Supervision and monitoring of agricultural autonomous robots: from design to implementation

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Plan

- CONTEXT
- OUR NEW ARCHITECTURE
- CONCLUSION AND FUTURE WORK

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Context

- Sandro Bimonte et al.: **On Designing and Implementing Agro-ecology IoT Applications: Issues from Applied Research Projects**. EDOC Workshops 2021: 204-209

Context

- Agro-ecology aims to develop new cultural practices that respect the environment and at the same time save production and biodiversity
- Agro-ecological system: need a comprehensive approach where versatile types of data can be integrated and analyzed in multiple spatiotemporal dimensions
- Data used by agro-ecology models are very diverse
  - environmental, agricultural, and socio-economic data
  - at different (micro and macro) spatial and temporal scales
  - also coming from mobile autonomous robots and drones

- Smart Farming adopt and implement new advances in information technology (e.g. Internet of Things, Big Data frameworks, computer vision, artificial intelligence)

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Context

- Recently, the Internet of Things (IoT) has received much attention in several application domains, such as:
  - Smart buildings and living, healthcare, environment, transport and mobility, energy, manufacturing, and also agriculture and agroecology

- Autonomous agricultural robots are unmanned ground vehicles equipped with sensors and actuators and capable of safely and autonomously performing one or more tasks while moving in a plot following a predefined trajectory
- Robots have an essential role to play for agro-ecology
  - they allow precise technical tasks
  - reduce environmental impacts

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Agricultural robots supervision

- This work is based on the French ISITE CAP2025 Superob project

- Goal of the project: develop and deploy an architecture for scheduling and monitoring field works of autonomous mobile robots used in agroecology practices

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LambdAgrIoT: a new architecture for robots supervision

- Geraldine André et al.: **LambdAgrIoT - A New Architecture for Agricultural Autonomous Robots' Scheduling: from Design to Experiments**. Cluster Computing Journal, 2022
- Bruno Bachelet et al.: **Towards an Architecture for Online Scheduling of Autonomous Robots in Agriculture: Open Issues**. International Journal of Smart Vehicles and Smart Transportation, 4(2), 2021
- https://youtu.be/hSt35G82rv4

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Motivation

- Many research works address smart farming

- but none has contributed with a fully featured architecture design for Robots monitoring and scheduling

=> We present a detailed analysis of requirements for real-life scheduling autonomous agricultural robots systems

⇒We propose the skeleton of an architecture for scheduling autonomous agricultural robots

  - based on the Lambda architecture

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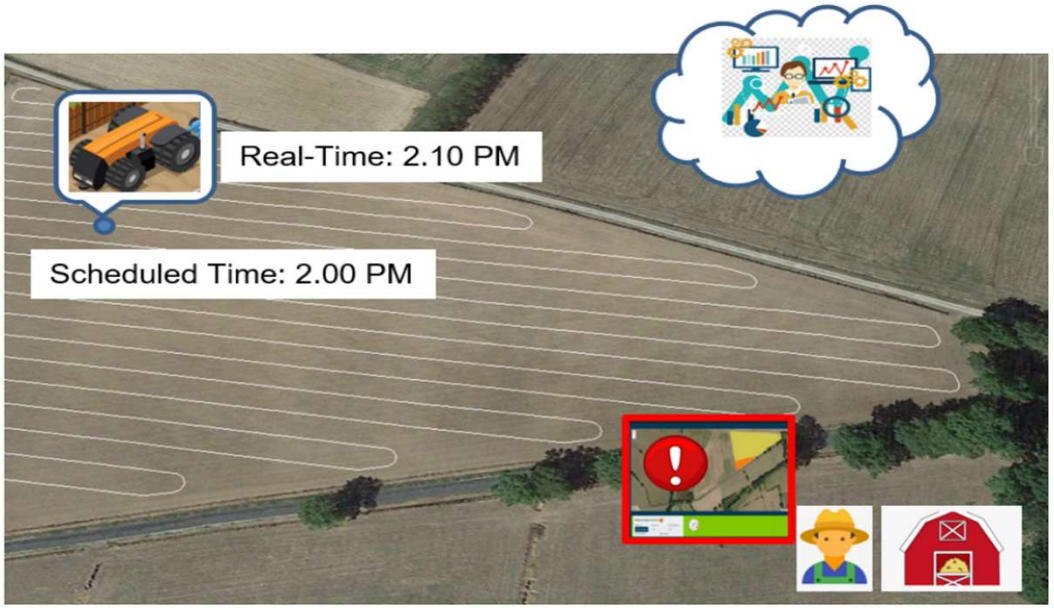
Requirements

