



**Alliance for
Internet of Things
Innovation**

IoT data marketplaces for the agri-food sector: a first look to use cases for smart farming and across the food chain

AIOTI WGo6 – Smart Farming and Food Security

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1. Introduction and motivation

Recent years have seen an increasing interest in the use of digital technologies as tools to contribute to the wide sustainability of the agri-food sector. Precision/smart farming, Agriculture 4.0, and the like, are concepts no longer attached to academic research but they have been making their way through the market and the real life of farmers during the past years. Smart farming techniques are being successfully applied in areas like optimization in the use of resources (water, fertilizers, pesticides...), monitoring of animal health and wellbeing, and decision making. Together with the increasing robotization of farming labour, they are having a positive impact in productivity and environmental footprint, in line with the Sustainable Development Goals (SDG)¹ and climate change strategies.²

In addition, digital technologies play a strong role in enabling food traceability throughout the whole food chain addressing food safety, fraud prevention, compliance with certifications and regulations, etc.

At the heart of this digitally-enabled revolution in the agri-food sector it is the data, which comes from multiple sources: remote sensing platforms, weather forecasting services, raw material market prices... and especially from the Internet of Things (IoT) gathering data directly from the field and the farm through sensing devices and connected machines (tractors, their implements, and smaller agri-robots). This new paradigm paves the way also to new data-driven business models for agriculture,³ and kickstarts the interest in data sharing⁴ mechanisms that can fully exploit the value of data for the benefit of the agri-food sector.

Interestingly, the agri-food sector in Europe has been probably the first industrial sector to devise a framework focused in data sharing, releasing the "*EU code of conduct on agricultural data sharing by contractual agreement*".⁵ Such code of conduct basically reflects the agreement of the main stakeholders on the principles that should regulate agricultural data sharing, building trust for the farming sector from the very beginning.

Despite the novelty of the data sharing trend in agri-food, a few private and public-private partnership initiatives of certain relevance are already established, like API-AGRO⁶ in France, DjustConnect ⁷ in Belgium, Join Data⁸ in the Netherlands, DKE agrirouter ⁹ in Germany and Agrimetrics¹⁰ in the UK. More recently, the European Agriculture Machinery industry released its strategy¹¹ for achieving the full roll-out of data sharing in the next years, building upon the code of conduct. Such strategy puts the focus on technology as the means for delivering the necessary trust and tools.

¹ <https://sustainabledevelopment.un.org/>

² https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

³ <https://ec.europa.eu/eip/agriculture/en/content/eip-agri-seminar-data-revolution-final-report>

⁴ <https://ec.europa.eu/eip/agriculture/en/publications/eip-agri-workshop-data-sharing-final-report>

⁵ https://copa-cogeca.eu/img/user/files/EU%20CODE/EU_Code_2018_web_version.pdf

⁶ <https://api-agro.eu/en/>

⁷ <https://djustconnect.be>

⁸ <https://www.join-data.nl/?lang=en>

⁹ <https://my-agrirouter.com/en/>

¹⁰ <https://agrimetrics.co.uk/>

¹¹ https://www.cema-agri.org/images/publications/press_releases/2020-02-05CEMA_Press_Release_Strategy_Agricultural_Machinery_Data-Sharing.pdf

The present AIOTI document also aims to provide more light on proper architectures and technologies for implementing data sharing frameworks (and more specifically, data marketplaces) suitable to agri-food applications, building on previous AIOTI work on distributed IoT data marketplaces.

The rest of this document is structured as follows:

- Section 2 provides a short description of a high-level generic architecture for IoT data marketplaces
- Section 3 analyses the application of the proposed high-level architecture to different agri-food use cases.
- Section 4 provides preliminary conclusions and recommendations

2. A high-level architecture for distributed IoT-enabled data marketplaces

Figure 1 shows the High-Level Architecture¹² proposed in a previous AIOTI paper, hereinafter the “AIOTI HLA”.

