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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Next Generation Networks – Service aspects: Service capabilities and service architecture

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Service model of the agriculture information based convergence service

Recommendation ITU-T Y.2245

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ITU-T Y-SERIES RECOMMENDATIONS

GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

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Recommendation ITU-T Y.2245

Service model of the agriculture information based convergence service

Summary

Agricultural data is the key foundation for smart farm models, in which a wide range of information and communication technology (ICT) such as the Internet of things and big data are converged, to be operated and managed. Given the fact that every single stage in smart farm models from crop growing to selling requires appropriate data, it is crucial to have a well-established service model for data collection and its provision. This service model should gather and process data before providing it for users to enhance their farm business. By convergence of various data collected from each stage of production, the model should ensure higher quality of service. During the production stage, the convergence services are provided to increase crop quality and yield and reduce farm maintenance costs. Recommendation ITU-T Y.2245 provides more details about the service model.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Y.2245	2020-09-29	13	11.1002/1000/14389

Keywords

Agricultural information repository, production stage, smart farming.

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FOREWORD

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Service model of the agriculture information based convergence service

1 Scope

This Recommendation addresses the service model of the agriculture information based convergence service. The scope of this Recommendation includes:

– Concept and service requirements for agriculture information based convergence service,

– Reference architecture for agriculture information based convergence service,

– Service scenario for agriculture information based convergence service at the production stage.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T T.135] Recommendation ITU-T T.135 (2007), *User-to-reservation system transactions within T.120 conferences*.

[ITU-T Y.4450] Recommendation ITU-T Y.4450/Y.2238 (2015), *Overview of Smart Farming based on networks*.

[ITU-T Y.2244] Recommendation ITU-T Y.2244 (2019), *Service model for the cultivation plan service at the pre-production stage*.

[ITU-T Y.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), *Architectural framework for machine learning in future networks including IMT-2020*.

[ITU-T Y.3600] Recommendation ITU-T Y.3600 (2015), *Big data – Cloud computing based requirements and capabilities*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 big data [ITU-T Y.3600]: A paradigm for enabling the collection, storage, management, analysis and visualization, potentially under real-time constraints, of extensive datasets with heterogeneous characteristics.

3.1.2 convergence service [b-ITU-T Y-Sup.3]: A service resulting from service convergence.

NOTE – In this Recommendation, service convergence is realized using content and functional convergence.

3.1.3 content convergence [b-ITU-T Y-Sup.3]: One aspect of the service convergence related to the combination or coordination of contents that are managed by different application service providers.

3.1.4 machine learning [ITU-T Y.3172]: Processes that enable computational systems to understand data and gain knowledge from it without necessarily being explicitly programmed.

3.1.5 service user [ITU-T T.135]: A person, an organization or any intermediate entity using the services provided by a service provider.

NOTE – Service users refer to farmers. Using the service will offer them chances to increase their crop yields, keep their crop growth at a consistent level, boost the efficiency of their equipment, and reduce their operational costs.

3.1.6 smart farming based on networks [ITU-T Y.4450]: A service that uses networks to actualize a convergence service in the agricultural field to attain more efficiency and quality improvement and to cope with various problems.

3.1.7 smart farming service provider [ITU-T Y.4450]: The service role that provides the requested smart farming services, such as providing a portal or consulting based on data gathered from agricultural fields, to requesting users.

NOTE – This Recommendation uses 'service provider' with the same meaning as that of 'smart farming service provider'.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 agriculture information: Information that refers to data used for the operation of smart farms, including raw data to analyse information related to the agro-industry, which becomes the basis of service and the service data, collected during/after the smart farming.

3.2.2 agro-industry: The agricultural activity of an area viewed as an industrial sector of the economy.

3.2.3 data convergence: Data processing that provides meaning to user-oriented customized information created based on the analysis of the relevance of large amounts of data.

NOTE – Service users are provided useful information resulting from data convergence of the overall data related to the agro-industry (e.g., seeding time decided by merging weather data and market data).

3.2.4 data convergence function: A function that provides meaning to user-oriented customized information created based on the analysis of the relevance of large amounts of data such as big data analysis or machine learning.

NOTE – This function should include AAA services.

3.2.5 data management function: A function that enables data collection, storage, management, monitoring, service delivery, and user feedback collection.

3.2.6 distribution data: Data related to the stages from shipment to selling of farm products, including shipments, loaded volume, origin and history, imported and exported volumes, grades, and price fluctuations.

3.2.7 growth data: Data consisting of information gathered from sensors, actuators, and environments that are required to grow and control crops, including data on environment, growth, production volume, and power usage.

3.2.8 information delivery: Sending information with guaranteed compatibility from service providers to service users.

3.2.9 information delivery function: A function to send information from service providers to service users with guaranteed compatibility.

3.2.10 smart farm: Farms that can control the growing environment for crops and livestock automatically and remotely by applying ICT to greenhouse farms, livestock farms, bare ground.

NOTE – This Recommendation focuses on greenhouse farms.

