



Universidade do Minho
Escola de Engenharia

 instituto de
telecomunicações

Internet of Everything 2025/2026

 DOCTORAL PROGRAMME
IN COMPUTER SCIENCE


COMPUTER
COMMUNICATIONS
AND NETWORKS



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IoE – TEAM

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- Computer Communications and Networks (CCN) Group

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- Aveiro Telecommunications and Networking Group (ATNoG)



Universidade do Minho
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universidade
de aveiro



IoE - Goals

- At the end of the course, each student should be able to:
 - Understand the different architectures for Internet of Everything (IoE) systems.
 - Explain the characteristics, costs, benefits, and threats of the different technologies available for perceiving data from the environment and acting in this same environment, considering security aspects.
 - Understand how data flows in IoE systems to perceive, analyze, visualize, and act in the environment and the associated security services.
 - Explain the characteristics and support the different protocols offer for communication between the components of an IoE system.
 - Understand the software components used in the layers of IoE systems
 - Have a vision of the application of IoE in different verticals and the associated business models

IoE - Syllabus

1. Internet of Everything (IoE): Definition, History, Perspectives and Architecture

1. Internet of Everything (IoE)
definition, history and
perspectives
2. IoE applications
3. Reference model and system
architectures for IoE

2. Perception and Communication Layer

1. Sensors, Actuators and Devices
2. Communication protocols
between sensors and devices;
devices and gateway; gateway
and Internet
3. Security Aspects
4. Opportunities and Challenges

3. Processing Layer

1. Middleware
2. Edge, Fog and Cloud
Computing
3. Big Data
4. Data Analysis
5. Web Visualization
6. Security Aspects
7. Opportunities and Challenges

4. Application Layer

1. Vertical applications
2. Integrations
3. Security aspects
4. Business models
5. Opportunities and Challenges

IoE - Evaluation

- SoTA Report (50%)
 - Group with three persons
 - Medical; Industrial; Energy
 - Report should focus the several layers
 - Sustainability; Security; Digital Divide: from societal and technical perspective
 - Challenges and Opportunities
- Hands-on Work (50%)
 - Teamwork
 - Using hardware/software platforms
 - Practical view of layers (perception; communication, processing; visualization)
 - Final Report and presentation

IoE - Evaluation

- SoTA Report (50%)
 - Group with three persons
 - Focus on key areas
 - Challenges and Opportunities
- Hands-on Work (50%)
 - Teamwork
 - Using hardware/software platforms
 - Practical view of layers (perception; communication, processing; visualization)
 - Final Report and presentation

IoE - Bibliography

- Perry Lea. *“Internet of Things for Architects: Architecting IoT solutions by implementing sensors, communication infrastructure, edge computing, analytics, and security”*, ISBN-13: 978-1788470599, 2018
- Kamlesh Lakhwani, Hemant Kumar, Joseph Kofi Wireko. *“Internet of Things (IoT): Principles, Paradigms and Applications of IoT”*, ISBN-13: 978-9389423365, 2020.
- X. Kong, Y. Wu, H. Wang, and F. Xia, “Edge Computing for Internet of Everything: A Survey,” *IEEE Internet Things J.*, vol. 9, no. 23, pp. 23472–23485, Dec. 2022 - <https://doi.org/10.1109/JIOT.2022.3200431>
- D. J. Langley, J. van Doorn, I. C. L. Ng, S. Stieglitz, A. Lazovik, and A. Boonstra, “The Internet of Everything: Smart things and their impact on business models,” *J. Bus. Res.*, vol. 122, pp. 853–863, Jan. 2021 - <https://doi.org/10.1016/j.jbusres.2019.12.035>
- W. Z. Khan, W. Rafique, N. Haider, S. Hakak, and M. Imran, *“Internet of Everything: Enabling Technologies, Applications, Security and Challenges”*, 2023- <https://doi.org/10.36227/techrxiv.21341796.v1>
- Recent literature about this area proposed during lectures

