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Supplement

ITU-T Y Suppl. 76 (09/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Supplements to the Y-series Recommendations – Supplements to the Y-series Recommendations related to IoT and SC&C

ITU-T Y.4000-series – Use cases of Internet of things-based smart agriculture

ITU-T Y-SERIES RECOMMENDATIONS

Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

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Supplement 76 to ITU-T Y-series Recommendations

ITU-T Y.4000-series – Use cases of Internet of things-based smart agriculture

Summary

Supplement 76 to ITU-T Y-series Recommendations surveys use cases related to smart agriculture from the perspective of, but not limited to: 1) smart greenhouse; 2) smart open field; 3) smart hydroponics; 4) smart livestock barn; and 5) smart agriculture data service.

Globally, difficulties in food supply and demand are expected due to problems such as climate change, water shortage, rapid urbanization, reduction of agricultural land and an aging population.

Smart agriculture is based on accurate data on the growth and environmental information of crops and livestock, and monitors the growth environment of crops and livestock anytime, anywhere, and prescribes them in a timely manner, even if less labour, energy and nutrients are introduced than before. It means agriculture that can greatly improve the quality and quantity of products.

In general, smart agriculture can remotely or automatically perform the maintenance and management of the growth environment of crops and livestock by using Internet of things (IoT), big-data, artificial intelligence, automation systems and robot technologies in greenhouses, vertical plant farms, open field farms or livestock barns.

Because there are a number of IoT devices applied to smart agriculture, it is very important to know their interaction for interoperability. For this reason, it is necessary to survey existing as well as forthcoming smart agriculture technologies and then based on the results, develop meaningful standardization work items.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
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Agricultural data service, animal health care, automated milking system, connected agricultural tractor, container-based plant farm, pest control using UAV, smart greenhouse, smart water management.

* To access the Recommendation, type the URL https://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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ITU-T Y.4000-series – Use cases of Internet of things-based smart agriculture

1 Scope

This Supplement provides use cases related to smart agriculture from the perspective of: 1) smart greenhouse; 2) smart open field; 3) smart hydroponics; 4) smart livestock barn; and 5) smart agricultural data service.

2 References

[ITU-T Y.4000]	Recommendation ITU-T Y.4000/Y.2060 (2012), *Overview of the Internet of things*.
[ITU-T Y.4122]	Recommendation ITU-T Y.4122 (2021), *Requirements and capability framework of the edge-computing-enabled gateway in the IoT.*
[ITU-T Y.4466]	Recommendation ITU-T Y.4466 (2020), *Framework of smart greenhouse service*.
[ITU-T Y-Suppl. 53]	ITU-T Y-series Recommendations – Supplement 53 (2018), *ITU-T Y.4000-series – Internet of things use cases*.
[EN 13031-1]	EN 13031-1:2019, *Greenhouses – Design and construction – Part 1: Commercial production greenhouses*.
[ISO 1496-1]	ISO 1496-1:2013, *Freight containers – Specification and testing – Part 1: General cargo containers for general purposes*.
[ISO 8026]	ISO 8026:2009, *Agricultural irrigation equipment – Sprayers – General requirements and test methods*.
[ISO 9635]	ISO 9635 (all parts), *Agricultural irrigation equipment – Irrigation valves*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 data services [b-ITU-T Y.3115]: Services that provide authorized consumers with the capabilities of collecting, processing, retrieving and sharing data within a single domain and across domains.

3.1.2 greenhouse [ITU-T Y.4466]: A facility that can control a crop-growth environment (i.e., light, temperature, humidity, etc.).

3.1.3 Internet of things (IoT) [ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

3.1.4 irrigation system [b-ISO 11738]: Assembly of pipes, components, and devices installed in the field for the purpose of irrigating a specific area.

3.1.5 optimal growth model [ITU-T Y.4466]: A recipe to set an environment to maximise crop productivity as well as quality according to the life cycle.

3.1.6 smart farm [ITU-T Y.4466]: A group of smart greenhouses under management of an administrator.

3.1.7 smart greenhouse [ITU-T Y.4466]: A facility that can control the environment of a greenhouse with minimum human intervention using Internet of things (IoT) technologies.

3.1.8 wireless power transmission [b-ITU-T Y.4202]: The transmission of power from a power source to an electrical load using the electromagnetic field.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AI Artificial Intelligence

AMM Agricultural Machinery Management

AMS Automated Milking System

API Application Programming Interface

EMC Electromagnetic Compatibility

FMD Foot and Mouth Disease

FOTA Firmware Over the Air

GNSS Global Navigation Satellite System

ICT Information and Communication Technology

ID Identifier

IoT Internet of Things

OTA Over the Air

RFID Radio Frequency Identification

RTK Real Time Kinematic

SOTA Software Over the Air

UAV Unmanned Aerial Vehicle

5 Conventions

None.

6 Recommended template for the description of a smart agriculture use case

Recommended template [ITU-T Y-Suppl. 53]

1. Title of the use case (title is strictly related to the application area addressed)
   a. Name of the use case
   b. Identifier (ID) of the use case (ID will be given by ITU-T SG-20 such as vertical name/001/16-17)

c. Version or revision history (such as No./month/year)

d. Source (country/ITU-T member/organization registered with ITU)

2. Objective of the use case (aligned with title, it has explanatory content)

3. Background

   a. Current practice (current process or context that will benefit from the implementation of the use case)

   b. Need for use case

   c. Country ecosystem specifics

4. Description

   a. Ecosystem description in terms of actors and business roles

   b. Contextual illustration

   c. Prerequisites

   d. Preconditions (if any)

   e. Triggers

   f. Scenario

   NOTE – The basic option is to have a single scenario per single use case. However, multiple scenarios for a single use case are not excluded; in which case, they are indicated in this same field as appropriate.

   g. Process flow diagram

   h. Post-conditions (if any)

   i. Information exchange

   NOTE – It is expected to have the information exchange (field i) associated with the process flow (and process flow diagram if any) (field g).

5. Architectural considerations

   a. Deployment considerations

   b. Geographical considerations

   c. Communication infrastructure

   d. Performance criteria

   e. Interface requirements

   f. User interface

   g. Application programming interfaces (APIs) to be exposed to the application from platform

   h. Data management

   i. Data backup, archiving and recovery

   j. Remote device management

   k. Startup and Shutdown process

   l. Security requirements

6. Potential market growth forecast

7. Implementation constraints (for the support of the use case)

8. Statutory compliance and related regulations

9. Available international standards

10. References (related to standards or other useful information)

11. General remarks

7 Classification scheme for the smart agriculture use cases

Table 1 outlines the classification for smart agriculture use cases.

Table 1 – Classification of smart agriculture use cases

ID category	Category of smart agriculture use case	Use cases
1	Smart greenhouse	Smart greenhouse Smart greenhouse with cloud and edge support
2	Smart open field	Smart water management Pest control using an unmanned aerial vehicle (UAV) Connected agricultural tractor
3	Smart hydroponics	Container-based plant farm
4	Smart livestock barn	Automated milking system (AMS) Animal health care
5	Smart agriculture data service	Agricultural data service

8 Smart agriculture use cases

8.1 Smart greenhouse

1. Title of the use case
   a. Name of the use case: Smart greenhouse
   b. ID of the use case: ID category 1 (Smart greenhouse) of clause 7
   c. Version or revision history: 1
   d. Source: Republic of Korea/ETRI
2. Objective of the use case

   This use case describes a method of automatically monitoring temperature, light intensity, humidity and soil moisture levels in a smart greenhouse and adjusting them to provide optimal conditions for crop growth.
3. Background
   a. Current practice

      Crop growth rate, harvest time and production volume are highly dependent on environmental factors. Therefore, many countries adopt greenhouses to provide crop growth conditions that are protected from external environmental influences. However, most greenhouses control the environment for crop cultivation manually. Maintaining a greenhouse crop cultivation environment on a large scale is challenging and heavily dependent on human resources.
   b. Need for use case

      Automatic monitoring and control of environmental conditions using IoT devices such as sensors to monitor environmental status, actuators to adjust environmental conditions and a controller to activate actuators so that the crop can be cultivated in an optimal environment.
   c. Country ecosystem specifics: None.

4. Description

a. Ecosystem description in terms of actors and business roles

The importance of smart agriculture in which information and communication technology (ICT) and agricultural technology are combined is emphasized due to world population growth, aging, climate change, decrease in the area of arable land and decrease in availability of labour due to urbanization.

A smart greenhouse, one of the smart agriculture fields, is relatively independent from the external environment such as temperature, humidity, and solar radiation. It uses various types of sensors and actuators installed in the smart greenhouse to monitor and adjust the environmental conditions for crop cultivating optimally. The sensors measure the vital parameters of the crop and communicate them to the controller, who then transmits them to the management system. Based on the type of crop and the data from the sensors, the management system analyses further actions and if required will direct the actuators via controller. In this way, a smart greenhouse improves the productivity of the crop cultivated in its environment.

b. Contextual illustration

To monitor and adjust the environmental conditions automatically, the smart greenhouse collects the environmental status information (measurement values) from each sensor, and then it activates appropriate actuators to adjust crop growth environmental conditions.

The names and roles of the actors involved in this use case are shown in Table 2.

Table 2 – Actor description for smart greenhouse

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not.
Sensor	A device that measures soil- and weather- conditions in a smart greenhouse. It delivers the measured data to the smart greenhouse management system.
Actuator	A device that adjusts soil- and weather- conditions of the smart greenhouse according to the controller's commands.
Controller	A device that aggregates sensing data from sensors and then delivers them to the smart greenhouse management system. According to the received optimal growth model, it controls one or more actuators installed in the smart greenhouse.
Gateway	A device that provides connection interface between the controller and the smart greenhouse management system.
Smart greenhouse management system	A system that with the help of big-data and artificial intelligence (AI) technologies analyses the aggregated data to produce an optimal growth model including an environmental control plan.

c. Prerequisites: None.

d. Preconditions

In order to transmit information of environmental status, control commands and execution results, an appropriate communication link is required. Since data volume is not huge, a broadband network is not required.

e. Triggers: None.

f. Scenario

– Sensors installed in the smart greenhouse measure environmental conditions (soil moisture, ambience temperature, sun light, humidity, etc.) and then send the information to the smart greenhouse management system.

– The smart greenhouse management system analyses the environmental conditions and then activates appropriate actuators to adjust crop growth environment optimally.

– Finally, the smart greenhouse management system confirms the activities.

g. Process flow diagram

Figure 1 shows the flow diagram of the smart greenhouse according to the scenario.

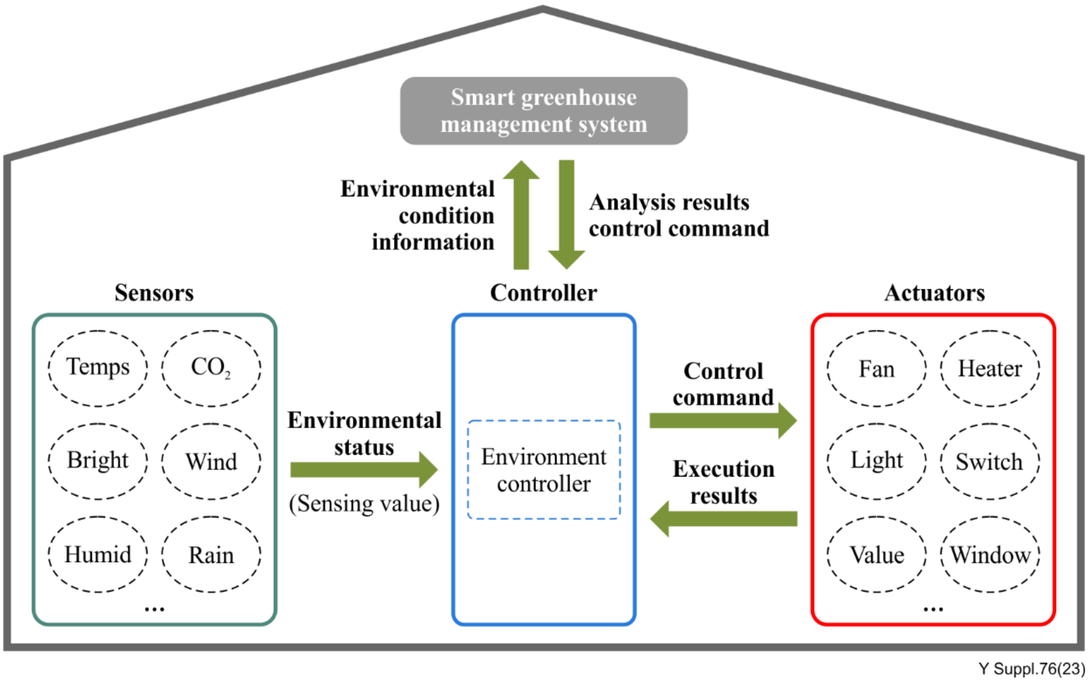

Figure 1 – Process flow diagram of the smart greenhouse

h. Post-conditions: None.

i. Information exchange

Each sensor provides information to the management system via the controller for further processing and action; examples of information include the type of sensor device and the measurement values (soil moisture, ambience temperature, rain, CO_2 levels, sun light, and humidity).

