AGRARIAN

FARMING ON THE EDGE

OPEN CALL 2

Technical Annex

Funded by the European Union

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Participant	Participant organization name	Short name	Country
1	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	NCSRD	EL
2	DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV	DLR	DE
3	LDO - SOCIETA PER AZIONI	LDO	IT
4	SOFTWARE IMAGINATION & VISION SRL	SIM	RO
5	UBOTICA TECHNOLOGIES LIMITED	UBO	IE
6	ADRESTIA EREVNITIKI IDIOTIKI KEFALAIOUXIKI ETAIREIA	ADRE	EL
7	ASOCIATIA PRODUCATORILOR DE PORUMB DIN ROMANIA	APPR	RO
8	AVIPE-ASSOCIACAO DE VITICULTORES DO CONCELHO DE PALMELA	AVIPE	PT
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10	EPSILON MALTA LIMITED	EPSIL ON	MT
11	MEDITERRANEAN AGRONOMIC INSTITUTE OF CHANIA	MAICH	EL
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13	SATELIO IOT SERVICES, SL	SATEL	ES

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1. Purpose of the Technical annex

The purpose of this annex is to provide applicants with an understanding of the main technical characteristics of the AGRARIAN testbeds and components that they will use during the implementation phase of their projects.

It is important to note that this document constitutes essential and complementary information to the **Applicants' Guide**.

Chapter 2 provides information about the AGRARIAN testbeds, while chapter 3 describes the AGRARIAN Dynamic Programmable Distributed Ecosystem, the Data Storage and the Agricultural Design Support System (ADSS).

It is noted that the proposed projects of Open Call 2 should run on **one of the testbeds**, while the proposed applications should consume real data from the proposed use case and send selected processed data to the AGRARIAN data storage. Finally, the **finalized applications should be containerized** in order to be stored in the AGRARIAN application repository and be handled from the AGRARIAN orchestrator.

2. AGRARIAN Testbeds

2.1 Testbed 1 (NCSRD) - Geosynchronous Satellite Communications with EDGE capabilities

Description

This testbed allows applications testing over a non-terrestrial network. A geostationary (GEO) satellite network emulator runs on NCSRD servers, which applicants can access using a VPN connection. The emulator consists of a ground terminal, a GEO satellite and a ground gateway. Applicants will install, run and test their applications on the testbed, validating the edge capability and performance of their applications over the satellite network.

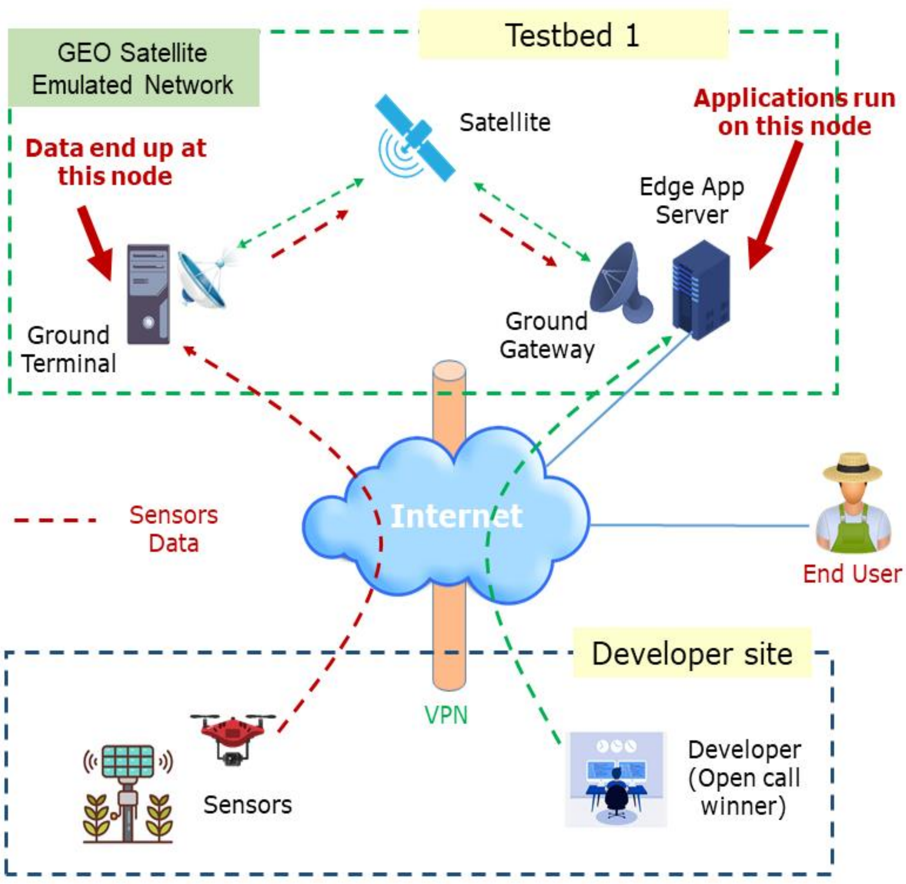

Figure 1: Testbed 1 (NCSRD)