3.2.11 smart farming: The procedure that converges ICT with the overall agricultural process from production, processing, distribution, and consumption.

NOTE – This Recommendation focuses on the production stage of smart farming.

3.2.12 solution: Information to service users to increase their crop yields, keep their crop growth at a consistent level, boost the efficiency of their equipment, and reduce their operational costs, converged from data gathered in the agro-industry, in response to service users inquiry.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AAA	Authentication, Authorization and Accounting
AIR	Agricultural Information Repository
CCTV	Closed Circuit Television
CPU	Central Processing Unit
DAS	Direct-attached Storage
DRM	Digital Right Management
DVR	Digital Video Recorder
EMI	Electro-Magnetic Interference
HDD	Hard Disk Drive
ICT	Information and Communication Technology
LED	Light-Emitting Diode
MPEG	Moving Picture Experts Group
OS	Operating System
PC	Personal Computer
RAM	Random Access Memory
UPS	Uninterruptible Power Supply

5 Conventions

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

The keywords "can optionally," "could" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

In this Recommendation, the words shall, shall not, should, and may sometimes appear, in which case they are to be interpreted, respectively, as is required to, is prohibited from, is recommended, and can optionally. The appearance of such phrases or keywords in an appendix or in material explicitly marked as informative are to be interpreted as having no normative intent.

This Recommendation uses 'service provider' with the same meaning as that of 'smart farming service provider'.

6 Concept of agriculture information based convergence service

The main purpose of developing an agriculture information based convergence service using ICT is to enhance crop productivity. In other industry groups ICT has been utilized, in conjunction with data collection and management, to develop new services. In the agro-industry various, limited in scope, applications using ICT have been developed. These applications use data collected from a selected subset of the various stages of agriculture production. The convergence service suggested in this Recommendation, is broader in scope and is intended to improve the information given to farmers thereby allowing for an increase in crop productivity. A service provider may use data from agricultural producers, distributors, and consumers to implement this convergence service.

A service user would use this service to obtain solutions during the crop production stage. A service provider may collect and manage data from greenhouse construction, greenhouses, logistics, and markets to provide solutions to service users during the crop production stage. The collected data and information would be analysed and converged by the service provider, in accordance with the service users request, and the resultant information would be provided to service users as solutions. Collaboration among entities is required to allow data sharing.

The agriculture information based convergence service demands ongoing data convergence, a type of content convergence which is an aspect of convergence service in [b-ITU-T Y. Sup-3]. The concept of the agriculture information based convergence service is shown in Figure 1.

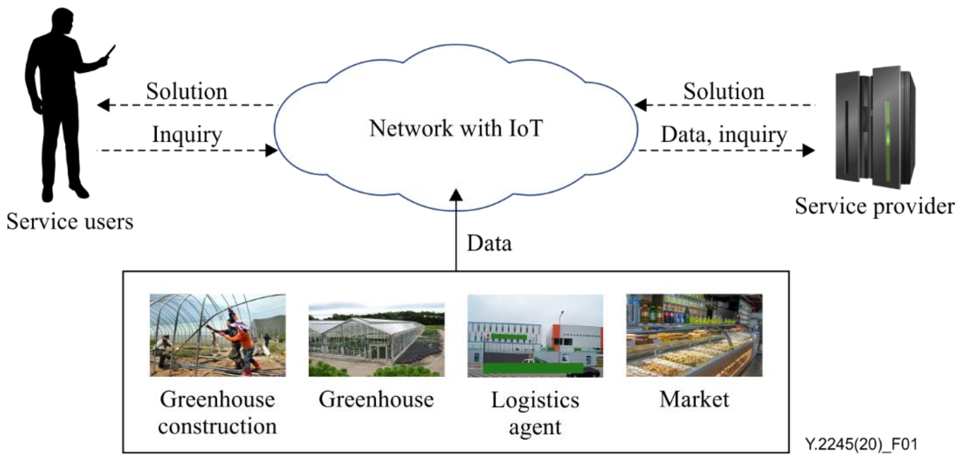

Figure 1 – Concept of agriculture information based convergence service

7 Service requirements for agriculture information based convergence service

7.1 Service requirements for data collection

It is required to accumulate data into an agricultural information repository (AIR) to support the agriculture information based convergence service. Data required throughout the agricultural process, encompassing the selection, growth and distribution of crops, should be gathered, analysed and shared with service users. Particularly in the case of collection, overall data related to the agro-industry, such as building greenhouses, growing crops, managing, distributing and consuming crops, should be collected. Collaboration is needed between companies and organizations that manage data related to this.

Data collection requires the following capabilities:

– The data needed for data convergence services should be collected and are based on overall data from the agro-industry, such as data measuring the growth and growth status of crops and data on crop distribution history of crops,

– Information from agriculture experts is required to be delivered to the AIR in conjunction with organizations that hold various data such as companies, government agencies, and statistics (status of greenhouse construction, system operation information, distribution of crop).

Considering these capabilities, it should include smart farm status data, environment data, growth data, environment control data, yields data, power usage data, and distribution data as shown in Table 1.