IoE Planning

• Theoretical and Practical Activities

Planning IoE (MAPI)					
Week	Start	End	Day	Theoretical (T) - Monday	Theoretical Practical (TP) - Monday
1	02/Dec	07/Dec	02	UC presentation, Motivation and Contextualization. Internet of Everything (IoE): Definition, History, Perspectives and Architecture; IoE applications; Reference model and system architectures for IoE	Presentation of available ITAV infrastructure. Initial design of a simple system - sensor/device/gateway data flow Selection of hardware devices Reading about devices; planning how to use them
2	09/Dec	14/Dec	09	Perception and Communication Layer Sensors, Actuators and Devices Communication protocols between sensors and devices; devices and gateway; gateway and Internet	Hands-on work development Sense data using an device (Perception and Communication Layer)
3	16/Dec	21/Dec	16	Perception and Communication Layer: Security Aspects; Opportunities and Challenges	Hands-on work development Connecting the device with the gateway (Perception and Communication Layer)
4	23/Dec	28/Dec	23	Feriado	Feriado
5	30/Dec	04/Jan	30	Feriado	Feriado
6	06/Jan	11/Jan	06	Processing Layer: Middleware; Edge, Fog and Cloud Computing; Big Data; Data Analysis	Hands-on work development Transmit data between gateway and the Internet (Processing Layer)
7	13/Jan	18/Jan	13	Processing Layer: Web Visualization; Security Aspects; Opportunities and Challenges	Hands-on work development Receive, store and visualize data in a remote system on the Internet (Processing Layer)
8	20/Jan	25/Jan	20	Application Layer: Vertical applications; Integrations	Hands-on work development Add other sensors; improve solution
9	27/Jan	01/Feb	27	Application Layer: Security aspects; Business models;	Hands-on work final presentation

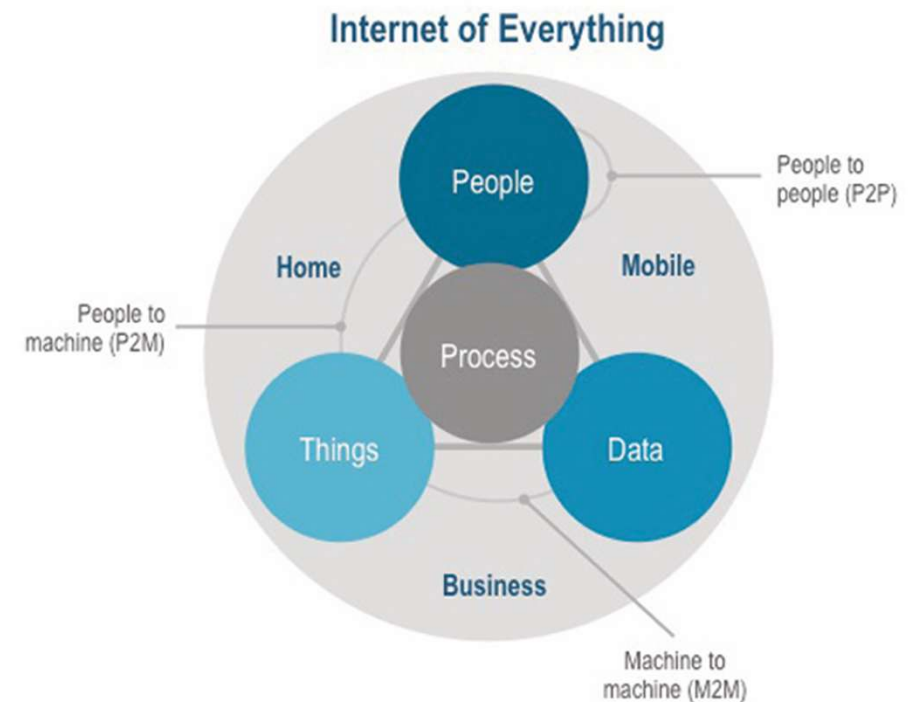
About me

- 1992 – Electrical/Computer Engineering at Federal University of Uberlândia (UFU)
- 1993 – Computer Science (UFU)
- 1992 – Build my own business. CAD/CAE Software Development partnered with AutoDesk
- 2002 a 2004 – Masters in Computing (UFU)
- 2005 a 2010: participation in several software projects on different business domains (UOL, Globo.com, Algar Telecom, VIVO, TIM, Bunge, etc.)
- 2008 – Started at UFU as a Professor
- 2010 a 2013 – Ph.D. in the University of São Paulo
- 2023 – Started at University of Minho (Portugal)
- Until here:
 - 32 years working as professional
 - 18 years in the industry;
 - 16 years in academia;
 - 12 years in international collaboration with Europe in funded projects by public (FP7, H2020, CAPES, CNPQ, FAPEMIG, FAPESP) and private partners (PETROBRAS, NOKIA, BRF, ALGAR TELECOM)
- Research focusing: Future Networks, IoT, Network Softwarization (SDN and NFV), and Future Intelligent Applications and Systems