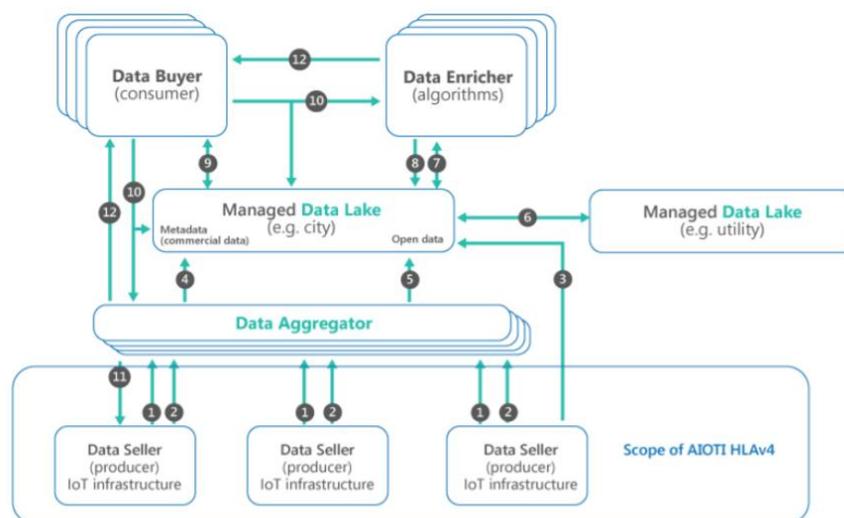


Figure 1: AIOTI high-level architecture for IoT-enabled data marketplaces

For the sake of completeness, a brief explanation about the elements featured in the figure is provided here, although a more detailed description can be found in the original AIOTI paper.

1. **Data Sellers** are entities deploying IoT infrastructures which generate data. These data sellers are interested in collecting data, either for self-exploitation or exploitation by others.
2. **Data Aggregators** are entities that aggregate data streams from different sources, merging such data streams to create more valuable sources of information, making them available to a Managed Data Lake.

¹² https://aioti.eu/wp-content/uploads/2019/02/IoT-data-market-places-drivers-and-architectures-white-paper-Elloumi-De_Block-Samovicz.pdf

3. **Managed Data Lakes** are entities that typically store a massive amount of data and metadata to enable data discovery and consumption by one or multiple Data Buyers.
4. **Data Enrichers** are entities buying/consuming data with the intention of applying algorithms to enrich data and resell new data sets as a value-added service, typically to provide data analytics yielding new insights and predictions.
5. **Data Buyers** consuming data streams or downloading data sets are interested in the additional value that external data can bring to their business.

It is important to highlight several aspects of the proposed AIOTI HLA:

1. The Data Lakes **do not store private or commercial data, which remain under control of the Data Sellers**. Instead, Data Lakes only store metadata and open data. Metadata would provide a semantic description of the data as well as the terms of contractual agreements governing data transactions. The concept of exposing the metadata in a third party Data Lake is called **mirroring**.
2. **Decentralization and federation**: the proposed reference architecture can be built without need for any central entity, thus providing a great flexibility to the data interaction scheme, and potentially offering a foundation for a fair distribution of revenue streams. The federation is achieved through the mirroring process.
3. **Cross-domain integration**: Managed Data Lakes could also contain mirrors of metadata from other data lakes, paving the way to cross-sectoral data sharing.

Please note that the mechanism for data monetization has not been described. Essentially, after discovery of data of interest to them, the Data Buyers would subscribe to an automated **smart contract** for the agreement (providing automated access to data) and immediate pay-out of the Data Sellers expected price.

3. Distributed data marketplaces in the agri-food domain

The application of the AIOTI HLA depicted in Figure 1 to other domains, such as mobility, has already been discussed.¹³ Here we are interested in discussing the suitability of such HLA to the agri-food domain by considering two specific examples derived from real use cases, which are described in the following.

3.1. Pest management service through the gaiasense™ system

Description of the use case

The gaiasense™ system¹⁴ is a technological solution offering a range of innovative smart farming services that provides next generation advice to farmers. Unlike other solutions, gaiasense is offered as an inexpensive service with zero technological related investment for farmers, making it accessible even to small farmers. The gaiasense system (see Figure 2 below)

¹³ <https://aioti.eu/whitepaper-did-we-just-reach-the-mobility-sector-data-marketplaces-tipping-point/>

¹⁴ <http://www.gaiasense.gr/en>

consists of an infrastructure of IoT devices called *gaiatrons*, a set of cloud computing services called *GAIA Cloud* and smart farming advisory services called *GAIA SmartFarm*.

Gaiatrons are telemetric autonomous stations which collect data from sensors installed in the field and record atmospheric (air temperature, relative moisture, wind direction and velocity, rain, leaf wetness) and soil parameters (temperature, moisture) and control irrigation systems. Gaiatrons are specially designed for providing exact fit to the operational requirements of *gaiasense*. Dense installation network under the canopy, large-scale deployment, low operation cost and mobility are some of these operational requirements in order for *gaiasense* to be viable and commercially successful.