The management system activates actuators with control information; examples of control information include the adjustment of temperature, humidity and ventilation.

After the activation is completed, the actuator provides the execution results to the management system; examples of execution results information include the operation result and energy consumption.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the installation and maintenance;

– the cost for the hardware such as sensors, actuators, controllers, and management systems;

– the cost for the software to operate the system and service;

– the cost for the network utilization;
– the cost for energy, water, fertilizer.

In addition, the followings should be considered for the smart greenhouse:

– the durability of hardware installed in greenhouse with high temperatures and humidity;
– the accuracy of the sensors;
– the light transmittance of the material used to build the greenhouse such as glass, vinyl, and polycarbonate as the light is a key factor of crop growing.

b. Geographical considerations: None.

c. Communication infrastructure

The smart greenhouse uses wired or wireless communication links for monitoring and controlling environmental conditions.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

The user interface for smart greenhouse should provide enough accessibility for who are not familiar with ICT.

g. APIs to be exposed to the application from platform: None.

h. Data management

It is required to store all data from sensors, actuators and controller in a general format independent of types of devices or its manufacturer. Accumulated data (big-data), will be used for precise farming, and will serve as basic materials to establish farmer's management and marketing strategies and optimal growth model for crops.

i. Data backup, archiving and recovery

Data for monitoring and control of environmental conditions must be stored for a considerable period. The more data collected, the more precise statistics and analysis are possible, which is directly connected to the productivity improvement.

However, when the amount of stored data becomes huge, the cost for maintenance and management of the storage space entails. Therefore, it is necessary to establish an appropriate data storage and management strategy in consideration of this.

Future technological advances will enable more accurate or highly efficient data acquisition, but compatibility with data acquired in the past must be ensured.

j. Remote device management

Status of sensors and actuators must be monitored remotely, and these devices must be immediately replaced, if a failure occurs, so it is necessary to manage the devices remotely. Over the air (OTA) capabilities, including firmware over the air (FOTA) and software over the air (SOTA), are recommended for software/firmware updates of remote IoT devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the smart greenhouse safe from malicious users, it is required to protect the devices, communication links and data for remote control. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast

According to a market analysis report [b-greenhouse], the global market of annual sales for smart greenhouse estimated at USD 1,470 million in 2020 is projected to reach USD 2,690 million by 2027 with an annual growth rate of 9.0% over the same period. In addition, according to another report [b-agrimarket], the global market for remote monitoring was valued at USD 340 million in 2021, and is expected to rise to USD 410 million in 2027 with an annual growth rate of 2.87%.

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on building, communication, electrical safety, environments, and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ITU-T Y.4466], *Framework of smart greenhouse service*.

10. References: None.

11. General remarks: None.

8.2 Container-based plant farm

1. Title of the use case

   a. Name of the use case: Container-based plant farm

   b. ID of the use case: ID category 3 (Smart hydroponics) of clause 7

   c. Version or revision history: 1

   d. Source: South Korea/ETRI

2. Objective of the use case

A farming method of growing plants using multi-tiered shelves with modular container boxes is described in this use case.

3. Background

   a. Current practice

   The size of the farmland that can be used for farming is decreasing due to global warming, such as water shortage, desertification, and climate change. One of the methods to face the pressure of increasing food demands is the container-based plant farming method. The container-based plant farming method is not a single-story farming method in the plain, but a farming method in which plants are grown using a multi-layered shelf in a designated indoor space.

   b. Need for use case

   The container-based plant farm does not depend on soil fertility, is not affected by the climate, and eco-friendly cultivation is possible without the intervention of external factors such as pests, so mass cultivation is possible with insufficient space. It also has the benefit of reducing the carbon dioxide emitted when produced in rural areas and delivered to cities.

   To make a vertical plant farm possible, it is needed to construct a separate building; but using modular container boxes instead of a separate building make it easy to implement and install the container-based plant farm even in cities.

   c. Country ecosystem specifics

The initial cost to install the container-based plant farming facilities is much higher than outdoor farming facilities, it may be difficult for the countries who cannot afford installation and maintenance costs for the container-based plant farming facilities.

4. Description

a. Ecosystem description in terms of actors and business roles

This use case involves the container-based plant farm using modular container boxes and a big data centre. The container-based plant farm is equipped with multiple sensors and actuators and is controlled by a controller.

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 3.

Table 3 – Actor description for container-based plant farm

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not.
Sensor	A device that measures soil- and weather- conditions in a container-based plant farm. It delivers these measured data to the smart greenhouse management system.
Actuator	A device that adjusts soil- and weather- conditions of the container-based plant farm according to the controller's commands.
Controller	A device that aggregates sensing data from sensors and then delivers them to the smart greenhouse management system. According to the received optimal growth model, it controls one or more actuators installed in container-based plant farm.
Gateway	A device that provides connection interface between the controller and the smart greenhouse management system.
smart greenhouse management system	A system that, with the help of big-data and AI technologies, analyses the aggregated data to produce an optimal growth model including an environmental control plan.

c. Prerequisites: None.

d. Preconditions

In order to obtain farming data from the container-based plant farms and to control them remotely, an appropriate communication link is necessary. Since data volume is not huge, a broadband network is not crucial.

e. Triggers: None.

f. Scenario

Sensors in the container-based plant farm monitors the cultivation condition such as light, temperature, humidity, carbon dioxide, etc. Actuators adjust the cultivation condition according to the controller's commands. A big data centre collects information regarding the cultivation conditions and status to establish a plan to maximize the productivity and quality of agricultural products.

g. Process flow diagram

The sensing information of the container-based plant farm is provided by sensors to a controller; the example of sensing information includes light intensity, temperature, humidity and carbon dioxide. Based on sensing information received from the sensors, the controller requests a series of actions to appropriate actuators; the example of actuator's actions includes turning on the light, increasing the temperature and spraying water. This sensing information and accompanied adjusting information are then transferred to the big data centre to establish a plan to manage the container-based plant farm.

h. Post-conditions: None.

i. Information exchange

The container-based plant farm is managed based on the plan established by a big data centre. To establish a management plan, a controller that controls the cultivation conditions of the container-based plant farm has to provide information about the environmental and control conditions; the information of environmental condition is sensing information produced by each sensor, and the information of a control condition is activity information performed by each actuator.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the installation and maintenance of the facility;

– the cost for the hardware such as sensors, actuators, controllers, CCTV, and management systems;

– the cost for software to operate the system and service;

– the cost for the network utilization;

– the cost for energy, water, fertilizer.

In addition, the following should be considered for the container-based plant farm:

– the cost for modular containers used for plant farming.

b. Geographical considerations: None.

c. Communication infrastructure

The communication between the container-based plant farm and a big data centre, and the communication between sensors/actuators and a controller are based on wired or wireless communication links.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface: None.

g. APIs to be exposed to the application from platform: None.

h. Data management

To counter the pressures of increasing food demand and climate changes, data management and utilization by means of IoT, big-data, analytics, and cloud computing are very important. IoT devices enable data collection; sensors installed in the container-based plant farm can produce information on soil, air and light in real time; actuators produce information of energy consumption. This information is collected with other information such as plant growth information in the cloud for multiple purposes; such as to predict plant growth, to minimize energy consumption and for further analytic purpose.

i. Data backup, archiving and recovery

When a big data centre is to establish the most optimal plan for the container-based plant farm, a plentiful qualified data is very essential. However, the qualified data cannot be acquired in a short time, it is important to manage data from long-term experience; the acquired data must be stored for decades.

j. Remote device management

Because sensors and actuators are exposed to a high humidity environment, their status must be monitored remotely and immediately replaced if necessary. OTA capabilities, including FOTA and SOTA, are recommended for software or firmware updates of remote IoT devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the container-based plant farm safe from malicious users, it is required to protect the devices, communication links and data for remote control. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast

NOTE – According to the report [b-vertical], the size of the global vertical agriculture market (not restricted to the container-based plant farm market only) is valued at USD 3.24 billion in 2020, and is expected to reach USD 24.11 billion by 2030, registering a CAGR of 22.9%.

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on container, communication, electrical safety, environments, and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ITU-T Y.4466], *Framework of smart greenhouse service*

– [ISO 1496-1], *Freight containers – Specification and testing – Part 1: General cargo containers for general purposes*.

– [EN 13031-1], *Greenhouses – Design and construction – Part 1: Commercial production greenhouses*.

10. References: None.

11. General remarks: None.

8.3 Smart greenhouse with cloud and edge support

1. Title of the use case

a. Name of the use case: Smart greenhouse with cloud and edge support

b. ID of the use case: ID category 1 (Smart greenhouse) of clause 7

c. Version or revision history: 1

d. Source: Republic of Korea/ETRI

2. Objective of the use case

A smart greenhouse service with cloud is based on a cloud technology by collecting and analysing both environmental and crop growth information in managing agricultural conditions of a smart greenhouse. In spite of the generic characteristics of cloud-computing capabilities, the smart greenhouse service with cloud may suffer from the communication fault due to electricity-blackout or cable-broken between local devices and cloud.

To overcome those weaknesses, edge-computing technology is introduced to extend cloud capabilities to local devices in the smart greenhouse; the smart greenhouse service with edge-computing technology support is called as "smart greenhouse service with cloud and edge support".

The smart greenhouse service with cloud and edge support can provide a fault-tolerant service over electricity-blackout or cable-disconnection and a low-delay communication to control the greenhouse in real time. Moreover, the smart greenhouse service with cloud and edge support can alleviate network cost by compressing local data destined to the cloud system.

Technologies applied in smart greenhouse service with cloud and edge support can also be deployed by livestock barns, UAVs and agricultural machinery.

3. Background

a. Current practice

The data required for the smart greenhouse service – as well as the users' demands of enhancing crop productivity and users' convenience – are increasing dramatically. To manage such large volumes of data, cloud-computing technology has been adopted in smart greenhouse service. In the meanwhile, to overcome network fault, edge-computing technology has been introduced as previously described.

In terms of data analysis, the edge device can perform lightweight analysis by itself compared to the cloud system to find an optimized solution for the specific environment in real time; in addition, the edge device interacts with the cloud system for more deep analysis.

b. Need for use case

Traditionally, adopting the cloud-computing technology in the smart greenhouse service reduces data handling burdens such as:

– to generate an optimal crop growth model;
– to help farmer's decision making; and
– to share data with neighbourhood farmers.

Because the smart greenhouse service with cloud and edge support takes advantages of the smart greenhouse service with cloud and the stand-alone smart greenhouse service in terms of network robustness and delay, managing costs, and security; it can easily be deployed by diverse applications, such as livestock barns and agricultural machines.

c. Country ecosystem specifics: None.

4. Description

a. Ecosystem description in terms of actors and business roles

In the smart greenhouse service with cloud and edge support, all meaningful information regarding the environmental, growth and farming is generated by the smart greenhouse. The edge device collects and analyses this information in real time. The cloud system accumulates and analyses that information in depth using big-data and AI technologies; after deep analysis, it provides an optimal crop growth plan to the edge devices and any requested users as needed. Examples of applications of the optimal crop growth plans include an optimal crop growth, an optimal crop harvest, and an optimal pest control. Users can also directly modify the cultivation plan received from the cloud system based on their agricultural knowledge from experience. Then, the cloud system or edge device operates the corresponding devices according to the user's modified plan to adjust the environmental conditions in the smart greenhouse. The results of these user interventions are then used as input to optimize the crop growth plans again.

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 4.

