FESB

Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture

University of Split, CROATIA

16 May 2024

Brief Introduction

Sérgio Ivan Lopes (sil@estg.ipvc.pt)

Assistant Professor, Instituto Politécnico de Viana do Castelo, Portugal
Researcher, Instituto de Telecomunicações, Aveiro, Portugal
Director-General, CiTin - Centro de Interface Tecnológico Industrial
IEEE Senior Member, Professional Activities Appointed Officer - Portuguese Section

About me

- Sérgio Ivan Lopes:
  - Website: www.sergioivanlopes.pt
  - Email: sil@estg.ipvc.pt
- Academic Background:
  - B.Sc. in Electronics and Telecommunications Eng.
  - M.Sc. in Biomedical Eng.
  - Ph.D. in Electrical Eng.
  - Postgraduate Diploma in Project Management (University of Porto).
- Assistant Professor the Technology and Management School of the Polytechnic Institute of Viana do Castelo (ESTG-IPVC)
- Director General at CiTin – Centro de Interface Tecnológico e Industrial
- Senior Researcher at Instituto de Telecomunicações
- IEEE Senior Member (S'11–M'15–SM'20)

ipvc Escola Superior de Tecnologia e Gestão

instituto de telecomunicações

universidade de aveiro

CiTin Associação Centro de Interface Tecnológico Industrial

IEEE PORTUGAL SECTION

THE IPVC

Instituto Politécnico de Viana do Castelo

ESE | School od Education

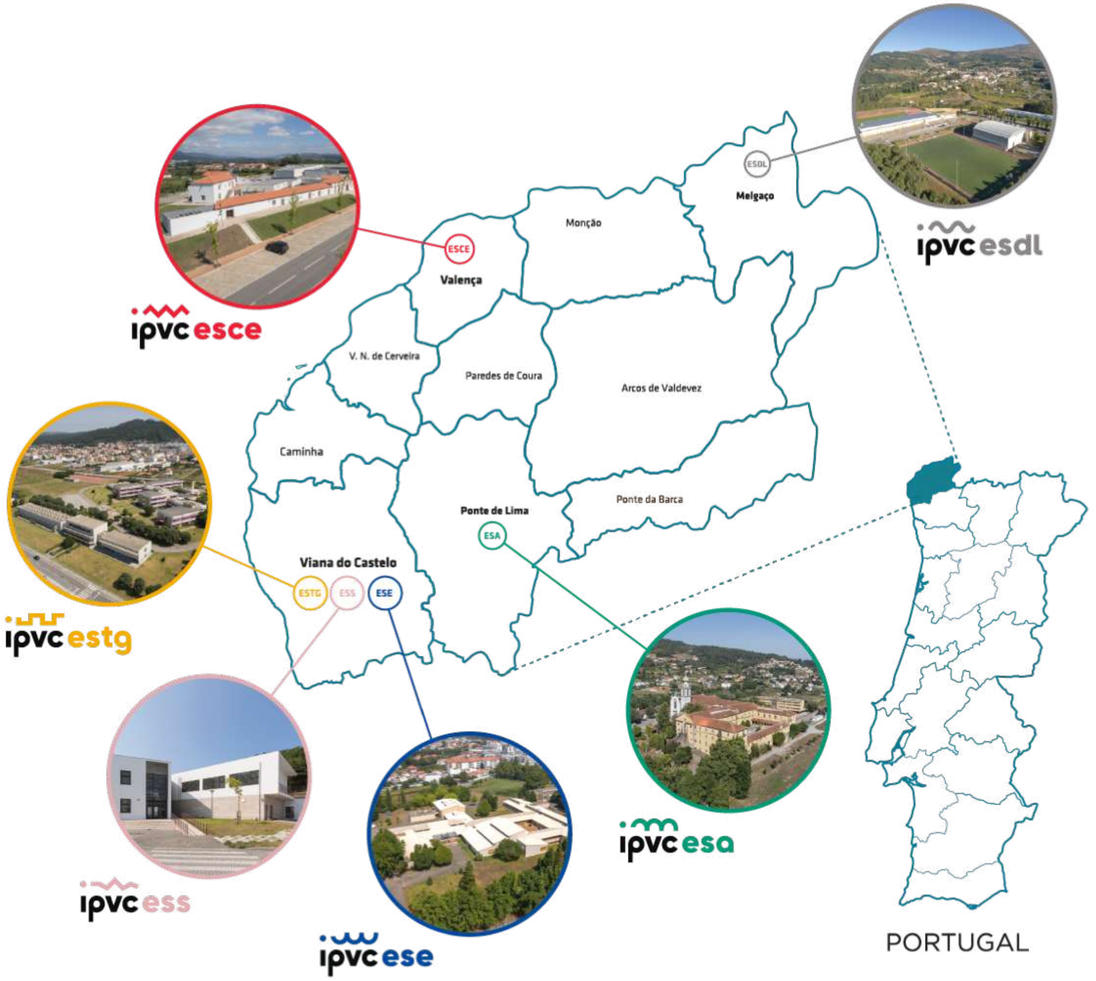
ESA | Agrarian School

ESTG | School of Technology and Management

ESCE | School of Business Sciences

ESS | Health School

ESDL | School of Sports and Leisure



OUR SCHOOLS

Instituto Politécnico de Viana do Castelo

ESE | School od Education

ESA | Agrarian School

ESTG | School of Technology and Management

ESCE | School of Business Sciences

ESS | Health School

ESDL | School of Sports and Leisure

IPVC IN NUMBERS

Instituto Politécnico de Viana do Castelo

TRAINING OFFER

21 CTeSP
26 UNDERGRADUATES
14 MASTERS
2 POSTGRADUATIONS
SPECIALISED TRAINING
LIFE-LONG TRAINING
JUNIOR & SENIOR ACADEMY

Courses opening in 2020/21

5289 STUDENTS

2020/21

878 CTeSP
3579 UNDERGRADUATES
787 MASTERS
45 POSTGRADUATIONS

934 GRADUATES

2019/20

216 CTeSP
602 UNDERGRADUATES
75 MASTERS
41 POSTGRADUATIONS

ERASMUS/IACOBUS MOBILITY

92 INCOMING STUDENTS
73 OUTGOING STUDENTS
18 INCOMING STAFF
16 OUTGOING STAFF
2019/20

94,5% UNDERGRADUATED EMPLOYABILITY IN 2020

95 FUNDED PROJECTS
75 NATIONAL
20 INTERNATIONAL
6.134.940,59€

SPECIALISED SERVICES
804.970,48€

R&D UNITS AND INTEGRATED MEMBERS

CISAS - 21
PROMETHEUS - 18
ADIT-LAB - 20
CIDESD - 4
UNIAG - 7
CIMO - 7
UICISA:E - 11
CITUR - 5

580 COLABORATORS

ND:188 D:392 (208 TI; 271, 1 ETI)
2020/21

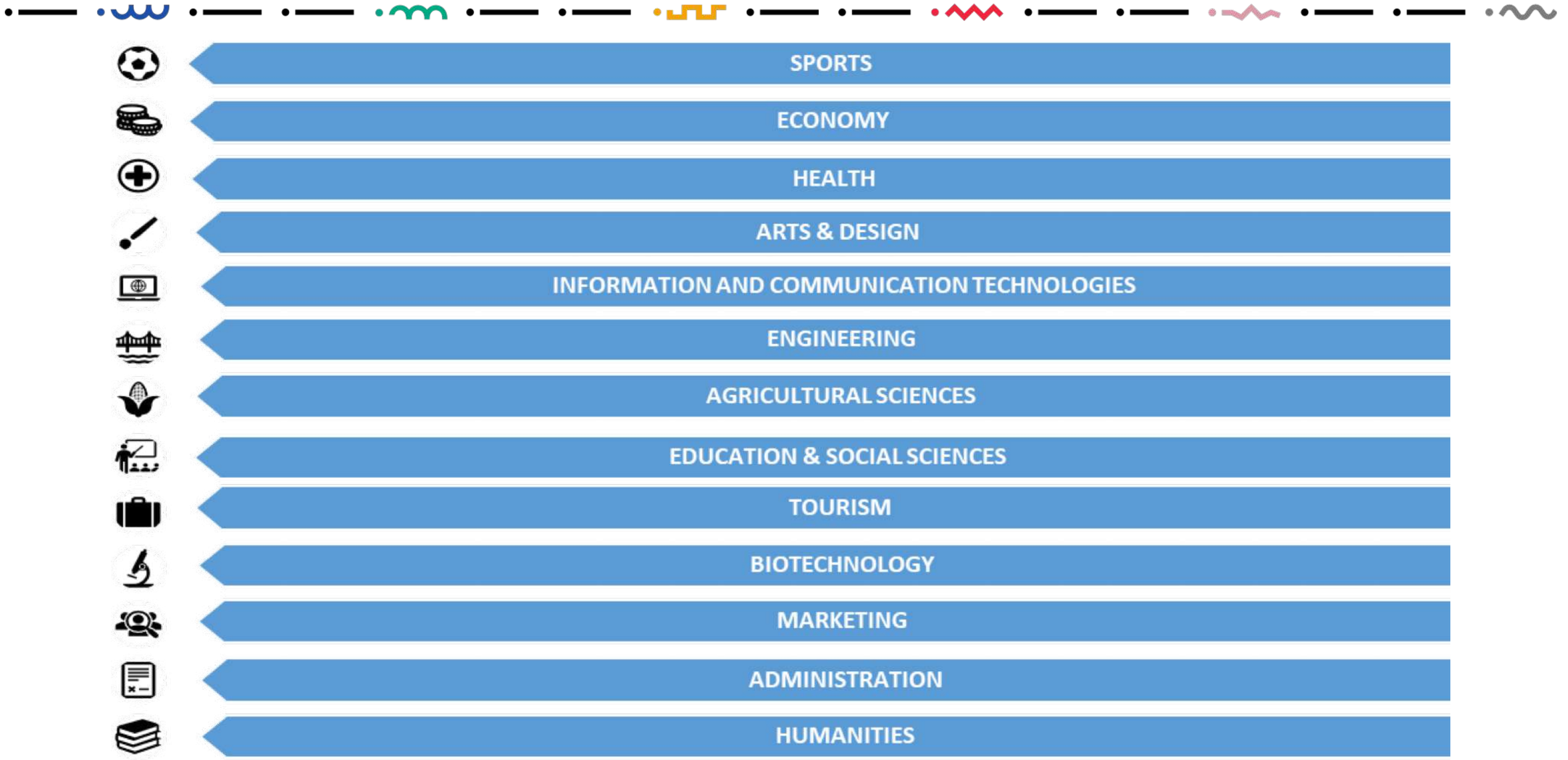
209 TEACHERS WITH PHD

(175 TI; 187,5 ETI)

53,3% (PhD- Teachers)
69,2% (PhD FTE)
84,1% (PhD FTT)
1/23 (PhD FTE - 1st and 2nd Cycle Student)
1/25 (PhD FTT - 1st and 2nd Cycle Student)

AREAS OF STUDY

Instituto Politécnico de Viana do Castelo



FESB

Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture

University of Split, CROATIA

16 May 2024

Fostering Sustainable Innovation in the Digital Age: From Theory to Impact

Sérgio Ivan Lopes (sil@estg.ipvc.pt)

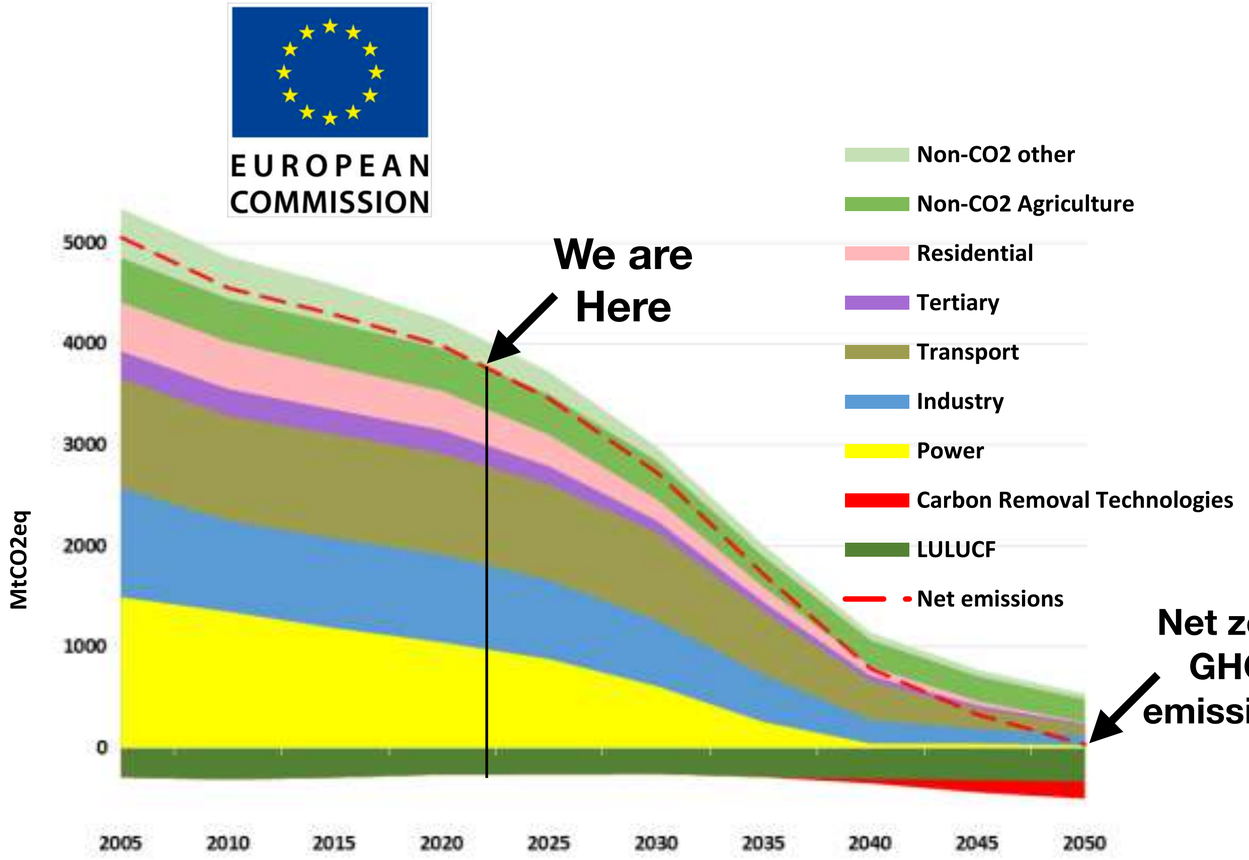
Assistant Professor, Instituto Politécnico de Viana do Castelo, Portugal
Researcher, Instituto de Telecomunicações, Aveiro, Portugal
Director-General, CiTin - Centro de Interface Tecnológico Industrial
IEEE Senior Member, Professional Activities Appointed Officer - Portuguese Section

Agenda

- A clean planet by 2050
- Sustainable Development in a Nutshell
- SDGs and IoT: Key Technological Enablers
- Designing (some) IoT-driven applications:
  - RnMonitor: IoT-Based Indoor Radon Gas Management
  - CoViS: IoT-Based Contactless Health Monitoring
  - IPVC S2S: Towards a Smart & Sustainable Campus
    - Refill_H20: Plastic Consumption Reduction on Campus;
    - BIRA: Bicycle Real-Time Tracking on Campus;
- Final Remarks

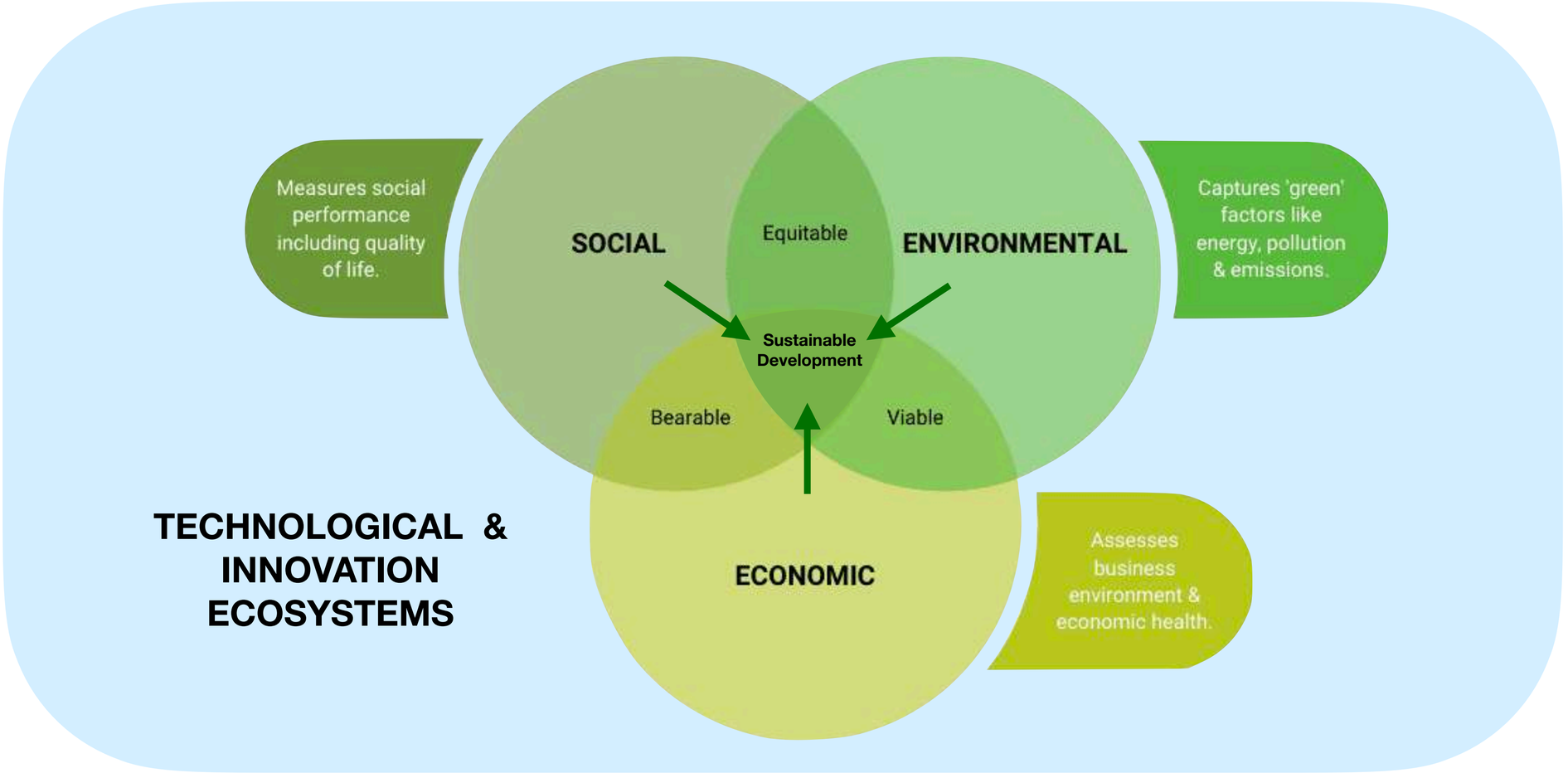
EU Vision for a clean planet by 2050

- **EU long-term strategy**: become climate-neutral by 2050 (net zero GHG emissions);
- **Radical transformations needed:** clean energy, efficient buildings, sustainable transportation, circular economy…
- There are four challenging perspectives: **technological**, **economical**, **environmental** and **social**.