GAIA Cloud combines the data collected from *gaiatrons* with data from other sources (i.e. weather forecast services and satellite images) and converts them into facts using advanced data analytic techniques. The embedded Decision Support System (DSS) transforms facts into an initial advice, which is accessible to farmers through the apps and certified agricultural advisors, which are employed by GAIA Sense business partners. The advisors are reviewing and evaluating the given information for providing the final advice and support to the farmers.

The advising and supporting services that are provided by the combination of the software and certified advisors are called *GAIA SmartFarm*, which currently provides Fertilization and Irrigation advice, as well as Pest Management/Hazard warnings.

Currently there are 26 pilot sites, in six EU countries, of *gaiasense* covering >60.000 ha and 17 different crops, offering SF services to 15.000 Farmers. The *gaiasense* technical components and services are also being validated and enhanced in the context of the significant innovation projects H2020 DataBio (www.databio.eu), H2020 SmartAgriHubs, H2020 IoF2020 and LIFE GAIA Sense.¹⁵

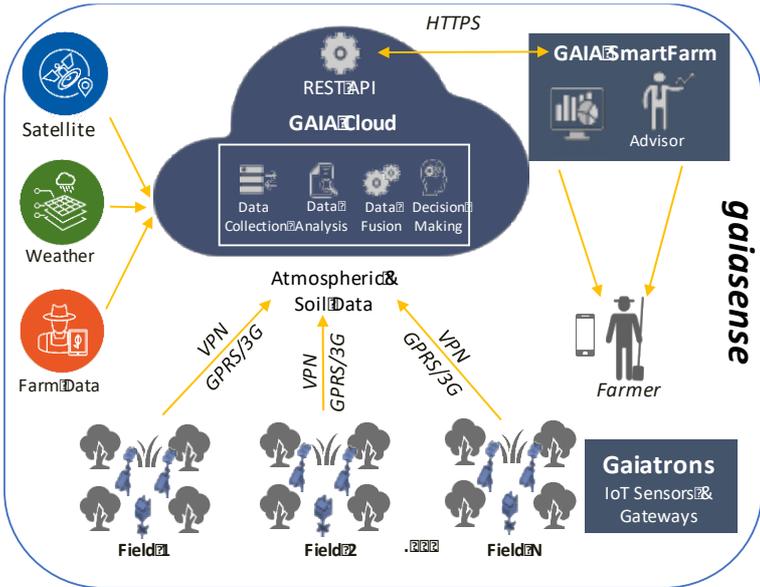


Figure 2: a deployment view of the *gaiasense*TM solution

¹⁵ www.lifegaiasense.eu

The giasense pest alert system

One of the core objectives of the giasense SF system is the accurate prediction of potential pest infestations and the provision of the respective advice to farmers. These predictions are based on scientific models that are expressed as computational algorithms and coded as self-contained plug and play software module components, which allow data input/output through harmonized APIs, and can be combined as needed. For example, pest management models accept as input a predefined set of data (e.g. current and historic environmental data, plants' phenological stages, history of past pest infestations) and produces risk limits (%) for each target disease and/or insect flights. Figure 3 illustrates in a conceptual manner the parallel utilization of different pest and disease estimation models along with the flow of information from the deployed sensors to the farmer.

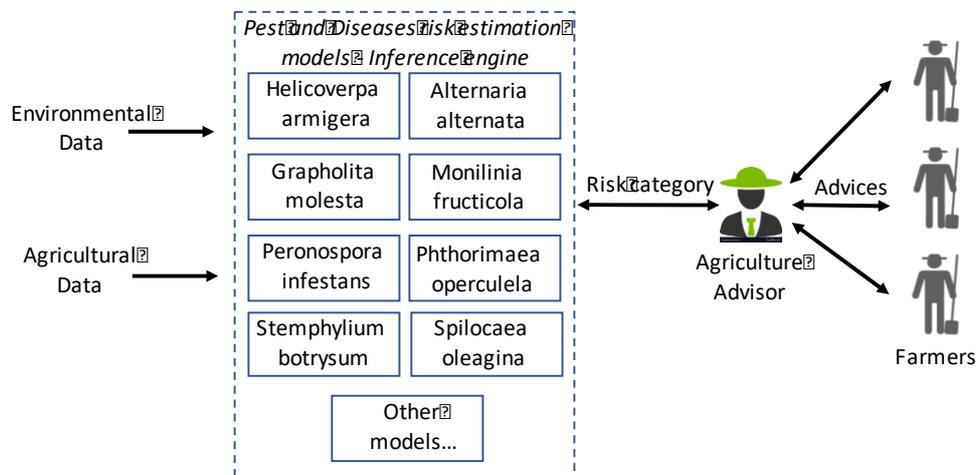


Figure 3: integration of pest management scientific models and conceptual flow of information