Table 4 – Actor description for smart greenhouses with cloud and edge support

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not.
Sensor	A device that measures soil- and weather- conditions in a smart greenhouse. It delivers these measured data to the edge device.
Actuator	A device that adjusts soil- and weather- conditions of the smart greenhouse according to the controller's commands.
Edge device	A device that aggregates sensing data from sensors and then delivers them to the smart greenhouse management system. According to the received optimal growth model, it controls one or more actuators installed in smart greenhouse.
Gateway	A device that provides connection interface between edge device and the smart greenhouse management system.
smart greenhouse management system	A system that, with the help of big-data and AI technologies, analyses the aggregated data to produce an optimal growth model including an environmental control plan for the edge device.

c. Prerequisites

An appropriate communication link is required to exchange information between the internal devices of smart greenhouses and the external device. In particular, a broadband link may be required for images or video information.

d. Preconditions (if any): None.

e. Triggers: None.

f. Scenario

Any sensing data generated from sensors are collected by the edge device. From the edge device perspective, the data collected from sensors can be used to make decisions to control greenhouse environmental conditions based on its control work plan; they are also delivered to the cloud system for in-depth analysis.

The cloud system, based on the data provided by edge devices, produces an optimal crop growth model for the edge device in return.

Any service user can inquire about the status of a specific farm, can change the environmental conditions or can manage devices installed in the specific farm.

g. Process flow diagram

Figure 2 shows a flow diagram of the smart greenhouse with cloud and edge support according to the scenario.

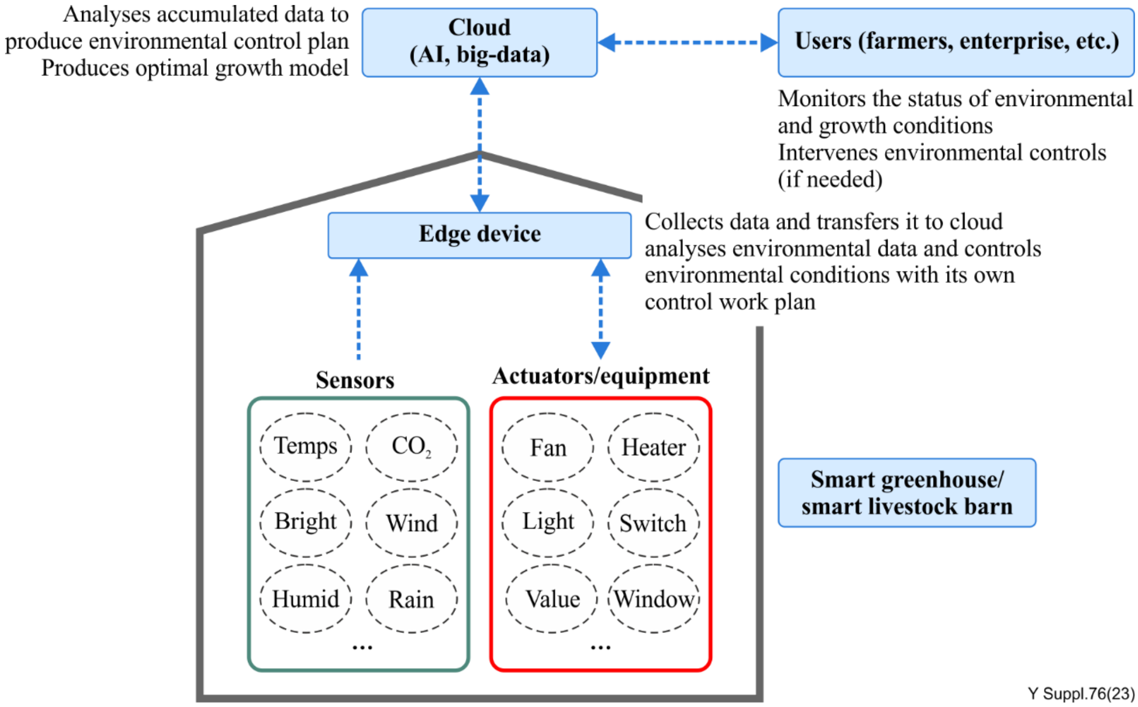

Figure 2 – Process flow diagram of a smart greenhouse with cloud and edge support

(Data acquisition and edge control) An edge device collects information from a number of sensors installed in a smart greenhouse to monitor environmental conditions. The edge device then pre-processes the collected data and conducts environmental control with its own control work plan - without interaction with the cloud.

(Creation of optimal growth model) The edge device then transmits the collected information (data) to the external cloud; because it already has processed the environmental information from sensors, it may transmit a part of or the whole information to the external cloud. The cloud, with the help of big-data and AI technologies, analyses the accumulated data to produce an optimal growth model including an environmental control plan for the edge device.

(Update of optimal growth model) After the cloud's optimal growth model provision, the edge device updates its control work plan.

(User's intervention) A user may monitor the status of environmental and crop growth conditions by accessing the cloud system. A user may control the environmental conditions by accessing the cloud system or by manipulating edge devices directly.

h. Post-conditions: None.

i. Information exchange: None.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the installation and maintenance of the facility;
– the cost for hardware such as sensors, actuators, and controllers (edge devices);
– the cost for software to operate the system and service;
– the cost for the network utilization;
– the cost for energy, water, fertilizer.

In addition, the following should be considered for the smart greenhouse with cloud and edge support:

– the number of farms which can be managed by a service provider for scalability purposes.

b. Geographical considerations: None.

c. Communication infrastructure

Wired or wireless communication links may be used: a narrowband link for the sensor data; a broadband link for large-capacity data such as video.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

A user interface is necessary of providing sufficient accessibility to users who are not familiar with ICT. The cloud system also needs to have manual input interfaces for changing specific optimal crop growth plans or responding to emergencies.

g. APIs to be exposed to the application from platform: None.

h. Data management

All data from sensors, actuators and controllers must be stored in a common format, regardless of device types or device manufacturers. For accurate data analysis, all data related to management information as well as environmental information and growth information should be expressed in a standardized way.

i. Data backup, archiving and recovery

All data must be stored in the cloud for a considerable period; some of the measurement data is stored in the edge device to make environment control decisions.

However, when the amount of stored data becomes huge, the cost for maintenance and management of the storage space entails. Therefore, it is necessary to establish an appropriate data storage and management strategy in consideration of this.

In addition, data compatibility for the past data must be ensured.

j. Remote device management

To enable the remote monitoring and the immediate replacement or adjustment of the smart greenhouse devices, it is necessary to provide capabilities to manage the smart greenhouse devices remotely. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of remote devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the smart greenhouse service with cloud and edge support safe from malicious users, it is required to protect the devices, communication links, and cloud system as well as remote control data. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast: None.

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on building, communication, electrical safety, environments, and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ITU-T Y.4466], *Framework of smart greenhouse service*

– [ITU-T Y.4122], *Requirements and capability framework of the edge-computing-enabled gateway in the IoT*

10. References: None.

11. General remarks: None.

8.4 Smart water management

1. Title of the use case

   a. Name of the use case: Smart water management

   b. ID of the use case: ID category 2 (Smart open field) of clause 7

   c. Version or revision history: 1

   d. Source: Republic of Korea/ETRI

2. Objective of the use case

   In agricultural area, water excess raises the risk of nutrient runoff while water shortage wither crops; they have a devastating effect on crop yields. To overcome such problem, a number of irrigation technologies for water management are employed to help retain water and capture nutrients in soil. This use case illustrates a smart water management in open field agriculture using smart irrigation technology.

3. Background

   a. Current practice

   Presently, a huge amount of water gets wasted during irrigation process. This is because the process of irrigation is scheduled automatically at a particular time, irrespective of the weather conditions and moisture present in the soil. To overcome this, a precision control of water in consideration with the crop-, soil- and weather- conditions is being considered very important. Example of crop condition includes crop phenomena such as evapotranspiration or stress level.

   b. Need for use case

   Proper control of water supply in the open filed can minimizes water wastage and prevent loss of nutrients to expect the best productivity. by implementing an IoT-based smart drip irrigation system. This saves water and fertilizer by allowing water to drip slowly to the roots of many different plants, either onto the soil surface or directly onto the root zone, through a network of valves, pipes, tubing, and emitters, based on soil and environmental conditions.

   c. Country ecosystem specifics

   Each country has different annual precipitations, soil moisture properties, and periods of dry and wet seasons. Also, depending on the geographic location of the country, the types of cultivated crops are diverted. So, it needs to deploy an effective water management system by considering these conditions.

4. Description

   a. Ecosystem description in terms of actors and business roles

   As shown in Figure 3, a smart water management system (aka, irrigation system) consists of sensors, controllers, and irrigation equipment. The smart water management service provider analyses data collected from the smart water management system to determine the required amount and time of watering. The smart water management service provider then operates the irrigation equipment (actuator) through the controller. If necessary, the smart water management service provider may collect external public data related to weather forecasts to establish a mid- and long- term water management strategy.

The smart water management service provider provides various optimal water management strategies according to the condition of location, climate, and soil of farmland, and types of crops to stakeholders such as farmers, manufacturers and government agencies. Farmers can utilize their own water management system independently, but also can receive automated water management service remotely through an external service provider. Manufacturers should guarantee that devices follow standardized data formats and interfaces to share data because devices from other manufacturers may not be compatible with each other. Government agencies should establish various policies for smart agricultural industry based on data from farmers and smart water management service providers.

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 5.

Table 5 – Actor description for smart water management

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not.
Sensor	A device that measures soil- and weather- conditions.
Actuator (irrigation equipment)	A device that supplies water according to the controller's commands.
Controller	A device that aggregates sensing data from sensors and then delivers them to the water management system. According to the received optimal watering model, it controls one or more actuators (irrigation equipment) installed in an open field.
Gateway	A device that provides connection interface between controller and the water management system.
Water management system	A system that analyses the aggregated data from sensors to determine the amount and timing of watering. It also establishes an optimal water management strategy by analysing these accumulated data to derive a more accurate mid- and long- term water management strategy; external public data can be used.

c. Prerequisites

The smart water management service requires a communication link for data exchange between sensors, controller, and irrigation equipment. Also, a broadband network may be required between the controller and the external cloud of the smart water management service provider.

Data must be stored in a common format, regardless of the device type or manufacturer. For accurate data service, data related to water management should be expressed in a standardized way.

d. Preconditions: None.

e. Triggers: None.

f. Scenario

(Data collection) Sensors installed in the ground or a meteorological station measure the temperature, humidity, insolation or soil moisture, and then transmit the measured data to the smart water management system of the service provider via the controller periodically. If necessary, the smart water management system may collect external data such as weather forecasts.

(Data analysis) The smart water management system analyses the collected data to determine the water amount and timing required for the crop. The smart water management system can establish an optimal water management strategy by analysing these accumulated data; to derive a more accurate mid- and long- term water management strategy; external public data can be used.

(Device control) The smart water management system generates control commands according to the analysis results and then transmits the control commands to the controller. Finally, the controller controls the irrigation equipment according to the received control commands.

NOTE – A number of ways to decide watering time are possible: by the pre-set time; by the accumulated light quantity; by the soil moisture; and by the user's intervention.

(Monitoring the management status) The farmer can monitor the water management status using the web or mobile devices. An intelligent water management service is necessary to minimize user's intervention. However, in order to respond emergencies or to modify the watering methods based on farmer's experiences, the smart water management service needs to allow farmer's intervention.

g. Process flow diagram

Figure 3 is a flow diagram of the smart water management service according to the scenario in entry f.

