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| Source:\* | JiEun Lee, Sejong University, love9ly@sju.ac.krJiHo Lee, Sejong University, twozio@sju.ac.kr JaeSeung Song, Sejong University, jssong@sejong.ac.kr  |
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#  Introduction

This contribution introduces a new use case for metaverse-based real-time smart farming.

-----------------------Start of change 1-------------------------------------------

## Use Case #n – Virtualised Smart Farm in Metaverse Space

## 7.2.1 Description

The objective of the metaverse-based real-time smart farming with IoT integration use case is to create a virtual representation of a smart farm within the metaverse, leveraging IoT data for real-time monitoring, control, and simulation of agricultural activities. This scenario envisions a smart farm where IoT devices are deployed extensively to monitor various environmental and crop conditions, such as soil moisture, temperature, and crop health. The described scenario also assumes that the IoT platform generates and stores modeling information for the various spatial details and non-IoT functional objects that comprise the actual space corresponding to the Metaverse virtual environment. These models are designed to mimic the physical characteristics and conditions of the actual farm environment as accurately as possible. This data is integrated into a metaverse service, enabling farmers, researchers, and students to interact with the farm in a virtual environment. Users can observe real-time conditions, simulate the effects of different agricultural practices, and make informed decisions on crop management without physically being on the farm. Implementing a metaverse-based real-time smart farming solution could offer an immersive agricultural education and training learning environment, and allow for the simulation of farming strategies to identify the most effective approaches before implementation in the real world. This approach enhances farm management and productivity and fosters a deeper understanding and engagement with agricultural ecosystems.

## 7.1.2 Scope

This scenario leverages IoT and metaverse technologies to simulate and manage agricultural environments, offering users virtual interaction with real-world farming conditions.

## 7.1.3 Actors

* Farmers: use the metaverse-based smart farm service for monitoring and decision-making.
* Smart farm IoT devices: deployed throughout the farm for data collection and smart farm management (e.g., sensors and actuators).
* Edge IoT platform: manages offloaded resources representing smart farm IoT devices from the IoT cloud platform.
* IoT platform: integrates and processes data from smart farm IoT devices at the edge for rapid updates to the metaverse environment.
* Metaverse service: hosts the virtual environment with real-time data to provide the metaverse service.

## 7.1.4 Pre-conditions

* IoT devices are deployed across a farm, collecting data (e.g., environmental conditions, crop health, status of soil) and managing smart farm (e.g., turn on/off LED lights, activate/inactivate fans)
* All the IoT devices are registered to the IoT platform.
* Metaverse service capable of reflecting a physical smart farm to the metaverse space via IoT service layer platforms.
* For Metaverse services, the IoT platform pre-stores and manages both the environmental data for spaces as defined by the Metaverse service, and the detailed modeling information for non-IoT functional objects (such as the color and material of walls, and the floor’s shape) within these spaces.

## 7.1.5 Triggers

Triggers for updating the metaverse environment in smart farming are rooted in real-time changes in farm conditions, such as weather changes or crop growth stages. It is essential to have accurate synchronizations between the virtual and real-world farms to reflect these dynamic changes. This process involves continuously updating the metaverse with real-time data on environmental conditions and crop health from IoT devices, ensuring the virtual environment mirrors the actual farm accurately. By categorizing data into three distinct types, the system ensures comprehensive and realistic farm simulations, allowing for informed decision-making and strategic planning in the metaverse.

Firstly, immediate reflection encompasses environmental conditions and crop health, constantly monitored by IoT devices. Their real-time data generates a real-time scene in the metaverse, empowering immediate decision-making based on the most up-to-date conditions. Imagine adjusting irrigation based on live moisture levels or taking pest control measures as virtual alerts flare.

Secondly, stable data types like soil composition and historical yield data serve as the bedrock of the virtual farm, informing its long-term potential. While not requiring constant updates, these elements remain crucial for strategic planning and understanding the overall farm health. They provide the essential context that guides metaverse-based management decisions.

Lastly, the periodic reflection data type encompasses factors like seasonal changes and market fluctuations. Periodic updates ensure the virtual farm remains relevant and aligned with real-world agricultural conditions and trends. This enables proactive adaptation to changes in the physical environment and market dynamics, ultimately optimizing farm performance.