Table 1 – Data categories

Types	Description
Smart farm status data	Data about the overall status of a farm where crops grow. This data helps to understand the current status of crops, identify in which area the farm is located, and what type of facility and equipment it has, such as: – status of farm, crop type, greenhouse type, – name of facility manufacturer, etc.
Environment data	Data about the environment inside and outside a greenhouse. This data helps to understand the current status of environment which influences the growth of crops the most, such as: – internal temperature and humidity, soil temperature and soil humidity, – CO_2 concentration, accumulated amount of insolation, etc.
Growth data	Data about the changes in crop growth. It shows how crops change over time. This data helps to understand the crop growth data, together with the environment data, can be utilized for analysis to find out the optimal growth condition for crops, such as: – weeks of growth, growth in length, accumulated growth in length, – leaf length and width, number of fruits per unit area, etc.
Environment control data	Data about actuators installed inside a greenhouse. By modifying dates, times, and conditions, the environment inside the greenhouse can be controlled, such as: – user identifier and facility identifier, model name and installed location, – person who modifies and date of modification, etc.
Yields data	Data about the yield of crops grown from a greenhouse. This data helps to understand the crop yields per a standard unit, such as: – adult and dwarf fruit tree, production volume, – production volume, etc.
Power usage data	Data about the amount of electricity used for operating a greenhouse. It aims to save energy by finding ways to minimize the use of equipment installed inside the greenhouse, such as: – temperature control criteria, external temperature, – internal temperature, power usage, etc.
Distribution data	Data about the stages where crops distributed and consumed after harvest. This data helps to understand the information about the shipments, storage status, and packaging methods for each crop, such as: – amount of shipment, loaded amount, distribution history, – packing material and charge, distribution cost, etc.

Data collection can be carried out applying data collecting devices as shown in Appendix II.

7.2 Service requirements for data convergence

Various services should be provided to farmers who grow crops on farms, extend greenhouses and ship grown crops. Services shall be provided as the solution resulting from data convergence on greenhouse construction, system operation, crop production, distribution status and consumption status.

The data convergence requires that:

– Data from farm or agricultural sector shall be delivered to the service provider's AIR by any means in the network,

– The data stored in the AIR should be analysed in the manner desired by the service user, utilizing various techniques (big data analysis, machine learning, etc.),

– The data to be analysed should be stored and managed by AIR, and each of the analysed information should have its own meaning (ontology, semantic web, etc.),

– It shall be possible to control the facilities at the production stage based on the analysed information.

7.3 Service requirements for information delivery

The analysed information from data convergence should be delivered to service users with the form in a comprehensive format. Service providers should provide the analysed information in the general form:

– It is required to be connected to a relevant network for information delivery,
– The analysed information should be delivered with the format and contents that service users can process and understand,
– It should be possible to allow service users to receive analysed information (consulting, documentation, automatic control, etc.).

8 Reference architecture for agriculture information-based convergence service

The reference architecture of this service consists of a data management function, a data convergence function, and an information delivery function as shown in Figure 2 taking into consideration the service requirements. The data management function is responsible for collecting and managing the data and information required for this service. The data convergence function promotes data analysis (e.g., big data, deep learning) at the request of the service user, attaches meaning to the analysed information and provides service to the service user based on the given meaning. The information delivery function is intended to provide manageable and understandable information from the service provider to the service user.

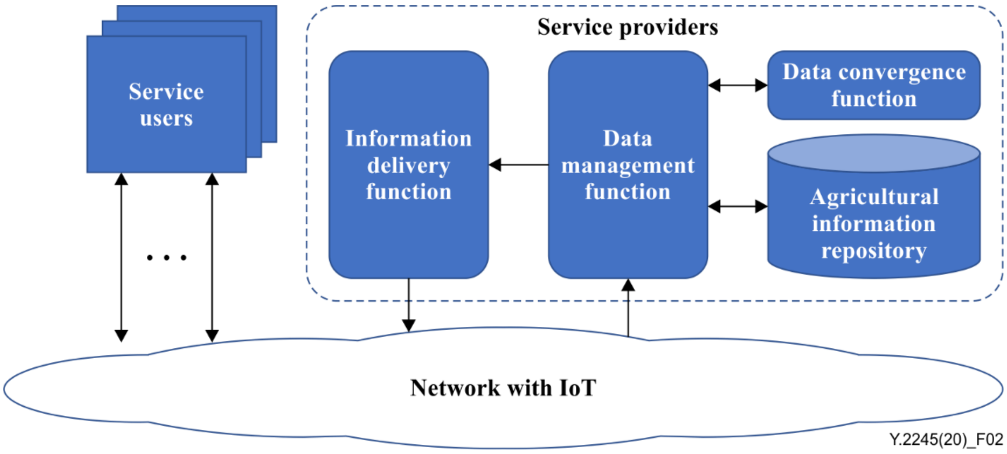

Figure 2 – Reference architecture for agriculture information based convergence service

8.1 Data management function

The data management function carries out the following functionalities:

– connecting to relevant networks for service users and managers at farms, distributors, and related companies to have access,

– supporting authentication, authorization and accounting (AAA) capability to verify, access and determine the identity for using the service,

– storing data measured at the smart farm area (e.g., farm status, internal and external environment, shipment status) in AIR,

– determining the convergence type according to the requested service type (e.g., commands or solutions for sowing, cultivation, management, harvest),

– conducting various filtering processes that are required to store or search data by discarding data deviating from pre-defined data range and format,

– gathering a variety of data including data from actual farms and meteorological institutes, and data about changes in crop growth and crop distribution status (when a user-customized data convergence service, utilizing the gathered data, is provided, it stores and manages the analysed information).