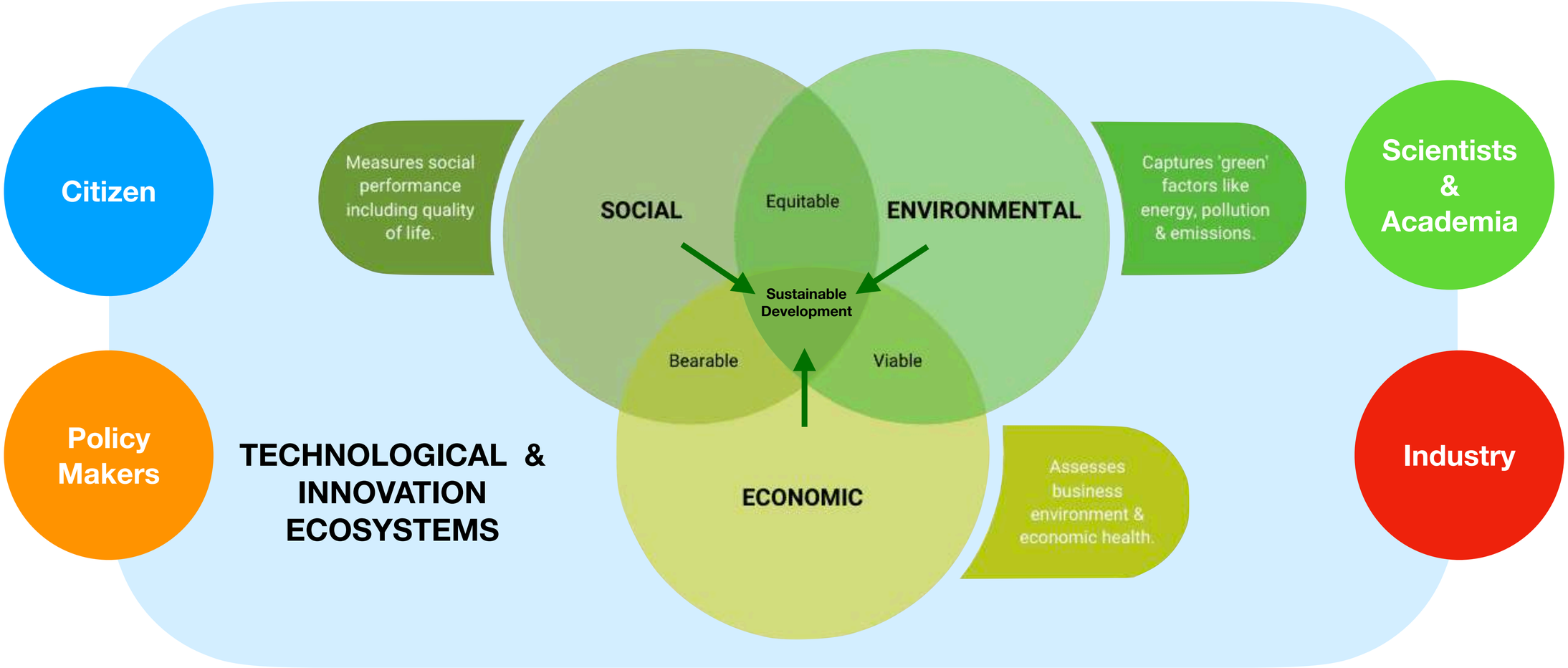


Source: World Economic Forum, "The EU wants to be carbon neutral by 2050", 2018, url: https://www.weforum.org/agenda/2018/12/european-union-aims-to-be-first-carbon-neutral-major-economy-by-2050

Sustainable Development in a nutshell

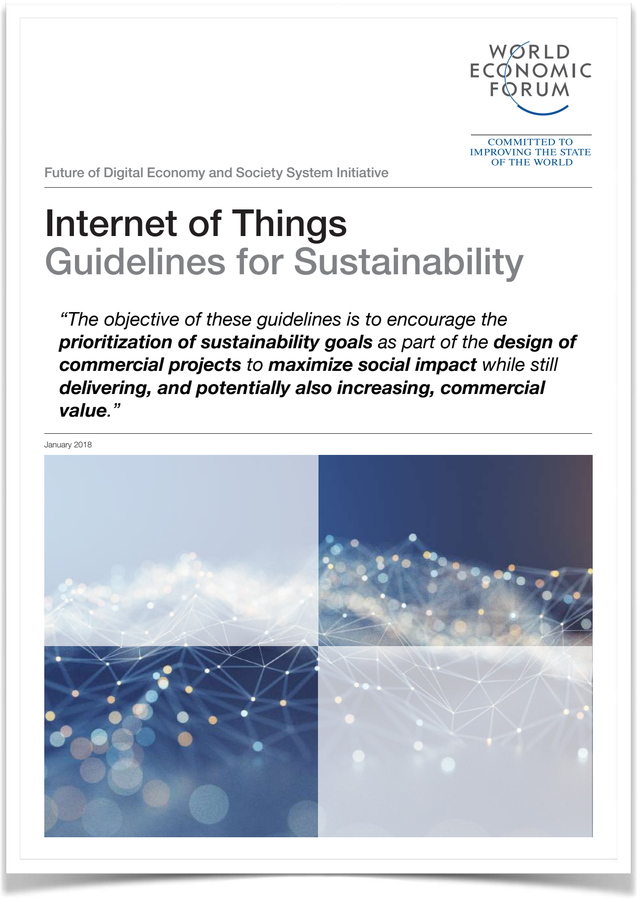


Sustainable Development in a nutshell

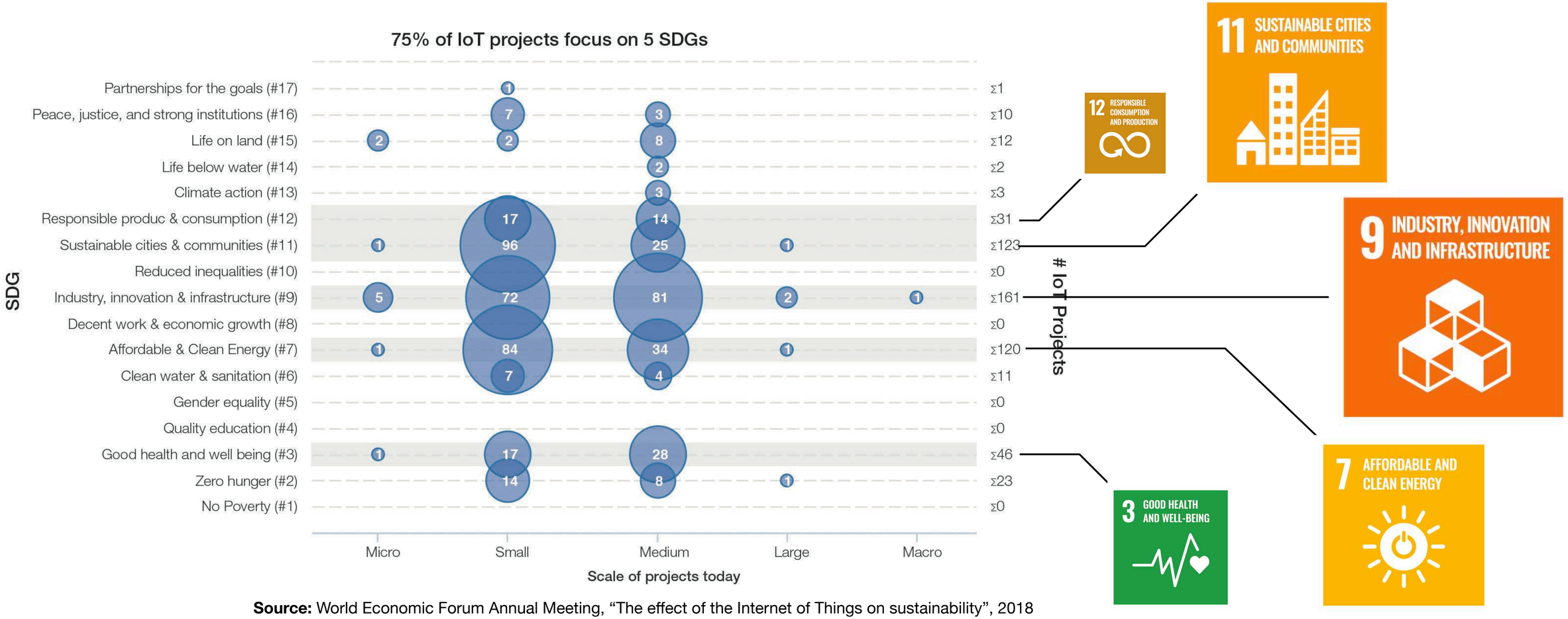


SDGs and IoT


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS

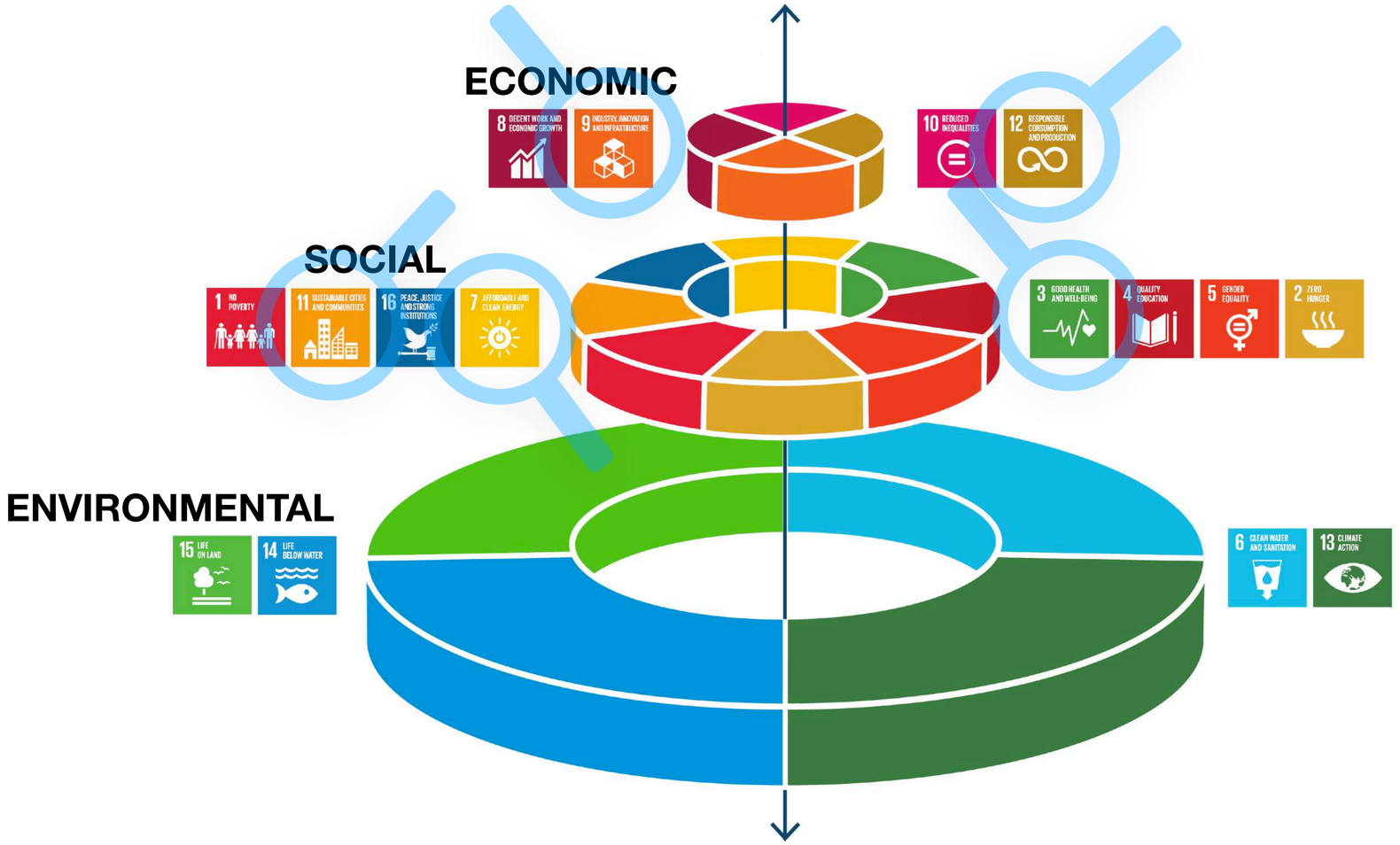

WORLD ECONOMIC FORUM
COMMITTED TO IMPROVING THE STATE OF THE WORLD
Future of Digital Economy and Society System Initiative
Internet of Things
Guidelines for Sustainability
"The objective of these guidelines is to encourage the prioritization of sustainability goals as part of the design of commercial projects to maximize social impact while still delivering, and potentially also increasing, commercial value."
January 2018

Common IoT Applications for SDGs



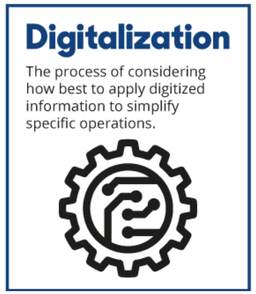
Source: World Economic Forum Annual Meeting, "The effect of the Internet of Things on sustainability", 2018
https://www.weforum.org/agenda/2018/01/effect-technology-sustainability-sdgs-internet-things-iot/

Common IoT Applications for SDGs



Key Technological Enablers

DIGIT… & IoT

			
Operational Focus	**Transformation of Data**	**Processing of Data**	**Taking Advantage of Information**
Goal	**Convert Processes from Analog to Digital**	**Automate Business Processes**	**Change the way organizations operate and think**
Activity	**Digitizing physical resources like paper documents, photos and videos**	**Creating a fully digital workflow process**	**Creating a new digital organization Holistic process of change**
Tools	**Internet of Things** Edge Computing and other technologies for converting	**Internet of Things** Fog/Cloud Computing AI, ML, DLTs IT systems and Applications	Digital Twins New Digital Technologies
Challenge	**Material**	**Financial**	**Human Resources**

