DDS Foundation Use Case

DDS-Foundation.org

Agriculture Sector

DDS in Digital Agriculture

by

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Executive Summary

This document provides an overview of a digital agriculture use case including the wide range of challenges and its solution architecture using the Data Distribution Service™ (DDS™) technology. The goal of digital agriculture and precision agriculture is to improve production while minimizing the cost and resource utilization.

Application

During the industrialization of agriculture, the mechanical machineries helped farmers reduce effort and time while increasing yield per acre. But the risks of rapid climate changes plus growing demand for food products in market (such as food supply chain, food processing industries) for an increasing population, have increased dramatically. This demand has created pressure on the existing agriculture methods with a wide range of challenges. At the same time, it has created areas of opportunity for improvement.

The integration of newer IoT technologies and devices into the agricultural practices is now pushing farmers to migrate to digital farming and precision agriculture. This advancement allows them to benefit from the current demand for agricultural products while resolving related challenges and risks.

Digital farming and precision agriculture is reliant on a system of sensors and controllers along with robust communication technologies on every piece of equipment, throughout every stage of the farming process. Each stage of the farming process requires/depends/combines the data from other stages to perform the work more efficiently:

1. Seeding and planting
    a. Data from sensors are used to monitor the soil quality, density, moisture and health (nutrient levels). This data is used to maintain the optimal conditions during seeding.
    b. Long-term weather, soil patterns, moisture and temperature monitoring help farmers to decide the optimal timeframe for crop cycle.
2. Fertilizing
    a. Soil health, quality, crop health and temperature are used to target areas in need for fertilizing.
    b. Drone are used to fertilize safely using data from real-time location, wind speed and object detection.
3. Irrigation
    a. Real-time moisture level, plant health and irrigation motor device control help in optimal usage of water.
4. Harvesting
    a. Continuous crop imaging data, real-time location and object detection data is gathered on farming machinery to help for efficient harvesting.
5. Weeding and crop maintenance
    a. Real-time imaging systems that are placed on GPS sensors and navigation systems help for automated crop maintenance.

The various types of sensors, drives and distributed control systems drive the need for a connected network which can facilitate the exchange of data in real-time/non real-time. This data-centric distributed system needs to be precise, highly complex, dynamic, secure and robust.

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Architecture

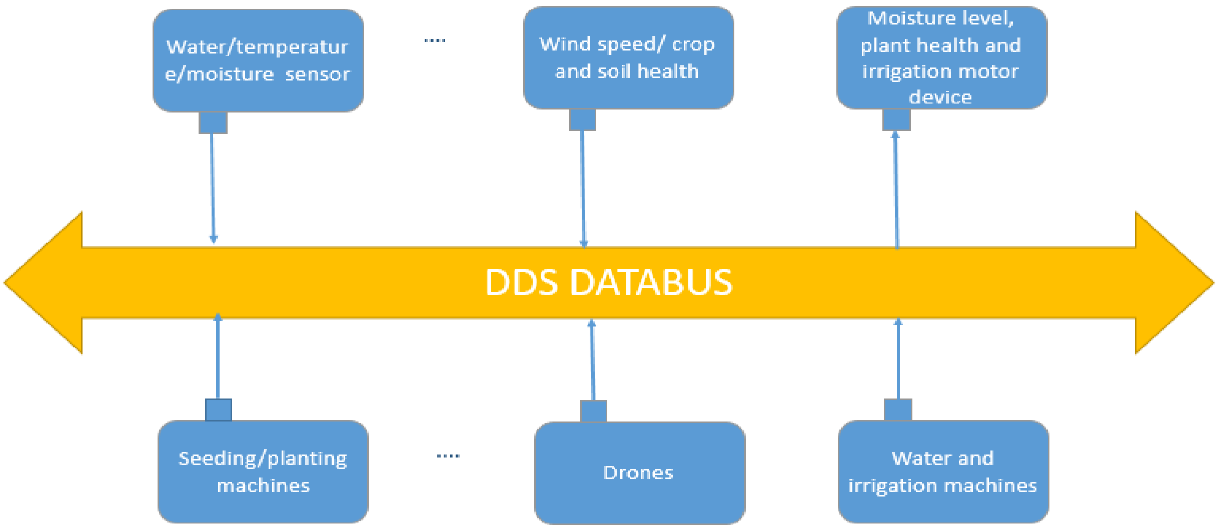

Figure 1: DDS digital agriculture logical view

How DDS addresses the need

DDS simplifies the complex requirements listed above in a scalable way, making the digital agriculture process more effective.

Flexible model design – The DDS data-oriented design and decoupling feature provides flexibility and modular structure in the system. For example, in the irrigation stage, the digital agricultural appliances such as moisture sensors, irrigation motors and soil health sensors need to be associated in one-to-one, one-to-many and many-to-one secenarios for exchanging information, in order to decide the size of the watering distribution areas and their quantity/duration. Using DDS, the equipment can be grouped as participants of different functional domains. Only the equipment belonging to the same domain can communicate with each other. DDS also enables a dynamic re-configuration of this association mapping during runtime.