8.2 Data convergence function

The data convergence function carries out the following functionalities:

– conducting a data convergence upon request of the service user who has joined the service,

– deciding which function will be suitable for processing data for each production stage, converging it with data for the entire production stage, and analysing the converged data, upon service users request (e.g., big data, machine learning),

– managing AIR where the data to be analysed are stored and each of the analysed information should have its own meaning (e.g., ontology, semantic web),

Data convergence function can provide services such as those listed in Table I.2.

8.3 Information delivery function

The information delivery function carries out the following functionalities:

– providing solution to service users through any means of the network,

– adapting the format and contents of analysed information to the form service users can manage and understand (e.g., control commands, consulting messages, images),

– providing solution according to the method requested by the service user when applying for service use.

9 Service scenario

9.1 Service scenario for solution

For farmers at the agricultural production stage, the service provider can deliver various services related to crop growth. The service provider proceeds with data convergence upon request from the service user. The analysed information is arranged in the way the service user wants. Subsequently, the solution is delivered to the service user based on the arranged information. The solution provided to the service user will be very helpful for them to make a decision at the production stage regarding the following issues:

– the optimal growth model for each crop,
– the prediction service for changes in crop growth and production volume,
– the reduction of electricity and water consumption by analysis,
– the management of the harvest cycle and storage,
– the care of the production facilities based on the convergence of diseases and insect pests.

Figure 3 shows the information flow for the solution.

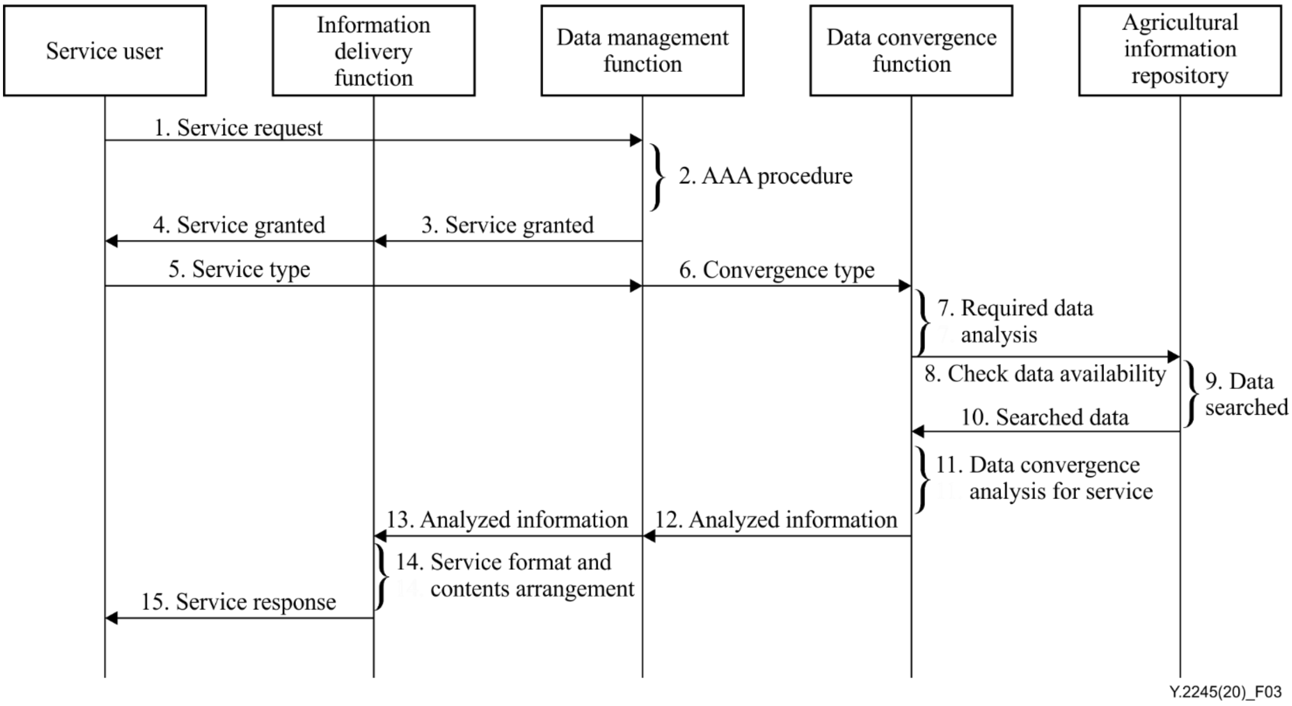

Figure 3 – Information flow for the solution

The following assumptions are made:

1) the service user is subscribed to a service provider and will be charged on the usage basis by each service provider,
2) digital right management (DRM) processing for license transaction in service providers is hidden,
3) the flows shown here are at high level and not meant to show the actual protocol procedures.