Key Technological Enablers

DIGIT… & IoT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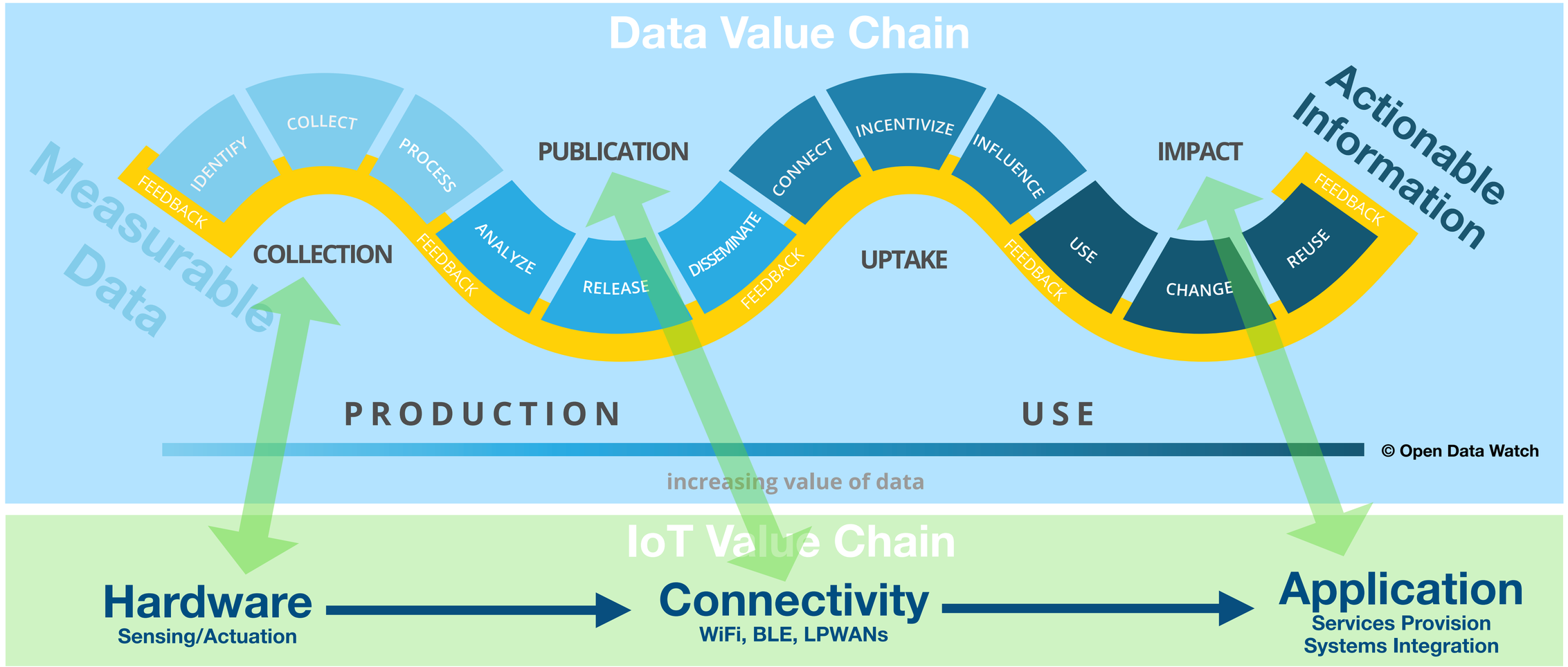
	Technological Enablers		

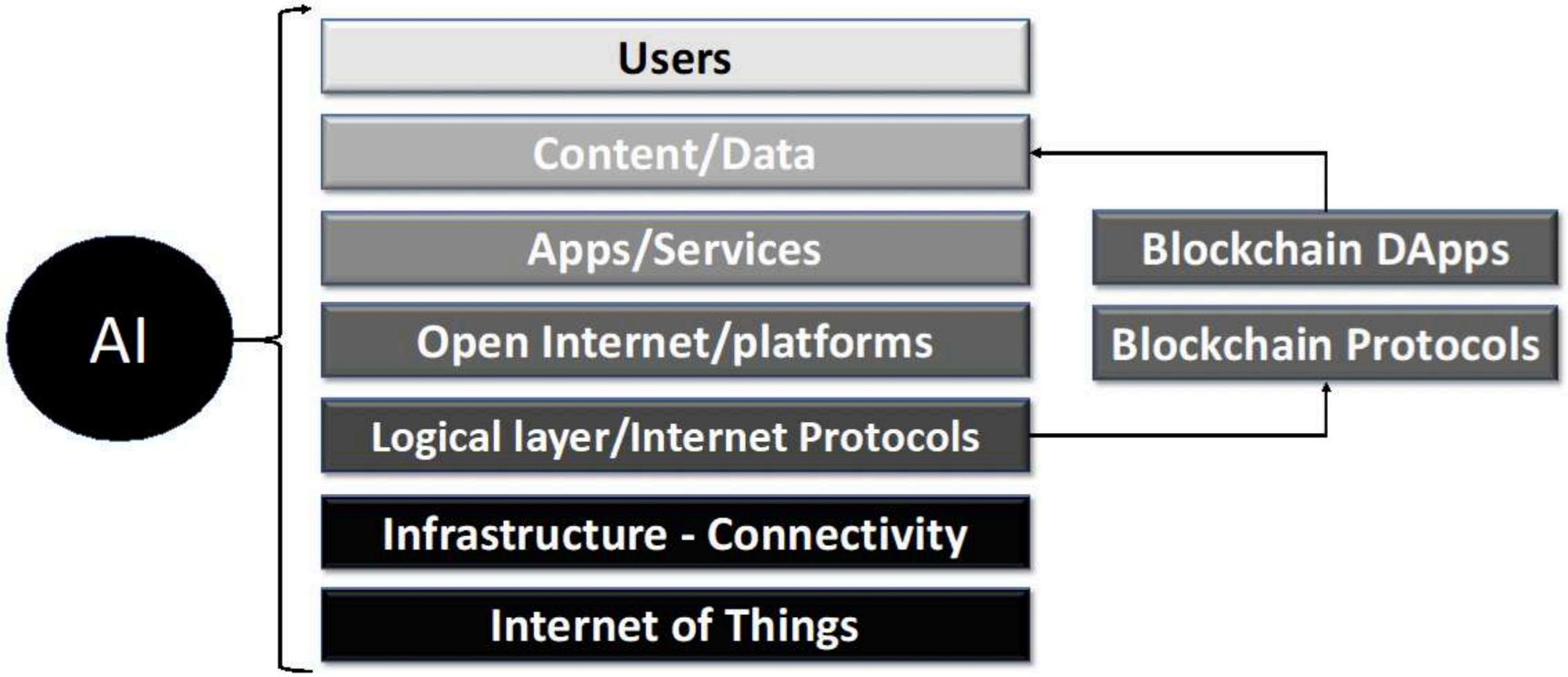
Key Technological Enablers

Data Value Chain & IoT



Key Technological Enablers

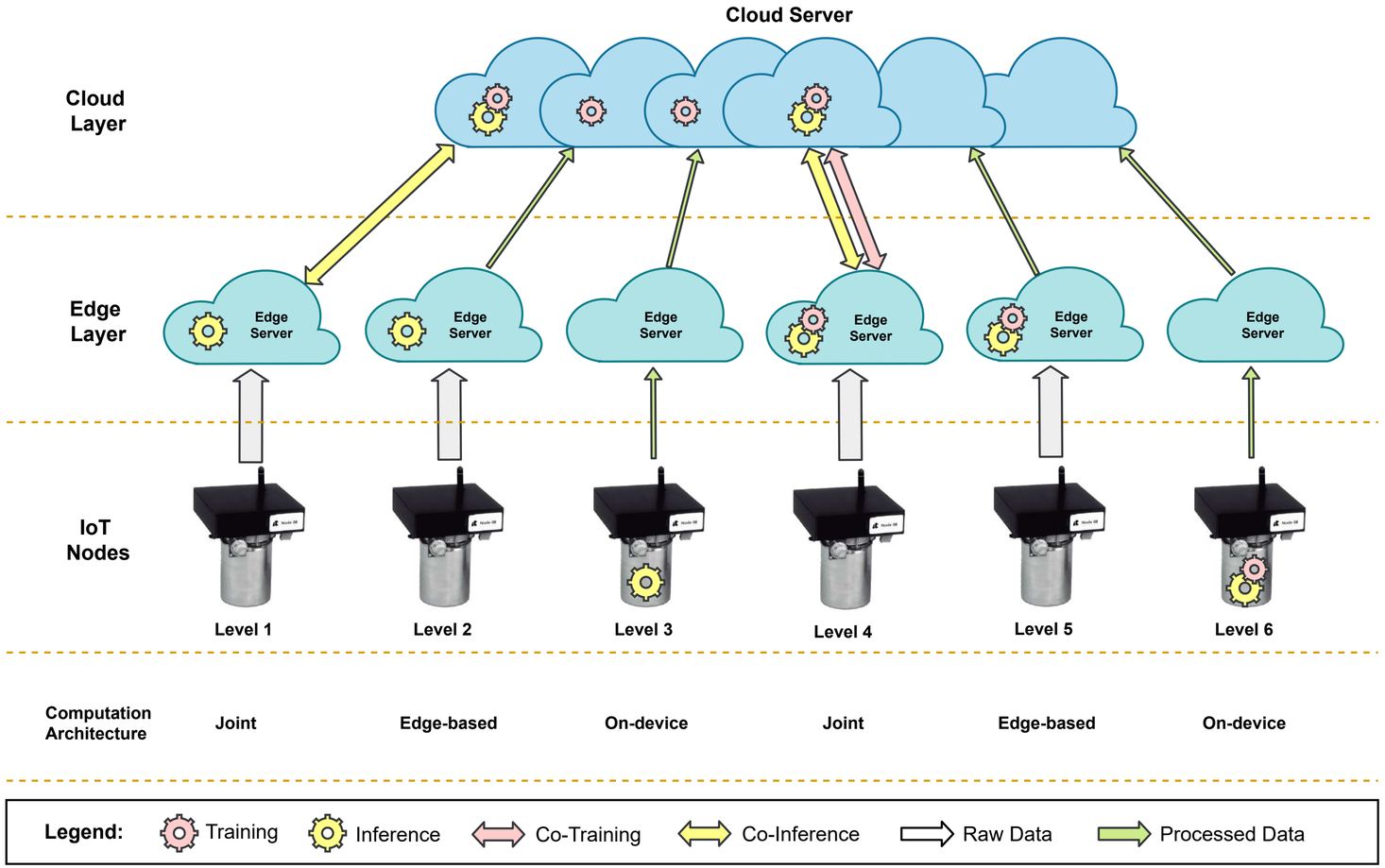
The New Digital Stack



Source: Andrea Renda and Moritz Laurer, “IOT 4 SDGS - WHAT CAN THE DIGITAL TRANSFORMATION AND IOT ACHIEVE FOR AGENDA 2030?”, CEPS, MARCH 2020.

Key Technological Enablers

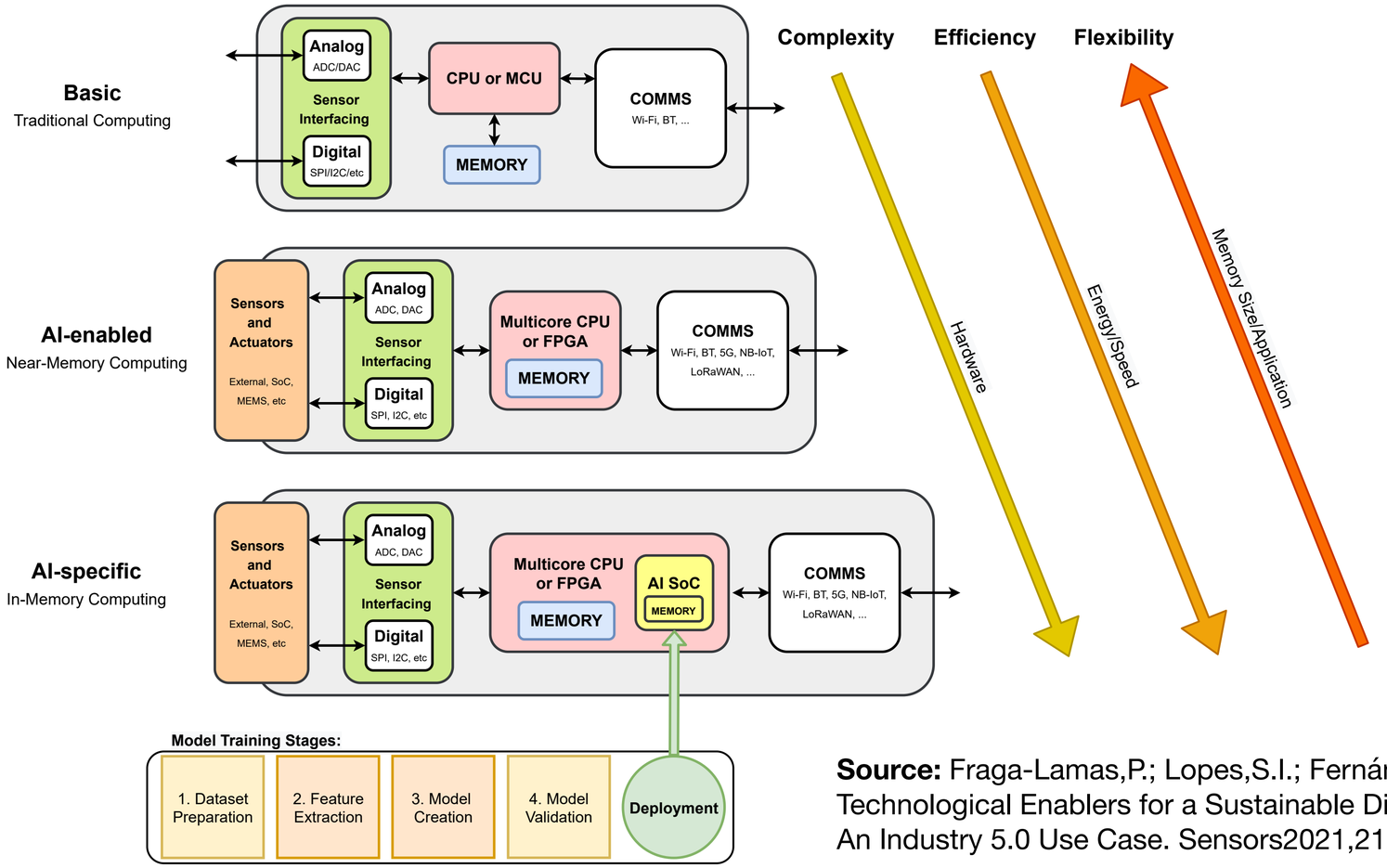
IoT & AI Convergence



Source: Fraga-Lamas,P.; Lopes,S.I.; Fernández-Caramés, T.M., Green IoT and Edge AI as Key Technological Enablers for a Sustainable Digital Transition towards a Smart Circular Economy: An Industry 5.0 Use Case. Sensors2021,21,5745. https:// doi.org/10.3390/s21175745

Key Technological Enablers

AIoT Device Architectures



Source: Fraga-Lamas,P.; Lopes,S.I.; Fernández-Caramés, T.M., Green IoT and Edge AI as Key Technological Enablers for a Sustainable Digital Transition towards a Smart Circular Economy: An Industry 5.0 Use Case. Sensors2021,21,5745. https:// doi.org/10.3390/s21175745

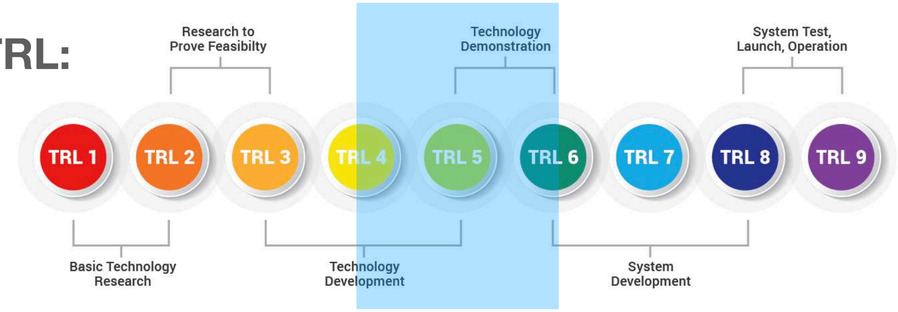
Designing IoT-Driven Applications

Designing IoT-driven applications

Indoor Air Quality Management

SDGs:

TRL:



RnMonitor

- **Funding:** POCI-01-0145-FEDER-023997

Cofinanciado por:

COMPETE 2020 PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO

PORTUGAL 2020

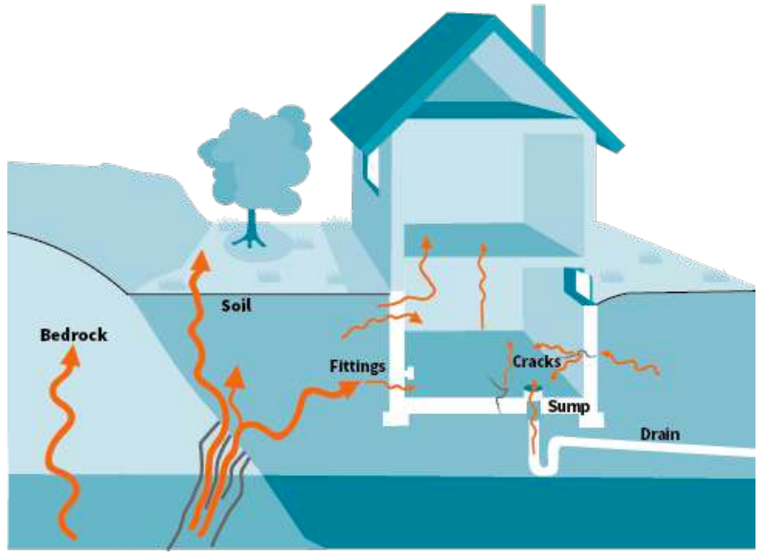
UNIÃO EUROPEIA
Fundo de Coesão

- **Website:** http://rnmonitor.ipvc.pt
- **Goals:**
  - Design a low-cost IoT-based Radon Gas Probe;
  - Design and develop a Cloud-based WebSIG platform for online radon monitoring and management.