Adaptation to the high-level architecture

One of the future objectives for the giasense smart farming system is to be interoperable with 3rd party services. To this end, data collected by the giasense IoT sensors network will be processed by pest forecasting scientific models that potentially can be provided by external entities. Based on the AIOTI high-level architecture (see Section 2), Figure 4 provides a high-level overview of the information flow among the key entities.

- **Data Seller:** the IoT infrastructure of the giasense SF system
- **Data Aggregator:** the cloud infrastructure of the giasense SF system
- **Managed Data Lake:**
 - a) A data hub/marketplace supporting the discovery of data utilised for the provision of agricultural related services (e.g. Regional agricultural authorities)
 - b) A data hub/marketplace supporting the discovery of data utilised for the provision of weather forecasting related services
- **Data Enrichers:** entities providing pest and diseases forecasting algorithms
- **Data Buyers:** Advisors, Cooperative(s), Farmer(s)

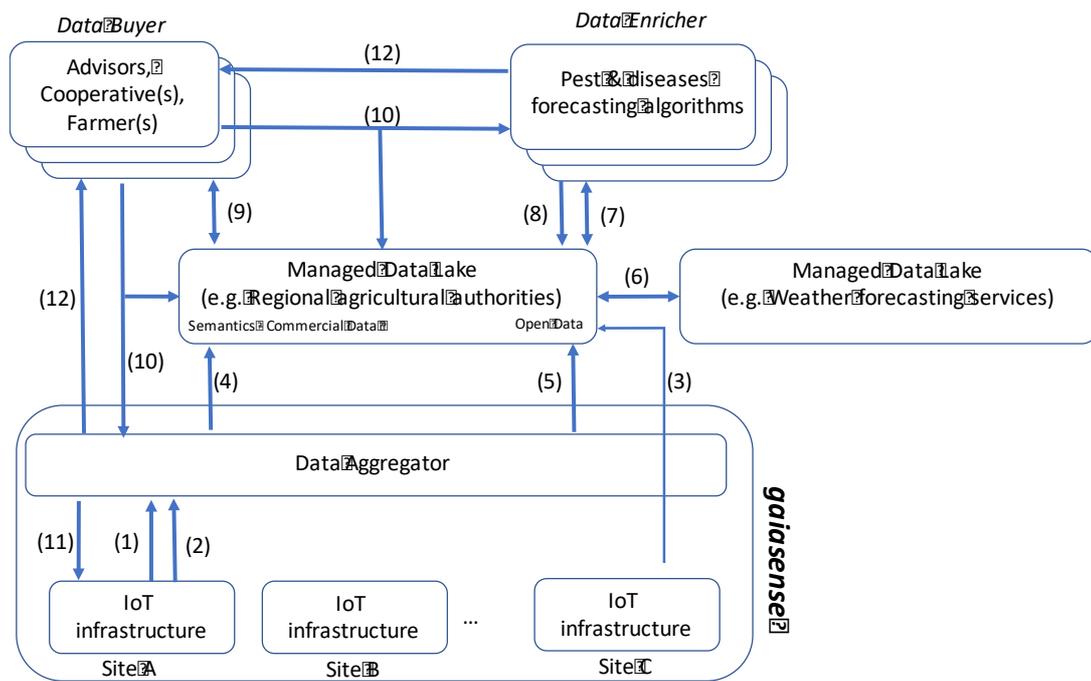


Figure 4: high-level architecture and information flow for an IoT data marketplace in support of pest management services provision

3.2 Livestock traceability through the food chain

Description of the use case

Consumers lost trust in brands, and are expecting transparency and labels with evidences instead. F2Fmarket.tech¹⁶ enables food producers to provide these evidences throughout the full food chain, i.e. from farm to fork.

F2Fmarket is a "Farm-to-Fork" supply chain implementation enabling transparency between producers and consumers, currently implemented on livestock (beef) in France. The collected livestock data comes from the IoT Infrastructure, feeding robots and surveillance systems, besides files input from transporters and laboratory results on nutrition and meat quality. Besides these available data, a specific focus lays also on the evidences around the animal well fare during its lifespan of in average 18 months. Surveillance systems, sensor data, interpreted and enriched by external algorithms are timestamped on a distributed ledger to prove that an animal was not attached and often running free outside.

