Design of Wireless Sensor Network based Smart Greenhouse System

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Abstract—**The WSN(Wireless Sensor Networks) technology is one of the important technologies to implement the smart society, and it could make many changes in the existing agricultural environment including livestock rearing, cultivation and harvest of agricultural products if such a WSN technology is applied to the agricultural sector. This study attempts to establish smart agricultural environment and improve productivity of the greenhouse's crops by proposing smart greenhouse system using WSN technology. In proposed smart greenhouse system, soil sensors and environmental sensors are installed inside/outside the greenhouse in order to collect environmental information for greenhouse's crop growth such as environmental information, and soil information, and these sensors construct a wireless sensor network each other to collect environmental and soil information in the greenhouse. In addition, CCTVs are installed inside/outside the greenhouse to collect image information in real time for collecting greenhouse and crop image information and preventing dangers such as burglary and fire. Such collected environmental and image information is stored in the server via the gateway, provided to users in real time through various interfaces, and environmental control facilities in the greenhouse could be automatically or manually controlled suitable to optimum growth environment of cultivated crops based on collected information. Farmers may increase production and improve crop quality through this smart greenhouse system and prepare a data base with information collected from environment factors and control devices of the greenhouse, which is expected to provide information for control strategy of greenhouse operation.**

Keywords-wireless sensor networks, middleware, smart, greenhouse

I. INTRODUCTION

WSN(Wireless Sensor Networks) is a technology that sensor nodes capable of computing and communication shall be deployed to various application environments so that they can form an independent network, then physical information collected by wireless from the network shall be utilized for monitoring and controlling etc.[1][2] This WSN technology contributes to realizing high productivity, safety and high humans life level through its application to various industries such as distribution, logistics, construction, transportation, military defense and medical service etc.[3]

In particular, it is labor-intensive industry compared to other industry, and when applying WSN technology to agricultural area which lacks IT technology application, added value and productivity of agriculture can be increased.[4][5]

Recently, various studies combining WSN technology with protected agriculture such as greenhouses and stables and precision farming has been conducted,[6][7] and advanced nations including EU and the U.S. have established monitoring system from cultivation environment to production management and distribution in order to secure production of agricultural and stockbreeding products and transparency of distribution routes.[8][9][10]

However, Korea lacks researches applying agriculture and IT technologies as well as tools to collect growth environment information and analyze monitoring data compared to advanced nations, and its cost of output is high but output is low because the level of optimized technology for environmental control is low compared to advance nations.[11]

In order to solve these problems, we would like to propose a smart greenhouse system applying WSN technology in this study.

The smart greenhouse system proposed in this study is a system that they install WSN and CCTV in the greenhouse to collect its environmental and visual information, and from which they can monitor the greenhouse via the Web outside the greenhouse and further can control the greenhouse's facilities by manual even in remote place.

In addition, greenhouse facilities could be automatically controlled based on the crop growth environmental value which is already set up and SMS notice service shall be provided to users when dangerous situation occurs.

The proposed system improves productivity by maintaining optimized environment for growth and development through information on environment for greenhouses and growth and development of the crop, and it not only reduces production cost by optimizing management of production components but also provides convenience to producers through wire-wireless remote automatic control of environment for growth and development of crops.

The composition of this article is as follows; Session 2 explains the structure of proposed smart greenhouse system structure and provided service process, and session 3 the results of realizing proposed systems. Finally, it conclusions in the last session.

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II. Design of the Proposed Wireless Sensor Networks based Smart Greenhouse System

A. System Structure

The proposed smart greenhouse system shall be classified to three layers as figure 1, and each layer is composed of the physical layer which consists of environmental sensor, soil sensor, CCTV and other control facilities of the greenhouse, and the application layer which consists of interfaces that support monitoring the greenhouse and controlling service of the crop growth environment, and finally of the middle layer which supports the communication between the physical layer and the application layer, and store the collected information of the greenhouse to data base, provides monitoring and controlling service as well as keeping optimal status of the crop growth environment.