RnMonitor

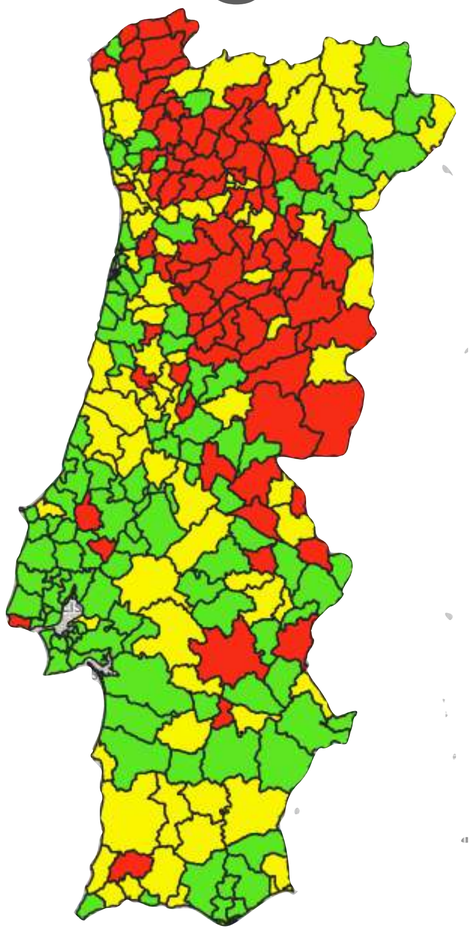
What is Radon

- Radon is a naturally occurring radioactive gas;
- It is continuously produced by the decay of uranium, which occurs naturally in soils and rocks;
- Once produced, Radon escapes into the open air unless it enters a building or enclosed space.
- WHO estimates that Indoor Radon is responsible for 20.000 lung cancer deaths per year.
- Indoor Radon is the 2nd leading cause of lung cancer, after tobacco.

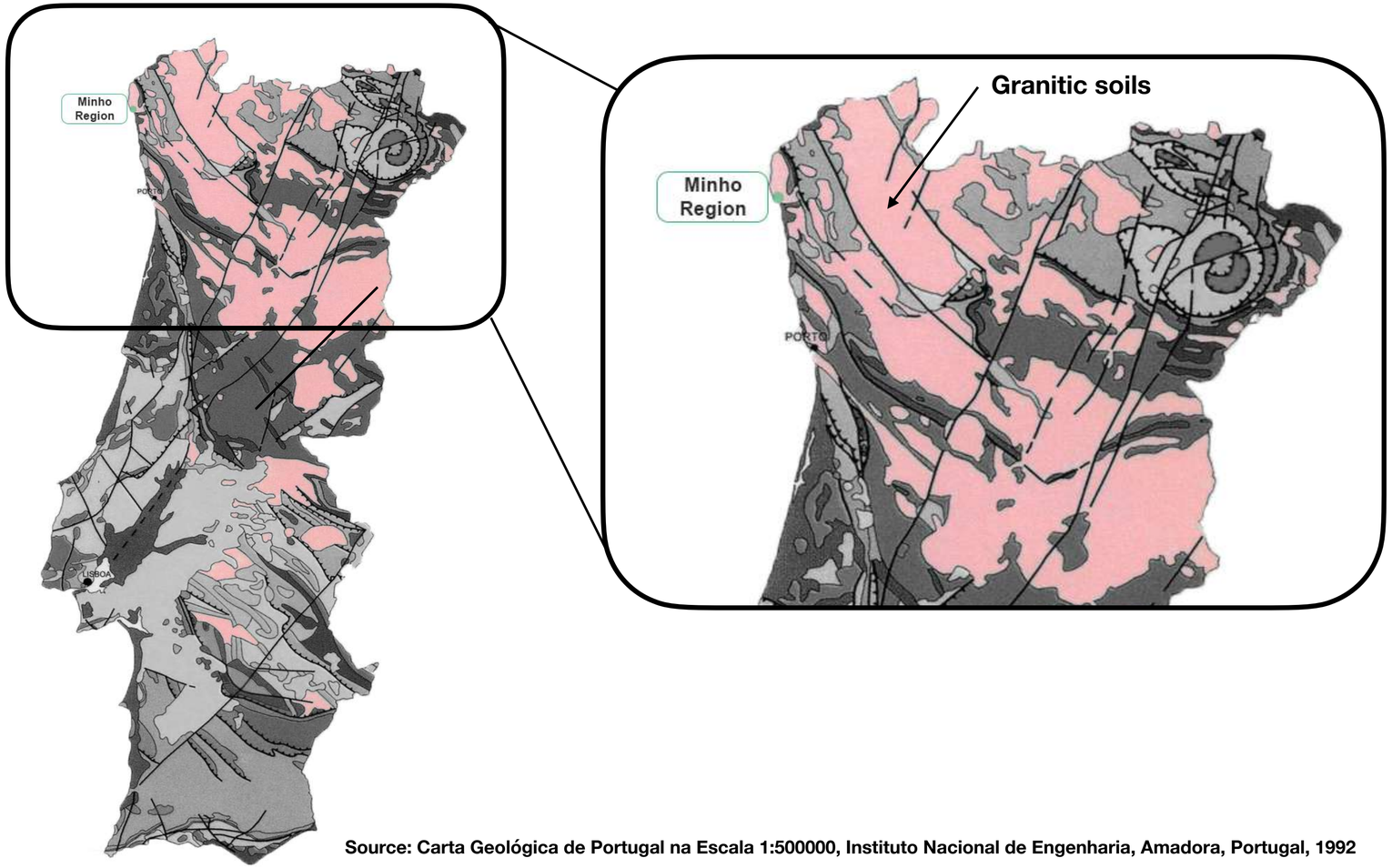


Rn radon

Portugal: Geology and Radon Potential



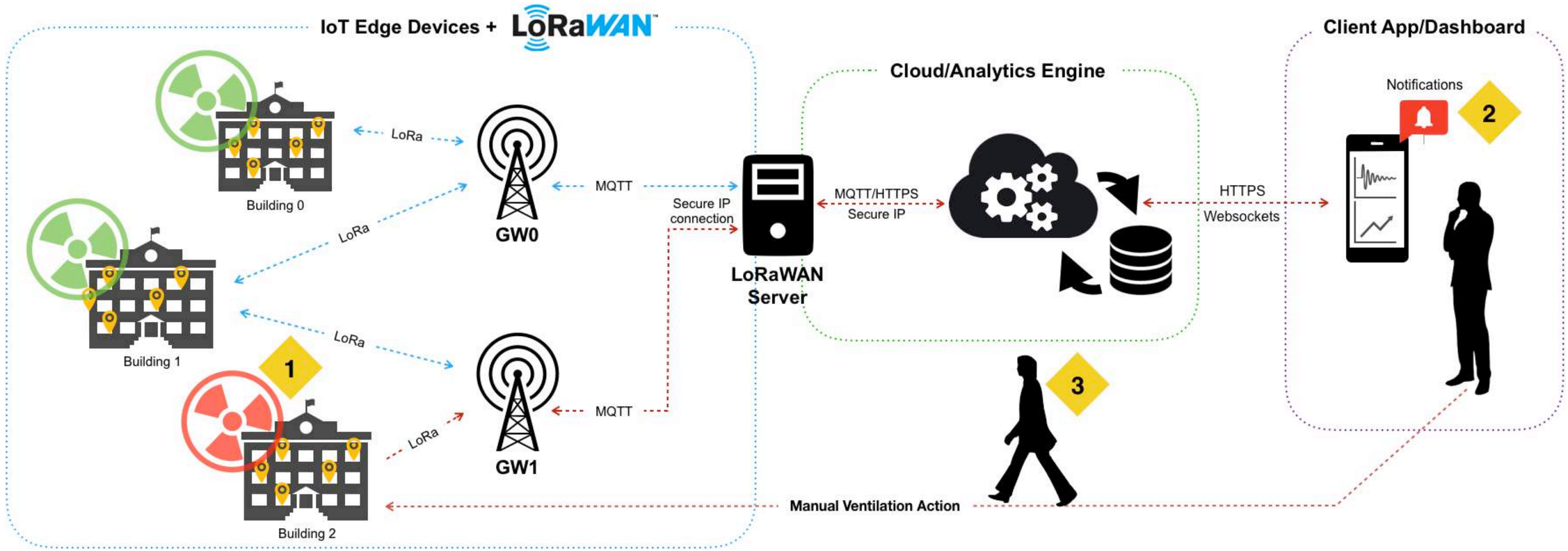
Source: Mapa de Risco de Radão, Instituto Tecnológico Nuclear, Portugal



Source: Carta Geológica de Portugal na Escala 1:500000, Instituto Nacional de Engenharia, Amadora, Portugal, 1992

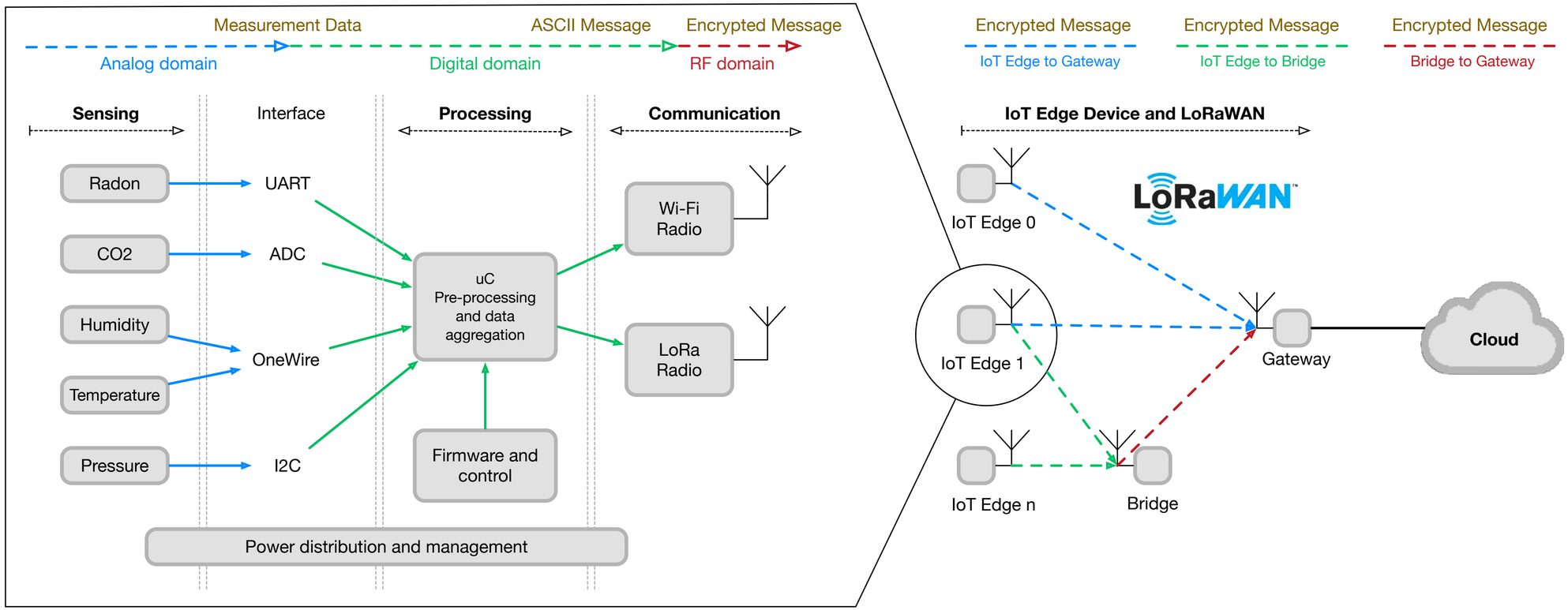
RnMonitor

RnMonitor: How it Works?



Source: S.I. Lopes, A. Cruz, P.M. Moreira, C. Abreu, J.P. Silva, N. Lopes, J. Vieira and A. Curado, "On the design of a Human-in-the-Loop Cyber-Physical System for online monitoring and active mitigation of indoor Radon gas concentration," 2018 IEEE International Smart Cities Conference (ISC2), Kansas City, MO, USA, 2018, pp. 1-8, DOI: 10.1109/ISC2.2018.8656777

RnProbe - IoT Device Architecture



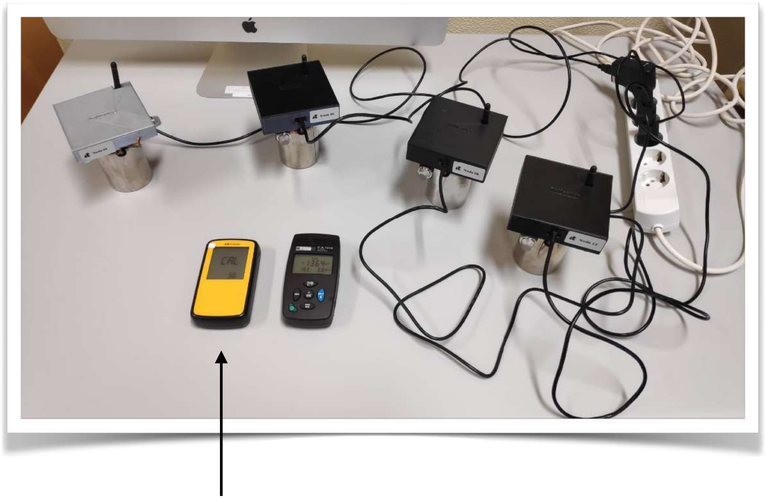
Source: F. Pereira, S.I. Lopes, N.B. Carvalho and A. Curado, "RnProbe: A LoRa-Enabled IoT Edge Device for Integrated Radon Risk Management", in IEEE Access, vol. 8, pp. 203488-203502, 2020, DOI: 10.1109/ACCESS.2020.3036980