Representative Example of an applicant's application

A proposed application may involve an AI model designed to detect signs of illness in sheep. This application is deployed on the Edge Application Server of AGRARIAN Testbed 1 and receives real-time data from field sensors via an emulated satellite link. Both the sensors and field data are provided by the applicant.

The application is required to forward selected, structured data (e.g. detected signs of illness) to the AGRARIAN Data Repository for further analysis and future use (e.g. by the AGRARIAN ADSS). Once finalized, the application will also be containerized and stored in the AGRARIAN Application Repository, enabling the AGRARIAN orchestration system to redeploy it on-demand in future scenarios based on user requests.

Applicants will also be responsible for evaluating the application's performance under the satellite communication conditions of Testbed 1, assessing metrics such as inference confidence, operational stability, processing efficiency and resource usage (e.g. RAM, CPU, storage, etc.).

2.2 Testbed 2 (DLR) - Non-Geosynchronous Orbit (NGSO) Satellite Communications with EDGE capabilities

Description

This testbed allows applications testing over a NGSO (i.e. LEO satellite constellation) satellite setup. More specifically, DLR testbed reproduces a small LEO constellation, composed of one ground station, a configurable number of satellites, and a configurable number of IoT nodes. The testbed features simplified edge functionalities implemented onboard satellites to analyse related edge computing performance when routing and load balancing are performed. The edge computing agent architecture implemented onboard satellites is such to accommodate more advanced data processing and computing functionalities and possibly to allocate a full-fledge edge computing service. Further to this, real data can be injected externally, either as inputs to the emulated IoT devices, or by interconnecting external servers to the IoT devices, these latters eventually acting as IoT gateway to access the satellite resources. These both options can be seen as external Apps to be provided by the interested developers.

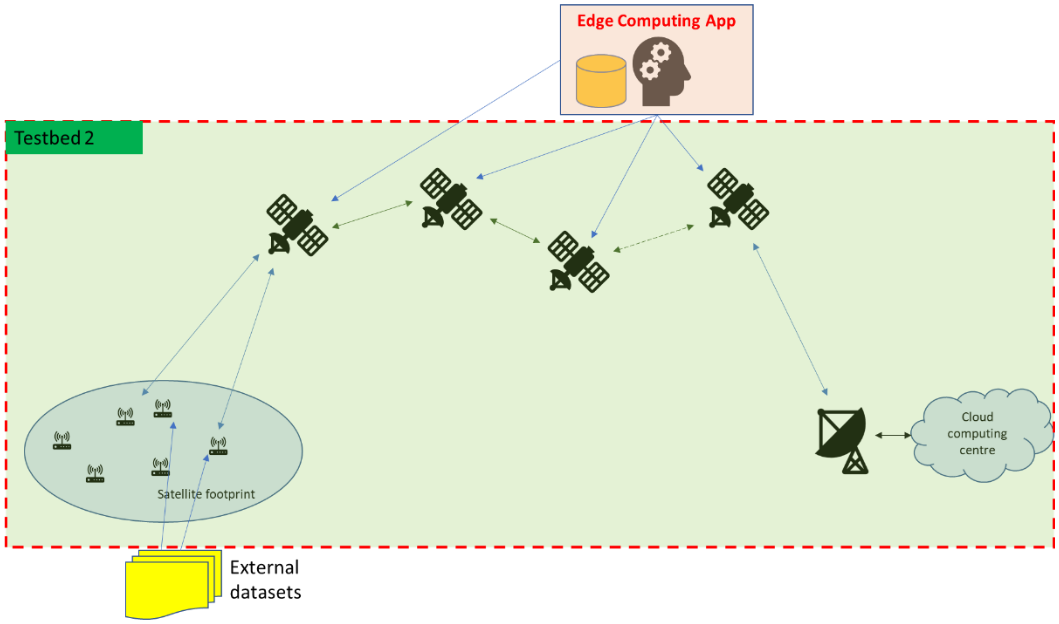

Figure 2: Testbed 2 (DLR)

Representative Example of an applicant's application

The monitoring of an agriculture field or herd health happens via dedicated sensors, whose data being generated are processed by dedicated Edge apps. These apps are integrated onboard the emulated satellite platform and are processing the data received over the emulated satellite link either directly from the IoT devices or from neighboring satellites. Furthermore, real data can be injected into the IoT device network, by integrating a dedicated data producer server, whose outputs are then forwarded by the IoT devices over the emulated link to the satellite constellation.