Internet of Everything (IoE)

- Internet of Things (IoT)
 - Connection of Things (sensors and actuators) to the Internet
- Internet of Everything (IoE)
 - Things, Data, Process and People
 - And beyond...
 - Internet of Industrial Things (IIoT)
 - Internet of Agricultural Things (IoAT)
 - Internet of Vehicles (IoV)
 - Internet of Nano Things (IoNT)
 - Internet of People and Senses (IoPS)

Figure 3. The What, Where, and How of the Internet of Everything.



Source: Cisco IBSG, 2012

[The Internet of Everything How More Relevant and Valuable Connections Will Change the World, 2012](#)

IoE Landscape

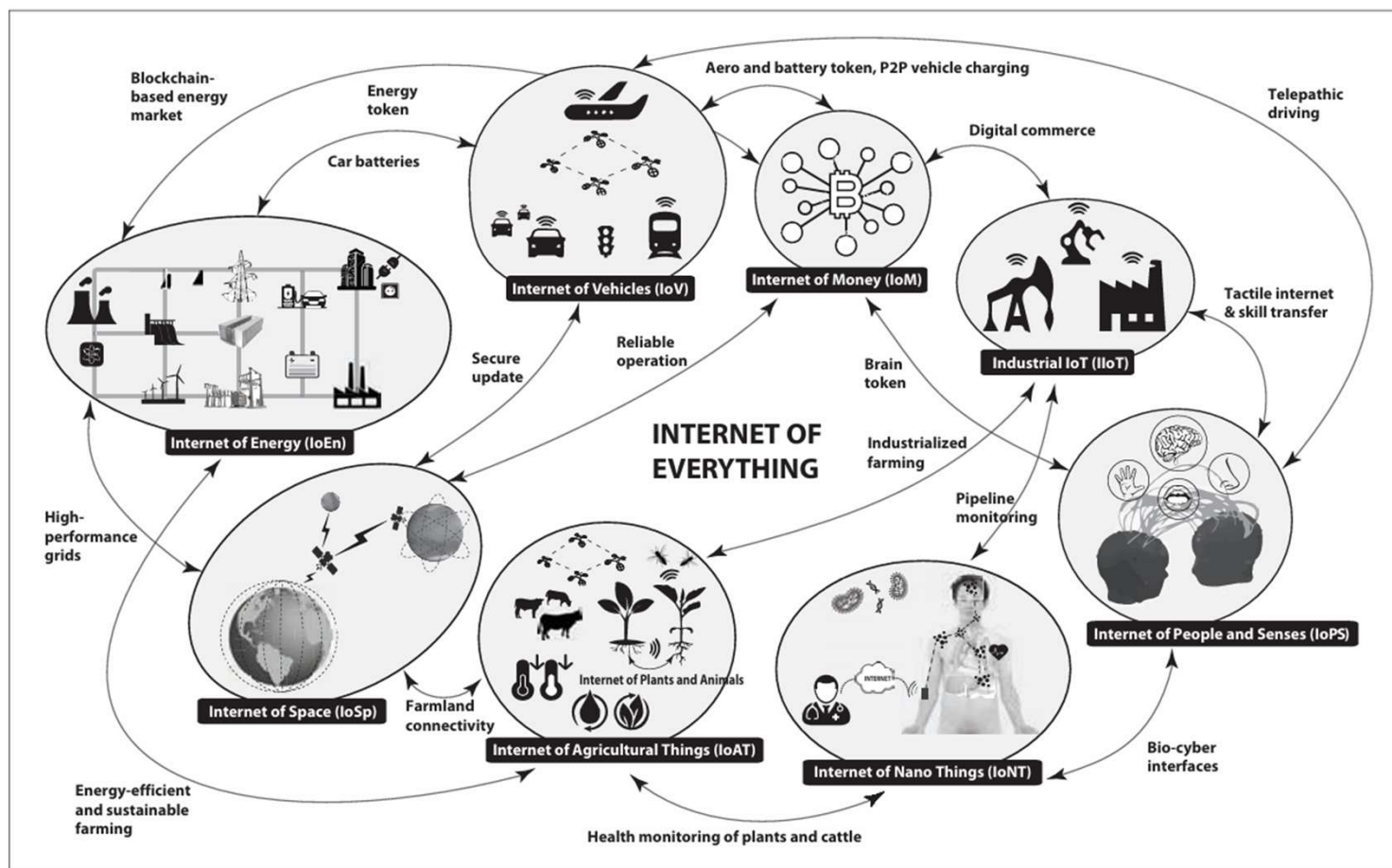
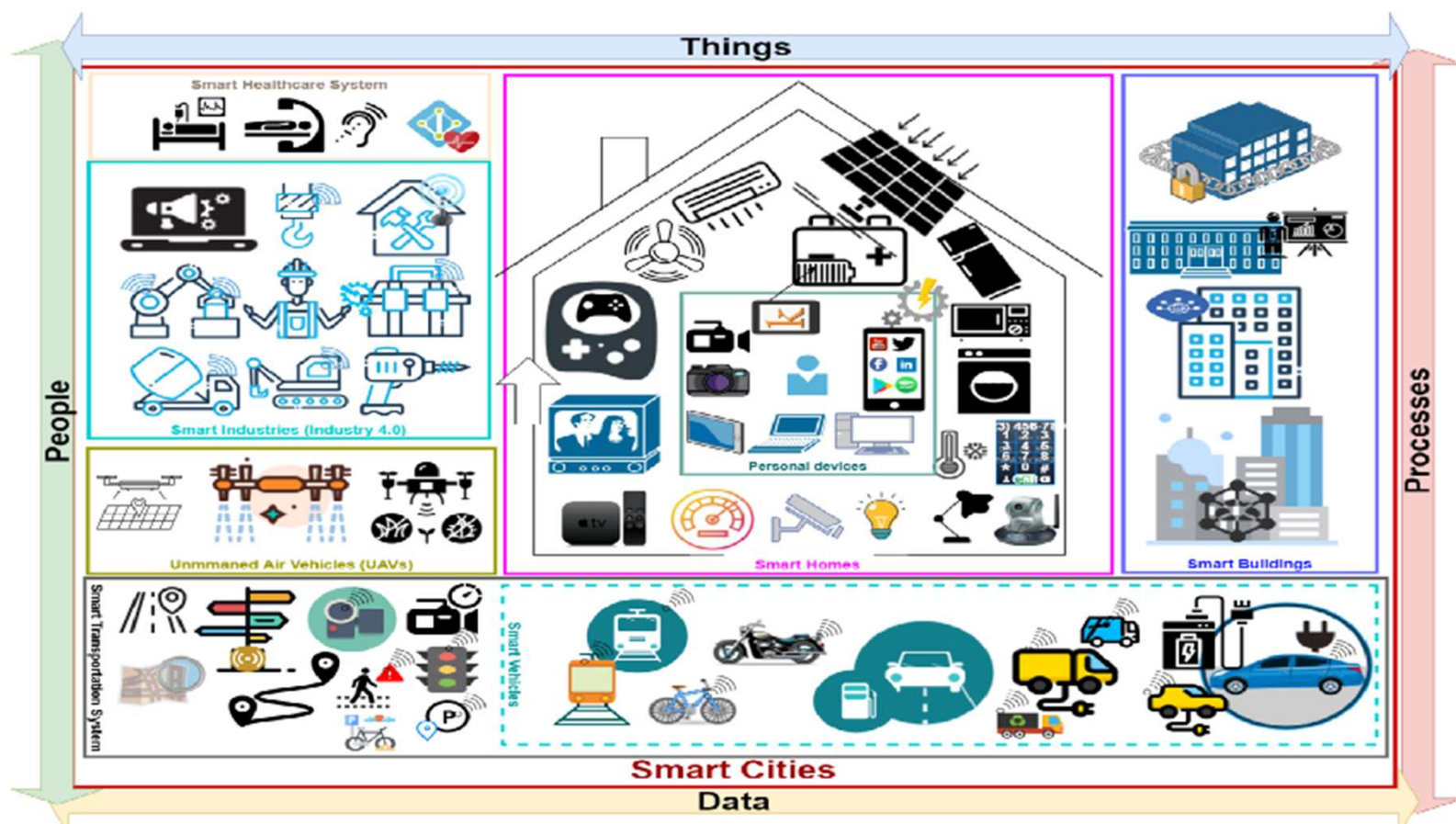


FIGURE 1. The envisioned IoE landscape with example interaction pathways enabled between different IoEs.