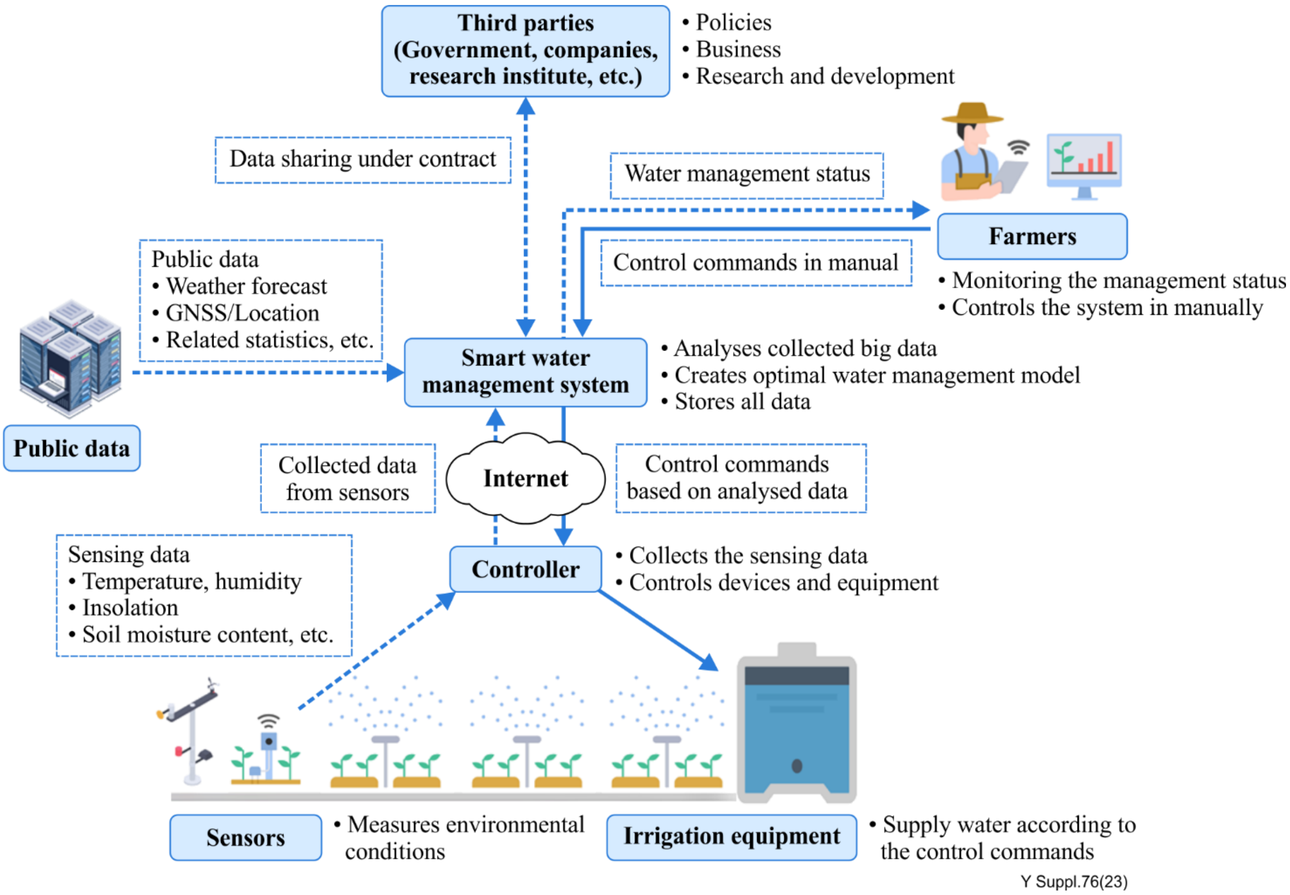

Figure 3 – Process flow diagram of smart water management service

h. Post-conditions: None.

i. Information exchange: None.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

- the cost for the installation and maintenance of the facility;
- the cost for the hardware such as sensors, actuators, controllers, and management system;
- the cost for the software to operate the system and service;
- the cost for the network utilization;
- the cost for energy, water, fertilizer.

In addition, the followings should be considered for the smart water management:

- the interworking with public data such as weather and geolocation data.

b. Geographical considerations: None.

c. Communication infrastructure

The smart water management system may use wired or wireless communication links to support various services. A narrow-band link can be used for the sensors, irrigation equipment, and controller installed in a farm. A low power wireless communication technology may be used to keep the devices alive for long period. However, a broadband link may be required between a farm and the smart water management system to aggregate data of large-capacity such as image or video.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

The user interface of the smart water management system should be able to provide sufficient accessibility to users who are not familiar with ICT.

g. APIs to be exposed to the application from platform: None.

h. Data management

Data for the smart water management service must be delivered and stored in a common format, regardless of device type or manufacturer. For the accurate data analysis, data should be expressed in a standardized way.

The accumulated data (big data) are analysed to provide various smart water management services; the data analysed can then form the basis to establish a marketing and an optimal water management strategy.

i. Data backup, archiving and recovery

To enable various services, data must be stored by the service provider for a considerable period. Because the considerable amount of accurate statistics and data can improve the capability of productivity prediction and user's convenience.

However, as the amount of stored data become huge, the maintenance cost for the storage space increased. Therefore, it is necessary to establish an appropriate data storage and management strategy.

Advanced future technologies may provide more accurate and high-efficient data acquisition means, however data compatibility for the past data must be ensured.

j. Remote device management

Remote device management is quite necessary in the water management service. The smart water management system and its users should be able to inquire about the operating status of devices for immediate device maintenance. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of remote devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the smart water management system safe from malicious users, it is required to protect the devices, communication links as well as remote control data. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast: None.

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, either no or more or less specific regulation on communication, electrical safety, and environments can be applied.

9. Available international standards: They include, but are not limited to:

– [ISO 8026], *Agricultural irrigation equipment – Sprayers – General requirements and test methods*

– [ISO 9635], *Agricultural irrigation equipment – Irrigation valves*

10. References: None.

11. General remarks: None.

8.5 Pest control using UAV

1. Title of the use case

a. Name of the use case: Pest control using UAV

b. ID of the use case: ID category 2 (Smart open field) of clause 7

c. Version or revision history: 1

d. Source: Republic of Korea/ETRI

2. Objective of the use case (aligned with title, it has explanatory content)

UAVs have been considered for potential use in pest control operations. UAVs equipped with cameras can be flown over open field, particularly those not currently receiving any pest control, to record the unique spectral signature of the vegetation and to detect the presence of pests. UAVs equipped with a sprayer can also apply pesticides to areas with diseases and pests based on prescriptions from the analysis results of the recorded data.

3. Background

a. Current practice

As the use of UAVs such as drones increases in the agricultural field, interest in pest control using UAVs is growing. For efficient pest control, UAVs equipped with high-performance cameras and sensors monitor a wide range of agricultural land in detail. Then, the monitored and collected data (images, videos) is precisely analysed using advanced analysis technologies such as AI. If it is determined that a pest has occurred, a control system activates any appropriate controls to minimize the damage can be caused by the pest.

b. Need for use case

The pest control using UAVs can prevent damage caused by pests and improve the productivity through early diagnosis and pre-emptive action for pests and diseases.

Automation in pest control solves the labour shortage caused by the decline of the agricultural population and the aging of the farmers, and provides convenience to the farmers. It may also reduce the frequency of contact with chemicals such as pesticides and protect farmer from serious side effects.

c. Country ecosystem specifics

The UAVs for smart agriculture must comply with various regulations related to operation of the UAVs.

The International Civil Aviation Organization and each country have also regulations for the safe operation and management of the non-military UAVs. Therefore, the UAVs for pest control must also be operated safely within the regulatory range such as flight altitude, flight area, and allowable weight of the payload.

4. Description

a. Ecosystem description in terms of actors and business roles

For the pest control service, the government or service provider builds up database related to these various types of pests, symptoms and control method. Image data and video data generated from UAVs and sensors are compared with information in the database, and analysed to make appropriate prescription. The analysed results including the prescription are transmitted to UAVs for control operation. The database should be always kept up-to-data based on data collected through a series of control process.

Farmers can own database and analysis system in their farmhouse. However, it is necessary to pay a considerable cost to secure high-performance computing resources and to manage a large-capacity storage space. Therefore, it is much more economical to use the database built in the cloud of service provider.

Sensors, UAVs, and equipment from different manufacturers may not be compatible with each other. For data sharing and analytics purpose, it is necessary to ensure that devices and equipment of different manufacturers have standardized data formats and compatible connection interfaces.

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 6.

Table 6 – Actor description for pest control using UAV

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not. In this use case, he monitors details and results of pest control from the remote.
UAV	A device that takes images or videos of farmland and crops. It also sprays pesticide according to the prescription from the pest control system.
Sensor	A device that measures soil- and crop growth-status. In this use case, sensors are installed in the UAVs.
Controller	A device that aggregates sensing data from sensors and then delivers them to the pest control system. According to the received optimal pest-controlling model, it activates pesticide sprayers. For quick and effective pest control, advanced technologies for high-quality image capturing, AI-based data analysis and deep learning-based pest detection are required.
Gateway	A device that provides connection interface between the controller and the pest control system.

Table 6 – Actor description for pest control using UAV

Actor name	Role description
Pest control system	A system that analyses the collected data using AI, big-data technologies to identify the occurrence of pests, the area and range of occurrence, and the types of pests.

c. Prerequisites

Efficient operation of UAVs is expected.

NOTE – Aspects related battery capacity and charging technologies may be relevant (e.g., wireless power transmission technology [b-ITU-T Y.4202] may be an option).

d. Preconditions: None.

e. Triggers: None.

f. Scenario

The pest control using UAVs proceeds in several stages, including data collection, data analysis and prescription, agricultural work, and data feedback and utilization. Farmers can monitor the details and results of the entire pest control stages through the web or mobile devices.

g. Process flow diagram

Figure 4 shows the flow diagram of the pest control using UAVs.

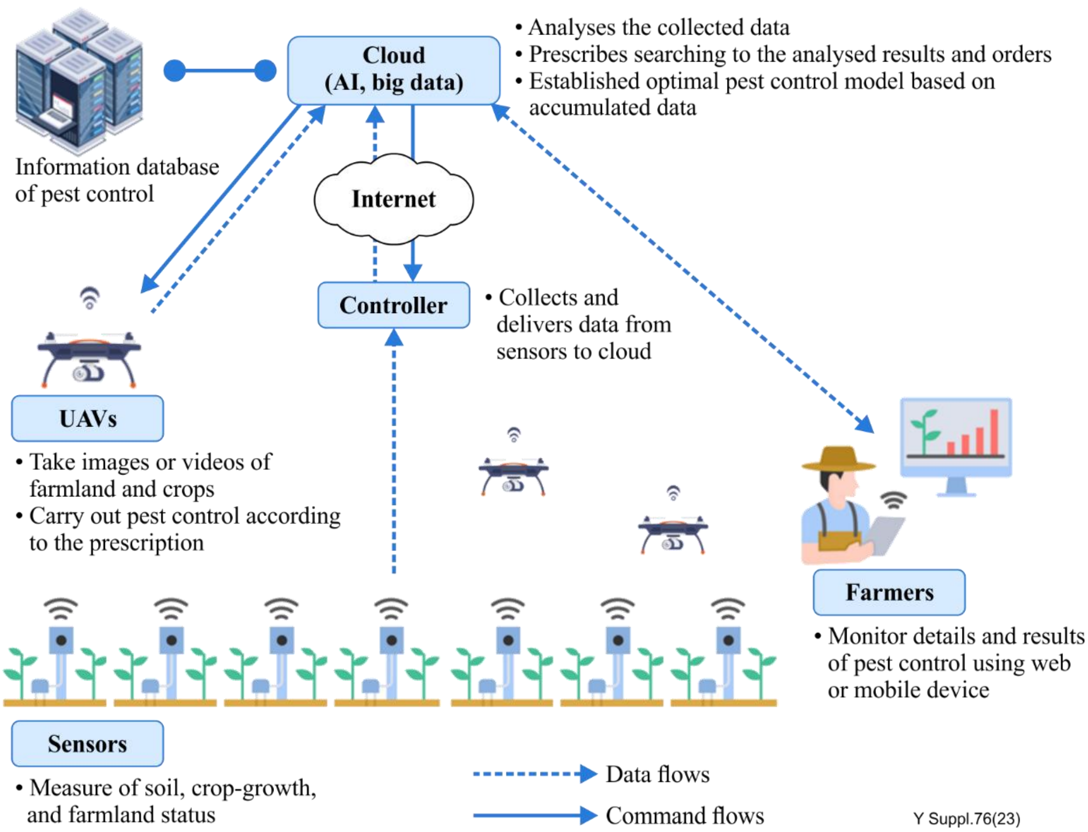

Figure 4 – Process flow diagram of pest control using UAVs

(Data collection) The UAVs take images and videos of farmland and crops using its high-performance cameras and sensors. Then, the UAVs send the captured data directly to the cloud system. The various sensors installed on the ground collect data such as soil condition, crop growth status, and shape and range of farmland. Then, the sensors transmit the collected data to the cloud system via the controller.

(Data analysis and prescription) The cloud system analyses the collected data using AI, big-data technologies to identify the occurrence of pests, the area and range of occurrence, and the types of pests. The cloud system creates a prescription including the type and amount of pesticide to be injected, an effective pest control method based on the analysed results. The prescription is delivered to the UAVs to perform the control operation. If necessary, the cloud system also utilizes external public data related to pest control to increase the accuracy.

(Agricultural work) Based on the prescription received from the cloud system, the UAVs start the control operation; the pest control using UAVs can intensively spray an accurate amount of pesticides in the occurrence range depending on the types of pests and the severity of symptoms.

(Data feedback and utilization) The cloud system stores and manages data collected from the entire process. The accumulated data is used as basic material to establish an optimal pest control plan according to the location and soil conditions of farmland, the type and status of crops, the pest occurrence, and pest types.

h. Post-conditions: None.

i. Information exchange: None.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the installation and maintenance of facility;
– the cost for the hardware such as image sensors, actuators, and cameras;
– the cost for the software to operate the system and service;
– the cost for the network utilization.