Descriptions of the flow are as follows:

1) service users request to have access to raw data and processed information,

2) the data management function carries out the AAA procedure for the requesting service users,

3) if the AAA result is OK, data management function sends information delivery function a message to notify that their service request is accepted and granted. If the service is unavailable, a denial of service message will be sent,

4) the information delivery function sends the service users the message saying 'service granted' from the data convergence function,

5) the service users send the service type that they wish, including services like the optimal growth model, the prediction service for crop harvest, or energy-saving environment control,

6) the data management function delivers the convergence type to the data convergence function,

7) the data convergence function determines the type of date to be retrieved according to the received convergence type,

8) the data management function checks the availability of data required for the data convergence function upon service users request,

9) the AIR queries the appropriate data for the requested checking,

10) the AIR returns the searched data to the data convergence function,

11) the data convergence function conducts data convergence for service using data retrieved from the AIR and generates the analysed information as the result from the convergence,

12) the data convergence function delivers the analysed information to the data management function,

13) the data management function delivers the analysed information to the information delivery function,

14) the information delivery function arranges the format and contents of the analysed information to provide services upon request of the service user,

15) the information delivery function sends the service response as the solution with the format and contents that the requesting service users can process and understand.

10 Security considerations

This Recommendation requires the use of IP-based networks. Thus, it is assumed that security considerations in general are based on the security of IP-based networks and thus it is required to follow the security considerations identified by clauses 7 and 8 of [ITU-T Y.2701].

Appendix I

Current agricultural problems and solutions

(This appendix does not form an integral part of this Recommendation.)

Despite its thousand years of history, agriculture is still greatly affected by natural environmental conditions such as soil, precipitation, amount of sunlight, humidity, temperature and seeds. Aside from the influences from the natural phenomena, agriculture as an industry has been also dealing with some modern issues such as decreases in the farming population, aging farmers, and the stagnating farm income. Overall, farmers have had hard times predicting their crop yields, maintaining the quality of crops, and delivering benefits in comparison with the appraised value of crops.

To address these issues, the concept of smart farming has been globally introduced, which is expected to strengthen the competitiveness of agriculture and ultimately to secure the production of high-quality crops. Going beyond simply operating the equipment based on the given environment information, Smart Farms have seen the rising necessities to introduce the state-of-the art, information and communication technology (ICT) to the agro-industry. If a wide range of services are properly designed and offered based on data collected from the pre-production stage to the distribution (consumption) stage of the agricultural supply chain, the challenges facing the agriculture sector today can be tackled in a more effective and faster way.

The Agriculture 1.0 era depends on manpower and animal power. The Agriculture 2.0 era, also called the Green Revolution, refers to the era when agricultural productivity was dramatically improved thanks to the development of fertilizers and pesticides by agricultural chemists. Followed by the Agriculture 3.0 era when precision farming and smart farming have started to thrive by fully utilizing ICT, the Agriculture 4.0 era is about to open a new chapter in the history of agriculture.

The Agriculture 4.0 era applies the key technologies of the Fourth Industrial Revolution to farming in order to make unmanned, intellectualized farm work possible. While the decisive elements of agricultural competitiveness have been land and labour from the Agriculture 1.0 to 3.0 era, it is forecasted that facilities, equipment and data will play a key role in the upcoming Agriculture 4.0 era.

Table I.1 – Keywords for agricultural development

Category	Agriculture 1.0	Agriculture 2.0	Agriculture 3.0	Agriculture 4.0
Keyword	Labour-intensive	Green revolution (Agrochemicals)	Precision farming (Smart farm)	Unmanned, autonomous operation (Robot, AI, big data)
Farm work	Animal power	Walking tractor	Riding tractor	Utilizing ICT

If technologies of the Fourth Industrial Revolution, such as big data, artificial intelligence, the Internet of things, and robotic technologies, are utilized for the development of agriculture on a full scale, a new era of agriculture will begin in which modern facilities, equipment, and data do not only do manual work for human beings, but also learn from experiences and accumulate the knowledge for future use. Agriculture in the Fourth Industrial Revolution era can be described with two keywords; datafication and servicification of agriculture. When converged with pesticides, seeds, and biotechnology, it is expected to create the most powerful synergy effects. It is anticipated that there will soon be a day when farmers can buy seeds together with the related data product. At farms, data will be accumulated and collected before being provided to corporate entities as feedbacks, which is expected to create much more powerful big data over time.