Compliance profiles and QoS:

- **Data Availability** – DDS provides a strong Quality of Service (QoS) policy to control the state of information throughout the system. For example, every piece of agriculture equipment/machinery offers unique services, yet the data availability requirement for precise agriculture is specific for each crop-cycle (i.e. each planting and seeding type) and the designated machinery.

  The QoS policy parameters in DDS, below, fulfill the data availability (i.e. state information of the equipment) requirement:

- *History:* The number of data samples to be stored can be configured.
- *Minimum profile:* The recent data sample or all data samples.
- *Lifecycle:* Removal of the data sample once the sensor is removed from the domain participant. This feature is helpful when the domain is re-configured and the existing samples are removed automatically from the system.
- *Lifespan:* The time period for which data samples to be kept on the system.

For each crop cycle, the system can be re-configured by feeding the respective configuration during the time of seeding. The DDS application running on the equipment allows for dynamic configuration. This guarantees the minimum resource utilization in the system.

- **Data timeliness** – In precision agriculture, the typical data exchange requirements are:
    - Continuous low granularity, bulk historical data, e.g. for weather and soil character patterns.
    - High-granularity non-real-time datasets in specific timeframes, e.g. for equipment health maintenance.
    - Real-time datasets, e.g. for navigation systems, location and drive control, object collision detection, fire/hazard detection.

  DDS promises timely data delivery with minimal overhead. For example, the drones and ground vehicles (used for moisturizing, fertilizing and spraying the pesticide) exchange location/navigation data with the central control system in real-time for monitoring the crops in the field. The onboard sensors exchange environment data including object detection, drive speed, etc. for navigation control and collision safety. On the other hand, the onboard cameras on the drones capture and share crop-area images to the central control system, which co-ordinates the ground machines to carry-out pesticide spray and fertilization of the particular crop area, automatically and efficiently. This minimizes the time and manages the agriculture crop with minimal resource utilization.

  Using the following DDS QoS parameters, the drones and ground machines transfer the data in real time:

    - *Latency_Budget:* Guarantee data delivery.
    - *Deadline:* Maximum amount of time to send/receive the data samples collected in the sensor. Once the deadline is crossed, the data samples will be dropped.
    - *Liveliness*: Ensures the entities' live status periodically.

Event handling – DDS listeners in the entity provide a mechanism for the middleware to asynchronously alert the application of the occurrence of relevant status changes.

For example:

- The sensors placed in field (temperature, moisture, humidity etc.) monitor standard attributes such as temperature, humidity and weather for every season. The pre-configured/predicted-pattern of temperature and humidity threshold values, alert the framers and other equipment to any abrupt change in environment parameters to prevent natural disasters (e.g.: crop fire, sudden flooding and water stagnation).

- The sensors on the drones and self-driving ground vehicles monitor/exchange position parameters and objects insight, to prevent collisions with wild animals or nearby agriculture appliances.

Using DDS, event handling of asynchronous events and conditional variables are shared on equipment including self-driving vehicles which alert among themselves to prevent damage and risks.

Live monitoring & control – Web-enabled DDS Services authenticate and control the DDS global data space (i.e. read/write topics) using standard web protocols such as RESTful, SOAP, HTTP etc, from the standard web client such as web browsers.

For example, in farming, there are a number of digital agricultural appliances involved in the agriculture field where the farmers need access to each resources to use the digital agriculture methods and processes effectively. This needs a simplified UI dashboard for data visualization and control. By leveraging DDS web services, the parameters (i.e. topic of the agricultural appliances) can be read/write remotely. The farmers can use the UI dashboard via the browsers in the handheld devices from any location to control the digital agricultural appliances.

Security – DDS security plugins and secure RTPS messages protect against the unauthorized access and subscription of data throughout the digital agricultural ecosystem. For example, there are different vendor-devices involved in the digital agriculture appliances, operating in an open area along with equipment in nearby farms. In this situation, the appliances must have high data security in order to avoid threats and vulnerability and at the same time prevent unintentional information sharing and cross-talk. Using DDS security configurations and security policies defined for data distribution, the explicit policies created for protecting DDS domains based on the data models can ensure that the equipment information is not visible or discovered between different configured domains.

Conclusion

Connected digital agriculture and sensors integrated on equipment make farming processes data-driven and data-enabled. Leveraging the rich functionality of DDS enables the digital agriculture ecosystem to perform as designed, through integration capabilities and features that addresses the vertical and horizontal needs such as security, scalability and robustness of data distribution. With DDS, real-time goals of digital agriculture can be realized cost effectively and without fragmentation of the system.

Authors

The DDS Foundation wishes to thank the following authors for submitting this use case.

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Appendix - Resources

1. **About DDS -** https://www.omg.org/spec/DDS/About-DDS/
2. **DDS security -** https://www.omg.org/spec/DDS-SECURITY/About-DDS-SECURITY/
3. **DDSI-RTPS -** https://www.omg.org/spec/DDSI-RTPS/About-DDSI-RTPS/