Guide [11].

The WSAN and sink node use the CC2420 radio module [12] for wireless communications. The CC2420 is an IEEE 802.15.4 compliant radio providing the PHY and some MAC functions. With sensitivity exceeding the IEEE 802.15.4 specification and low power operation, the CC2420 provides reliable wireless communication. The CC2420 is highly configurable for many applications with the default radio settings providing IEEE 802.15.4 compliance.

The wireless sensor and actuator nodes use the ST M25P80 40MHz serial code flash for external data and code storage. The flash holds 1024kB of data and is decomposed into 16 segments, each 64kB in size. The air temperature & humidity sensors, light sensors, and soil humidity sensors are integrated into these sensor nodes.

3.3. Embedded software solutions

In this solution, I use Contiki operating system to build the network. Contiki [13] is an open-source multi-tasking operating system targeted at microcontrollers with small amounts of memory, such as wireless sensor network nodes. A typical Contiki configuration is 2 kilobytes of RAM and 40 kilobytes of ROM. Contiki is written in the C programming language and has been developed at the Swedish Institute of Computer Science since about 2004. The Contiki collect protocol [14] implements a hop-by-hop reliable data collection mechanism. Data is sent via a tree topology to a sink node. Figure 10 shows an example data collection tree.

An overview of the Contiki collect protocol is given in figures 11 and 12. These figures illustrate the response of the collect protocol to some events: an incoming data packet, and the sending of a message by the application using the data collection tree protocol.

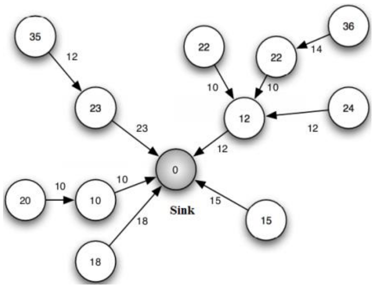

Figure 10. An example data collection tree

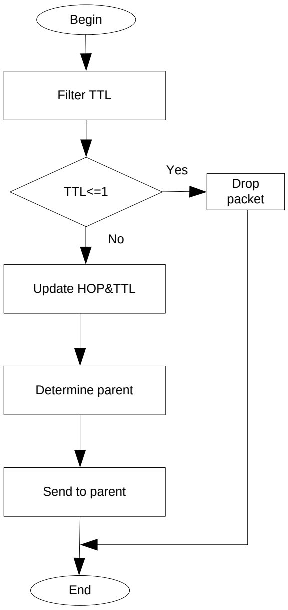

Figure 11. Incoming data packet

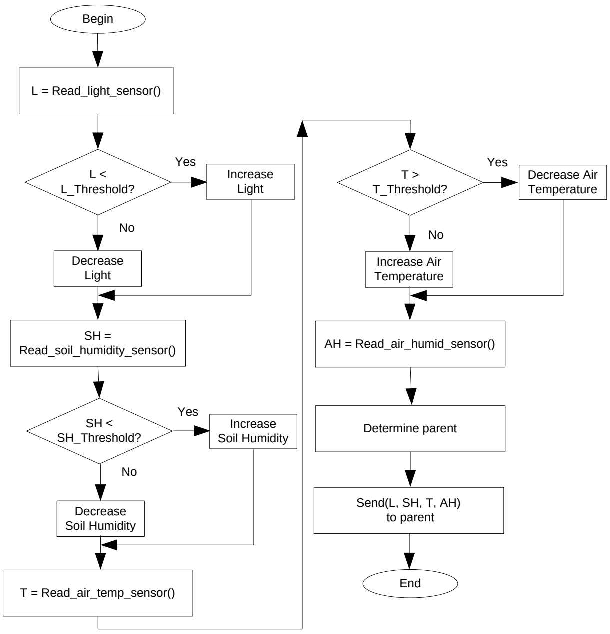

Figure 12. A message sent by the application using the collect tree protocol

3.4. Software for the local computer

I design software for the local computer. This software allows users to configure the program and control the wireless sensor and actuator nodes (see figure 13). Figure 14 shows the user interface of the software.

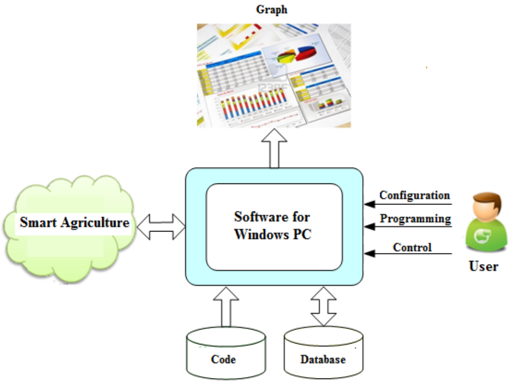

Figure 13. Software for the local computer

Thời gian gửi cố định 60 giây
Thời gian gửi ngẫu nhiên 60 giây
Số lần truyền lại 31 từ (0 - 31)
Số lần gửi về 0 (0 = gửi mãi mãi)

Figure 14. The user interface

4. Experiment and comparison

I have deployed two solutions in a greenhouse. Figure 15 illustrates a wireless sensor and actuator node deployed in the greenhouse.

Figure 15. Deploying a wireless sensor and actuator node in the greenhouse

The experiments show that both solutions can operate well in real conditions. The environmental parameters of the greenhouse are sent periodically to the webserver/local computer. The systems of light, fan, and pump are controlled automatically by sensor nodes. Table 1 shows a comparison between two solutions. Users can choose the solution that is suitable for their applications.

Table 1. A Comparison between two solutions

Features	Smart agriculture using internet of things technology	Autonomous smart agriculture model
Microcontroller	MSP430G2553 Tiva TM4C1294	MSP430F1611
Radio transceiver	CC2530	CC2420
Communication range	< 1,000m	< 80m
Centre Frequency	2.4 GHz	2.4 GHz
Operating system	No	ContikiOS
Network Topology	Mesh, Star	Tree
Sensors	Temperature, Humidity, Light, Soil Humidity...	Temperature, Humidity, Light, Soil Humidity...
Monitoring parameters via the Internet	Yes	No
Software	Web Server	Local computer

5. Conclusions

In smart agriculture, a system is built for monitoring the crop field with the help of sensors (light, humidity, temperature, etc.) and automating the irrigation, lighting, and ventilation systems. The farmers can monitor the field conditions remotely. In this paper, I propose two solutions for the smart agriculture system. The farmer can operate mobile phones from anywhere at any time. My solutions can group many farmers into it and also the specialist. This is more suitable for agriculture dependent countries like Vietnam.

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