The application is required to forward selected, structured data to the AGRARIAN Data Repository for further analysis and future use (e.g. by the ADSS). Once finalized, the application will also be containerized and stored in the AGRARIAN Application Repository, enabling the AGRARIAN orchestration system to redeploy it on-demand in future scenarios based on user requests.

2.3 Testbed 3 (SATELIOT & UBOTICA) - LEO-Based NB-IoT Testbed for Onboard Edge AI Data Processing

Description

This testbed integrates capabilities from SATELIOT and UBOTICA to simulate service provisioning of non-terrestrial NB-IoT communications via a Low Earth Orbit (LEO) satellite with onboard AI capabilities. This setup supports narrowband IoT use cases (data rates up to 250 kbps) and enables onboard edge deep learning inference. The system emulates a dual-mission payload, managing storage and processing of both Earth Observation (EO) imagery and IoT sensor data onboard the satellite. The objective is to enable Open Call Developers to validate applications that leverage the joint use of IoT data and EO imagery for onboard inference.

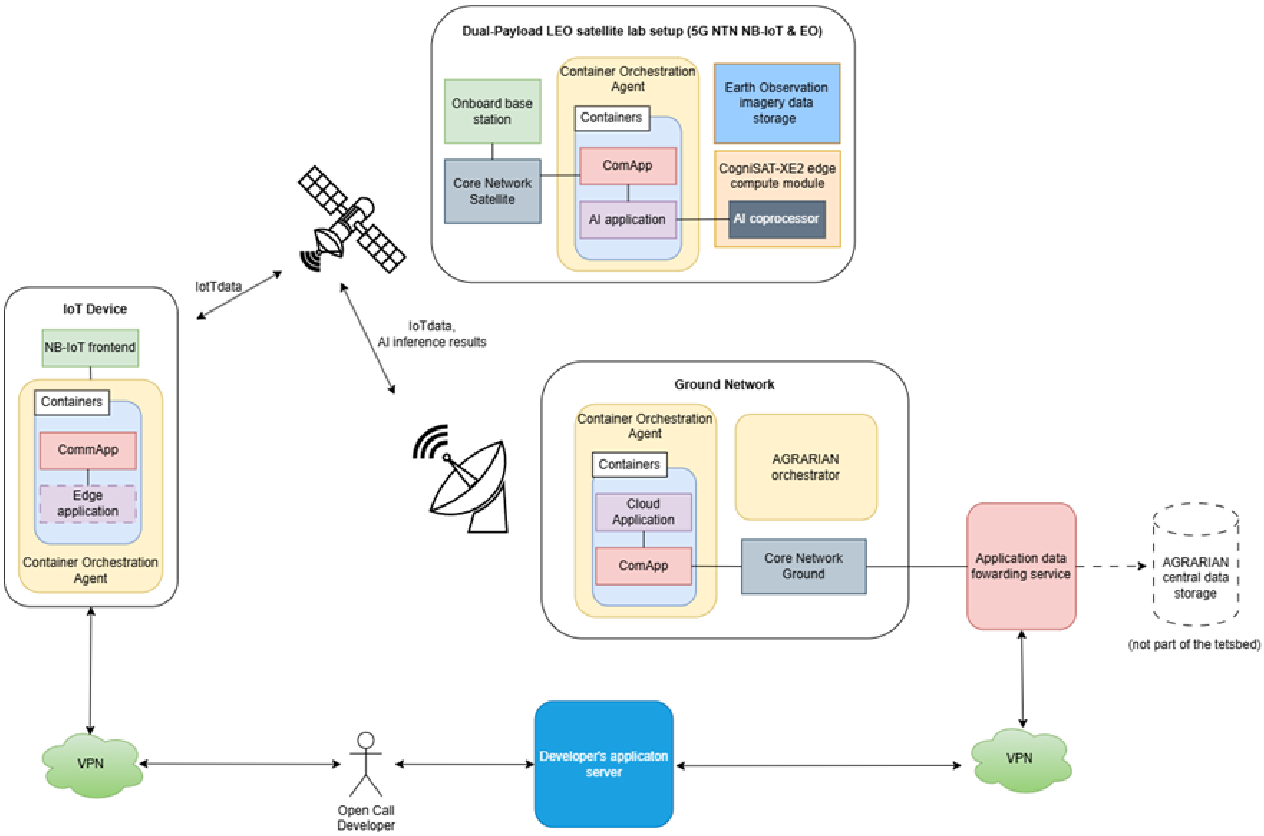

Figure 3: Testbed 3 (SATELIOT & UBOTICA)