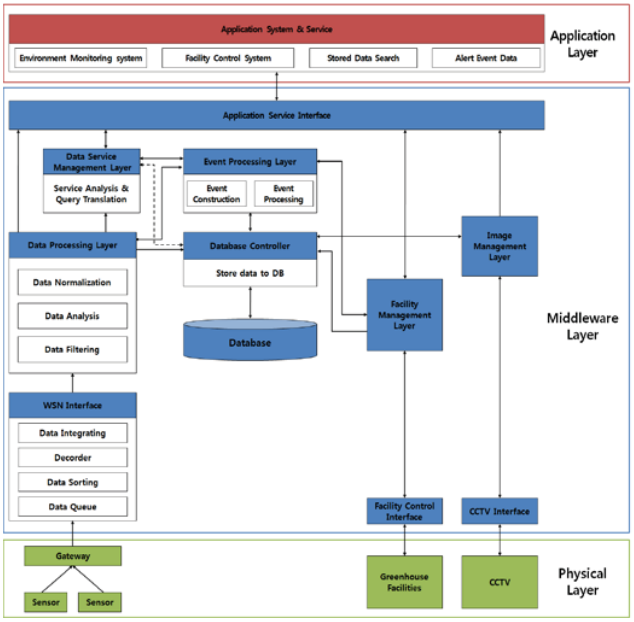

Figure 1. Smart Greenhouse System Structure

Physical layer is composed of sensor collecting information on external and internal environment of greenhouse and growth of crops, CCTV collecting information on images of greenhouses, and environment control facilities to create the optimized environment for greenhouse's crops.

Sensors are broadly divided into environment sensor collecting information on internal and external environment and growth sensor collecting information on growth of crops. Environmental sensor measure information of internal and external environment of greenhouse such as intensity of illumination, temperature, humidity, wind direction, wind speed EC, pH, and CO2, which affect the growth of crops. Growth sensor measures change of growth and development of crops such as temperature of leaves and parts of stems, weight of plant body, fruit temperature and volume.

CCTV is installed inside and outside of greenhouses and internal CCTV is for collection of information of images of crops and external one for prevention of dangers such as burglary and fires.

Environment control facilities include ventilation and heating systems that can control greenhouse environment which affects the growth of crops such as illumination, temperature, EC, pH, and CO2, systems to keep warm for reduction of energy, systems of controlling curtains to shade the light according to the intensity of light, systems for circulating fans to control the circulation of air inside of facilities, systems to control temperature of hot water, working fluid, and systems to control an artificial source of light according to external intensity of light, and each facility of environment control is controlled by power controller.

Middleware layer has features to collect data occurred in the physical layer such as environmental sensors and soil sensors installed for monitoring the greenhouse environment, and to lower the load on the application program by filtering real time information and provide data which application program requests.

In order to meet all these requirements, the middleware layer has functions to refine, filter and convert the collected information and support functions to recognize the situation and process and control the respective situation information when an event occurred.

The WSN interface layer provides a common interface function to heterogeneous sensors, and offers continuous monitoring and control functions for status of sensor networks.

DPL(Data Processing Layer) plays a role to provide a function to process various queries for data collected from the WSN infrastructure and a real-time management function for sensor information. In addition, the data processing layer employs a data management component, which delivers valid messages to the upper layer and supports queries of various forms by filtering data for reducing system's load that could be generated due to an enormous amount of data collected via sensors.

EPL(Event Processing Layer) is composed of an event construction and an event processing, and the event construction builds up the WSN data received from the lower layer as a simple event. The event processing specifies a reference value through a complex event language defined by the upper application layer and builds up the constructed simple event as a significant event considering the reference value.

DC(database controller) stores data generated in real-time into the database, supports queries of the application layer to use data at the time when the data is needed, and stores and updates the reference data for automatic control and condition notification of greenhouse facilities.

FML(Facility Management Layer) converts the control signal transmitted from the application layer or EPL to a proper typed data format, and transmit it to the greenhouse control facility to control, and transmit the status, operation time and

control frequency of the control facility to DC to store them into the database.

IML(Image Management Layer) provides the Web with stream data of images taken from CCTV and classifies them to the greenhouse ID and camera number etc to store into the database.

The database plays a role to store environmental data collected from sensors installed inside/outside the greenhouse, image data collected from CCTVs, conditions, operating time and the number of controls of greenhouse controlling facilities, environmental reference values for automatic control and condition notification into each table.