Adaptation to the high-level architecture

The F2Fmarket.tech implementation fully embraces the concepts as described in the AIOTI HLA (see Section 2). Secondary, the F2Fmarket ecosystem is used as an important case study around interoperability between different data lakes with similar business models based on 'revenue splits' and co-creation empowered by Distributed Ledger Technologies.

¹⁶ <http://www.f2fmarket.tech/>

Figure 5 and the description below shows the mapping between the F2Fmarket.tech main components and the AIOTI HLA.

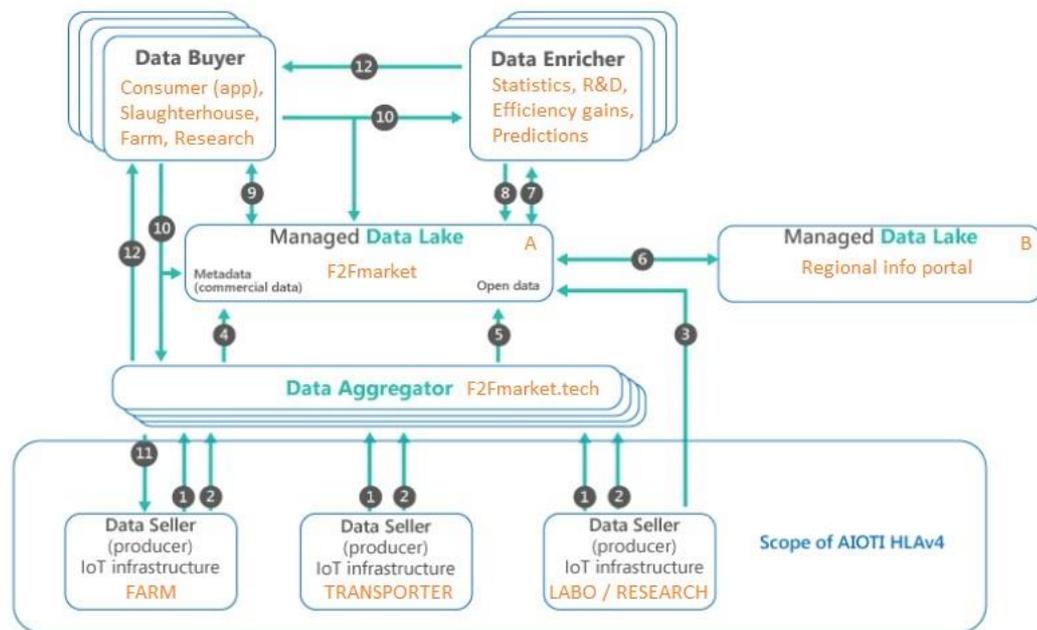


Figure 5: high-level overview of the information flow among the different stakeholders in F2Fmarket.tech

- **Data Seller:** the IoT infrastructure of farms and transporters, besides file systems of slaughterhouses and labos.
- **Data Aggregator:** integrated within the cloud infrastructure of F2Fmarket.tech
- **Managed Data Lake:**
 - A data hub/marketplace supporting the discovery of data utilized for the provision of the F2Fmarket consumer portal and services around the supply chain
 - A data hub/marketplace supporting the discovery of data utilized to optimize operations and improve internal processes (e.g. efficiency gains, cost reductions)
- **Data Enrichers:** entities providing tools to enable interpretation on raw datasets
- **Data Buyers:** farm, use-case stakeholders, consumer organizations, F2Fmarket (app)

The first data lake depicted in Figure 5 (A) was implemented on open source Ethereum, with case study to be fully interoperable with a second data lake (B) implementation based on Hyperledger. To this end, F2Fmarket.tech uses data mirroring based on metadata standard and virtually creates a single (data) market.