Table I.2 – Experience-based and data-based agriculture

Category	Experience-based farming	Data-based farming
Sowing	– Subjective selection of varieties – Seeding time decided based on experiences	– Goal-oriented development/selection of varieties – Seeding time decided based on the environment data
Cultivation/ Management	– Fertilizing/watering based on farmers' experiences – Labour-dependent farm working – Pest management after signs of pest detected	– Precise forecast and control of fertilizing/watering – Automated/mechanized farm working – Monitoring and controlling signs of pests
Harvest/ Storage	– Harvest time decided based on experiences – Labour-dependent harvesting	– Harvesting decided based on quality/distribution data – Automated selection/packaging
Process/ Distribution	– Quality level determined by visual inspection – Distribution/selling based on experiences	– Standardization of quality for productization – Distribution/selling based on real-time market data
Overall	– Dependent on farmer's experience and know-how – Inefficient crop management – Passive response to changes of climate, environment, and market	– Precise forecasting based on accumulated data – Precise forecast and efficient management of farm work – Active response to climate, environment, and market situations

The datafication of agriculture will open up a new path for the servicification of agriculture. To form every single agricultural activity into data, smart sensors are used to collect data and carry out monitoring. Data will be accumulated and integrated to form big data which will be then analysed in order to establish detailed farming plans. Farm work will be carried out according to the plans by the state-of-the-art agricultural machines in a more precise way.

In fact, the servicification, which develops and commercializes a service model based on a series of related processes, has already begun in the agricultural sector. There are Priva, dedicated environment control system for horticulture, and FieldScripts by Monsanto which analyses the climate and soil data of farms. Other examples are the FieldsView digital farming platform by the Climate Corporation and Lettuce Bot which removes weeds only by using machine learning algorithms. Engineers from the Netherlands and Japan have been collaborating to develop various kinds of vegetable-picking robots. All of these examples demonstrate how servicification has rapidly grown in the agricultural sector.

If agricultural data is collected, managed, and then utilized to accomplish the servicification of data, it will contribute to the global production of high-quality crop. Increases in the amount and quality level of crop production will ultimately provide a solution to alleviate poverty, cope with famine, and ease food shortages in the world.

Appendix II

Equipment for convergence services

(This appendix does not form an integral part of this Recommendation.)

In this appendix, the categories of equipment installed inside greenhouses will be described and components of each category will be introduced. Only the equipment installed inside greenhouses will be considered. The equipment can be broken down into three categories, that is, integrated controller, environment data collecting device, and data management device as shown in Table II.1.

Table II.1 – Equipment categorization

Categories	Equipment	Components
Integrated controllers	Actuators	Circulation fan, blackout shade opener, side/roof window opener, air conditioner and heater, irrigated water supplier, thermal screen opener, nutrient solution device, CO_2 supplier, etc.
Environment data collecting device	Interior environment sensing device	Temperature, humidity, CO_2, soil, nutrient solution, EC, PH, etc.
	Exterior environment sensing device	Temperature, humidity, wind direction, precipitation, solar radiation, etc.
Data management device	Cameras	CCTV, web cameras
	Recording device	DVR
	Computer equipment	PC, monitors, UPS, etc.

II.1 Integrated controller

The following are expected characteristics of the integrated controller:

– The integrated controller should be able to receive and/or request the environment data from sensor nodes.

– The integrated controller should be able to send control signals to control nodes and check the running condition.

– The integrated controller should be able to send/receive the environment data and control signals to/from the greenhouse operation management system.

– In case of emergency such as a network disconnection with the greenhouse operation management system, the integrated controller should be able to perform the control functions independently and store collected data from sensor nodes for a certain period of time.

II.2 Sensor nodes

Sensor nodes consist of sensors and communication modules, transmitting sensed values to the greenhouse integrated controller. See Table II.2.

– Requirements:
  - Sensor nodes should include wire/wireless communication modules which can communicate with the greenhouse integrated controller.
  - Sensor nodes should be able to transmit values measured by sensors to the integrated controller.
  - Sensor nodes should be powered by permanent power supply or batteries.

- Sensors should be plug-and-play sensors that are easy to change or add.