The application service interface plays a role to deliver and establish the range of services established by the application. And data stored in the DB could be searched and stored by connecting the DB controller for demands of the application. In addition, it supports various queries to constitute flexible connections between applications and hardwares.

Application layer is composed of application services supporting various platforms such as web, PDA, smart-phone, which can provide users with crop growth information monitoring services, greenhouse environment monitoring services, greenhouse image monitoring services, crop growth and development environment control services.

B. Service Processes

Crop growth information and greenhouse environment monitoring services save greenhouse's crop growth and development information such as information of internal and external environment of greenhouse such as intensity of illumination, temperature, humidity, wind direction, wind speed, EC, pH, and CO2, which collected from sensors installed in greenhouses and information of growth and development of crops such as temperature of leaves and parts of stems, weight of plant body, fruit temperature and volume, and it shows this information to producers through GUI. The Figure 2 shows the process of operation of monitoring services for growth and development of crops and greenhouse environment.

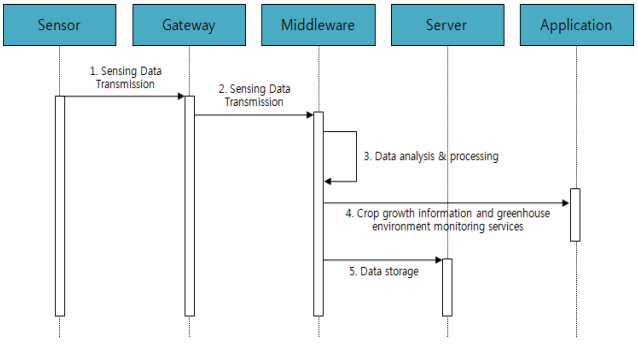

Figure 2. Greenhouse Environment & Crop Growth Information Monitoring Service Operations

Image monitoring services for greenhouses are to provide producers and consumers with images of greenhouses and crops through CCTV installed inside and outside of greenhouses. The Figure 3 shows operation process of image monitoring services.

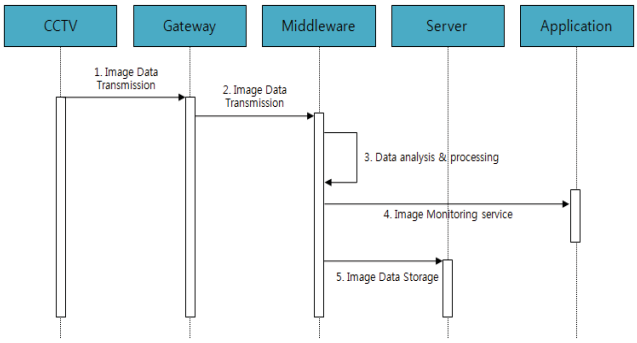

Figure 3. Greenhouse Image Monitoring Service Operations

Greenhouse facility control service is a service which controls the greenhouse control facility automatically in order to keep the optimal crop growth environment based on the collected information from the greenhouse or helps users controlling the facility manually. The Figure 4 shows the process of operating automatic control services of greenhouse environment control facilities.

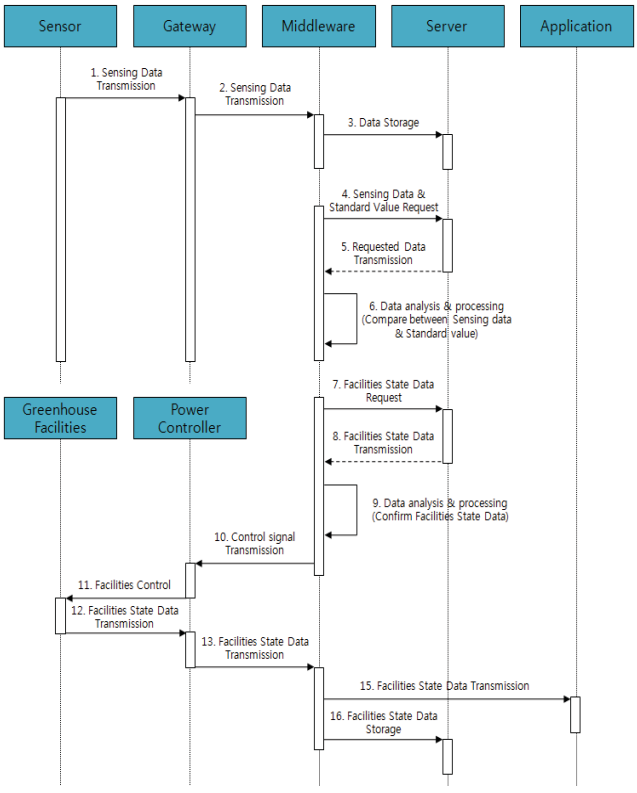

Figure 4. Greenhouse Facilities Automatic Control Service Operations

The Figure 5 shows manual control services of greenhouse environment control facilities.