- Monitoring of autonomous agricultural robots is made according to:
  - the compatibility of a robot and its equipment with an agricultural task to be done
  - the temporal availability of a robot and its associated equipment
  - the compatibility of meteorological conditions with an agricultural task

Requirements

- An online re-scheduling computation service that must be executed to find out (whenever possible) the best alternative trajectory
  1. Robot fault
  2. Delay alert
  3. Meteorological alert



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Requirements

- Data:
  - complex spatio-temporal
  - stream
  - historical
  - Big Data

- Queries:
  - Analytical queries
  - Continuous queries
  - (CRUD) queries

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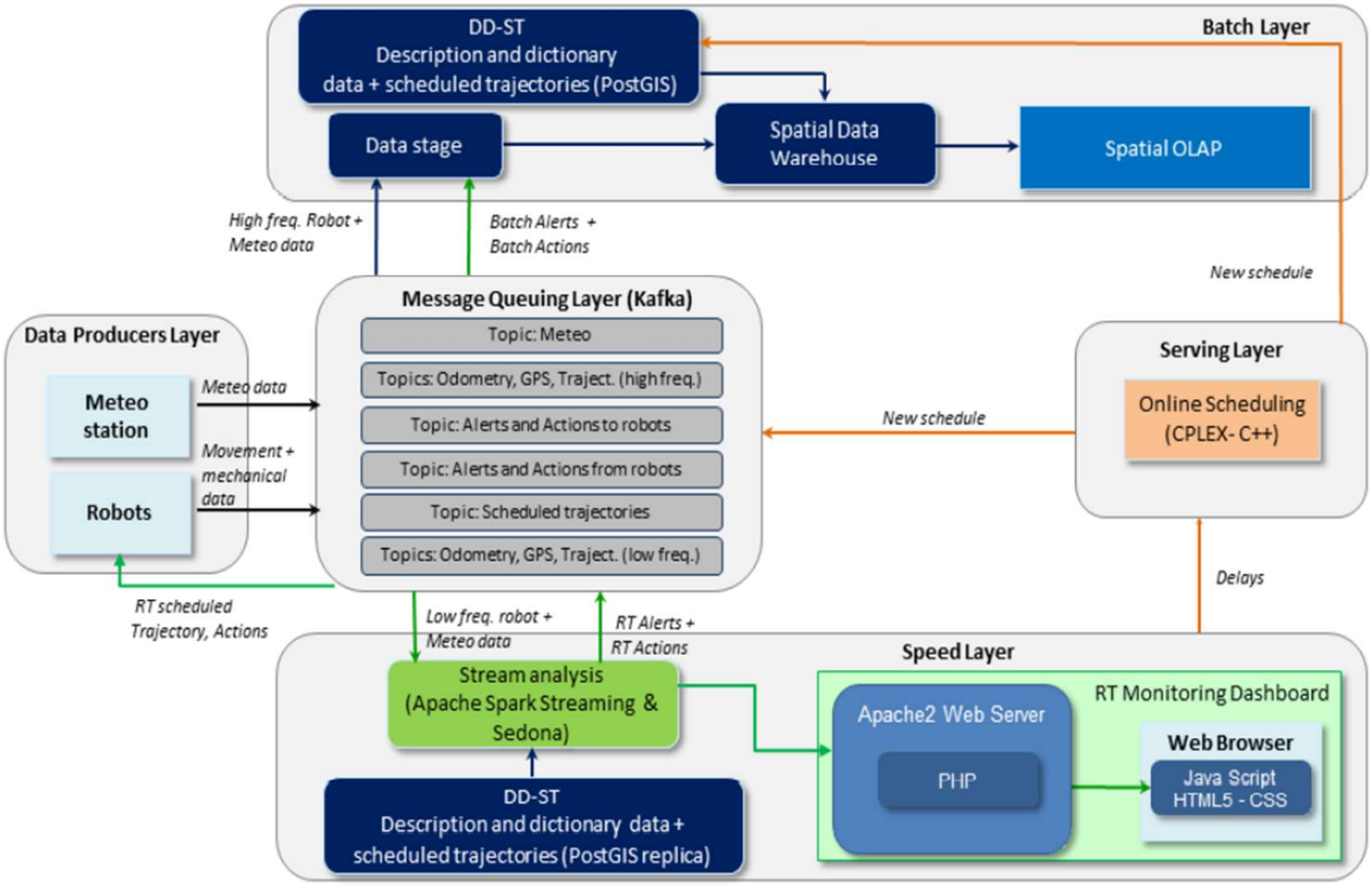
Requirements