In addition, the following should be considered for the pest control using UAVs:

– the cost for the UAVs;
– the operation efficiency capabilities of a UAVs for the pest control purpose;
– the network capability of real-time communication between UAVs and cloud;
– the UAV related regulation.

b. Geographical considerations

For pest control using UAVs, there must be no dangerous obstacles within their flight range that interfere with the flight or cause an accident.

c. Communication infrastructure

A wireless communication link is required between various sensors and controller installed in a wide range of farmland. The UAVs also require a wireless communication link to transmit the observed data to the cloud system. Since the amount of data collected from the sensors is not large, a narrow-band link is sufficient. However, a broadband link is required between the UAVs and the cloud system in order to transmit data of large-capacity such as image or video.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

The user interface of the pest control using UAVs should provide sufficient accessibility to users who are not familiar with ICT.

g. APIs to be exposed to the application from platform: None.

h. Data management

Data for the pest control using UAVs must be delivered and stored in a common format, regardless of device types. For the accurate data analysis, data should be expressed in a standardized way.

The accumulated data (big-data) will be analysed to provide various service for the Pest control using UAVs, and then these analysed data will become basic to establish the marketing and optimal pest control strategy.

i. Data backup, archiving and recovery

To enable various services, data must be stored by the service provider for a considerable period. Because the considerable amount of accurate statistics and data can improve the capability of productivity prediction and user's convenience.

However, as the amount of stored data become huge, the maintenance cost for the storage space increased. Therefore, it is necessary to establish an appropriate data storage and management strategy.

Advanced future technologies may provide more accurate and high-efficient data acquisition means, however data compatibility for the past data must be ensured.

j. Remote device management

Remote device management is quite necessary in the pest control with UAVs. The farmer should be able to inquire about the operating status of UAVs, and to immediately repair or replace the failed ones. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of remote devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the system for pest control using UAVs safe from malicious users, it is required to protect the devices, communication links as well as remote control data. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast

The UAVs market in open field agriculture is expected to value USD 5.7 billion in 2025 compared to USD 1.2 billion in 2020 at a CAGR of 35.9%. It is expected to overtake the market size of facility of greenhouse in the near future [b-Market].

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on communication, electrical safety, environments, and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ISO 16119 (all parts)], *Agricultural and forestry machinery — Environmental requirements for sprayers*

– [ISO 16122 (all parts)], *Agricultural and forestry machines – Inspection of sprayers in use*

10. References: None.

11. General remarks: None.

8.6 Connected agricultural tractor

1. Title of the use case
   a. Name of the use case: Connected agricultural Tractor
   b. ID of the use case: ID category 2 (Smart open field) of clause 7
   c. Version or revision history: 1
   d. Source: Republic of Korea/ETRI

2. Objective of the use case

   Agricultural tractors can offer new connected services with the help IoT technologies. These services range from the OTA software and firmware updates to the intelligent tractor management using data from the field. Such services provide greater efficiency in farming, by enabling farmers to use agricultural tractors more effectively, reducing the need for manual labour, and ensuring equipment readiness to work when required.

3. Background
   a. Current practice

      Tractors have traditionally been used on farms to mechanize various agricultural works, such as ploughing, tilling, and planting. Tractors offer advantages on not only farms but also lawns and gardens. With the help of a global navigation satellite system (GNSS) and real time kinematic (RTK), recent tractors allow creating routes for the tractor, carrying out automatic steering for accurate row guidance, and controlling the amount of fuel usage and lubricants. In addition to GNSS and RTK, a new technology emerged called connected tractors with which a user can perform agricultural works remotely.

   b. Need for use case

      The agricultural machinery management (AMM) system for connected tractors determines the resources required (amount and time) for agricultural work; according to the requirements, it plans the tasks and assigns the tractors necessary for their execution. After completing the agricultural work, each tractor reports the work results to the AMM system. The tractors in operation can be connected to the AMM system at any time to share the progress of agricultural work in real time. By monitoring nearby tractors' work progress, any idle tractor can be put in to shorten work time.

      Because tractors are one of the most important agricultural machineries to save labour, it is necessary to address connected agricultural tractor with this use case.

   c. Country ecosystem specifics: None.

4. Description
   a. Ecosystem description in terms of actors and business roles

      The AMM system manages the information related to agricultural work schedule, agricultural tractor's operation status and input history, work results, and breakdown or failure history. The AMM system also analyses the information by using AI and big-data technologies to establish an optimal production management strategy of improving farm's productivity.

      The manufacturers and maintenance companies of agricultural tractors can provide the best maintenance service by collecting information such as operation status, breakdown history. A tractor manufacturer can design more advanced agricultural tractors by analysing such information. Farmers can monitor the tractors' operational status and the agricultural work progress anytime and anywhere to address breakdowns or failures.

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 7.

Table 7 – Actor description for connected agricultural tractor

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not. In this use case, the farmer operates one or more tractors.
Tractor	A device (machinery) to mechanize various agricultural works by installing agricultural implements, such as ploughing, tilling, and planting.
Sensor	A device that can sense tractors operation and its location.
Controller	A device that aggregates sensing data from sensors and then delivers them to the AMM system.
Gateway	A device that provides connection interface between controller and the AMM system.
AMM system	A system that manages the connected tractor and decides the required resources (amount and time) for agricultural works; according to the requirements it plans the agricultural works.
Manufacturers	Companies that provide maintenance service by using information provided by the AMM system.

c. Prerequisites: None.

d. Preconditions: None.

e. Triggers: None.

f. Scenario

According to the agricultural work schedule, an appropriate tractor to perform the relevant agricultural work is selected. The selected tractor performs agricultural work according to the AMM system's agricultural work execution order. The tractor reports all information generated during agricultural work performance to the AMM system. The AMM system manages the agricultural work progress based on the information reported and updates the management plan of the connected agricultural tractors optimally. Finally, farmers monitor the progress of agricultural work remotely using mobile devices.

In order to respond to an emergency, a command to change or stop a job can be transmitted manually.

g. Process flow diagram

Figure 5 shows the flow diagram of the connected agricultural tractor according to the scenario.

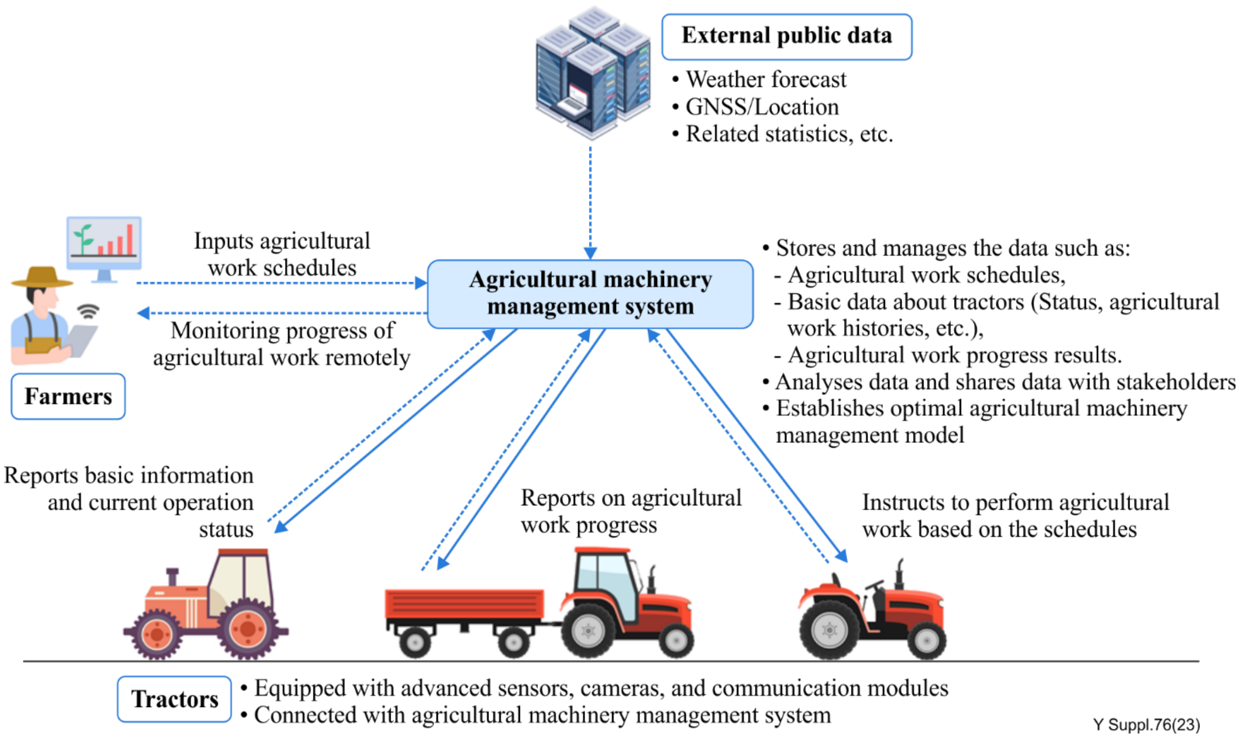

Figure 5 – Process flow diagram of the connected agricultural tractor

(Data generation) The farmer creates an agricultural works plan including the type of agricultural work, the target farmland, and the expected work time into the AMM system. After the AMM system's successful connection to tractors, basic data (operation status, existing agricultural work input history and current location, etc.) for tractors is delivered. Based on this information, the designated tractor moves to the relevant farmland to perform agricultural work, and then periodically reports about the agricultural work progress, unexpected events, and work results to the AMM system.

(Data collection) The AMM system collects and stores data related to the progress and results of agricultural work, the operation status of the tractors such as breakdowns or failures, and the status of farmland and crops.

(Data analysis and utilization) The AMM system comprehensively analyses the collected data and compares it with the agricultural work schedule. The analysis results are used to optimally update the existing agricultural tractor management method, and through this, the tractor's operational efficiency and farmhouse productivity can be improved.

h. Post-conditions: None.

i. Information exchange: None.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the tractor including sensors, controllers, and management system;
– the cost for the software to operate the system and service;
– the cost for the network utilization.

In addition, the followings should be considered for the connected agricultural tractor:

– the cost for the connected agricultural machinery;
– the network capability for real-time communication;

– the integration complexity with other agricultural machinery, such as pesticide sprayers, robot harvesters and flatteners.

b. Geographical considerations

Because open field agriculture is performed on farmland on a wide scale in general, consideration of such geographical characteristics is necessary for the efficient operation of an AMM system.

c. Communication infrastructure

Because of the geographical characteristics of open field agriculture, a wireless communication link, for example, using GSM, UMTS, LTE, CDMA and 5G/IMT-2020, is required between the tractors and the AMM system. For the purpose of image or video exchange a broadband wireless communication link for example, using 4G or 5G/IMT-2020, is required. To identify the location and the agricultural work route, vehicle-positioning devices with a GNSS or RTK capability need to be supported. Any appropriate means of communication for remote monitoring and for real-time interruption in case of emergency is required.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

The user interface of the AMM system for the connected agricultural tractor should be able to provide sufficient accessibility to users who are not familiar with ICT.

g. APIs to be exposed to the application from platform: None.

h. Data management

Data for the AMM system for the connected agricultural tractor must be delivered and stored in a common format, regardless of device types or manufacturers. For the accurate data analysis, data should be expressed in a standardized way.

The accumulated data (big-data) will be analysed to provide various service, and then these analysed data will become basic to establish the marketing and optimal AMM strategy.

i. Data backup, archiving and recovery

To enable various services, the data must be stored by the service provider for a considerable period. Because the considerable amount of accurate statistics and data can improve the capability of productivity prediction and user's convenience.

However, as the amount of stored data become huge, the maintenance cost for the storage space increased. Therefore, it is necessary to establish an appropriate data storage and management strategy.

Advanced future technologies may provide more accurate and high-efficient data acquisition means, however data compatibility for the past data must be ensured.

j. Remote device management

The farmer should be able to inquire about the operating status of tractors, and to immediately repair or replace the failed ones. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of the AMM.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the AMM system for the connected agricultural tractor safe from malicious users, it is required to protect the devices, communication links as well as remote control data. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast:

According to Global Market Insight, a market research institute for smart agriculture, the global autonomous agricultural machinery market is expected to $96.1 billion in 2027 compared to $61.6 billion in 2021, at a CAGR of 7.7%. In particular, the connected tractor market is expected to $47.8 billion in 2027 compared to grow from $30.9 billion in 2021 [b-Auto equipment].