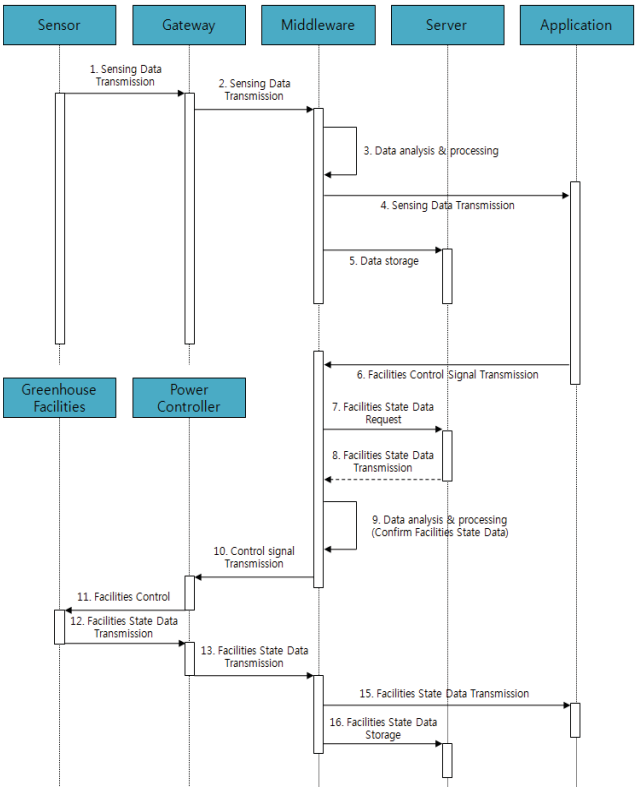

Figure 5. Greenhouse Facilities Manual Control Service Operations

Greenhouse situation alarming service is to prevent dangerous situations in advance by informing users of change of weather and conditions of greenhouses and letting them take measures. The Figure 6 shows operation process of greenhouse situation alarming service.

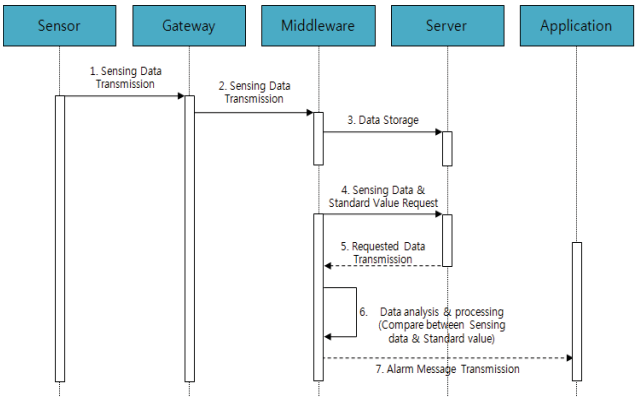

Figure 6. Greenhouse Situation Alarming Operations

III. Implementaion of the Proposed Wireless Sensor Networks based Smart Greenhouse System

A. *Implementation*

In order to measure information of internal and external environment for greenhouse, sensors were installed inside and outside of greenhouses as seen in Figure 7, and external weathers such as temperature and humidity of outside and inside of greenhouses, speed of light, and wind speed and direction and internal weathers such as temperature, relative humidity, intensity of light in the upper and lower parts of crops, and the amount of penetration of light.

Figure 7. Environmental Sensor

In addition, since management of rooting zone which greatly affects absorption of nutrient solution culture considering the characteristics of greenhouse's crop cultivation, which mainly uses nutrient solution culture is very important, the amount, EC and pH of supplying liquid, the amount, EC, and pH of waste liquer, rate of absorption and temperature within culture medium, and temperature of supplying water and waste liquer, which affect rooting zone of plants inside of greenhouses, were measured by installing sensors to collect information of environment of rooting zone as seen in Figure 8.