RnMonitor

RnProbe - Prototype Validation

Prototype

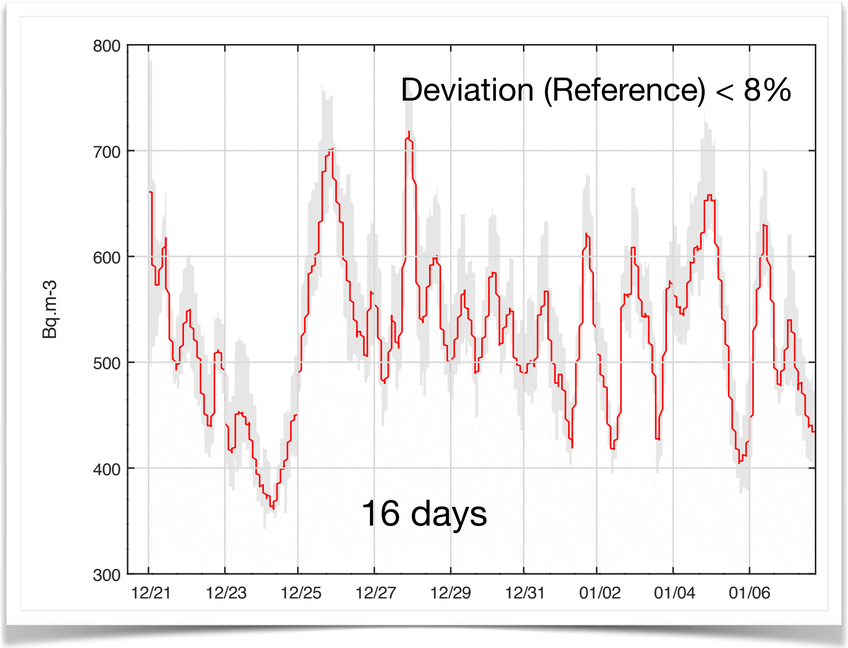
Experimental Apparatus



Reference Instrument

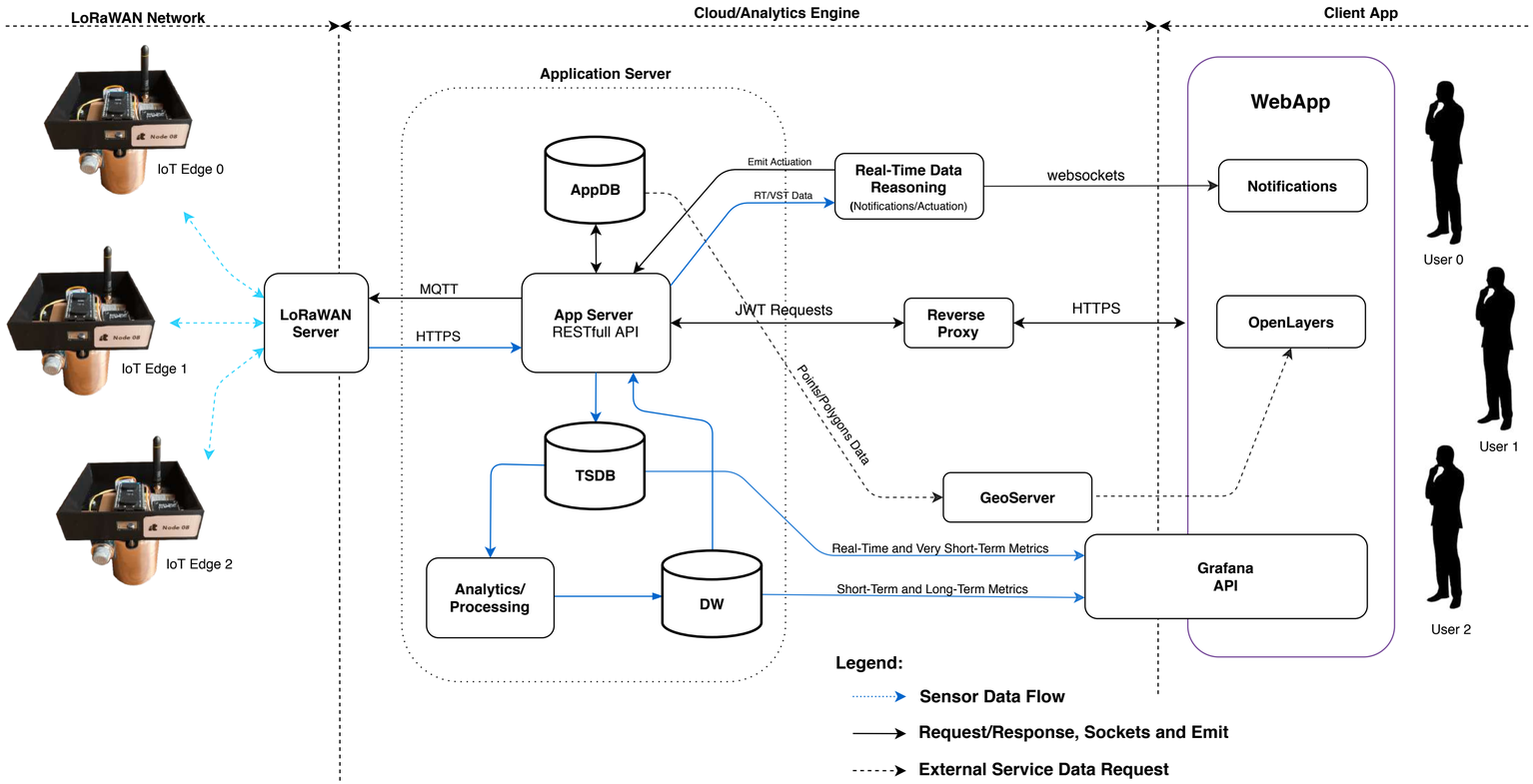
Experimental Validation

	D03	D07	D09	D12	Reference
Arith. Mean ($Bq.m^{-3}$)	537	534	477	550	509
Stand. Dev. ($Bq.m^{-3}$)	72	79	66	80	112



Source: F. Pereira, S.I. Lopes, N.B. Carvalho and A. Curado, “RnProbe: A LoRa-Enabled IoT Edge Device for Integrated Radon Risk Management”, in IEEE Access, vol. 8, pp. 203488-203502, 2020, DOI: 10.1109/ACCESS.2020.3036980

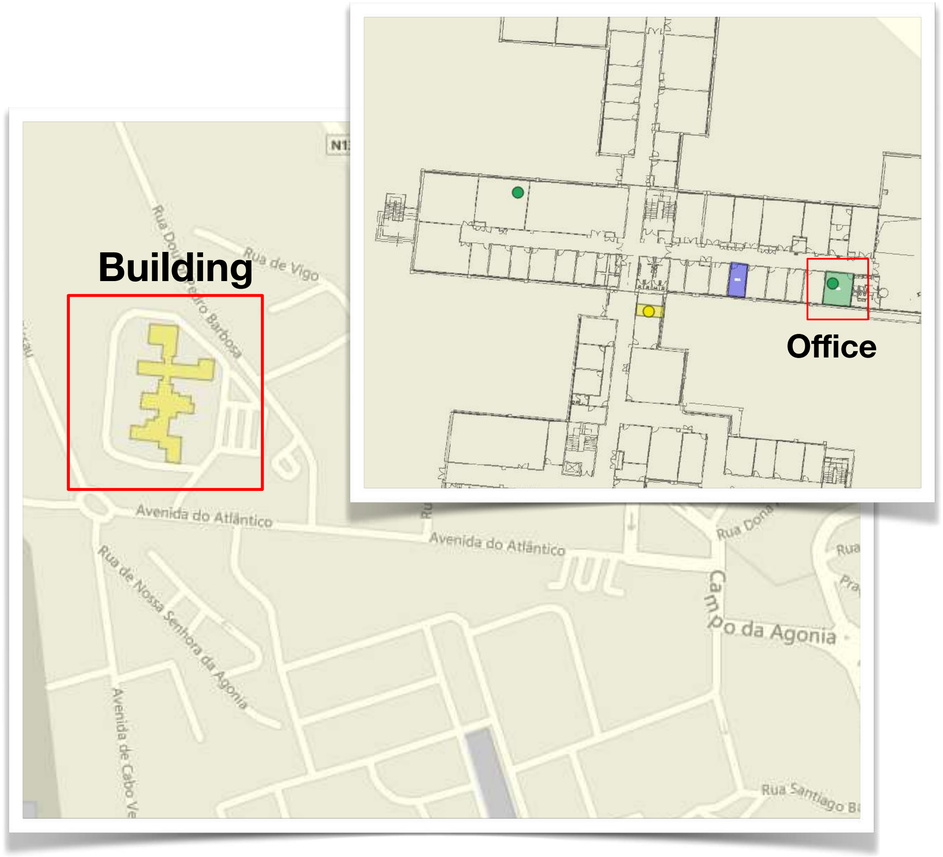
RnMonitor: System Architecture

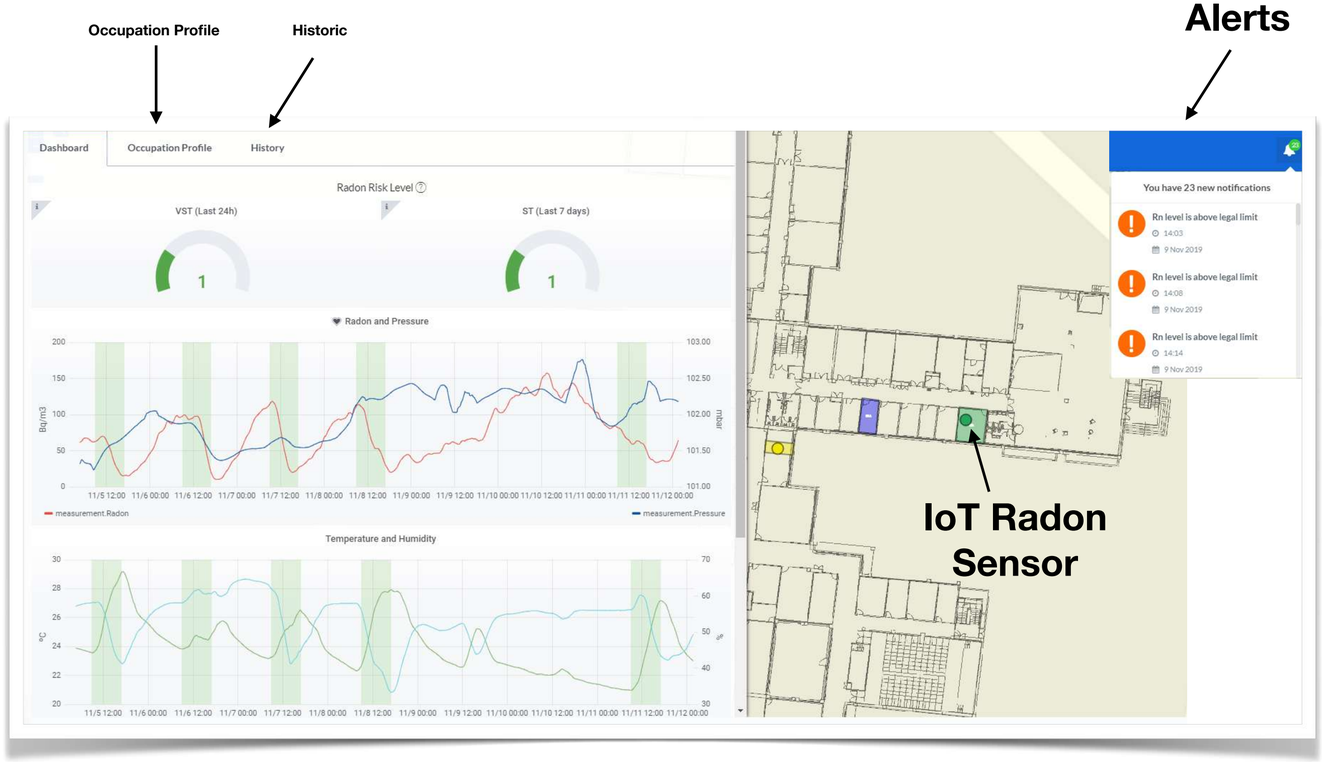


Source: S. I. Lopes, P. M. Moreira, A. M. Cruz, P. Martins, F. Pereira and A. Curado, "RnMonitor: a WebGIS-based platform for expedite in situ deployment of IoT edge devices and effective Radon Risk Management," 2019 IEEE International Smart Cities Conference (ISC2), Casablanca, Morocco, 2019, pp. 451-457, DOI: 10.1109/ISC246665.2019.9071789

RnMonitor

RnMonitor: WebGIS Client App

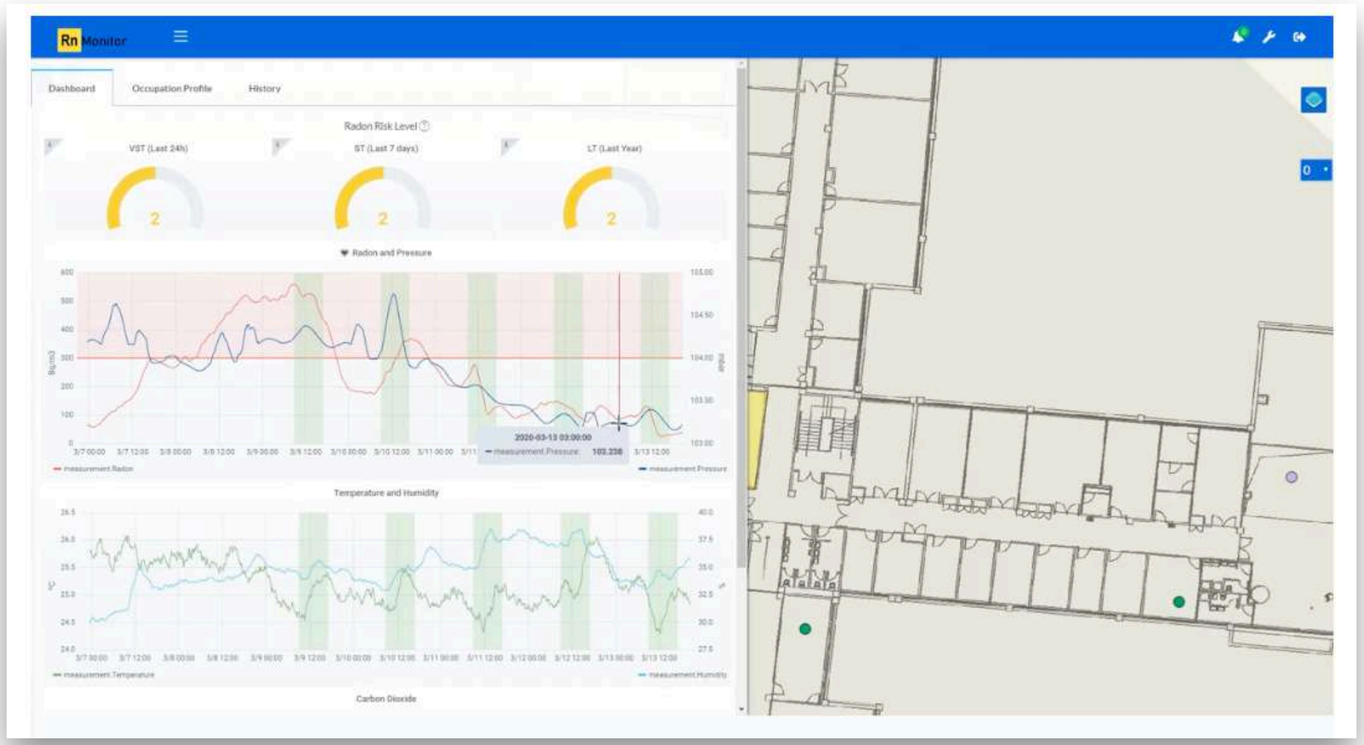




The RnMonitor Ecosystem

IoT-based Sensor RnProbe

RnMonitor IoT Platform

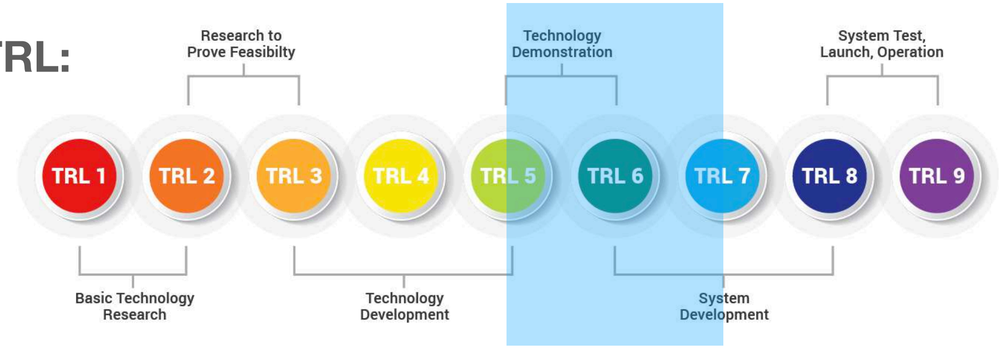


Designing IoT-driven applications

Contactless Health Monitoring

SDGs:

TRL:



- **Project Name:** Contactless Vital Signs Monitoring in Nursing Homes using a Multimodal Approach
- **Funding:**

COMPETE 2020 PORTUGAL 2020 UNIÃO EUROPEIA Fundo Europeu de Desenvolvimento Regional

- **Website:** https://covis.wavecom.pt
- **Partners:**

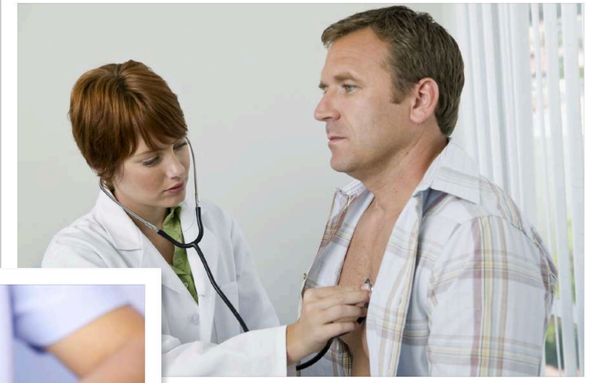
wavecom instituto de telecomunicações ipvc ISEL

- **Goals:**
  - Develop a low-cost IoT device for contactless vital signs monitoring;
  - Development of a digital platform to track the patient's health status to assist healthcare professional on their job;
  - Not for diagnostic purpose;

Designing IoT-driven applications

Conventional Vital Signs Monitoring

Respiratory Rate



Pulse

Body Temperature

- **Conventional methods** contact-based:
  - require the use of contact sensors; properly placed by a health professional;
  - inconvenient for regular measurements and impractical for long-term monitoring.
- **Respiratory Rate:**
  - Stethoscope + Medical Practice
- **Pulse (Heart Rate):**
  - ECG, Medical Practice
- **Body Temperature:**
  - Contact-based thermometers
  - Proximity IR sensors