[Internet of Everything \(IoE\) — From Molecules to the Universe, 2024](#)

Internet of Everything

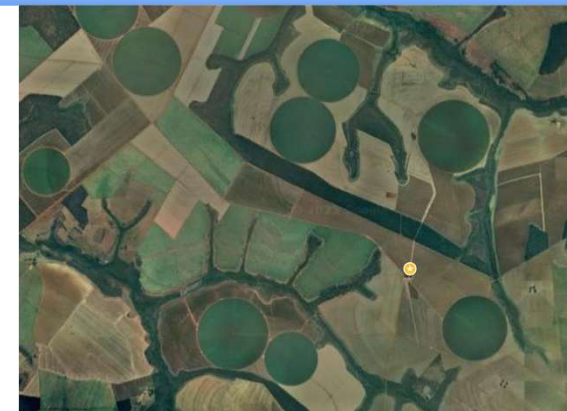
- IoE Ecosystem



[Internet of Everything: Enabling Technologies, Applications, Security and Challenges, 2023](#)

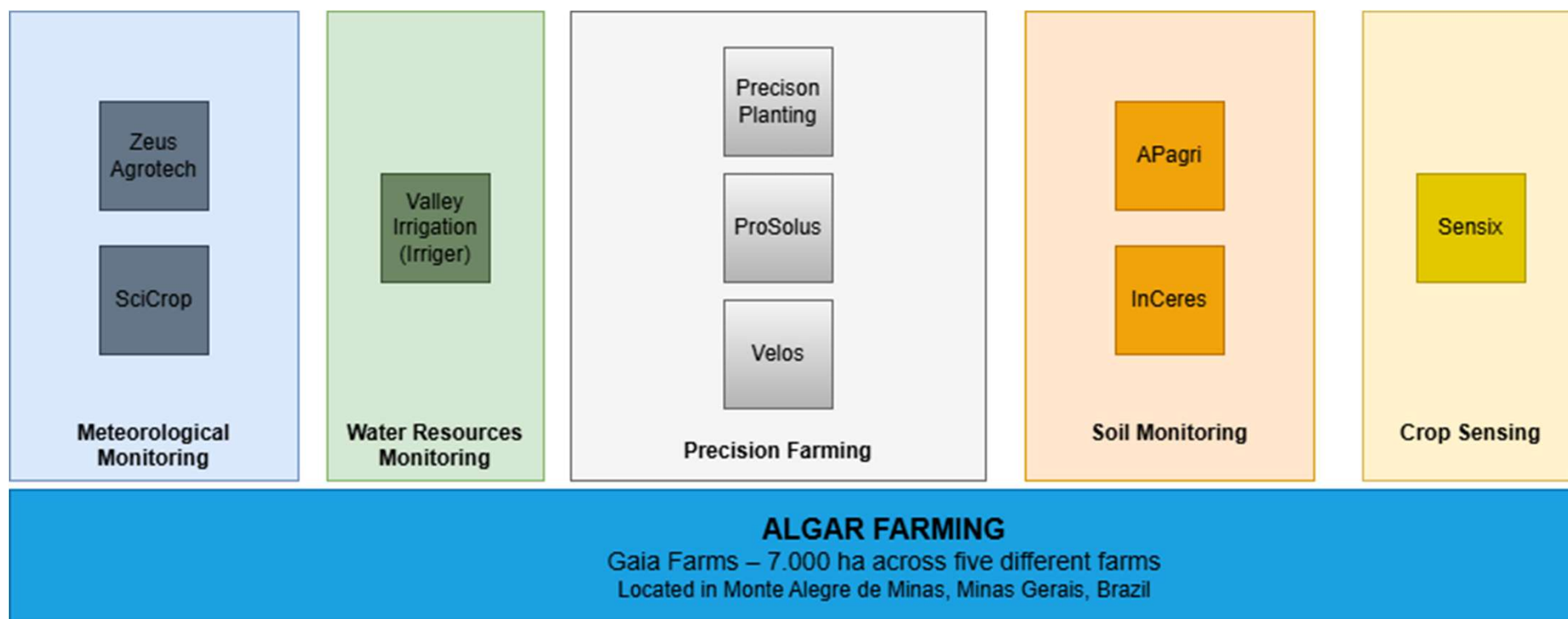
AgroConnect: A Large Scale IoT Pilot in Agriculture