Figure 8. Rooting Zone Sensor

In order to understand information of growth and development of crops, sensors were installed like Figure 9 and temperature of plants inside of greenhouses, temperature of upper and lower parts of stems, temperature and volume of fruits, weight of body of plants, plant heights of body of plants, the amount of water and light that crops absorb, yields, and rate of increase of weight of the body of plants are measured.

Figure 9. Crop Growth Sensor

In order to create the optimized crop growth environment based on the crop growth information from sensors installed in inside and outside of greenhouses, weather information of inside and outside of greenhouses, and information of rooting zone environment, environment control facilities are installed in greenhouses and in order to control these facilities, Power controller was installed as seen Figure 10.

Figure 10. Greenhouse Facilites and Power Controller

In order to monitor and control greenhouses, as seen in the figure 11, GUI for managers is developed as Web environment. WAS uses Tomcat-6.0.20 and database mysql 5.0 which is the safest version among the versions that are currently released.

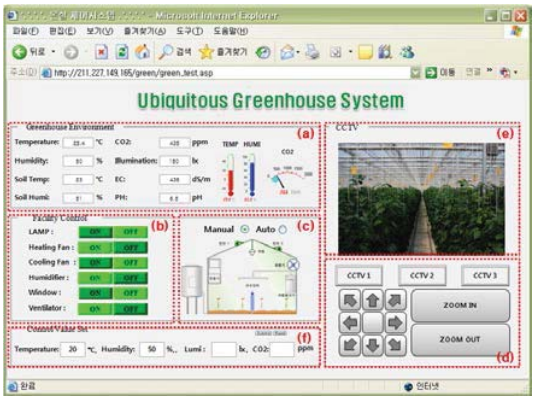

Figure 11. Smart Greenhouse System Web GUI

In GUI for manager, the values of sensing which are measured in sensors installed inside and outside greenhouses are appeared in (a), and (b) shows control of equipment in greenhouses and its conditions. (c) expresses the conditions of equipment in (b) as graphics. (d) is the part to control CCTV, (e) the part to show collected images through CCTV, and (f) the part to enter standard values for automatic greenhouse control.

B. Results

As a result of applying the proposed system as mentioned above to actual greenhouses, information of environment and images in greenhouses is collected through sensors and image supervision camera, and GUI which is intuitive to users can monitor and control conditions of greenhouses. The Figure 12 is a graph that shows data of environment to growth and development measured by installing the proposed smart greenhouse system to greenhouse.

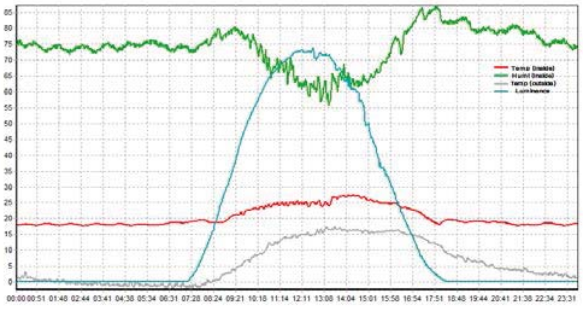

Figure 12. Greenhouse Environment Data Graph (2010.2.23)

IV. CONCLUSIONS

This study proposes smart greenhouse system for comprehensive management of greenhouses requiring precise management of environment for crop growth and development.

The proposed system is composed of physical layer, middleware layer and application layer, and components of each layer collect and manage information of environment for growth and development within greenhouses. Not only the information is delivered to users but remote manual and automatic control in greenhouses also improves users' convenience and productivity, and based on the data of environment for growth and development gained by operating the system, the optimized environment for growth and development of greenhouse's crop is created.

To prove the proposed system, it was tested in greenhouse by installing sensors including sensors for soils, environment, temperature and humidity of leaves and CCTV and was implemented. As a result of the implementation, monitoring and controlling of the environment for growth and development could be conducted through GUI and the results of sensors monitoring related to controlling greenhouses and controlling shows that there is no wrong operation.

Through the study, It is expected that applying the proposed system to greenhouse farms shall help saving labour cost and

producing high quality crops, and further obtaining competitiveness of our agriculture

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