The testbed implements a phased approach to AI model deployment to an emulated CubeSat environment. This consists of edge compute hardware controlled by a Ubotica server. This edge compute hardware consists of using Ubotica's XE2 coprocessor, specialised hardware that is used onboard CubeSats. AI models and ML algorithms will need to be ported and compiled to run on this platform.

This phase allows developers to assess model performance, accuracy, and resource utilization (e.g., inference time, memory footprint) on the target hardware. This step reduces deployment risks by ensuring model optimization prior to full system integration. Once the model has been finalised it can then be containerised as part of the second phase and prepared for use in the full test bed environment outlined previously.

Developers will simultaneously integrate with SATELIOT's laboratory infrastructure via secure VPN access. This access extends to the emulated IoT device and the application data forwarding service. To initiate data transmission through the NB-IoT link, developers must provide raw IoT data to the in-lab IoT device. This can be achieved either by establishing a data pipeline from a physical IoT device at the developer's premises or by pre-loading collected IoT data directly onto the in-lab IoT device.

In the second step, developers can deploy the validated AI model onboard the emulated satellite environment. Additionally, if required, the architecture supports the deployment of edge applications on the emulated IoT device or on a cloud node, accommodating applications with varying resource requirements.

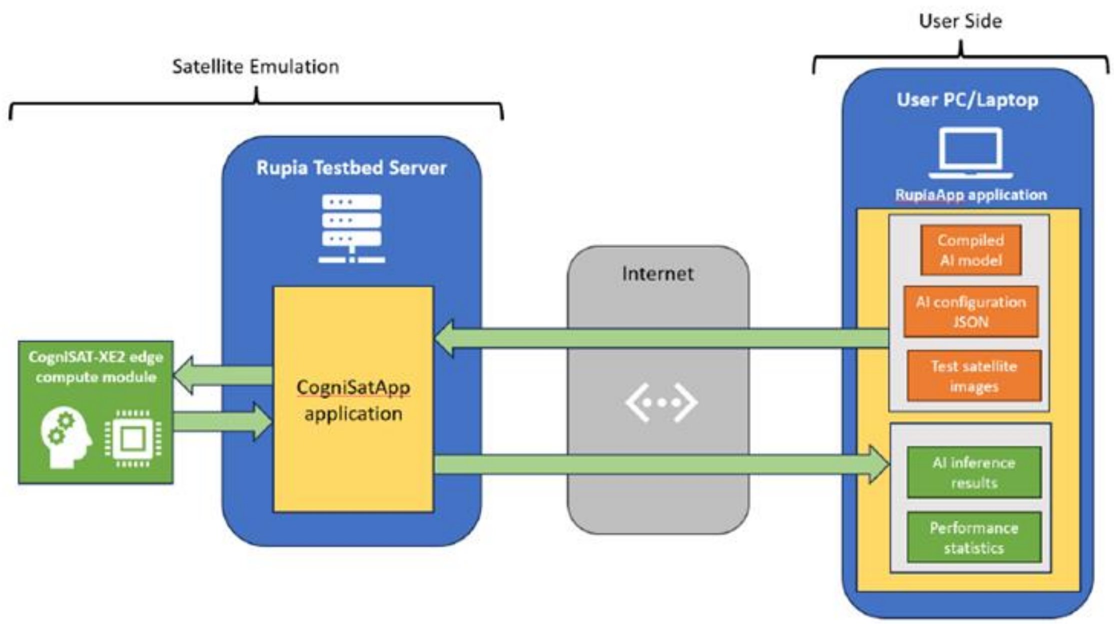

Figure 4: UBOTICA's dedicated environment for model iteration

Once the data is transmitted from the satellite to the Ground Network, to complete end-end data delivery, the developer will also receive VPN access to Sateliot's application data forwarding service. This service functions as an intermediate server, facilitating the transfer of processed data to the AGRARIAN central storage and to the developer's external application server, if required.