3.3 Data sharing in the dairy sector through DjustConnect™ platform

Description of the use case

The EU dairy sector is the second biggest agricultural sector in the EU, representing more than 12 % of total agricultural output. Most of the milk produced is delivered to dairies for further

processing, and around 12 000 processing plants are employing 300.000 people in the EU. A significant characteristic of the dairy sector is that predominantly organized in cooperatives, which hold a 55 % market share and are active in almost every part of the food supply chain. These cooperatives¹⁷ can be as large as world-leading multinational companies or as small as SMEs or micro-enterprises, they are strong competitors on the dairy market, and they provide their members with market access and bargaining power. Milk price volatility, the specialized sector structure, climate change, unfair trading practices, and new consumer and society requirements are significant challenges of the EU dairy sector and especially the EU milk farmers. The latest need to deal with some time irreconcilable problems. Significant price variations, together with weak bargaining power, making it difficult to run a sustainable business, especially when a farm has planned investments based on higher average milk prices. It is consensus accepted that the EU dairy sector must become more resilient and sustainable. From an economic point of view, it is necessary to lower production costs to improve competitiveness, while also increasing the financial resilience of dairy farms confronted with high price volatility and market uncertainty. At the same time, the dairy sector must be more efficient in the use of natural resources such as water and feed and do more to control the environmental impact of breeding activities (reducing greenhouse gas emissions, water pollution, etc.)¹⁸.

DjustConnect platform launched officially in 2019, and the initial aim of this public-private partnership (PPP) data-sharing initiative led by ILVO (www.ilvo.vlaanderen.be), is to support the dairy sector to increase the economic resilience of farms and to provide the ability to the milk farmers to participate as data originator¹¹ (or owner) and provider^{Error! Marcador no definido.} (or seller) in an API economy. At the end of February 2020, the platform demonstrated their abilities throughout a real-world use case where several governmental organizations and dairy companies act as data producers and consumers. The beneficiary of the new services (<https://ikmnet.be>) is more than 4000 farmers. Those can make use of the services built on top to reduce the Food Safety and Integrated Chain Monitoring (ICM) related administration burden and to participate in the Data Economy without losing their ability to control their data (Code of Conduct in Agricultural data sharing). Meanwhile DjustConnect is deploying in other sectors, outside dairy, by supporting new use cases and applications.

DjustConnect platform

DjustConnect is a public cloud platform for data sharing, exchange, and re-use that aims to provide a trusted and innovative data and services ecosystem for the AgriFood Industry and the farmers. This primary business objective is supporting by the provision of a set of data sharing and application integration services. The data sharing services are following the IDSA Reference Architecture Model. Actors can make use of the DjustConnect services: to aggregate and publish data resources, to define and store resources metadata, to authorize access and provide consent under conditions, to monitoring data transactions, and to enrich the data using hybrid integration patterns.

Both data sharing and application integration services, leverage open source and native cloud services to deliver to the AgriFood community, a digital transformation toolbox that can be used immediately and without investment cost by the actors for the development of digital products and services (API Economy for revenue generation).

¹⁷ Dairy cooperatives are a specific form of producer organisation (PO) often engaging in processing activities. POs are encouraged and supported by the CAP, and governed by the CMO Regulation.

¹⁸ The EU dairy sector: Main features, challenges and prospects
[https://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI\(2018\)630345](https://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI(2018)630345)

The latest becomes possible because DjustConnect leverage the Azure EiPaaS3 and IoT abilities, including API Management, Logic Apps, Service Bus, Event Grid, and Data Factory. The components mentioned above support the development of a decentralized data model, allowing real-time access to up to date information and the federation of data resources as exist in multiple cloud or/and premise systems (cloud-cloud, cloud to/from on-premises).

Adaptation to the high-level architecture

The DjustConnect implementation fully embraces the concepts as described in the AIOTI HLA (see Section 2). The architecture model of DjustConnect, supported by platform APIs, can give the ability to actors perform different roles and deliver their own data sharing services like identity, broker service or vocabulary provider. DjustConnect collaborates with other platforms to increase data sharing service interoperability supporting this way the development of EU AgriFood data space. Through its adaptation to the HLA DjustConnect enables "cross-platform" and "cross-domain" data processing business services creating a high potential for a sustainable business model.

Figure 5 and the description below shows the mapping between the DjustConnect main components and the AIOTI HLA.

- **Data Seller:** the IoT infrastructure of farms, transporters and milk buyers, together with IT systems of other actors (labs, auditing system etc.).
- **Data Aggregator:** integrated within the cloud infrastructure of DjustConnect.
- **Managed Data Lake:**
 - A data hub/marketplace supporting the discovery of data utilized for the provision of the DjustConnect consumer portal and services around the AgriFood/dairy sector.
 - A data hub/marketplace supporting the discovery of data utilized to optimize operations and improve internal processes (e.g. ontological services)
- **Data Enrichers:** entities providing tools to enable the generation of smart data.
- **Data Buyers:** Farm Advisors, Governmental organizations define policy, application providers like IKM.NET.