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on building, communication, electrical safety, environments, animal welfare and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ISO 5231:2022], *Extended farm management information systems data interface (EFDI) – Concept and guidelines*

– [ISO 10975:2023], *Agricultural machinery and tractors – Auto-guidance systems for operator-controlled tractors and self-propelled machines – Safety requirements*

– [ISO 11783 (all parts)s], *Tractors and machinery for agriculture and forestry – Serial control and communications data network*

– [ISO 4254-6:2020], *Agricultural machinery – Safety – Part 6: Sprayers and liquid fertilizer distributors*

– [ISO 4444:2022], *Agricultural sprayers – Recording of spray drift parameters*

10. References: None.

11. General remarks: None.

8.7 Automated milking system

1. Title of the use case

a. Name of the use case: Automated milking system

b. ID of the use case: ID category 4 (Smart livestock barn) of clause 7

c. Version or revision history: 1

d. Source: Republic of Korea/ETRI

2. Objective of the use case

Milking is the most labour-intensive work in the dairy farming. This use case introduces the AMS for the entire milking process of udder cleaning, milking, collecting and sterilizing the milk, and analysing component for hygienic and efficient milking using various sensors, cameras, laser equipment, and robots.

3. Background

a. Current practice

Unlike other agricultural fields, dairy farming requires considerable labour forces for feeding, milking, breeding, and manure processing, as well as environment control of livestock barn. In particular, more than 40% of the total labour time for a milk cow is spent on the milking.

Recently, dairy farming advanced countries are developing various technologies for the IoT based AMS, also called robot milking, to save labour for milking.

b. Need for use case

Unlike conventional milking methods (pipeline, herringbone, tandem machines, etc.) in which humans directly milk 1-2 times a day, the AMS has the advantage of being able to milk 24 hours a day.

The introduction of the AMS can solve the labour shortage through efficient distribution of labour forces. In addition, the AMS is needed to improve both milk yield and quality, and reduce the incidence of disease in cows.

c. Country ecosystem specifics: None.

4. Description

a. Ecosystem description in terms of actors and business roles

If the AMS is not properly operated and managed, the system usability will be reduced, and the production and quality of milk will be significantly affected. Therefore, system manufacturers must provide consulting services and systematic follow-up services for the stable operation of the AMS. The heterogeneous sensors, devices, equipment constituting the AMS should generate data in a standardized way. Data expressed in a standardized way is important for AI-based analysis and processing. The installation of the high-tech AMS in a small dairy farm requires significant costs. Therefore, it needs to create a foundation to promote the spread of the AMS.

b. Contextual illustration

The AMS performs milking automatically with minimal intervention of farmers by using sensors, 3D cameras, laser equipment, and robot arms.

The names and roles of the actors involved in this use case are shown in Table 8.

Table 8 – Actor description for automated milking system

Actor name	Role description
Farmer	A person who works on a dairy farm, whether the owner or not.
Sensor	A device that is used to identify a cow, to detect cow's teats
Actuator (robot arm)	A devices that attaches and detaches milking cups to and from target teats and milk from the attached milking cups.
Milk tank	A tank that stores the milk. To keep milk fresh, it provides cooling features. In addition, the investigation of quality by analysing milk composition takes place.
Controller	A device that aggregates sensing data from sensors and then delivers them to the AMS. Based on the sensing data, it actuates robot arms.
Gateway	A device that provides connection interface between controller and the AMS.
AMS	A system that consists of sensors and actuators (robot arms) to milk automatically.
Production management system (PMS)	A system that aggregates data of the entire milking process: the identification of a cow; the amount and quality of milk; and the events during milking.

c. Prerequisites: None.

d. Preconditions: None.

e. Triggers: None.

f. Scenario

When a cow enters the milking room, the AMS determines whether it is the one to be milked using sensors attached in or outside the body of cow. If the cow is the right one, then the AMS identifies the position of the teat with 3D cameras as well as laser equipment installed in the milking room, and attaches the milking cup to the identified teat accurately using robot arms. After the positioning is completed, the AMS performs operations such as washing, milking, disinfecting, and composition analysing in succession. When all the operations are completed, the milk is collected in a milk tank with a cooling function to keep the milk fresh. Farmers can be notified with the necessary information and can enquire about the status of cows, production and quality of milk through the mobile devices.

g. Process flow diagram

Figure 6 shows the flow diagram of the AMS in dairy farm according to the scenario.

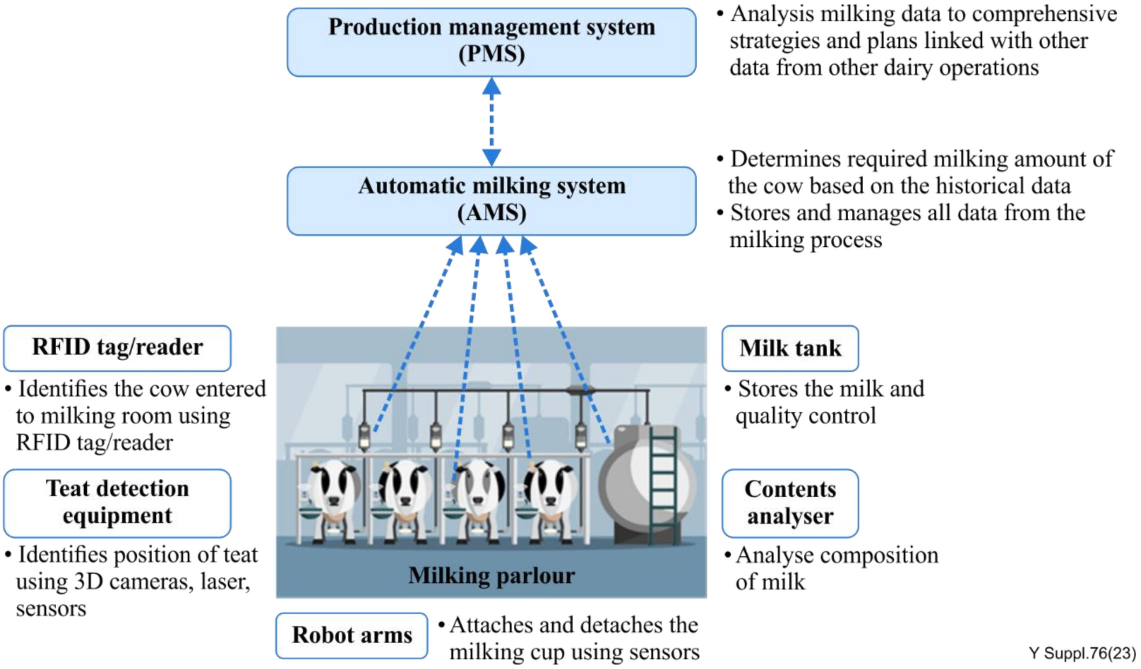

Figure 6 – Process flow diagram of the AMS in dairy farm

(Cow identification) When a cow enters the milking room, ID of the cow is identified using radio frequency identification (RFID) tag/reader attached to cow. Based on previous data such as the number and amount of milking of a cow, the AMS determines whether it can be milked and the target milking volume.

(Milking) The AMS finds the exact position of teats using 3D cameras as well as laser equipment and various sensors. The robot arms attach the milking cup to the identified teat quickly and accurately. Then, the AMS start milking work. Milking operation consists of disinfection before and after the milking (control of diseases by removing contaminants and bacteria), milking (monitoring the amount of milking using sensors), and composition analysing of milk (contents analysis of fat, protein, and lactose). When the milking operation is completed, the milk is collected in a cooling milk tank to keep it fresh.

(Data generation or collection) In the milking operation using the AMS, data such as health status, disease management data, milking amount, and composition analysis results are generated. In addition, such information as the time required in milking per cow, the number of cows milked in that day, and the total milking amount is created. All these data are shared with the Production Management System (PMS).

(Data utilization) Data for feeding, milking, calving, disease control, and breeding management in a dairy farm need to be analysed to determine their interrelationship in the PMS. The results of this analysis are used to establish comprehensive strategies and plans for production and operation management of the dairy farm.

h. Post-conditions: None.

i. Information exchange: None.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the installation and maintenance of the facility;
– the cost for the hardware, the AMS composed of sensors, actuators (robot arms), 3D cameras, laser equipment, and more;
– the cost for the software to operate the system and service;
– the cost for the network utilization.

In addition, the following should be considered for the AMS:

– the means of identifying animals;
– the coexistence of fixed and mobile communications;
– the hazard to the animal health condition caused by electromagnetic compatibility (EMC) of the AMS.

b. Geographical considerations: None.

c. Communication infrastructure

Wireless or wired communication link is required between the AMS and sensors, cameras, equipment installed in the milking room. In order not to interfere with the free movement of cows and the operation of other breeding management system, it is advantageous to use the wireless communication means. In addition, an RFID communication link is required to identify cows entering milking room.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

The user interface of the AMS should be able to provide sufficient accessibility to users who are not familiar with ICT.

g. APIs to be exposed to the application from platform: None.

h. Data management

Data for the AMS must be delivered and stored in a common format, regardless of various device types or manufacturers. For the accurate data analysis, data should be expressed in a standardized way.

The accumulated data (big-data) will be analysed to provide various service for the AMS, and then these analysed data will become basic to establish strategies for the production and business management of the dairy farm.

i. Data backup, archiving and recovery

To enable various services, data must be stored by the service provider for a considerable period. More accurate statistics and analysis of more data are required to improve productivity and convenience of automated dairy farming, as well as to provide more diverse services to users.

However, as the amount of stored data become huge, the maintenance cost for the storage space increased. Therefore, it is necessary to establish an appropriate data storage and management strategy.

Advanced future technologies may provide more accurate and high-efficient data acquisition means, however data compatibility for the past data must be ensured.

j. Remote device management

Remote device management is quite necessary in the AMS. The farmer should be able to inquire about the operating status of devices, and to immediately repair or replace the failed ones. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of the AMS.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the AMS safe from malicious users, it is required to protect the devices, communication links as well as data for remote control. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast

According to DataM intelligence, a market research institute, the global milking system (robot) market's CAGR from 2021 to 2028 is expected to 14% [b-milking robot].

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on building, communication, electrical safety, environments, animal welfare, and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ITU-T Y.4482], *Requirements and framework for smart livestock farming based on the Internet of things.*
– [ISO 20966:2007], *Automatic milking installations – Requirements and testing*
– [WOAH (2023)], *Terrestrial animal health code*, 2 vols. Paris: World Organisation for Animal Health

10. References: None.

11. General remarks: None.

8.8 Animal health care

1. Title of the use case

a. Name of the use case: Animal health care

b. ID of the use case: ID category 4 (Smart livestock barn) of clause 7

c. Version or revision history: 1

d. Source: Republic of Korea/ETRI

2. Objective of the use case

To keep animals healthy, it is important to quarantine unhealthy animals from the rest in a livestock barn. IoT and AI assisted animal health care technologies can help farmers to keep the animals safe by tracking their behaviours and conditions, by monitoring their health conditions, and by quickly alerting a farmer if potential diseases are detected.

3. Background

a. Current practice

According to the OECD [b-OECD2017], a number of foot and mouth disease (FMD) cases occurred in Korea in the 2000s. FMD is a viral acute livestock contagious disease that occurs in two-hoofed animals such as cattle, pigs and sheep, and is known as a most dangerous class A virus that spreads quickly. FMD is transmitted directly by contact with the mucus, saliva or faeces of infected animals or indirectly by vehicles and wild animals. In particular, it is a highly contagious virus that spreads rapidly to all other animals even if only one in a herd is infected, because it is transmitted through the respiratory tract.

In Korea, starting with the culling of 2 216 animals in 2000, about 3 479 962 animals were culled by 2011, with a total cost of KRW 2 738.3 billion (USD 2.3 billion). Culling means slaughtering animals within a certain radius to prevent the spread of an infectious disease from animals. Usually, live burial is selected for economic reasons.

b. Need for use case

The best way to prevent FMD, which is a critical airborne respiratory infection, is to quickly vaccinate unaffected animals. Also, in case of farmers, thorough disinfection before and after entering the farm, and wearing shoes dedicated to the barn when entering and leaving the barn are required. For the general public, it is important to actively cooperate by passing through the disinfection facility when visiting a livestock barn. However, to prevent FMD, more important than these is to control the environment or identify abnormalities.

This use case is to provide a practical example how to identify abnormalities through IoT data aggregation and analysis.

c. Country ecosystem specifics

Initial cost to install the IoT and AI assisted FMD prevention system would be very high. However, it is beneficial after the first installation by reducing the loss of animals.