Table II.2 – Types and description of sensor

Category	Purpose	Description
Interior sensors	Temperature	– Temperature sensor is the most basic sensor for creating/controlling the growth environment for crops. The inner temperature, related to crop development, fruit fertilization, and pest and disease outbreaks, has the most substantive effect on the crop growth. – To keep the temperature at an optimal level, windows and curtains are used. Water supply by the irrigation system and temperature control by boilers are conducted.
	Humidity	– Humidity is closely related to pest and disease outbreaks. In case of high humidity, probability for pest and diseases is high. Low humidity, causing troubles for crops to breathe, may disrupt the supply of nutrients. – Humidity can be controlled by opening or closing windows.
	CO_2	– The CO_2 concentration can be used to decide whether the environment is suitable for photorespiration. In case of low CO_2 concentration, crops cannot initiate photorespiration, slowing down the crop development. – When high solar radiation activates crops, increasing the CO_2 supply can prevent problems from occurring in crop growth.
	Soil water temperature (in case of soil water culture)	– The soil water sensor detects the humidity from soil, determining whether soil contains a proper amount of moisture for crop growth. – The soil temperature sensor detects the temperature of soil, determining whether the soil has a proper temperature for crop growth. – If the soil moisture is high, roots are submerged in water and crops cannot breathe. In case of low moisture in soil, crops cannot be supplied with water and thus nutrients.
	Soil culture information (fertilizer management)	– This sensor measures the fertilizer concentration and the salinity of soil. The sensed values are analysed to manage the amount and frequency of fertilizer. – The sensor uses the EC sensor and the pH sensor.
	Soil culture information (fertilizer management)	– This sensor measures the fertilizer concentration and the salinity of soil. The sensed values are analysed to manage the amount and frequency of fertilizer. – The sensor uses the EC sensor and the pH sensor.
	Nutrient solution information (in case of solution culture)	– Nutrient solution refers to nutrients supplied to crops. Each crop has different levels of nutrient supply. Sensors measuring EC, pH, soil temperature are the basis of determining the nutritive conditions of crops. Nutrient solution supply is determined by data collected from this sensor. – To control EC, pH, and soil temperature, the mixing ratio of nutrients are varied. – The nutrient solution information sensor can be chosen from either a solution sensor or a soil sensor based on a decision made from discussions with farm owners. In other words, the sensor can be either a solution information sensor (solution EC sensor, solution

Table II.2 – Types and description of sensor

Category	Purpose	Description
		pH sensor) or a soil information sensor (soil moisture sensor, soil temperature sensor).
Exterior sensors	Temperature and Humidity	– This sensor measures outside temperature and humidity. – Based on the outside temperature and humidity data, the optimal level of temperature and humidity inside greenhouses can be achieved by controlling ventilation through roof windows and modifying the setting of blackout shades/thermal curtains.
	Wind direction/velocity	– Wind direction/velocity data is used for controlling the safety of greenhouse facilities (shades, props, greenhouses, etc.) During the summer season when the windows of greenhouses are often open, wind direction/velocity may have sudden changes in temperature inside greenhouses. – If there is a possibility that the inner temperature may change due to wind direction/velocity, the windows of greenhouses will be modified to control the inner temperature. – If damages due to strong wind are expected, necessary measures such as protecting vinyl greenhouses will be taken.
	Precipitation (rain detection)	– This sensor detects the rainfall. – In case of rain, the windows of greenhouses will be closed to prevent crop damages due to rain.
	Solar radiation	– This sensor measures the amount of solar radiation outside of which data can be the basis of guessing the amount of photosynthesis. – Based on the solar radiation measured outside, curtains at greenhouses will be controlled.

* When installing the temperature, humidity, and CO_2 sensors, a site inspection should be performed to understand the environment of greenhouse facilities and determine the best locations for those sensors.

* Depending on the nature of the crop to be grown, sensors which have more than two functions can be installed based on prior consent with farm owners.

II.3 Control nodes

Control nodes consist of actuators and communication modules, controlling actuators based on messages transmitted from the integrated controller. See Table II.3.

– Requirements for actuators:
  - Actuators include wire/wireless communication modules that can communicate with the integrated controller.
  - Actuators receive signals from the integrated controller and actuate the control devices.
  - Actuators should be able to transmit the condition of control nodes and control state to the integrated controller.

Table II.3 – Types and application

Type	Applications
Circulation fan	– Based on the collected data from the temperature/humidity sensors installed inside greenhouses, circulation fans are used to control the ventilation of each greenhouse unit. – The maintenance status of temperature/humidity inside greenhouses can be monitored by mobile devices connected to the service system. In case of abnormal values detected, users can set their own thresholds. If a sensed value is outside the normal range, the abnormality is informed to the service users and the system automatically initiate the controlling process. * The operation of automatic controlling process should be able to be checked outside by CCTV or other monitoring devices. (Optional)
Side/roof window opener	– Based on data gathered from the temperature/humidity sensors inside and outside greenhouses, side windows will be controlled to provide the optimal environment for crop growth. – Right and left side windows should be tilted or opened at different degrees from each other. * If right and left side windows open/close together at the same degree with each other, the current condition and farm owners' requests will be incorporated into consulting reports. – Controlling the vent should be done by opening roof windows and side windows to the opposite direction from the direction of wind. – The operation cycle of roof windows and side windows should be able to be set up in different stages depending on the nature of crops. – When opening or closing windows, the pre-set value and the outdoor temperature sensor are connected automatically. Depending on the outdoor temperature, the window opening/closing degree should be modified. In case of any deviation, additional control is required. – Rainfall data gathered from the rainfall sensor installed outside greenhouses will be the basis of controlling side windows and roof windows of greenhouses.
Thermal screen opener	– Thermal screen for keeping plants warm should be controlled based on the amount of solar radiation outside greenhouses, outdoor temperature, and temperature/humidity inside greenhouses.
Blackout shade opener	– Blackout shade should be controlled based on the amount of solar radiation outside greenhouses, outdoor temperature, and temperature/humidity inside greenhouses. – The solar radiation amount measured by the solar radiation sensor will control the blackout shade in consideration of the greenhouse materials and their penetration rates.
CO_2 Supplier	– Based on CO_2 data gathered by the CO_2 sensor inside greenhouses, the CO_2 supplier controls the CO_2 generator or operates side/roof windows or ventilation fans in order to maintain the CO_2 concentration at an appropriate level.
Nutrient solution device (in case of solution culture)	– From the two types of nutrient solution information sensors, soil data gathered by the soil information sensor (soil moisture rate, soil EC senor) should be provided to farmers who can then modify the solution controller based on his understanding on the nutrient solution data. – The solution data gathered by the solution information sensor (solution EC sensor, solution pH sensor, solution temperature sensor) installed at the solution container should be provided to farmers who can then modify the solution controller based on his understanding on the nutrient solution data.