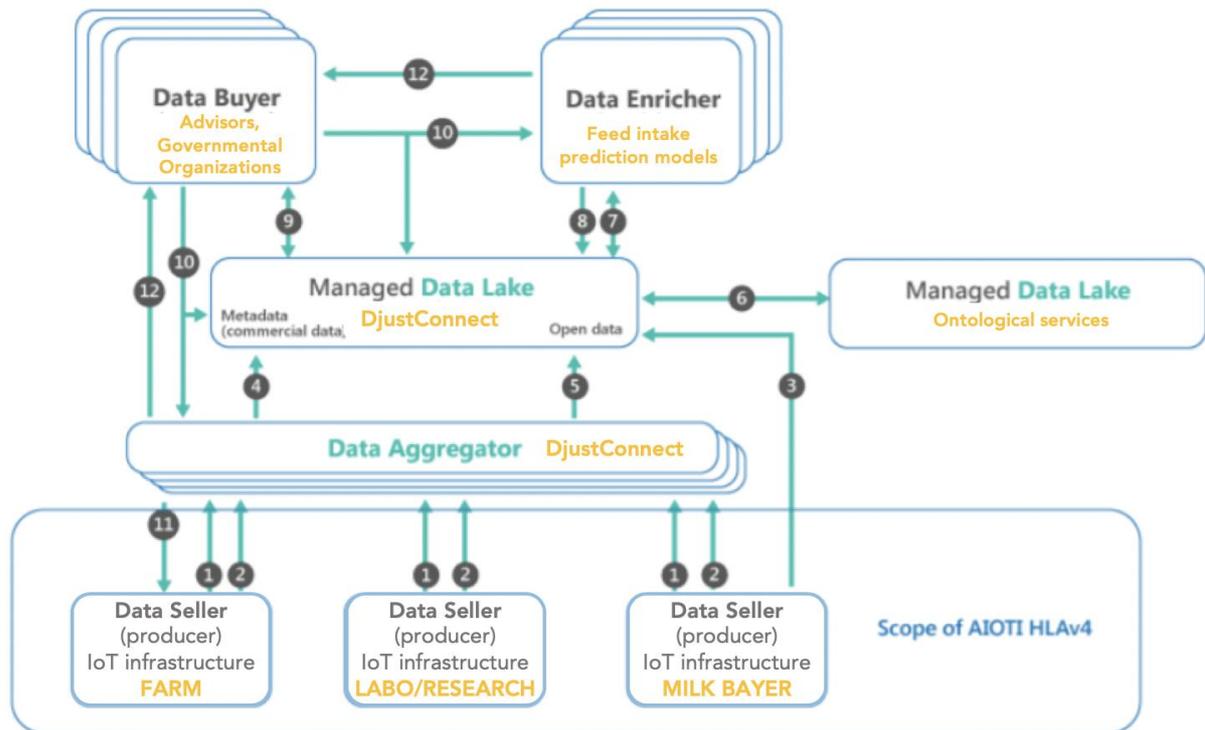


Figure 6: high-level architecture and information flow for an IoT data marketplace in DjustConnect™

4. Conclusions and recommendations

The three examples analysed in Section 3 show that relevant use cases in the agri-food sector can be fitted within the high-level data sharing architecture described in Section 2.

- The case of the pest prediction system shows how a decentralized data sharing scheme can support the creation of an open, data-driven smart farming ecosystem. In the analysed example, one of the benefits would come from the enlargement of the number of external entities (data enrichers) that can provide new added-value services over the data.
- The 'F2F' traceability system is a paradigmatic example of a use case involving multiple stakeholders across the food supply chain that can mutually benefit from a transparent yet accountable data sharing scheme.
- The DjustConnect initiative shows that a digital implementation of the code of conduct is possible allowing various actors in the AgriFood community, can collaborate digitally, providing to all the opportunity to participate in the development of a regional and domain specific (AgriFood) data space with full respect for the farmer as data originator.

In all cases, the distributed nature of the data sharing architecture is an essential feature that empowers the data seller/owner to keep his/her relevant data private and under control as needed.

Furthermore, looking at the three examples described in Section 3 it is easy to imagine the **cross-domain** interest of some stakeholders within the F2F ecosystem to consume AgriFood datasets coming from synergy of platforms, enriched them further and deliver to consumers useful info related to Food Safety and Quality. For instance, make available to the consumers trusted information related to the use and the correct application of pesticides, the use of antibiotics and medicines, the hygiene score of cows and stables or the water re-use in milking machines.