4. Description

a. Ecosystem description in terms of actors and business roles

This use case, as shown in Figure 7, involves a livestock barn with unique data sets and a cloud with AI, biotechnology and veterinarian to produce an animal health care plan for a farmer in charge of the livestock barn by analysing accumulated data sets.

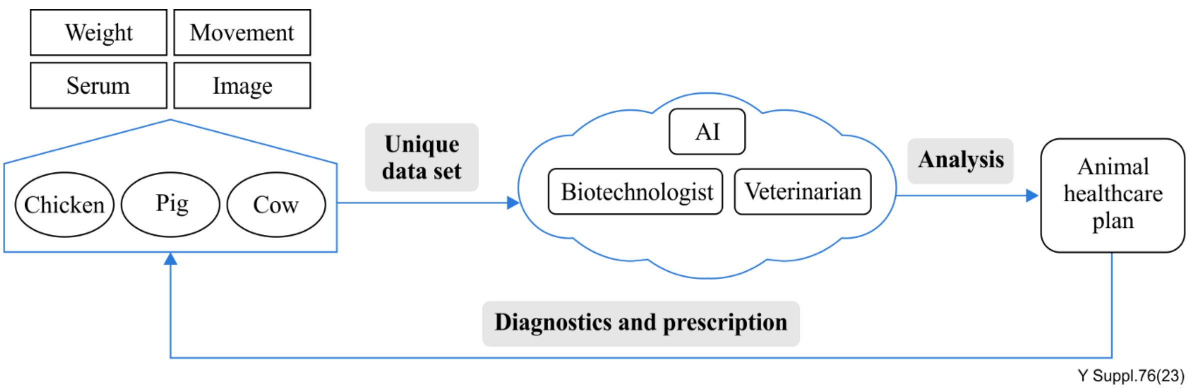

Figure 7 – Actors and roles of animal health care service

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 9.

Table 9 – Actor description for animal healthcare

Actor name	Role description
Farmer	A person who works on a farm, whether the owner or not.
Veterinarian	A person who is specialized in the diagnosis, treatment, and prevention of diseases and injuries in animals. He/she gives prescriptions based on data analysis results.
Sensor	A device that collects comprehensive data on animal such as weight, movement, blood and so on.
Gateway	A device that provides connection interface between sensor and the animal health care system.
Animal health care system	A system that aggregates sensing data from sensors and then analyses them to derive a draft diagnosis result for veterinarian's prescription.

c. Prerequisites: None.

d. Preconditions

In order to obtain sensing and image data from the livestock barns as well as animals, an appropriate communication link and identification methods of each animal are necessary. Since the size of data would be large, a narrow-band link is not appropriate.

e. Triggers: None.

f. Scenario

The animal health status is identified through analysis of multi-type of data collected in relation to the animal's growth and then an appropriate prescription is provided to the farmer.

g. Process flow diagram

The animal health care service is based on IoT, data and AI technologies. In detail, it manages and analyses the animal health status continuously based on the collected data, and keeps animal's health with the help of AI and veterinary expertise. It consists of the following three stages:

– (Step 1) Collecting comprehensive data on animal (weight, movement, blood, etc.);
– (Step 2) Analysis of the animal's health data through comprehensive application of AI, bio-technology, and veterinary knowledge to derive a first opinion, then optimization of the health care plan with AI based on the opinion;
– (Step 3) A veterinarian precisely diagnoses and prescribes based on data analysis results.

h. Post-conditions: None.

i. Information exchange

Comprehensive information on animal (weight, movement, blood, etc.) is provided from a farmer to the animal health care service system, and the prescription information for the animal is provided from the animal health care service system to the farmer.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

– the cost for the installation and maintenance of the facility;
– the cost for the hardware such as sensors and gateways;
– the cost for the software to operate the system and service;

– the cost for the network utilization.

In addition, the followings should be considered for the animal health care:

– the cost for the professional advice from a veterinarian;

– the hazard to the animal health condition caused by EMC from ICT equipment.

b. Geographical considerations: None.

c. Communication infrastructure

For the external cloud to collect the animal's health conditions of the livestock barn in real time, a broadband communication infrastructure must be provided between the cloud and the livestock barn consisting of a number of sensors and cameras.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface: None.

g. APIs to be exposed to the application from platform: None.

h. Data management

It is required to store all data from sensors, actuators and cameras in a general format independent of the types of devices or their manufacturer. Accumulated data (big-data), will be used to counter the pressures of increasing food demand and climate changes.

i. Data backup, archiving and recovery

When a big data centre is considered to accumulate data from the livestock barns and the animals, a plentiful qualified data is very essential. However, the qualified data cannot be acquired in a short term, it is important to manage the data from long-term experience; the acquired data must be stored for multiple decades.

j. Remote device management

Because sensors, actuators, and cameras are exposed to a very-humid and toxic-gas environment, their status must be monitored remotely and immediately replaced if necessary. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of remote devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the animal health care system safe from malicious users, it is required to protect the devices, communication links as well as data for remote control. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast: None.

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, no or more or less specific regulation on communication, electrical safety, animal welfare, and food safety can be applied.

9. Available international standards: They include, but are not limited to:

– [ITU-T Y.4482], *Requirements and framework for smart livestock farming based on the Internet of things*

– [WOAH (2023)], *Terrestrial animal health code* 2 vols. Paris: World Organisation for Animal Health

10. References: None.

11. General remarks: None.

8.9 Agricultural data service

1. Title of the use case
   a. Name of the use case: Agricultural data service
   b. ID of the use case: ID category 5 (Smart agriculture data service) of clause 7
   c. Version or revision history: 1
   d. Source: Republic of Korea/ETRI

2. Objective of the use case

A smart agriculture service consists of a production stage, a distribution stage, and a consumption stage. At each stage, various kinds of data are produced; such data for environmental conditions, growth status of crops or livestock, processing and sales. A data service of smart agriculture collects, analyses and reproduces the data generated from each stage; and a user of the smart agriculture service can use the data in the form of a service.

3. Background
   a. Current practice

As the smart agriculture is widespread and user's demands are diversified, various types of data are produced to form various types of services. Accordingly, the smart agriculture is evolving into a data service-based industry where cloud, big-data, and AI technologies are involved. The data for the smart agriculture includes the following information:

– A production data consists of, for example, data on management (type of cultivated crop, type and size of farm facility), environment (temperature, humidity), control (control command, execution results), and growth (yield, pests, diseases), etc.

– A distribution data consists of, for example, data on history (cultivation history, sales history), whole sales (real-time price, transaction volume), etc.

– A consumption data consists of, for example, data on point of sale, sales (transaction volume, consumption trend) and authentication (eco-friendly certification).

   b. Need for use case

The data service for smart agriculture collects, analyses and reproduces all data from the entire stages of the smart agriculture service to improve productivity. The purpose of the smart agricultural data service is:

– to establish a precise production plan;

– to manage production and consumption of agricultural products;

– to control pest and disease;

– to provide an effective decision-making support system;

– to manage operation and fault condition of the smart agriculture system; and,

– to reduce labour cost and input material for cultivation.

A consumer can purchase high-quality agricultural products through the smart agricultural data service that provides agricultural product quality information such as eco-friendly certification or sales history.

   c. Country ecosystem specifics: None.

4. Description

a. Ecosystem description in terms of actors and business roles

As shown in Figure 8, actors involved in the smart agriculture are a data producer, a data prosumer, a data consumer, and a data service provider. The role and example of each actor is as follows:

– A data producer produces data by collecting data from the smart greenhouses or the smart livestock barns, and then provide the data to the service provider.
– A data service provider processes and analyses the data from the data producers and the data prosumers with the help of cloud, big-data, and AI technologies. In order to provide a specific service according to the data user's request; and,
– A data consumer utilizes the data provided by the data service provider for its own purposes. Examples of the data consumers include famers, homes, government agencies and research institutes.
– A data prosumer acts as the data producer and as the data consumer at a same time. An example of the data prosumer is agricultural product distributors.

b. Contextual illustration

The names and roles of the actors involved in this use case are shown in Table 10.

Table 10 – Actor description for agricultural data service

Actor name	Role description
Data producer	The entity that produces data related to agricultural products. Examples of data producer include sensors, actuators, controllers, and operation system installed in the smart green house, smart open field, smart livestock barn, or smart orchard.
Data prosumer	The entity that produces data as well as consumes it. In terms of production, it produces new types of data making usage of external public data such as weather, map, statistics on storage, distribution, processing and sales market.
Data consumer	The entity that utilizes data to improve agricultural productivity, to establish agricultural policies, and to develop new technologies or services. An example of data consumer is a farmer.
Data service provider	The data service provider that provides data service to data consumers as well as the data prosumer. By using AI and big-data technologies, it analyses aggregated data to provide any specific services, for example such as yield prediction.
Other data service provider	A data service provider served by other company or organization. Depending on the policy, the kinds of served data can be different from one data service provider to another one.
Public data service provider	A data service provider with public purpose. An example of this service provider is public weather forecast service provider.
Farmer	A person who works on a farm, whether the owner or not.

c. Prerequisites;

A good communication link for data exchange between devices is necessary for the smart agricultural data service. Especially a broadband communication link may be required between the smart greenhouse (or the livestock barn) and the external cloud system of data service provider.

d. Preconditions: None.

e. Triggers: None.

f. Scenario

All data generated from the smart greenhouse (or the smart livestock barns) are collected and then transmitted to the data service provider to be analysed and reproduced. Sometimes, new types of data can be reproduced with the aid of external public data. The data is provided to the data consumer and the data prosumer in the form of a service to improve agricultural productivity, to establish agricultural policies, and to develop new technologies or services.

g. Process flow diagram

Figure 8 shows a flow diagram of the agricultural data service according to the scenario.

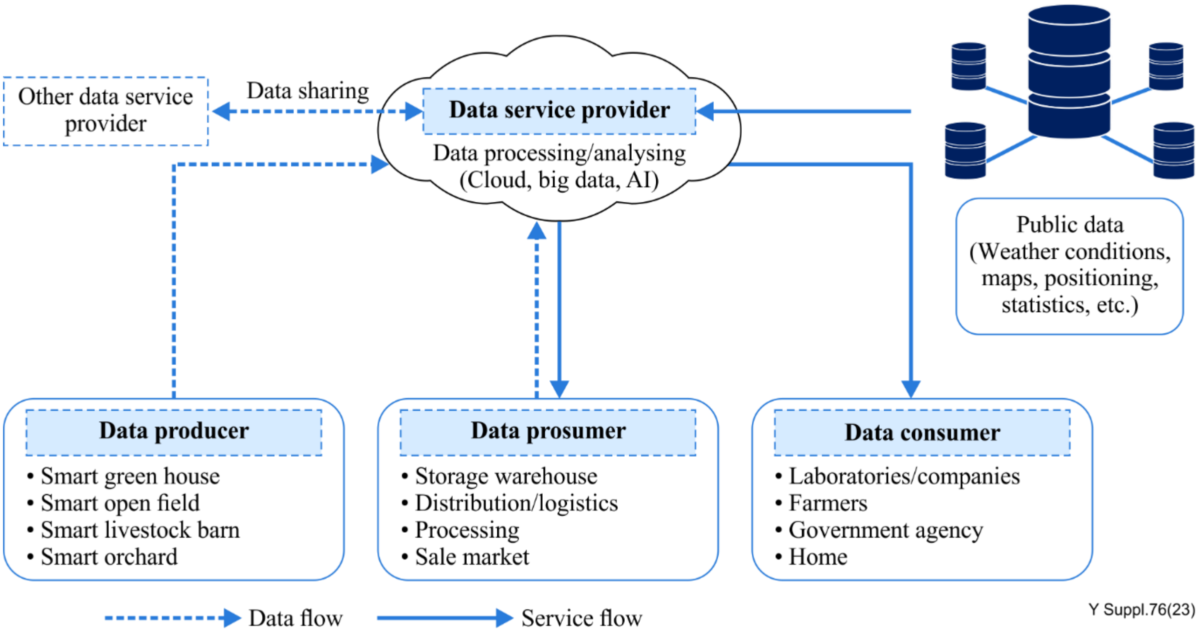

Figure 8 – Process flow diagram of agricultural data service

(Data aggregation) All data produced from sensors, actuators, controllers, and operation system installed in the smart greenhouse (or the livestock barn) are periodically transmitted to the data service provider. In addition to this, the data related to agricultural products, such as processing, distribution, and sales, are transmitted to the data service provider.