- Rural network:
  - Robots <-> Cloud
    - Access Network

LambdAgrIoT

LambdAgrIoT is composed of five layers



LambdAgrIoT

- Data producers layer: represents data sources deployed in the field, i.e., robots and meteorological stations
  - They produce data that are sent to the Message queuing layer
- Message queuing layer: is in charge of managing data (messages) that are exchanged by different layers
  - Robots also receive data from this layer
- Speed analysis layer: provides tools for analyses of data in a real time
  - The layer is deployed in each farm
- Serving layer: supports scheduling robots and their tasks
- Batch analysis layer: centralizes all data from all farms and it supports the management and the analysis of historical data

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LambdAgrIoT

- Speed analysis layer: provides tools for analyses of data in a real time
  - The Stream Analysis module consumes data streams produced by data producers (robots, weather station), and published in specific Kafka topics
  - The analysis of data streams allows:
    - (1) tracking work progress in real time (calculate delays if any)
    - (2) signaling alerts and recommending corrective actions.
  - we use Apache Spark and Apache Spark Streaming
    - In order to handle spatial data and spatial operators we use Apache Sedona

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LambdAgrIoT

- Speed analysis layer: provides tools for analyses of data in a real time
  - Description and Dictionary data, and Scheduled Trajectories (DD-ST) is a transactional spatial database that aims to store data used by the system
  - It is deployed on top of PostgreSQL relational database, implementing the PostGIS spatial extension