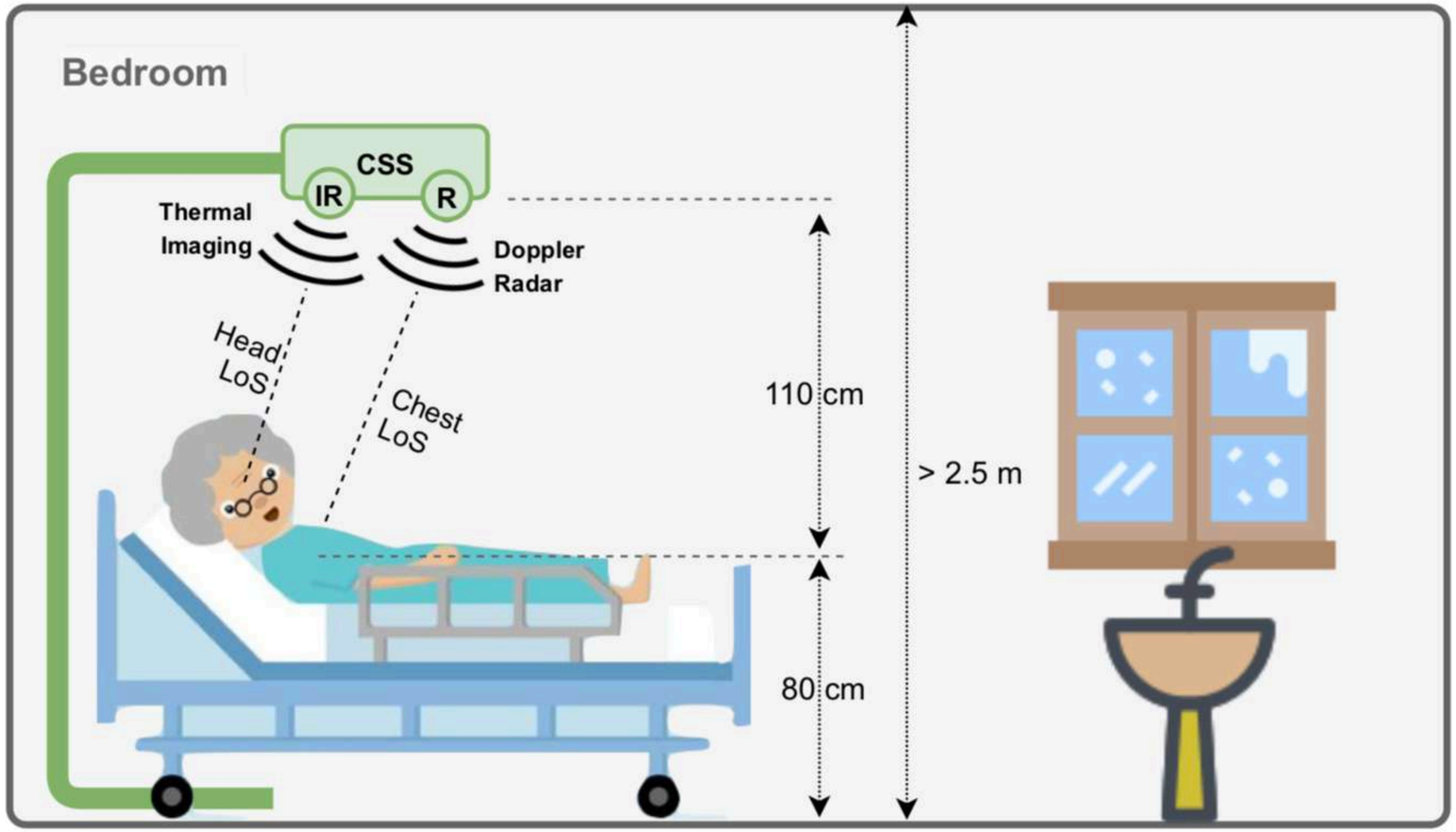
Designing IoT-driven applications

Contactless Vital Signs Monitoring (VSM)

- do not require physical attached electrodes;
- eliminates restrictions on the person's movement;
- more comfortable;
- less invasive for patients;
- relevant for remote acquisition > minimizes contact with health professionals;
- reduces the probability of infection.

Designing IoT-driven applications

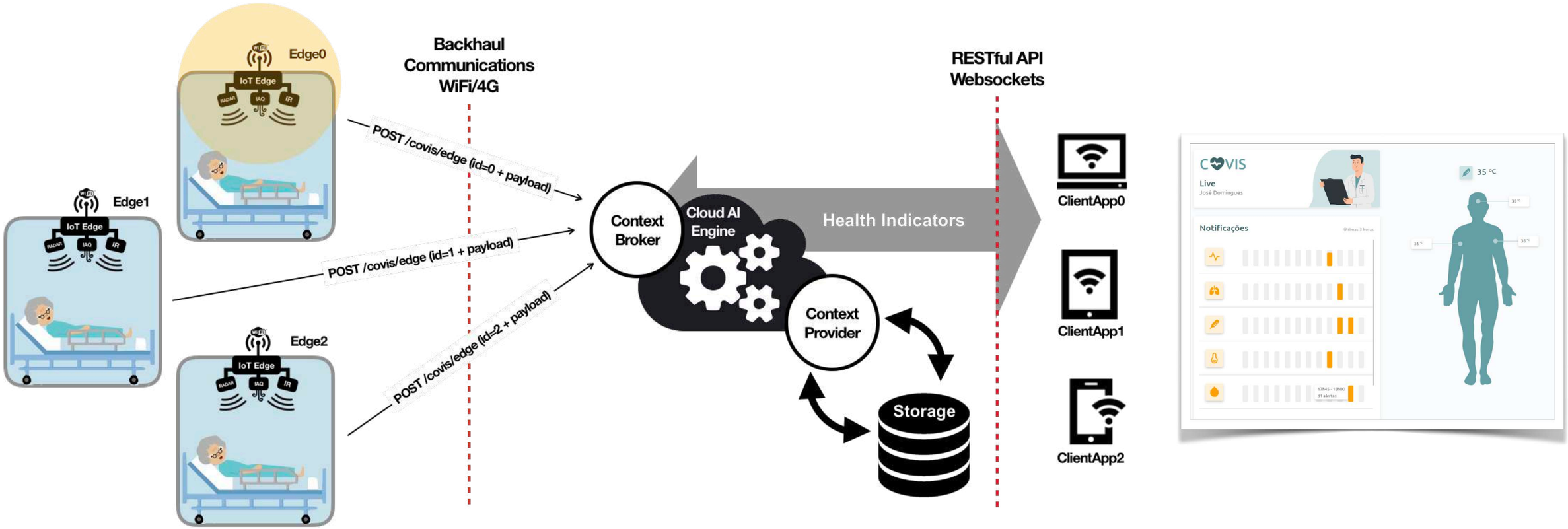
Contactless Vital Signs Monitoring (VSM)



Low-Cost Thermal Imaging + Doppler Radar

Designing IoT-driven applications

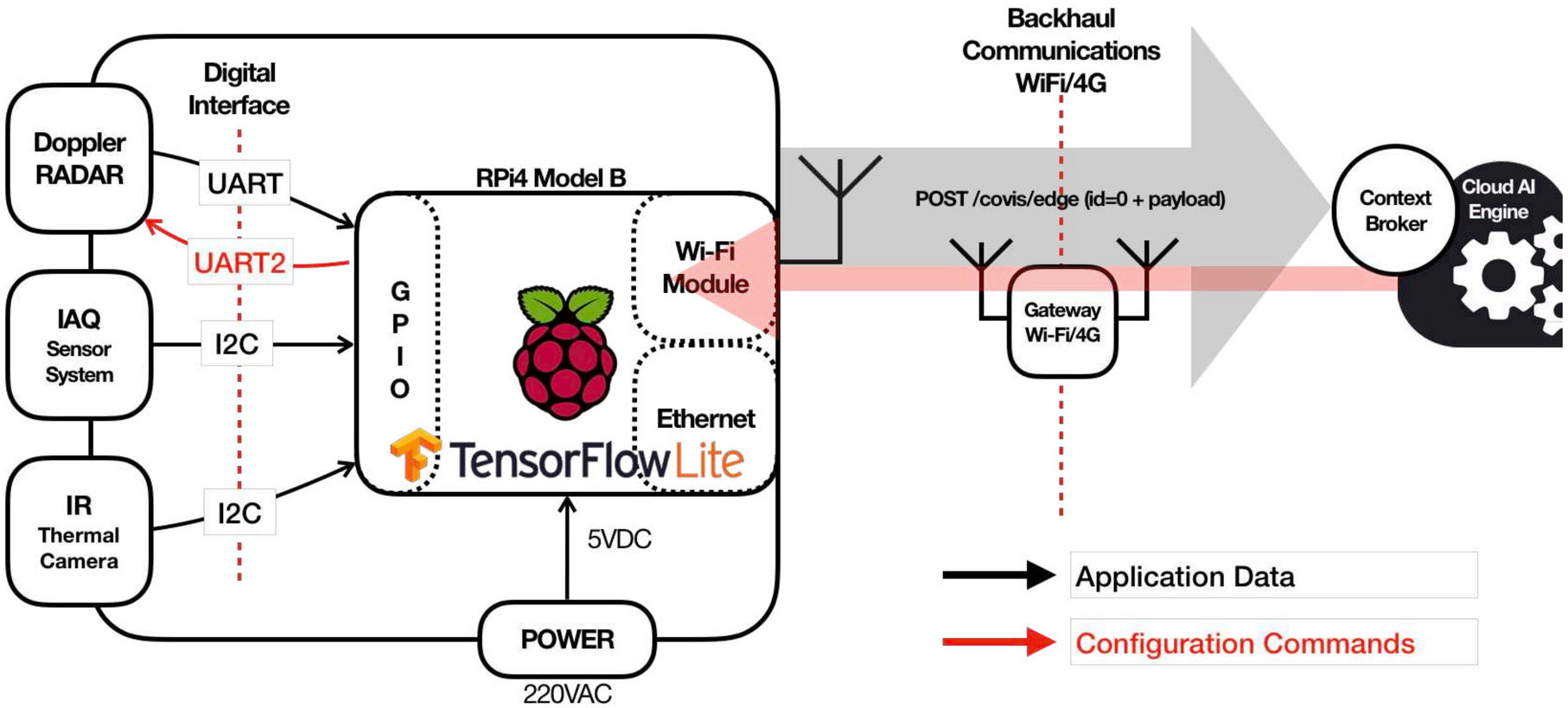
System Architecture



Source: S. I. Lopes, P. Pinho, P. Marques, C. Abreu, N. B. Carvalho and J. Ferreira, “Contactless Smart Screening in Nursing Homes: an IoT-enabled solution for the COVID-19 era,”, 17th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 2021, pp. 145-150,

Designing IoT-driven applications

IoT Edge Architecture

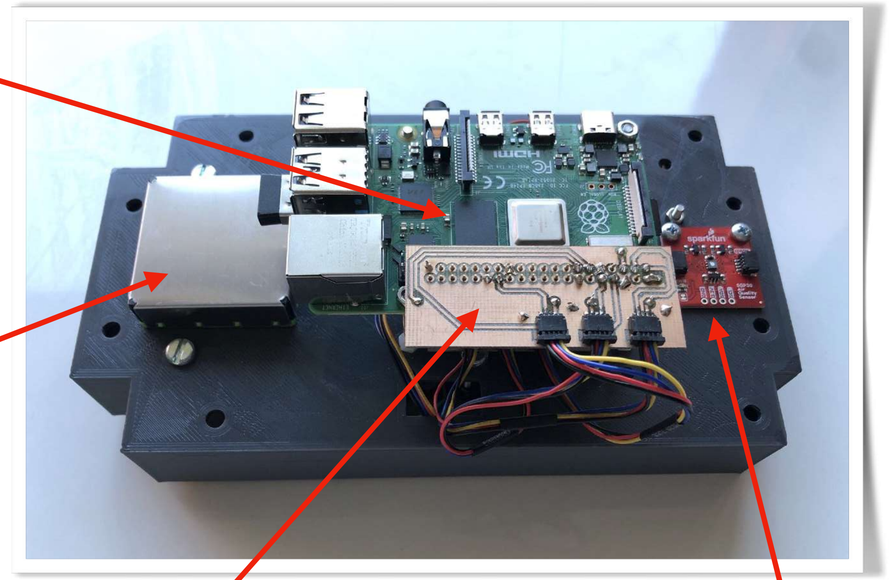


Source: S. I. Lopes, P. Pinho, P. Marques, C. Abreu, N. B. Carvalho and J. Ferreira, “Contactless Smart Screening in Nursing Homes: an IoT-enabled solution for the COVID-19 era,”, 17th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob), 2021, pp. 145-150,