(Data analytics and reproduction) Using AI and big-data technologies, the data service provider analyses the received data, and if necessary, it reproduces new types of data with external public data (weather, map, statistics information, etc.). Deducing time data for seeding from external- and local-data can be one of examples of reproducing new types of data.

(Data distribution) Both aggregated and reproduced data can be provided to the data consumer as well as the data prosumer in the form of a service.

(Data consumption) The data is utilized to improve agricultural productivity, to establish agricultural policies, and to develop new technologies or services.

h. Post-conditions: None.

i. Information exchange

Data such as environmental data, growth data, and farm management data produced in the smart greenhouse (or the livestock barn) is transmitted to the data service provider. The data service provider analyses the received data, and then provides the analysed results to the data service users (data consumer, data prosumer). Data from processors, distributors, and sellers of agricultural products are also transmitted to the data service provider.

5. Architectural considerations

a. Deployment considerations

The followings should be considered in general:

- the cost for the installation and maintenance of the facility;
- the cost for the software to operate the system and service;
- the cost for the network utilization.

In addition, the followings should be considered for the agricultural data service:

- the cost for the data service usage;
- the security- and reliability-level of data service.

c. Communication infrastructure

Wired or wireless communication links to support various services are necessary. A narrow-band link can be used for the sensors installed in a farm, but a broadband link may be required between a farm and the data service provider to exchange large-capacity data and video data.

d. Performance criteria: None.

e. Interface requirements: None.

f. User interface

The user interface of the data service provider should be able to provide sufficient accessibility to users who are not familiar with ICT.

g. APIs to be exposed to the application from platform: None.

h. Data management

All data from sensors, actuators and controllers must be delivered and stored in the data service provider in a common format, regardless of the type of devices and its manufacturer. For the accurate data analysis, all data related to required data services should be expressed in a standardized way.

i. Data backup, archiving and recovery

To enable various data services, all data must be stored in a cloud system for a considerable period. For more accurate statistics and analysis results, which can improve productivity and convenience of farms, a considerable volume of data is necessary.

However, when the amount of stored data becomes huge, the cost for maintenance and management of the storage space entails. Therefore, it is necessary to establish appropriate strategies of data storage and management.

In addition, the data produced in the future should be compatible with the existing accumulated data.

j. Remote device management

To enable the data sources be monitored remotely, and be immediately replaced, it is necessary to provide capabilities to manage the devices remotely. OTA capabilities, including FOTA and SOTA, are recommended for software / firmware updates of remote devices.

k. Startup/Shutdown process: None.

l. Security requirements

To keep the smart agricultural data service safe from malicious users, it is required to protect the communication links as well as data for remote control. IoT devices should be secured on the platform for managing the device identities for the life cycle [b-ITU-T Y.4218].

It is required to provide security capabilities to overcome vulnerabilities related to devices and communication links by multi-factor user authentications and regular software and firmware updates.

6. Potential market growth forecast: None.

7. Implementation constraints: None.

8. Statutory compliances and related regulations

Depending on countries and regions, either no or more or less specific regulation on communication, electrical safety, and environments can be applied.

9. Available international standards: They include, but are not limited to:

– [ITU-T Y.2243], *Service model for risk mitigation service based on networks*

[ITU-T Y.2245], *Service model of the agriculture information based convergence service*

10. References: None.

11. General remarks: None.

Appendix I

Examples of experience for each use case

This appendix illustrates examples of experience worldwide for the different use cases described in this Supplement.

I.1 Smart greenhouse

– A company in the Netherlands is using hydroponics to produce a variety of crops, utilizing sensors and automation to manage the production process (https://www.priva.com/horticulture/greenhouse-climate-control?p=1#overview-7be814c4ab).

– A company in the United States uses a vertical farming system with LED lighting and hydrogenation technology to produce plants 365 days a year (https://www.aerofarms.com/how-we-grow/).

– A company in the United Kingdom is using vertical farming and AI to produce plants. The company is also introducing automated operations using robots and drones (https://www.intelligentgrowthsolutions.com/product/growth-towers).

– A company in Korea provides a smart farm solution that enables complex environmental control and integrated management in greenhouse. The smart farm solution uses sensors and actuators for crop growth, enables remote control using mobile devices and data collection, and applies cloud and AI technologies to optimize the crop production process (http://www.ubncorp.kr/eng/sub0301.php).

– A company's climate-controlled greenhouse projects in Israel enable crops to grow fast, efficiently and sustainably in any season and under almost any external conditions, based on the expertise in environmental management (https://www.netafim.com/en/greenhouse/project-management).

I.2 Container-based plant farm

– A company in the United States is utilizing technology to grow plants in containers. The company utilizes LED lighting and automation technology to optimize crop production. The company also offers a mobile application to monitor crop production in real-time (https://www.freightfarms.com/container-farming).

– A company in Japan is developing technology to grow plants using shipping containers. The company utilizes IoT technology and AI to automate the crop production process, and monitors conditions such as temperature, humidity, and CO_2 concentration required for crop production in real time (https://www.espec-mic.com/indoor-farming-equipments).

– A company in Korea has developed a vertical plant farm using container boxes to enable urban agriculture. Each container box below is equipped with sensors, actuators and controllers (https://nthing.net/veg).

– A company in China offers a modular smart farm system that uses technologies such as environmental control, automation, and data analysis to grow crops in small spaces. The system improves crop productivity, minimizes water and energy consumption, and enables sustainable farming and urban agriculture (https://www.alescalife.com/our-tools/).

I.3 Smart greenhouse with cloud and edge support

– A company in the United States providing worldwide cloud service has been offering an edge aided smart greenhouse service since 2017 (https://aws.amazon.com/ko/blogs/iot/aws-iot-driven-precision-agriculture).

– A company in Israel has developed a technology to predict crop production by automatically measuring crop growth status as well as water supplement. A solution product from the company, can measure and analyse soil conditions through the cloud. It also allows users to access their own data anytime and anywhere (https://cropx.com/cropx-system/field-data/).

- A company in Japan provides an agricultural ICT cloud service that can monitor the status of a smart greenhouse based on machine-to-machine technology; networking of various sensors and terminals is the key to this service. The agricultural ICT cloud service improves accuracy of predict production volume and production time, by using the on-site collected and accumulated environmental data (https://www.nec.com/en/global/solutions/m2m/prod-sv/prod-sv1.html).
- Another company in Japan provides an agricultural production and facility management service based on the cloud. The service collects daily farm work records, weather information and image information, and then provides them to users with additional information such as external weather- and geo-information (https://www.seraku.co.jp/en/service/midoricloud).
- Another company in Japan provides a cloud-based agricultural service platform for the food and agriculture industry. It uses advanced technologies such as sensors, AI, and big-data to monitor crop conditions, optimize production, and ensure food safety. Farmers can access real-time data and make informed decisions to improve farm management (https://www.fujitsu.com/global/documents/about/ir/library/presentations/presentation-20150226-01.pdf).

I.4 Smart water management

- A company in Israel has developed a technology that utilizes IoT and smart sensor technology to automatically regulate the hydration and nutrient supply of crops and monitor their growth in real time to determine the optimal time and amount of irrigation. This increases crop productivity and reduces the cost and labour required for farming (https://cropx.com/cropx-system/irrigation-planning).
- A company in Korea developed an AI based smart water management system that reduces water amount and labour while improving the quality of crops. This system diagnoses the crop's bioreaction information with imaging technology and determines the timing of water supply. Comparing to the existing water management system that relies on only soil moisture sensor, this water management system increased crop's weight and sugar by 14% ~ 26% and 8% respectively, and reduced water consumption and labour force by 25% ~ 31% and 95% respectively (https://www.rda.go.kr/board/board.do?mode=view&prgId=day_farmprmninfoEntry&dataNo=100000759428).

I.5 Pest control using UAV

- A company in the United States provides a service using thermal imaging cameras to determine the optimal amount and type of nitrogen and fertilizer input per unit area of farmland has been developed. In addition, agricultural UAVs (drones) are used to quickly analyse the farmland- and crops- conditions and provide data necessary to establish a cultivation plan and forecast a production of farmland (https://sentera.com/products/fieldcapture/).
- A company in the Netherlands provides services using drones that can analyse chemical properties and moisture of soil, and growth process of potatoes. By introducing this service, the average production of potato per unit area has increased more than doubled compared to the typical farmland (https://www.flagshipfarmers.com/media/1039/van-den-borne-flagship-farm_casestudy.pdf).
- A drone manufacturer in China has developed drones for efficient crop monitoring and agricultural works management. The products use high-performance cameras and sensors to monitor the status of crops and farmland, and AI-based data analysis in the cloud to detect disease and pest outbreaks and accurately apply fertilizer (https://ag.dji.com/cn).

I.6 Connected agricultural tractor

- A company in Germany has developed a tractor with Connected Farming System (CFS), which is equipped with autonomous functions such as ISOBUS (ISO 11783), Guidance, and

Fleet management, can perform various precision farming remotely (https://www.sdfgroup.com/en/smart-farming-solutions/smart-farming-solutions).

- Another company in Germany provides a solution to improve the efficiency and productivity of smart agriculture by integrating agricultural machinery – tractors – with digital technologies. The solution includes features such as remote services for managing the tractors, telematics, real-time data transfer to cloud, and farm management software (https://www.claasharvestcentre.com/new-machinery/tractors/connected-machines-tractors).
- A company in the United States provides an advanced system for precision farming. The system includes automatic steering, guidance to improve the accuracy and efficiency of agricultural works, optimized input management, and data-driven monitoring and management for remote tractor (https://www.caseih.com/apac/en-int/products/advanced-farming-system).
- A company in Japan has developed a cloud-based AMM support solution, in which not only tractors but also rice transplanters and combine harvesters can be connected each other. Through interaction with agricultural machinery, this solution enables data driven automation that can support effective agricultural operations (https://www.yanmar.com/global/agri/smart_agri/smartassist.html).

I.7 Automated milking system

- A dairy farm solutions provider in the Netherlands, which accounts for more than 65% of the global milking system market, has launched a system that automates the entire process from production to distribution of milk. The AMS of this company provides convenience to dairy farmer by providing system control solutions and consulting services. The dairy farmers can monitor the status of the milking by using the web or mobile devices connected to the AMS (https://www.lely.com/solutions/milking/).
- A company in Denmark provides a dairy farm management program that effectively store and manage data generated in the entire business process from mating, pregnancy, calving, disease control, milking, feeding, and shipping. In the dairy farm, the central computer is connected to the pocket computer of the employees. The farmer can establish prospects and plans for farm management based on the data (https://meetings.eaap.org/wp-content/uploads/2014/S53b_01.pdf).
- The 'IoF2020 project' [b-IoF2020a] in Europe is a project to build an information network in all European agriculture industry based on IoT, and to utilize the data (big-data) through this information network. In particular, the 'Internet of Dairy Farming' program [b-IoF2020b] researched real-time monitoring methods for effective breeding management of livestock by combining dairy farming technology and IoT technology (https://www.wur.nl/en/project/the-internet-of-dairy-farming.htm).

I.8 Animal health care

- A company in Korea has developed a smart animal health care service that can manage pig's conditions in real time and receive consultation from a veterinarian in the following manners (https://aidkr.com):
  a) Pig blood is directly collected and classified into immune status, immune activation ability, and immune antibody formation according to 32 variables, and it is scored for the livestock barn;
  b) Sensors are installed in the livestock barn to manage the livestock barn condition;
  c) When temperature or gas of the livestock barn excess a certain level, an alarm is sent to help a farmer's prompt responding.

NOTE – According to the results of company's own data analysis in 2018, the monthly antibiotic usage was reduced by up to 83%, the overall management cost decreased by 43%, and the mortality rate was also reduced by 30%, thereby increasing productivity.

I.9 Agricultural data service

– The Japanese government has supported research regarding data services for the smart agriculture [b-Society 5.0], in which a crop or farmland diagnosis, a water management system, a smart machinery development, and a data sharing are being researched (https://www.naro.go.jp/english/socierty5-sdgs/about.html).

– The Japanese government also provides an agricultural data collaboration platform as a hub for connecting various data sources and services to facilitate the provision and sharing of useful information for all those involved in agriculture. By securing and organizing various independent agricultural data, such as existing environmental data, crop information, production management plans, technical know-how and various statistics, the platform makes them available to those engaged in agriculture (https://wagri.net/en-us/aboutwagri).

– The Korean government has developed a data platform using AI technology that analyses environmental and growth data from a smart greenhouse, and then provides information of optimized cultivation conditions to farmers (https://smartfarm.rda.go.kr/).

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