Data sharing schemes will likely become essential elements for supporting the “Farm to Fork EU strategy for food sustainability” which is currently under preparation.¹⁹ Issues like provenance of food, environmental footprint associated to food production (e.g. greenhouse emissions, use of pesticides and fertilisers, use of irrigation...), or data related to animal welfare and health (for instance use of antibiotics) will benefit from distributed data sharing schemes like the ones presented in this document, provided that the trust component is properly embedded in the system.

There are further aspects that should be examined.

1. In relation to the **EU code of conduct on agricultural data sharing**

The EU code of conduct on agricultural data sharing identified a set of requirements that must be fulfilled by data sharing transactions in order to enable an adequate trust level. Namely:

- a. Need for and agreement/contract in place
- b. Definition of obligations for the parties : warranties and indemnities.
- c. Clarify which data is collected
- d. Clarify which services are delivered
- e. Clarify purpose(s) for the use of the data
- f. Clarify whether and under what conditions data is shared with other parties
- g. Clarify possibility of unilateral change of agreement terms
- h. Possibility to opt out the service and have own data revoked
- i. Confidentiality terms

In distributed data marketplaces like the ones described in this paper, those requirements must be fulfilled by technical means. It would be necessary to study up to what extent **smart contracts** (the mechanism envisaged in the AIOTI HLA) would suffice to comply with those requirements, and which additional/other security elements would be needed to provide full trust in the system.

Other potentially open questions include the interoperability (including proper metadata standards), and specially mechanisms for **data monetization**.

2. In relation to the **common EU agriculture data space**

The European data strategy²⁰ acknowledges the essential role to be played by data in the development of all sectors of economy and society. This European approach will be both cross-sectoral and specific for strategic sectors, including agriculture. In particular,

¹⁹ https://ec.europa.eu/food/farm2fork_en

²⁰ <https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy>

the strategy indicates that *"data is one key element to enhance the sustainability performance and competitiveness of the agricultural sector"*.

It should be studied how the distributed data sharing architectures can fulfill the requirements for the EU agriculture data space, some of which are already advanced in the aforementioned strategy document:

- a. It should support **precision/smart farming approaches at farm level, by combining** the processing and analysis of food production data with other data on the supply chain and other types of data, such as earth observation or meteorological data.
 - b. It should be a **neutral platform** for sharing and pooling agricultural data, including both private and public data
 - c. It should support **monitoring** and **implementation** of common agriculture policies
 - d. It should help **reducing administrative burden** for government and beneficiaries
 - e. It should support the emergence of **data-driven ecosystems** based on **fair contractual relations**.
3. In relation to the **governance structure** of data sharing initiatives
- a. It should be studied whether the assignment of roles that are crucial for the overall functioning in the governance system of a data space to "neutral actors" can be an element to deliver increased trust in data sharing initiatives and accelerate the adoption of data sharing best practices in AgriFood.

List of contributors

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About AIOTI

AIOTI is the multi-stakeholder platform for stimulating IoT Innovation in Europe, bringing together small and large companies, start-ups and scale-ups, academia, policy makers and end-users and representatives of society in an end-to-end approach. We work with partners in a global context. We strive to leverage, share and promote best practices in the IoT ecosystems, be a one-stop point of information on all relevant aspects of IoT Innovation to its members while proactively addressing key issues and roadblocks for economic growth, acceptance and adoption of IoT Innovation in society.

AIOTI's contribution goes beyond technology and addresses horizontal elements across application domains, such as matchmaking and stimulating cooperation in IoT ecosystems, creating joint research roadmaps, driving convergence of standards and interoperability and defining policies. We also put them in practice in vertical application domains with societal and economic relevance.

AIOTI is a partner for the European Commission on IoT policies and stimulus programs, helping to identifying and removing obstacles and fast learning, deployment and replication of IoT Innovation in Real Scale Experimentation in Europe from a global perspective.

AIOTI is a member driven organisation with equal rights for all members, striving for a well-balanced representation from all stakeholders in IoT and recognizing the different needs and capabilities. Our members believe that we are the most relevant platform for connecting to the European IoT Innovation ecosystems in general and the best platform to find partners for Real Scale Experimentation.

AIOTI WGo6 is the key meeting point of EU-based stakeholders interested in developing and exploiting the benefits of IoT (technologies, ecosystem and infrastructure) in the domains of farming for food production and food safety, from farm to fork. The scope of the working group encompasses precision farming (IoT devices, data management tools and issues) applied to multiple farming modalities, food traceability and safety, considering the business, policy and societal dimensions.