Representative Example of an applicant's application

An agricultural technology company aims to develop an AI-powered livestock health monitoring application for remote grazing areas. Their solution focuses on early detection of health anomalies in individual animals to improve herd management and reduce losses. Small, low-power IoT devices attached to livestock collect vital signs (e.g., body temperature, activity levels) and transmit this narrowband IoT data to the emulated LEO satellite.

Onboard the LEO satellite, a pre-validated AI inference model is deployed and processes this IoT data, fusing it with any available Earth Observation (EO) imagery of the grazing area. This onboard AI identifies patterns indicative of illness or distress, generating alerts that are then transmitted to the ground network. The processed data is forwarded to the applicant's farm management platform, enabling immediate veterinary intervention or herd separation, ultimately enhancing livestock productivity and reducing animal deaths in challenging terrains.

The application is required to forward selected, structured data to the AGRARIAN Data Repository for further analysis and future use (e.g. by the ADSS). Once finalized, the application will also be containerized and stored in the AGRARIAN Application Repository, enabling the AGRARIAN orchestration system to redeploy it on-demand in future scenarios based on user requests.

3. AGRARIAN Components

3.1 Dynamic Programmable Distributed Ecosystem

The AGRARIAN project implements a robust distributed architecture and orchestration mechanism to facilitate application deployment across the different testbeds. This system provides developers with a set of tools required to manage their applications throughout the entire lifecycle.

At the core of this architecture is an Orchestrator, implemented as a K3s server. This orchestrator is responsible for the seamless deployment and management of containerized applications across all interconnected testbeds (Testbed 1, Testbed 2, Testbed 3) and their respective edge, fog, and cloud nodes (e.g., IoT devices, satellite nodes, and cloud nodes). It manages the lifecycle of applications, ensuring they are deployed to the appropriate computational resources based on their requirements. Furthermore, a GRAFANA dashboard is integrated to provide comprehensive system health monitoring.

To support this deployment process, the project provides an Application Repository, which is a private Docker image registry that serves as a centralized storage for the containerized version of all applications developed for the open calls. Developers interact with a Development Dashboard (a private GitHub repository) and an integrated CI/CD pipeline, powered by tools like GitHub Actions. This pipeline enables automated testing and containerization of applications, ensuring they are properly packaged and validated before being uploaded to the central applications repository. All data generated and processed within the testbeds is centrally stored in a Central Data Storage system, ensuring data persistence and accessibility.

Final users, primarily agricultural producers, interact with the system via a Customer Portal. Through this portal, they can request the deployment of specific applications and directly visualize the resulting data output. Furthermore, the AGRARIAN ADSS provides these users with actionable insights derived from the aggregated data from all testbeds, supporting informed decision-making.