Table II.3 – Types and application

Type	Applications
Water, fertilizer supplier	– Data gathered by the soil moisture sensor installed inside greenhouses should be used to help the supply of water and fertilizer to each greenhouse unit.
Air conditioner. heater	– Operation of air conditioners and heaters should be controlled based on the amount of solar radiation outside greenhouses, outdoor temperature, and temperature/humidity inside greenhouses.

II.4 Data management device

Table II.4 provides information on data management device.

Table II.4 – Data management device

Category	Sub-category	Component
Video equipment	Camera	CCTV, web cameras
	Recording device	DVR
Data management	Computer device, etc.	PC, monitors, UPS, etc.

– Data management device consists of video equipment (CCTV, web cameras, recording device) for participating business partners to monitor their crop growth and security, and computer device for the greenhouse operation management system.

II.5 Video equipment

The following is information related to video equipment and functional requirements as provided in Tables II.5 to II.8:

– Camera

- There should be two cameras; a monitoring camera for inside the greenhouse to check the growth and development of crops, and a security camera for outside the greenhouse to ensure the security of the premise and facility.
- The monitoring camera should provide the functions to take close-ups of crops and check the environment inside the greenhouse. The crop monitoring data should be stored every day at the greenhouse operation management system.
- The security camera should have clear night vision and support motion detection. Recorded video should be stored so that video data can be checked later if needed.
- Appropriate lenses should be chosen and applied based on the purpose of cameras.
- Live video should be able to be monitored in real time.
- Functional requirements.

Table II.5 – Camera for functional requirements

Category	Requirements
Functions	Functions such as auto sensitivity control, auto white balance, and lens calibration should be included.
Durability	Highly durable against external vibration, external shocks, and EMI noises
Intensity of illumination	The lowest intensity of illumination should be under 0.5 lux (in case of cameras whose definition is over a megapixel, the lowest intensity of illumination for cameras is

Table II.5 – Camera for functional requirements

Category	Requirements
	under 1.0 lux.). Regardless of whether it is day or night, cameras should be able to provide a video from which objects can be identified.
Image pickup device	The number of pixels should be over 410 000 pixels.
Network (optional)	Depending on its purpose, the camera can be used as a network camera.
Others (optional)	For greater convenience in monitoring, cameras with remote controls and zoom function are recommended.

Table II.6 – Lens for functional requirements

Purpose	Requirements
Monitoring	Wide-angle lenses are recommended in consideration of videotaping distance and angle.
Security	Telephoto lenses are recommended in consideration of the purpose of videotaping, keeping the premise and facilities safe.

– Recording Device

- Recording devices that are compatible with cameras should be selected.

Table II.7 – Recording device

Feature	Specification
Resolution	Minimum 320x240 ppi or higher
Frame rate	Minimum 5 fps or higher
Storage duration	Minimum 30 days or longer
Playback quality	Maintain the same image quality as recorded
Operation system	Compatible with other devices
Compression	Support MPEG4, MJPEG, Wavelet, H.264
Network	Include IP port capable of remote transmission
Connectivity	Can be connected to sensors and detectors

- In case of using web cameras, storage medium should be configured which can store the CCTV footage in real time and support the data searching and back-up functions. As for the storage configuration method, direct-attached storage (DAS) is recommended which connects a server and a storage one on one.

– Network

- Network should have a frequency bank (speed) which can transmit high-definition videos for live monitoring.

Table II.8 – Computer device

Type	Specification
PC	CPU 2.8GHz, dual-core or higher, RAM 2G or faster, HDD 500G or larger (including the operating system and software for management)* PC data back-up
Monitor	24 inch or larger, LED monitor, resolution 1920*1080, response time 5ms, brightness 250 cd/㎡, contrast ratio 1000:1 or higher
OS	Windows 7 (home premium) or later version, Linux
Others	The latest vaccine programs should be installed (free), and update should be available any time. * Software's required for smart greenhouses should be installed and run without any technical issues.

– Others

UPS: An uninterruptible power supply (UPS) should be installed based on the electricity consumption so that the computer system can operate even when the greenhouse operation system and the integrated controller are turned off due to power outage.

Bibliography

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