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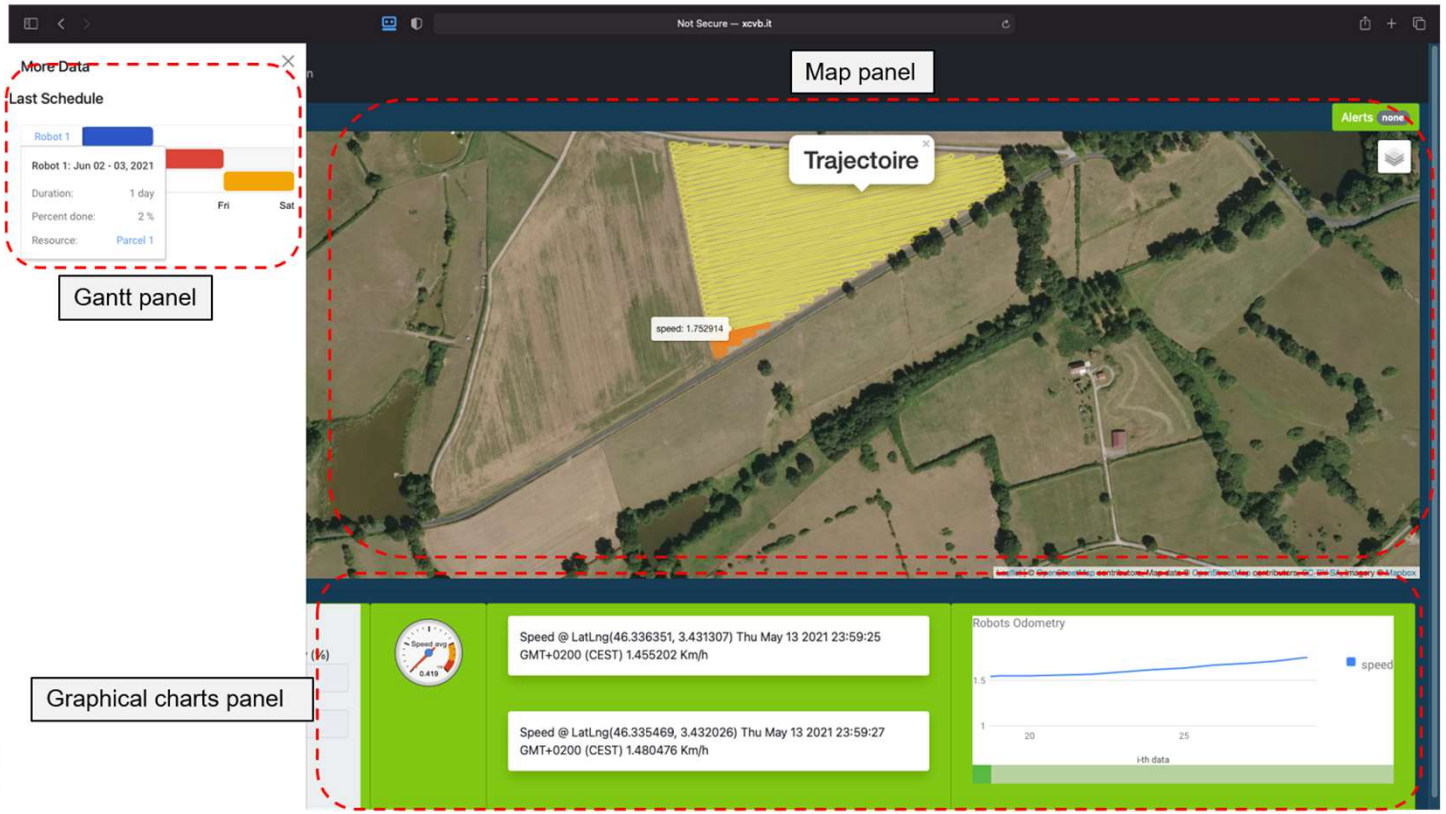
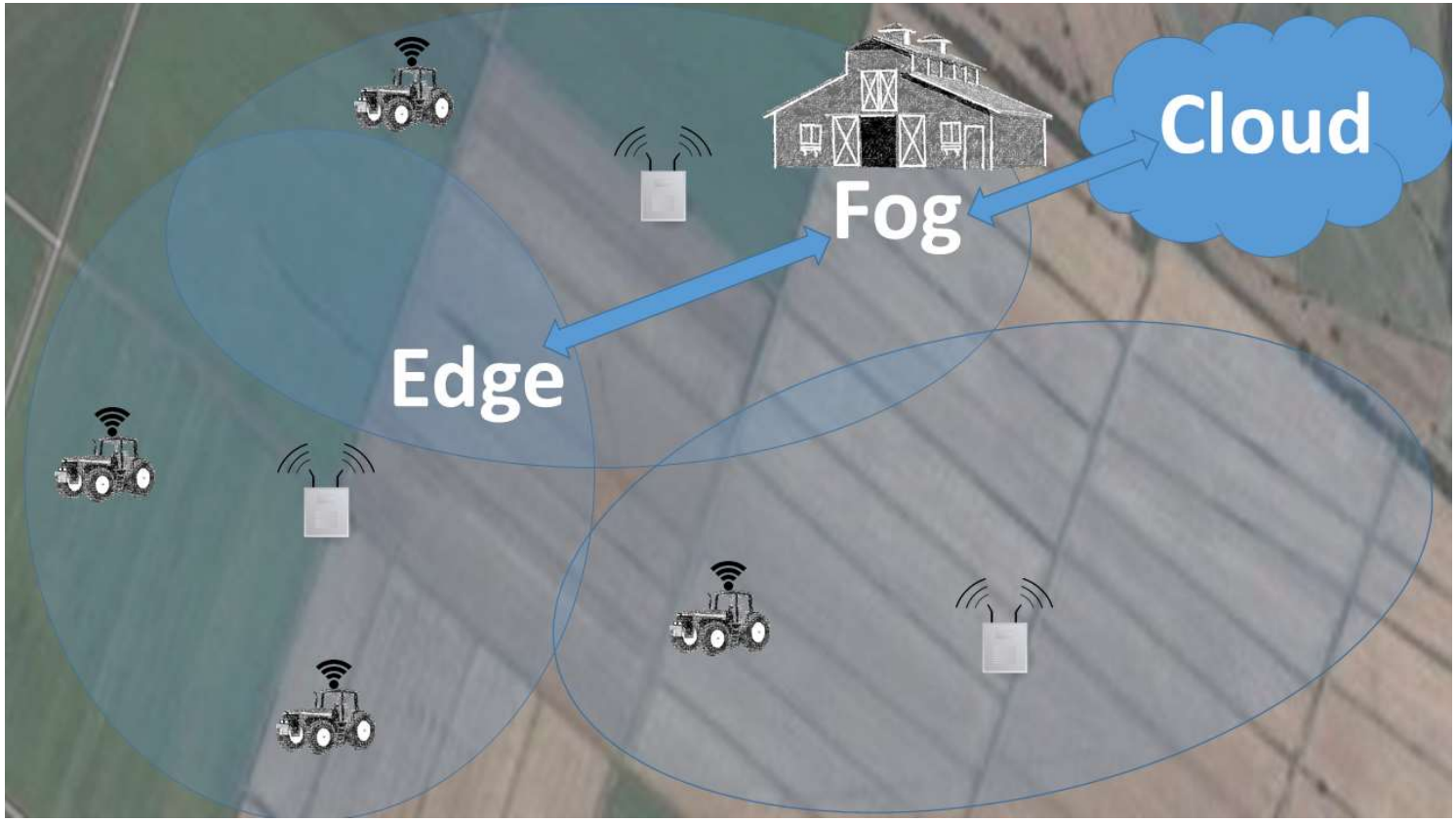
LambdAgrIoT