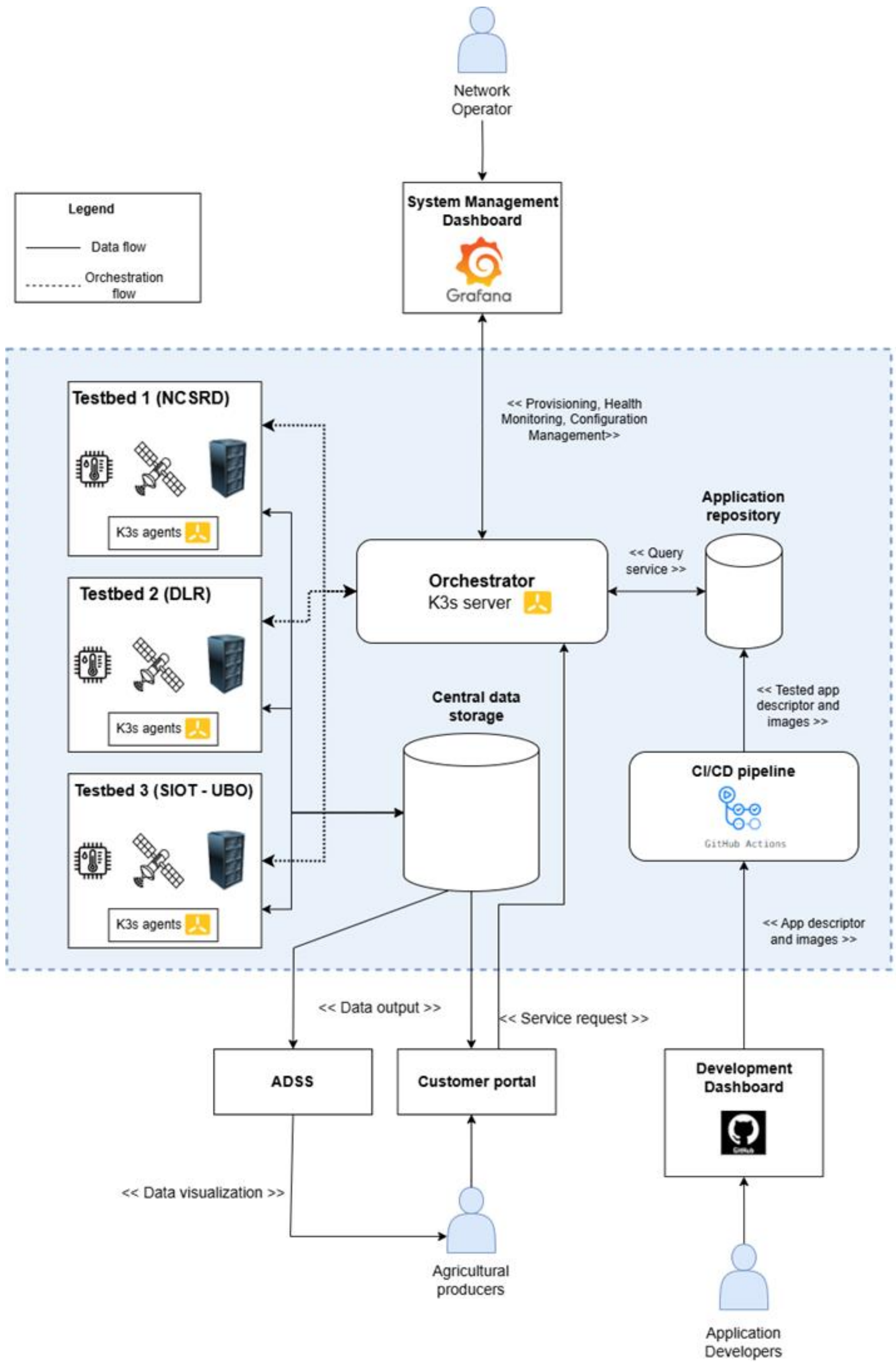

Figure 5: AGRAIRAN distributed architecture

3.2 Data Storage

3.2.1 System Overview

The agricultural data storage system is a modular, extensible database architecture designed to integrate diverse datasets originating from multiple agricultural applications. Built on PostgreSQL, this schema accommodates structured information ranging from weather data, crop development, pest monitoring, soil characteristics, and satellite readings, to metadata such as measurement units and sensor types. It supports interoperability and future scalability, making it possible to incorporate new data types like emerging crop varieties or sensor parameters without overhauling the core model. The database is an essential component of a broader ecosystem used by the ADSS, which consumes this structured data for advanced analytics and decision support across the agricultural industry.

3.2.2 Purpose and Usage

This data storage system underpins the ADSS by acting as a central repository that consolidates historical, biological, and environmental data needed for precision agriculture. ADSS accesses this repository via a REST API, enabling seamless integration and interaction with the stored data. Through this API, ADSS performs data normalization, querying, aiding in real-time decision-making for farming operations. Developers of agricultural applications, such as pest alert systems or weather forecasting tools, can build their own services on top of this schema. These services feed their outputs into the database through an API interface, allowing ADSS to use cross-application data insights to drive intelligent decision-making. For example, an AI-based pest prediction tool can store its predictions in the system, which ADSS can later combine with weather and soil data for deeper insights.