Beyond the dynamic data types mentioned before, the system incorporates an additional segment: static data type. This encompasses elements essential for constructing a virtual metaverse farm that accurately reflects its real-world counterpart, such as walls, soil textures, furniture, and built structures.

Unlike dynamic data which requires continuous updates, static data remains relatively unchanged once incorporated into the metaverse environment. This static component serves as the foundation upon which the dynamic elements interact and evolve, providing a sense of spatial grounding and realism within the virtual farm.

By intelligently categorizing data and fostering seamless reflection between the real and virtual metaverse worlds, this system creates a truly interactive metaverse farm experience. This empowers farmers to make informed decisions and develop strategic plans in real-time, ultimately contributing to a more sustainable and productive agricultural future.

## 7.1.6 Normal Flow

This section outlines the step-by-step process flow for a real-time smart farming use case within a metaverse environment, leveraging data exchange between the physical farm and its virtual representation:

* Step 1 (Data Acquisition): The IoT devices deployed in the physical smart farm continuously collect data regarding environmental conditions (e.g., soil status, temperature, humidity).
* Step 2 (Data Processing and Storage): The IoT platform receives the collected IoT data, processes it for any necessary transformations or analysis, and stores it for future reference and potential use in decision-making..
* Step 3 (Data Transmission to Metaverse): The metaverse service utilizes either a notification or retrieval mechanism to fetch the latest data from the IoT platform. This ensures the virtual farm accurately reflects the current state of the physical farm.
* Step 4 (User Interaction and Metaverse-based Control): The Metaverse service utilises the detailed modeling information corresponding to a given virtual space and data from IoT devices to create and offer users a virtual smart farm within the Metaverse that mirrors the physical smart farm. Users within the metaverse smart farm can access and analyse the reflected data to gain insights into the real-world farm's current conditions. Based on these insights, they can perform various control actions within the virtual environment. This might involve adjusting irrigation systems, activating climate control mechanisms reflected in the metaverse, or triggering other actions that translate into commands sent to the physical farm's IoT devices. Additionally, the metaverse service can be configured to automate specific farm operations based on predefined rules and the reflected status of the virtual environment. For instance, an automated watering schedule established within the metaverse can trigger real-world irrigation systems based on sensor readings.
* Step 5 (Metaverse State Update): Following user interactions or automated processes within the virtual environment, the metaverse service updates its internal state to reflect any changes that have occurred.
* Step 6 (Updated Data Transmission to IoT Platform): Based on the received data and established configurations, the IoT platform transmits appropriate commands to the corresponding IoT devices within the physical smart farm, enacting the desired actions in the real world.



Figure 7.2.6-1 An interaction flow between physical farm and virtual farm

## 7.1.7 Alternative Flow

None

## 7.1.8 Post-conditions

None

## 7.1.9 High Level Illustration

This illustration encapsulates the dynamic interaction between the physical and virtual realms in metaverse real-time smart farming. The IoT devices are pivotal in gathering critical data on crop health and environmental factors such as soil moisture, temperature, and nutrient levels. Not only environmental data collected from IoT devices, but also detailed modeling information (such as soil types, wall colors, desk shapes) about a given space should be considered as IoT data and systematically managed on an IoT platform for Metaverse services. The IoT device and spatial modeling information collected on the IoT Cloud Platform are used by Metaverse applications to create and maintain spaces and objects in the virtual environment that mirror real world. Any updates made by users in the Metaverse virtual space are reflected back to the IoT platform and subsequently applied to the corresponding real-world IoT devices.

Users within a metaverse service monitor the smart farm and perform various actions (e.g., turn on lights, open windows) in real-time. Such actions performed within the metaverse are then transmitted to the physical farm through IoT platforms. This continuous cycle of monitoring, decision-making, and implementation exemplifies an innovative approach to farming that bridges the physical and virtual worlds.



Figure 7.2.9-1 Example for metaverse-based real-time smart farming

## 7.1.10 Potential Requirements

1. The oneM2M System, leveraging its comprehensive model, shall be able to replicate the physical world environment, including deployed IoT devices, objects, and surroundings like walls, within the metaverse virtual space.