- Large Scale IoT Pilot in agriculture
 - Algar Farming
 - 7.000 ha across five different farms nearby (Águada Rica, Cachoeira, Colorado, Gaia e Santa Marta)
 - Pilot happened in 1.758,46 ha
 - Farms located in [Monte Alegre de Minas, Minas Gerais, Brazil](#)
 - Deployment of in a real environment several IoT solutions
 - Meteorological Monitoring
 - [Zeus Agrotech](#); [SciCrop](#)
 - Water Resources Monitoring
 - [Valley Irrigation\(formerly known as Irriger\)](#)
 - Precision Farming
 - [Precison Planting](#); [ProSolus](#); [Velos](#)
 - Soil Monitoring
 - [Apagri](#); [InCeres](#)
 - Crop Sensing
 - [Sensix](#)
 - Evaluate these IoT solutions available on the the market
- Pilot Final Report
 - [AgroConnect: Projeto Piloto de IoT na Agricultura em Larga Escala, 2021](#)



AgroConnect: A Large Scale IoT Pilot in Agriculture

- IoT solutions deployed



- Key take-away
 - IoT separated solutions; IoE integrated view!

Challenges and Opportunities in Different areas

- Networking & Connectivity
 - Seamless integration of heterogeneous technologies (5G/6G, Wi-Fi, LoRa, satellite), scalability to billions of devices, spectrum sharing, and interoperability.
- Data & Intelligence
 - Managing massive data streams with edge/fog computing, AI/ML for distributed learning and context awareness, and ensuring trustworthy AI.
- Security, Privacy & Trust
 - Lightweight security for constrained devices, identity and trust management, privacy protection, and resilience against large-scale attacks.
- Sustainability & Energy
 - Green IoE solutions, energy harvesting, lifecycle management of devices, and AI-driven energy/resource optimization.
- Human–IoE Interaction
 - User-centric and ethical design, immersive and multisensory interfaces (VR/AR/XR, tactile internet, BCI), and digital twins of people and processes.
- Governance & Policy
 - Global standards alignment, data sovereignty, legal frameworks for autonomous systems, and inclusive/ethical regulation.
- New Applications and Enablers
 - Healthcare, smart cities, industrial IoE, agriculture, education, climate monitoring, and future enablers like 6G and quantum-enhanced IoE.

Research Trends & Challenges on a Layered View

- **Architecture**

- **Trends:**

- Cloud–edge–device continuum
 - AI-native orchestration (SDN/NFV, slicing)
 - Digital twins & data-centric design
 - Zero-trust & confidential computing

- **Challenges:**

- Interoperability across domains
 - End-to-end QoS/QoE guarantees
 - Safe & explainable AI-driven control
 - Sustainable architectures

- **Computing & Processing**

- **Trends:**

- Edge-first AI, federated & continual learning
 - Serverless & WASM at edge
 - In-network computing (DPUs, smartNICs)
 - Stream/CEP analytics
 - Privacy-preserving ML (FL + DP + HE)

- **Challenges:**

- Latency–accuracy–energy–cost trade-offs
 - Heterogeneous accelerator scheduling
 - Drift, skew, and observability in ML
 - Constraints of tiny devices

- **Sensing & Communication**

- **Trends:**

- Energy-harvesting & TinyML sensors
 - 6G-ready links: THz, NTN, RIS
 - Deterministic networking (TSN, tactile)
 - Multi-RAT convergence
 - Semantic communications

- **Challenges:**

- Energy vs reliability trade-offs
 - Localization & time sync at scale
 - Robustness in interference/adversarial RF
 - Spectrum coexistence & regulation

- **Application Layer**

- **Trends:**

- Industry 5.0 & digital twins
 - Smart grids & energy markets
 - C-V2X & cooperative mobility
 - Digital health & wearables
 - XR/metaverse & tactile internet

- **Challenges:**

- Safety & certification in CPS
 - Data governance & privacy
 - QoE-centric SLAs
 - Human factors (transparency, accessibility)



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Thank you!

We welcome you to the IoE World!


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