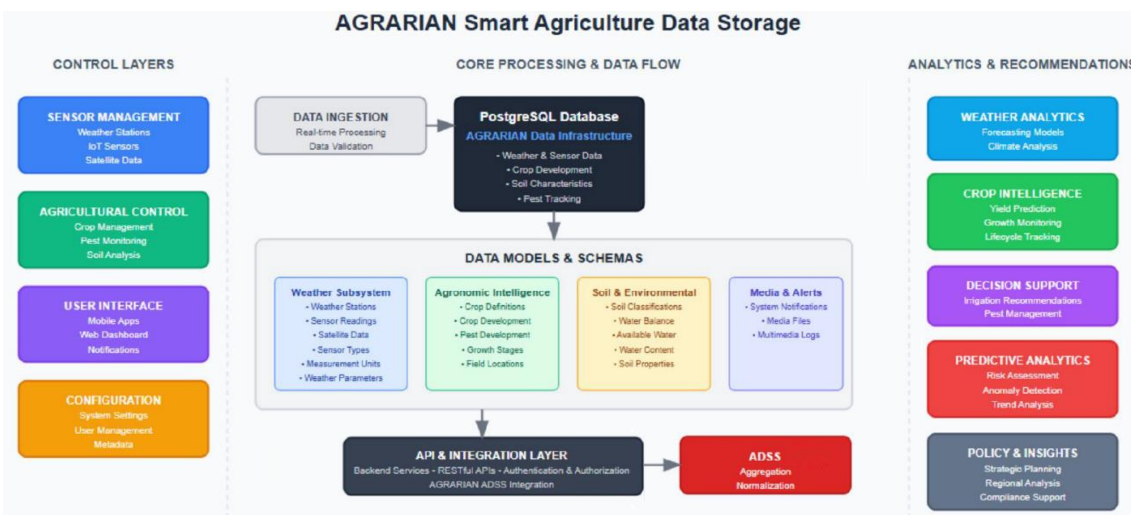

Figure 6: AGRARIAN Data Storage

3.2.3 Developer Collaboration and Data Integration

To enable this ecosystem, developers will be contacted and engaged directly to identify the specific types of data their applications generate or require. They will be asked to provide standardized datasets aligned with the database schema to ensure compatibility and integrity. These contributions are critical for ADSS to perform comprehensive analysis, as it relies on data sourced from various applications to operate effectively. The schema's modularity not only ensures ease of integration for current applications but also supports the seamless addition of new services in the future. This collaborative, schema-driven approach facilitates a agricultural data infrastructure that empowers data-driven agricultural decision-making.

3.3 Agricultural Design Support System (ADSS)

To address the connectivity and monitoring challenges faced by remote and rural areas, ADSS integrates advanced modules like Coverage Planning, Terrain Analysis and Remote Localization. These capabilities allow it to dynamically adjust its strategies based on geographical and infrastructural conditions, ensuring accurate data delivery and real-time monitoring.

At the core of its privacy-preserving design is edge processing, which allows data to be processed and secured locally, in compliance with GDPR regulations. This decentralized model enhances both security and responsiveness.

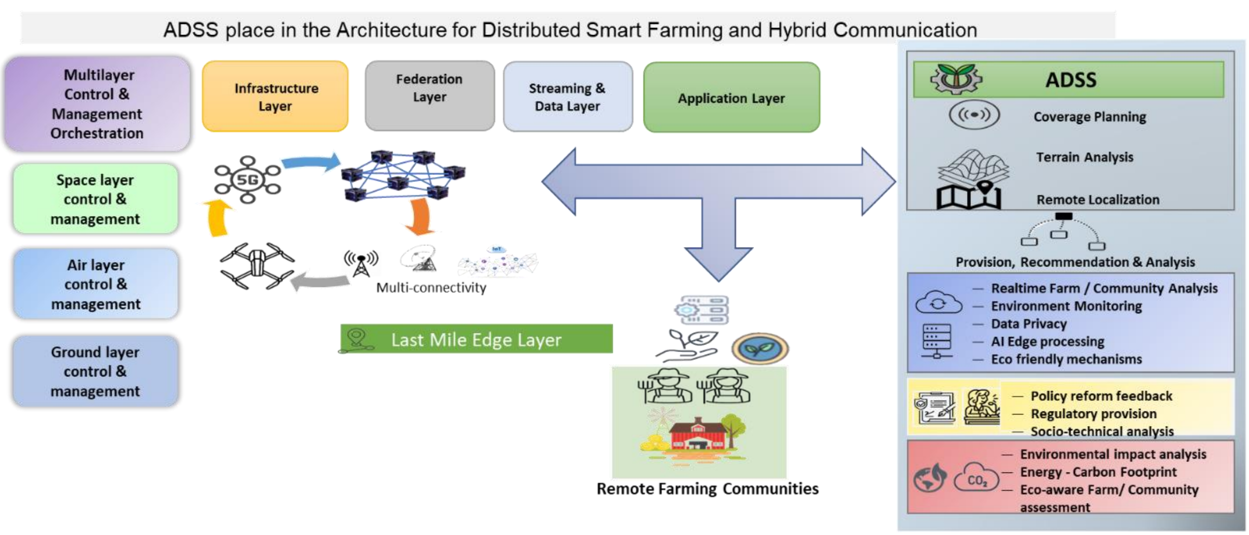

Figure 7 ADSS in the context of Smart Farming

ADSS further supports inclusive and environmentally responsible development by enabling local stakeholders to act on real-time insights. Through scalable, sustainable interventions, the platform contributes to reducing digital exclusion and driving progress aligned with long-term regional needs.