- Speed analysis layer: provides tools for analyses of data in a real time
  - RT Monitoring Dashboard Module is used to analyze and visualize data computed in the Stream analysis module



LambdAgrIoT

- **Edge, Fog, Cloud architecture**



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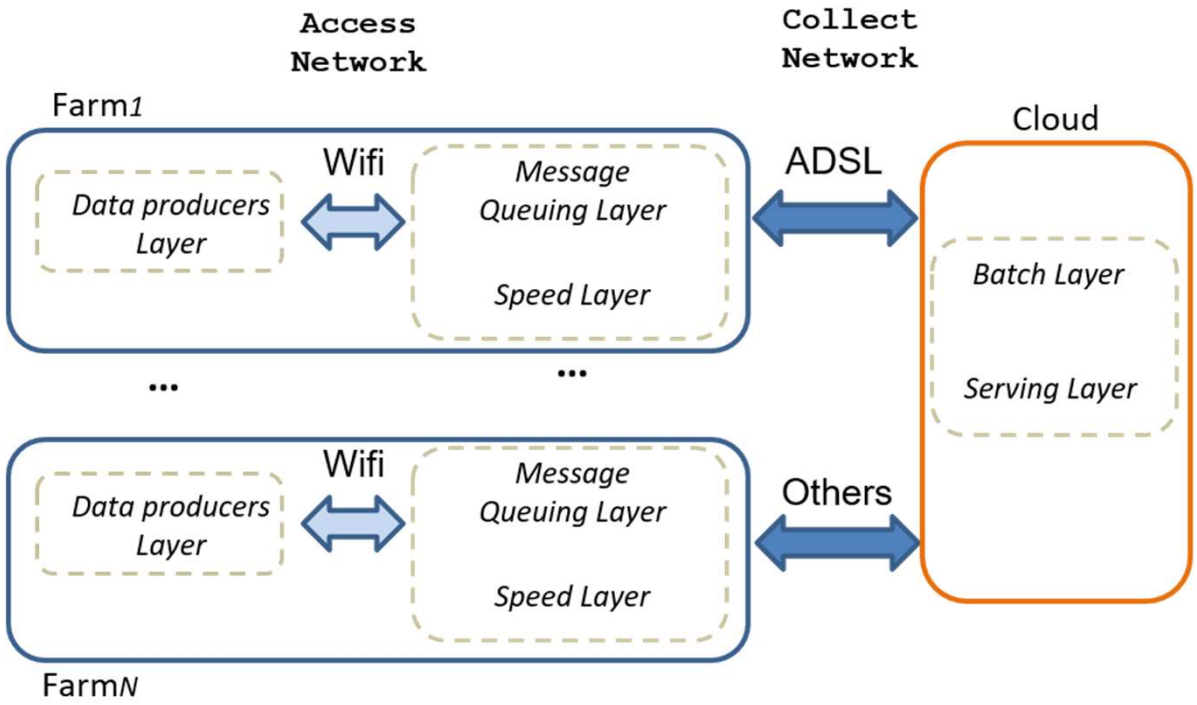
LambdAgrIoT

- **Edge, Fog, Cloud architecture**



Conclusion and Future work

Conclusion

- Agro-ecology aims to develop new cultural practices that respect the environment and at the same time save production and biodiversity
- Data used by agro-ecology models are very diverse
  - environmental, agricultural, and socio-economic data
  - at different (micro and macro) spatial and temporal scales
  - also coming from:
    - IoT
    - Autonomous robots

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Conclusion

- Monitoring and Online Scheduling of autonomous agriculture robots needs ad-hoc Data & Network architecture No work addresses these issues
- We propose the LambdAgrIoT architecture
  - Based on the Lambda architecture

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Future work

- How to make automatic implementation of our UML profiles?
- How to define some implementation guidelines for multi-model data warehouse?
- How to make the LamdAgrIoT architecture resilient and adaptive?
- Move towards large scale real life tests

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Thanks for your attention

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Open source code is here

https://www6.inrae.fr/tools4bi/

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