AGRARIAN's ADSS platform redefines digital innovation in agriculture by placing farmers and rural communities at the heart of technology design and decision-making. Built on a multidisciplinary, multi-stakeholder approach, the system ensures that real-world needs drive technical development, resulting in resilient, inclusive, and policy-aligned solutions. Rather than imposing technology, ADSS empowers end users to shape it according to their context.

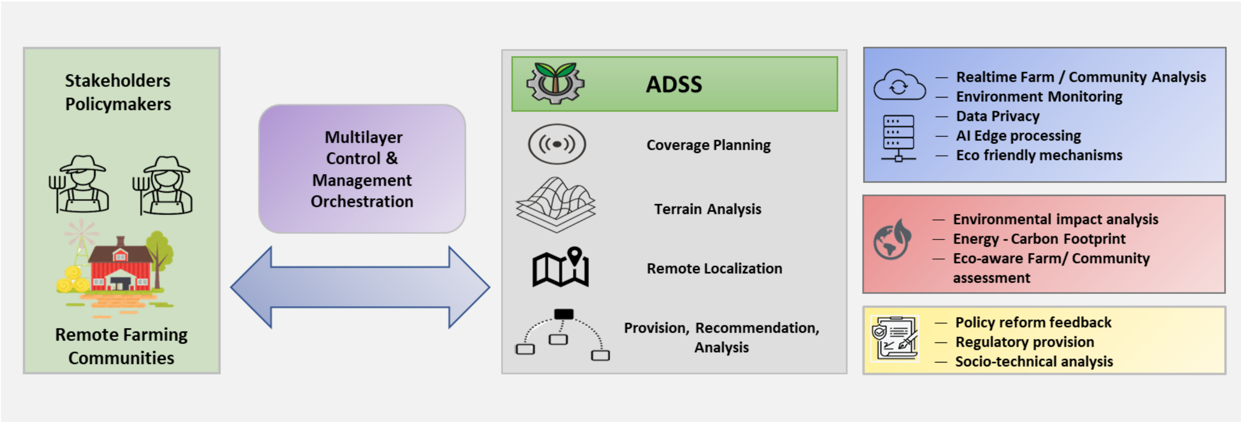

Figure 8: ADSS role in digital innovation for agriculture

The ADSS platform integrates a REST service through which it retrieves pre-processed information available from specialized databases (e.g., sensor measurements, weather forecasts, event notifications, images, and video streams). This data undergoes a final stage of intelligent manipulation and filtering at the platform level, aimed at optimizing relevance and accuracy.

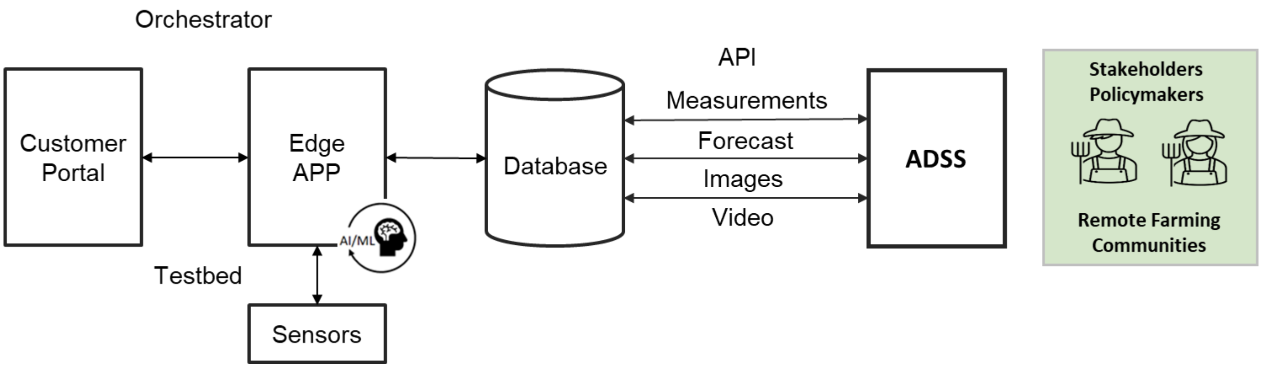

Figure 9: ADSS and AGRARIAN Data Storage (Database)

Subsequently, the information is displayed within a flexible and interactive graphical interface, designed to support real-time decision-making. The platform also provides automatically generated suggestions based on contextual analysis and integrated predictive models, thus enhancing the decision-making process from the end-user's perspective.