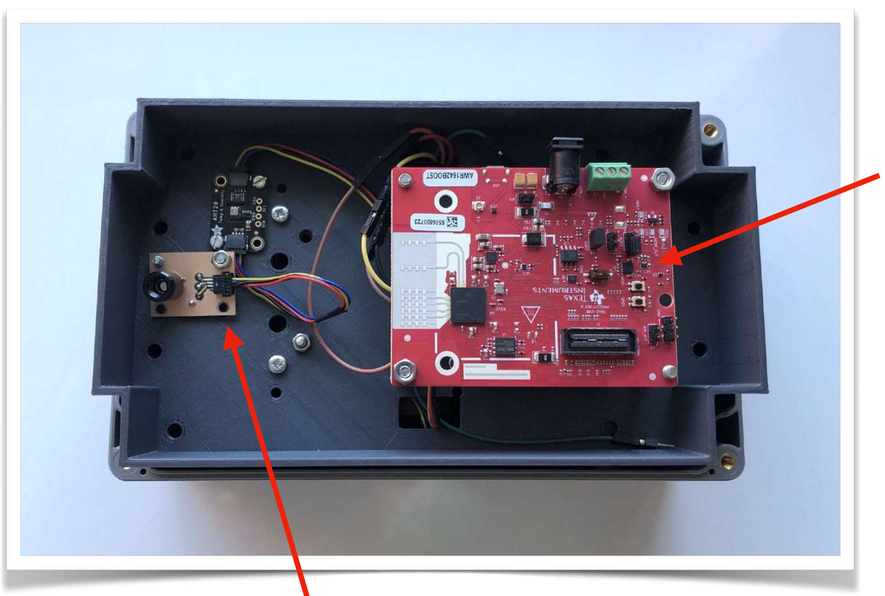
Designing IoT-driven applications

IoT Edge Prototype

Top View

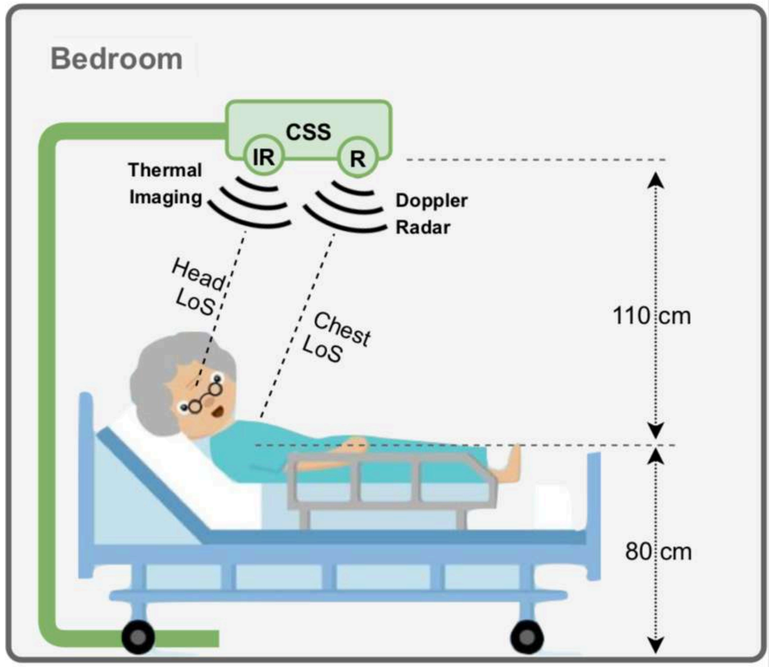


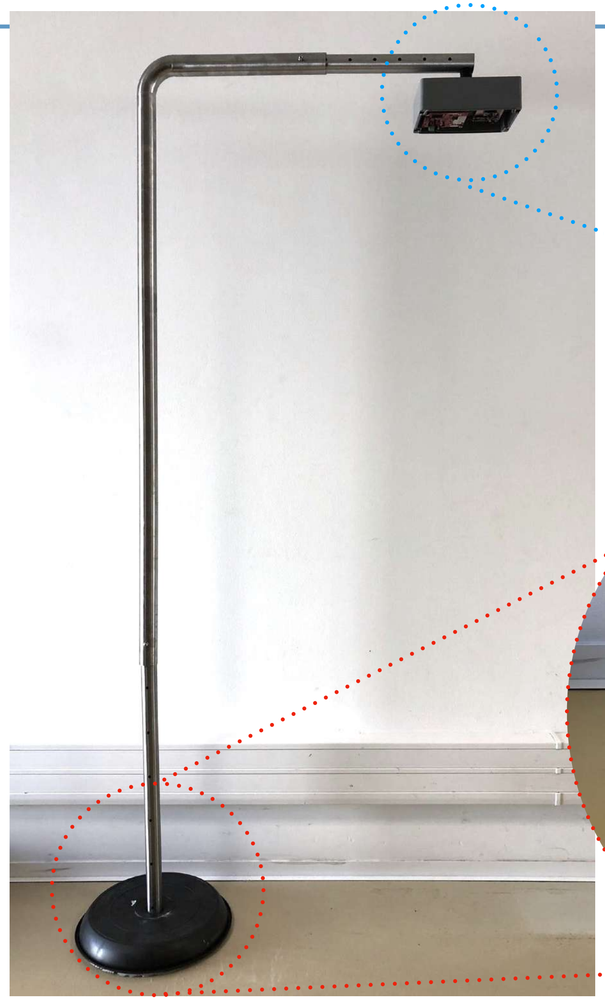
Bottom View

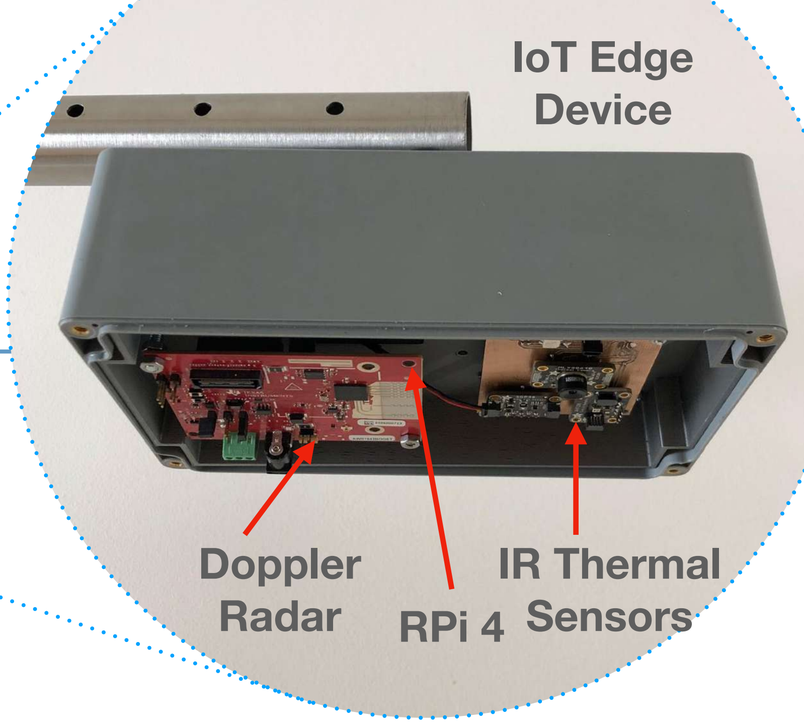


Designing IoT-driven applications

Prototype



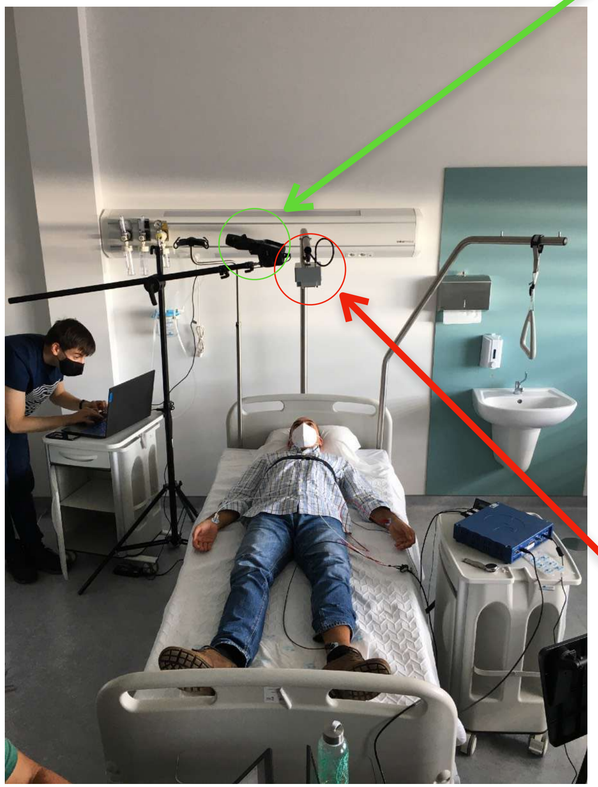




Concrete base

Designing IoT-driven applications

CVSM System Validation



FLIR E54 Reference Thermal Camera

Contactless VSM IoT Device

Biopac Reference Instrument

Designing IoT-driven applications

CVSM System Validation - Relative Error

- 5 distinct users where evaluated in three distinct positions (Tilted Bed, Lying Up, and Laying Sideways);
- Each experiment took 5 minutes and were taken with users at rest (immobilized);
- Average values have been obtained in each experiment;
- Relative Error obtained in comparison with the reference instruments.

Heart Rate			
Rehearsal	Tilted bed	Lying up	Lying sideways
3	6.724%	6.791%	0.695%
4	5.84%	1.651%	4.343%
5	1.323%	9.644%	6.683%
6	7.384%	11.11%	4.062%
7	5.154%	4.542%	19.339%

Respiratory Rate			
Rehearsal	Tilted bed	Lying up	Lying sideways
3	4.236%	1.533%	12.211%
4	1.865%	9.392%	1.214%
5	5.97%	6.776%	0.989%
6	1.91%	0.827%	1.223%
7	2.849%	12.073%	7.283%

Body Temperature			
Rehearsal	Tilted bed	Lying up	Lying sideways
3	6.946%	7.082%	5.993%
4	4.52%	5.493%	2.966%
5	nan%	1.662%	5.005%
6	0.242%	0.066%	1.028%
7	3.258%	2.254%	3.519%

Error < 10% in 87.5% of the cases

Error < 5% in 37.5% of the cases

Error < 10% in 85% of the cases

Error < 5% in 56,3% of the cases

Error < 10% in 93.8% of the cases

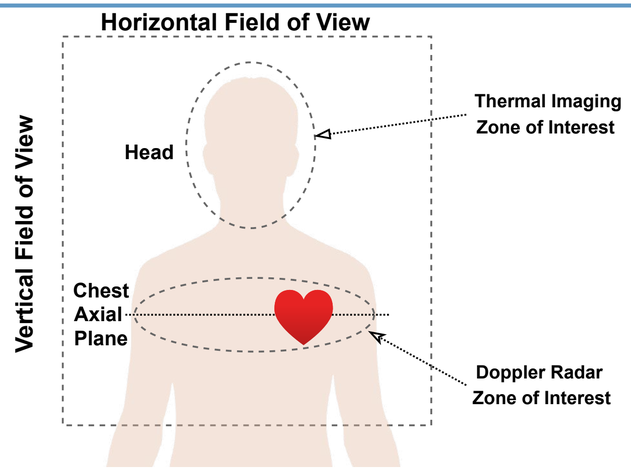
Error < 5% in 56.3% of the cases

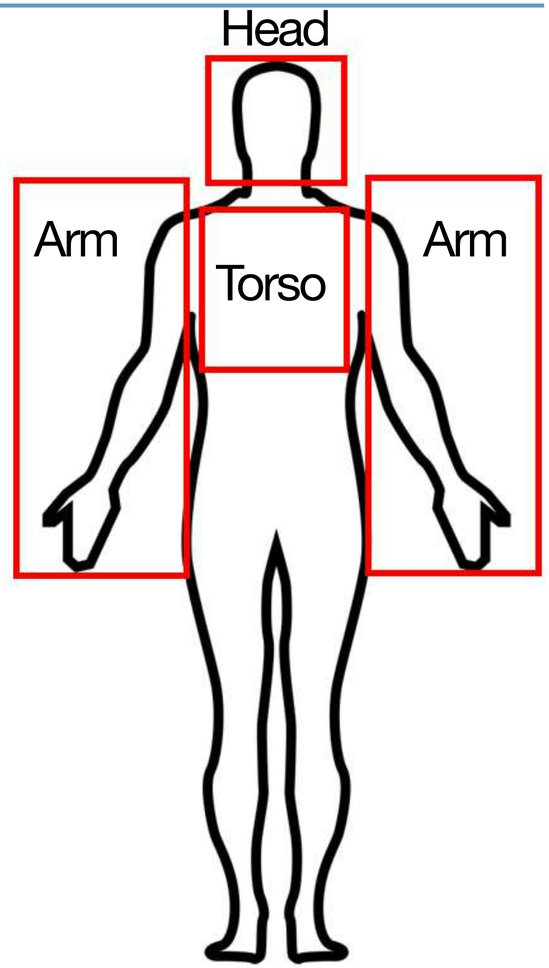
Errors outside medical grade scale > focus on assisting Healthcare professionals, not on diagnosis.

Designing IoT-driven applications

EdgeAI for Body Parts Identification

- Relevant for RoI Identification:
  - Head
    - Thermal Imaging RoI
  - Chest Axial Plane
    - Doppler Radar RoI
- Evaluated with FLIR E-54:
  - Thermal Images
  - RGB Images
- Future evaluation with FLIR Lepton

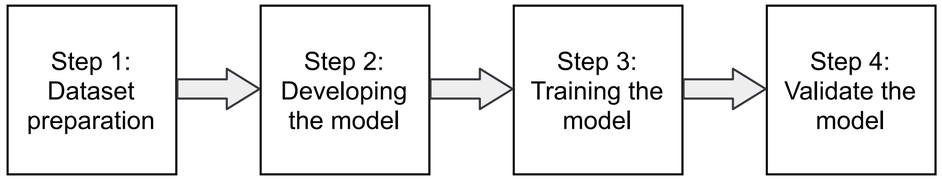


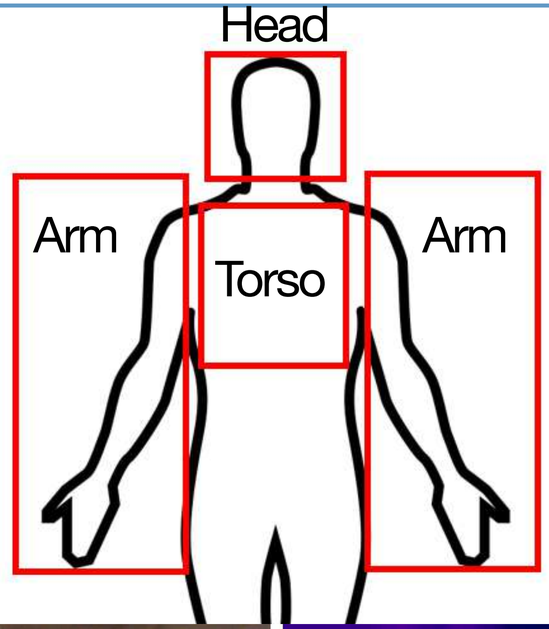


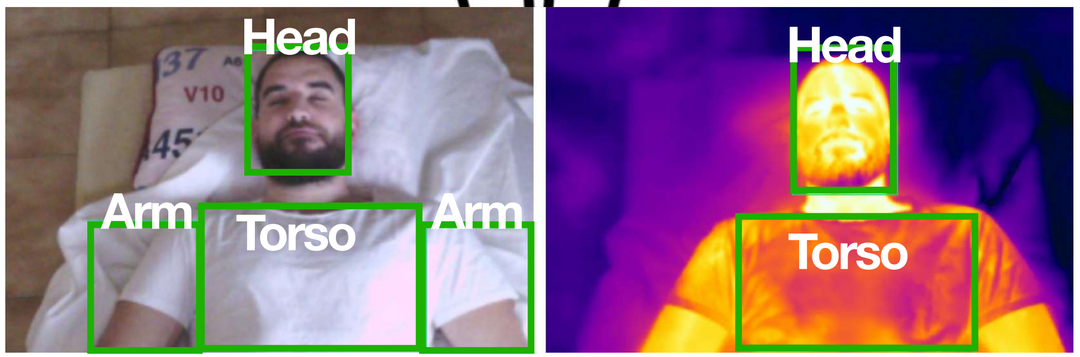
Designing IoT-driven applications

EdgeAI for Body Parts Identification

- Two models have been trained using a pre-defined object detection algorithm in Tensorflow:
  - SSD MobileNet V2 FPNLite model > TensorFlow Lite
    - RGB 640x640
    - Thermal 320x320
- Methodology:

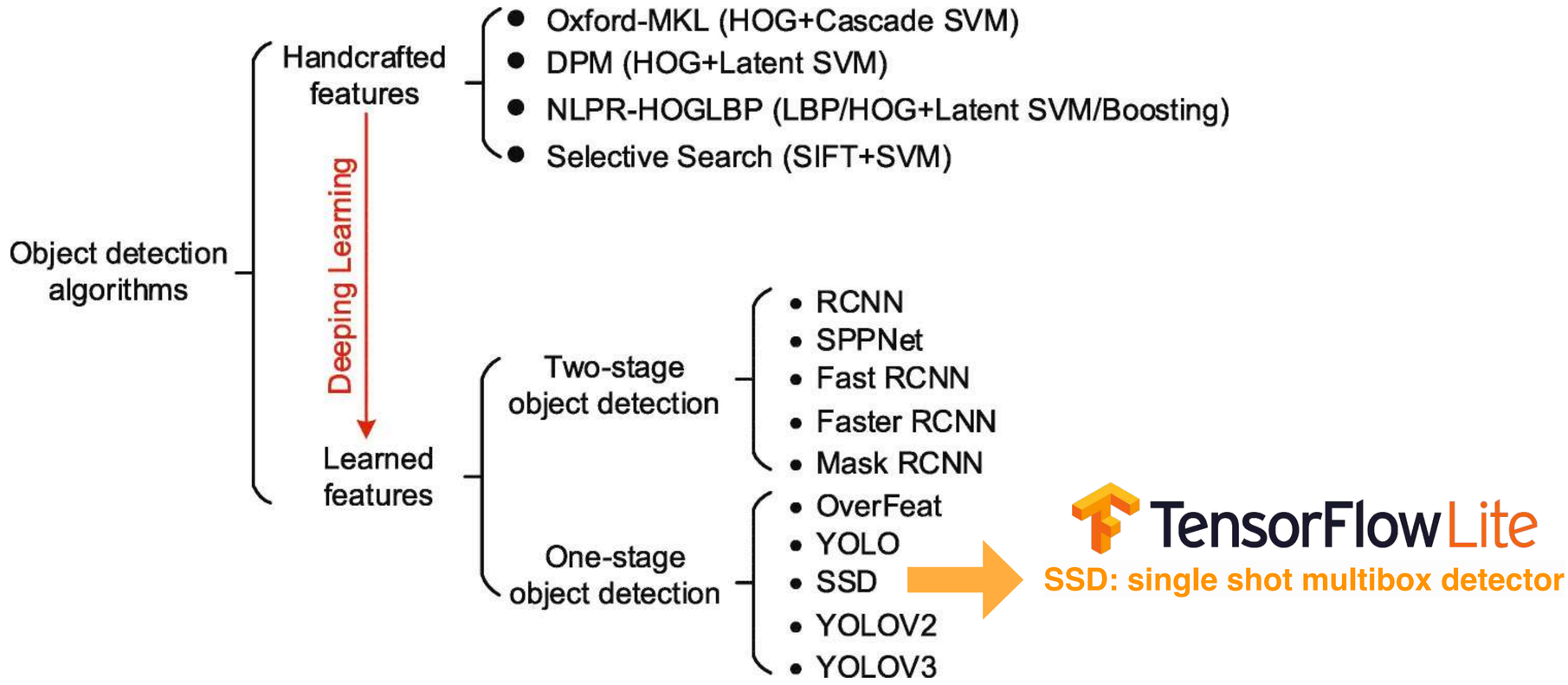






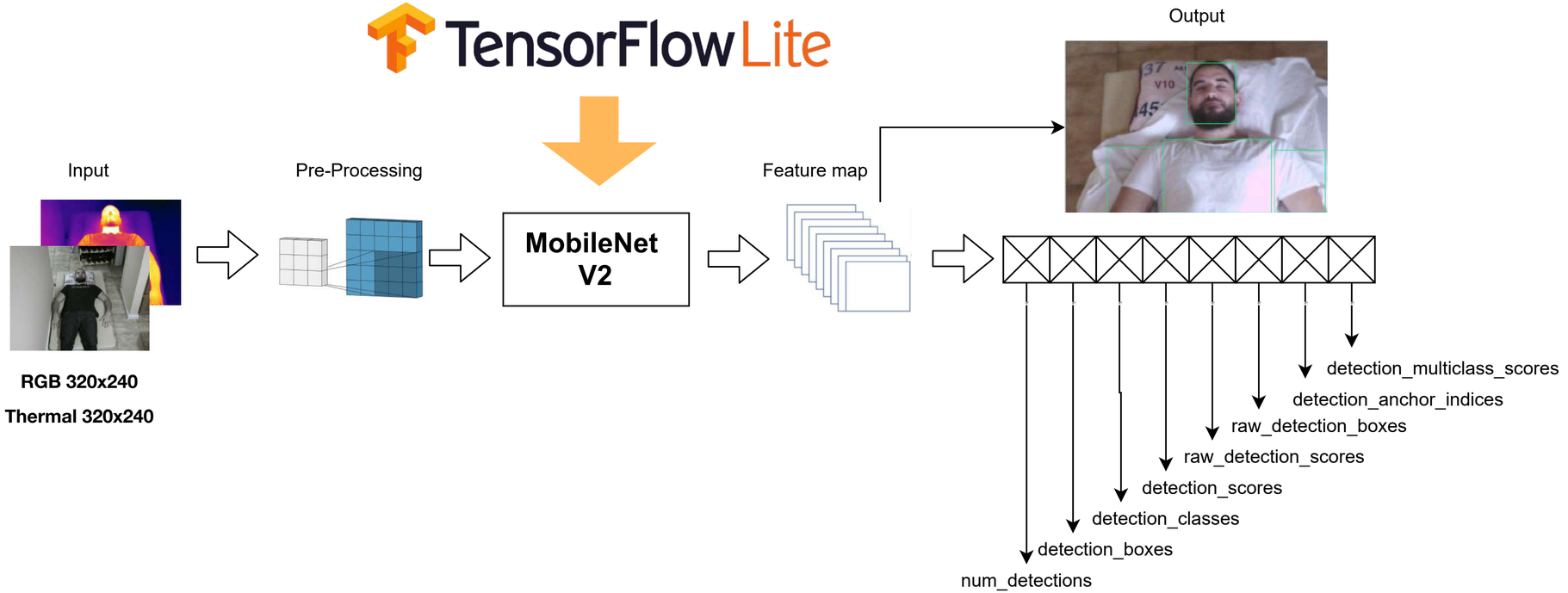
Designing IoT-driven applications

EdgeAI for Body Parts Identification



Designing IoT-driven applications

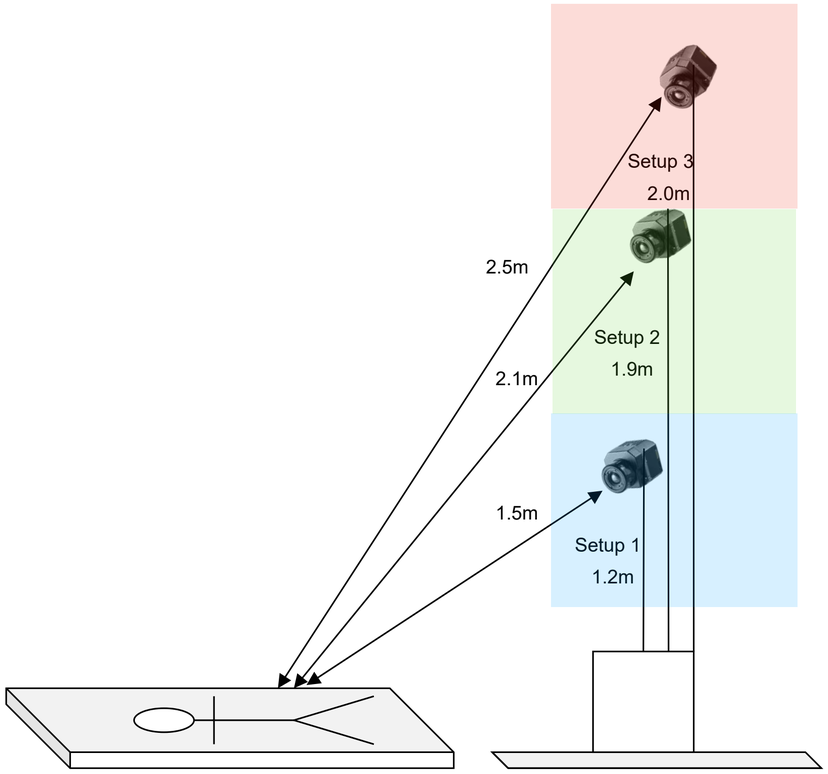
EdgeAI for Body Parts Identification



Source: D. Rocha, P. Rocha, J. Ribeiro, and S.I. Lopes, “Identification and Classification of Human Body Parts for Contactless Screening Systems: an Edge-AI Approach”, Edge-IoT 2021 – 2nd EAI International Conference on Intelligent Edge Processing in the IoT Era, Virtual, November 24-26, 2021.

Designing IoT-driven applications

EdgeAI for Body Parts Identification



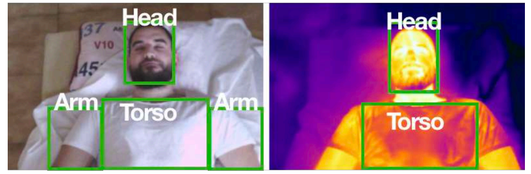


Table 1. Results summary for the three evaluated setups.

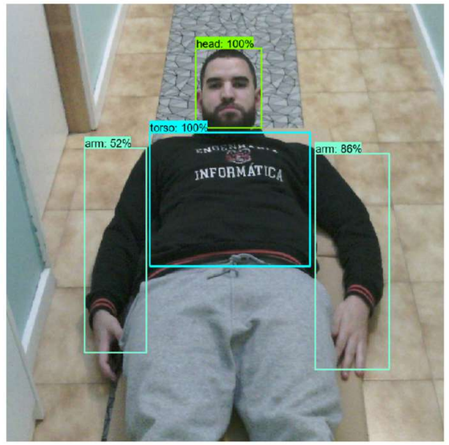
	Setup 1		Setup 2		Setup 3		Total	
	RGB	Thermal	RGB	Thermal	RGB	Thermal	RGB	Thermal
Accuracy					**> 97%**			
Head	95.51%	90.69%	97.82%	97.78%	99.97%	96.93%	98.97%	96.70%
Torso	90.50%	46.99%	77.19%	41.54%	94.45%	42.10%	89.42%	42.64%
Arms	38.87%	-	46.41%	-	63.27%	-	56.39%	-
Confidence					**> 95%**			
Head	95.23%	88.89%	95.76%	96.88%	100.00%	95.05%	98.40%	95.18%
Torso	83.33%	37.78%	61.86%	33.59%	92.45%	31.45%	83.33%	32.89%
Arms	22.62%	-	19.49%	-	52.34%	-	40.87%	-
Number of Images	42	45	118	128	278	283	438	456

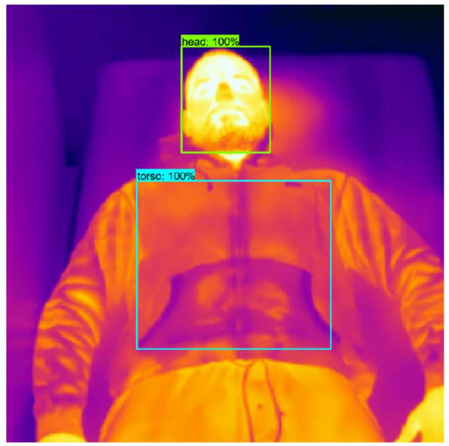
Source: D. Rocha, P. Rocha, J. Ribeiro, and S.I. Lopes, “Identification and Classification of Human Body Parts for Contactless Screening Systems: an Edge-AI Approach”, Edge-IoT 2021 – 2nd EAI International Conference on Intelligent Edge Processing in the IoT Era, Virtual, November 24-26, 2021.

Designing IoT-driven applications

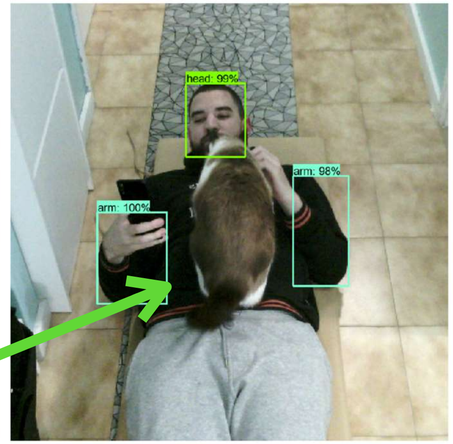
EdgeAI for Body Parts Identification

- Examples of results obtained with normal images (setup 3):



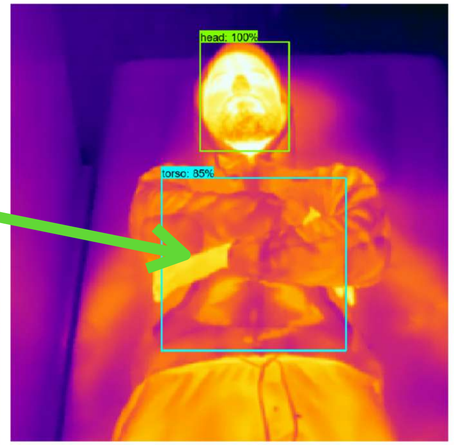


- Results obtained with images with artefacts (setup 3):



Cat

Arms crossed



IPVC-S2C

IPVC-S2C: Towards a Smart & Sustainable Campus

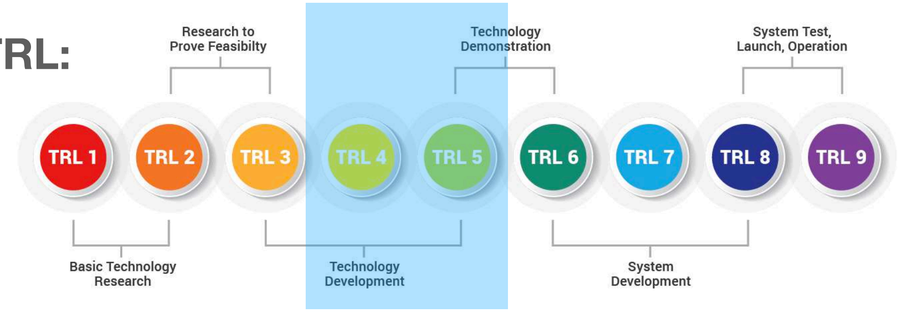
Instituto Politécnico de Viana do Castelo

SDGs:

4 QUALITY EDUCATION

11 SUSTAINABLE CITIES AND COMMUNITIES

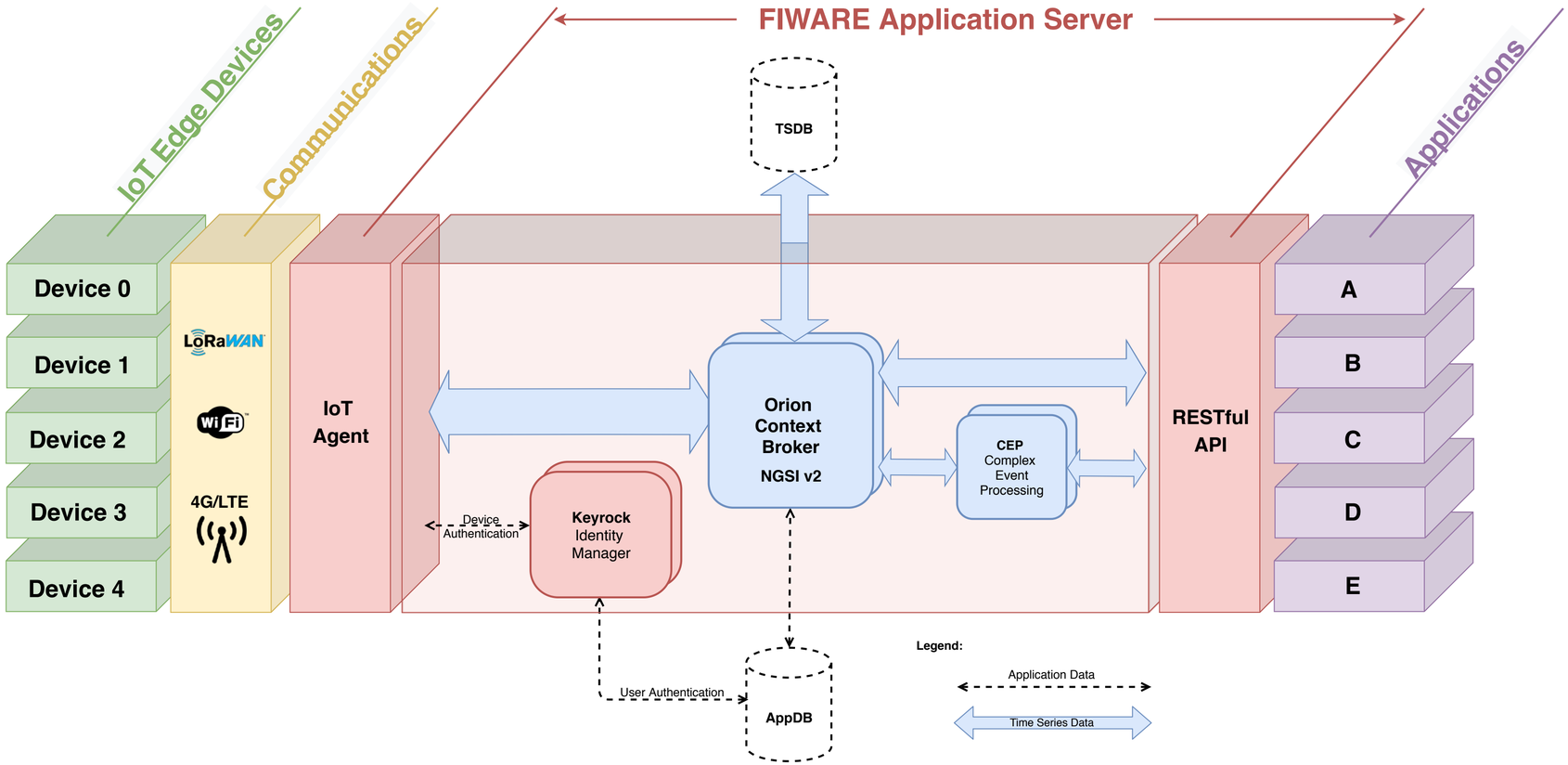
TRL:



- **Goals**:
  - Think the campus as a “small” City;
  - Aggregate IoT projects within the same platform;
  - Share IT and IoT resources;
  - Create awareness towards sustainable practices by integrating:
    - IoT technologies;
    - Learning activities, i.e. Project-based Learning;
    - R&D activities

IPVC-S2C

IPVC-S2C: Towards a Smart & Sustainable Campus

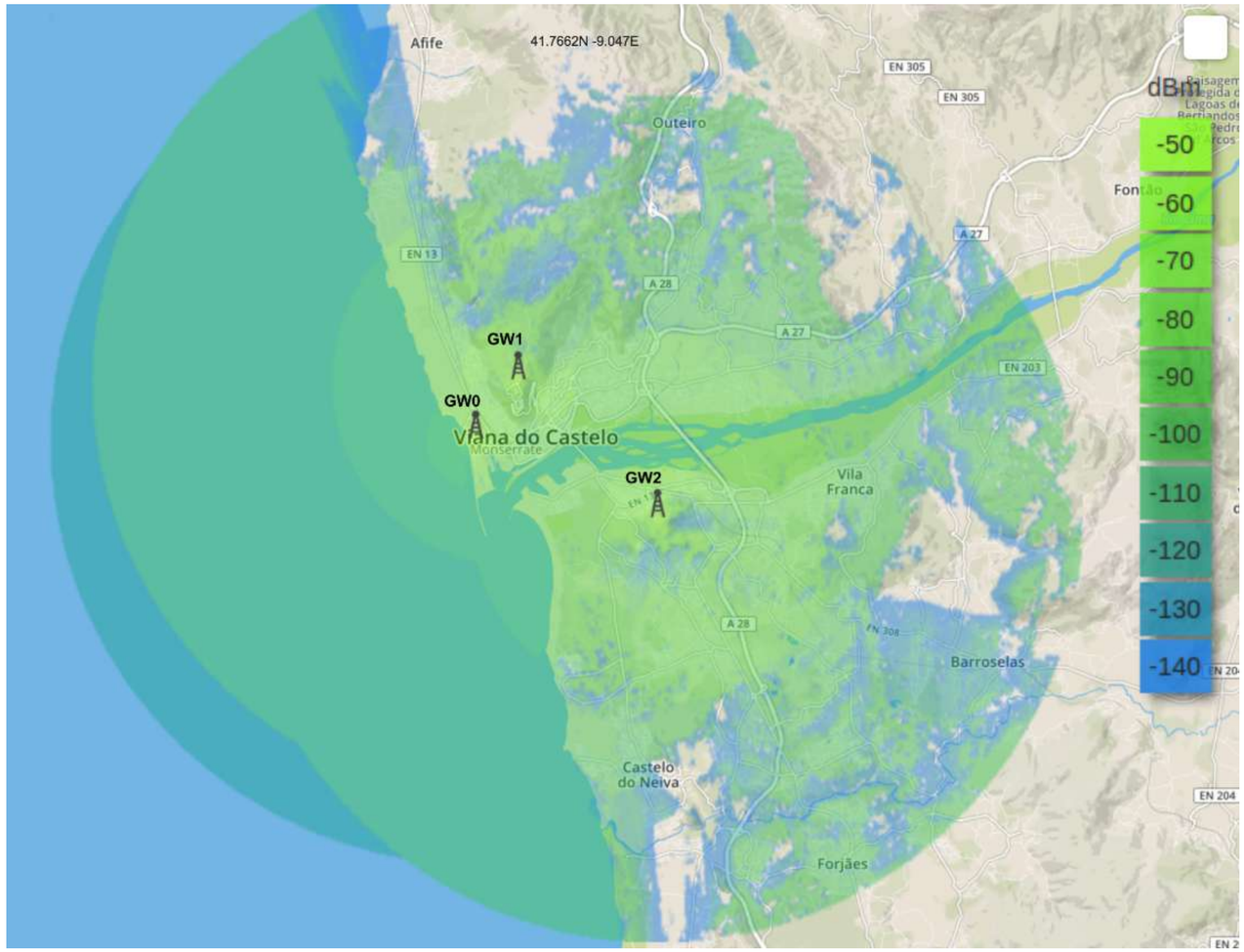


Source: P. Martins, S.I. Lopes, A. M. R. Cruz and A. Curado, “Towards a Smart & Sustainable Campus: An Application-Oriented Architecture to Streamline Digitization and Strengthen Sustainability in Academia”, Sustainability 2021, 13, 3189, DOI: 10.3390/su13063189.

Designing IoT-driven applications

IPVC-S2C

LoRaWAN @ Viana do Castelo



LoRaWAN™

- Cobertura estimada com 3 GWs:
  - GW0 @ ESTG-IPVC;
  - GW1 @ Monte Santa Luzia;
  - GW2 @ Monte Galeão:

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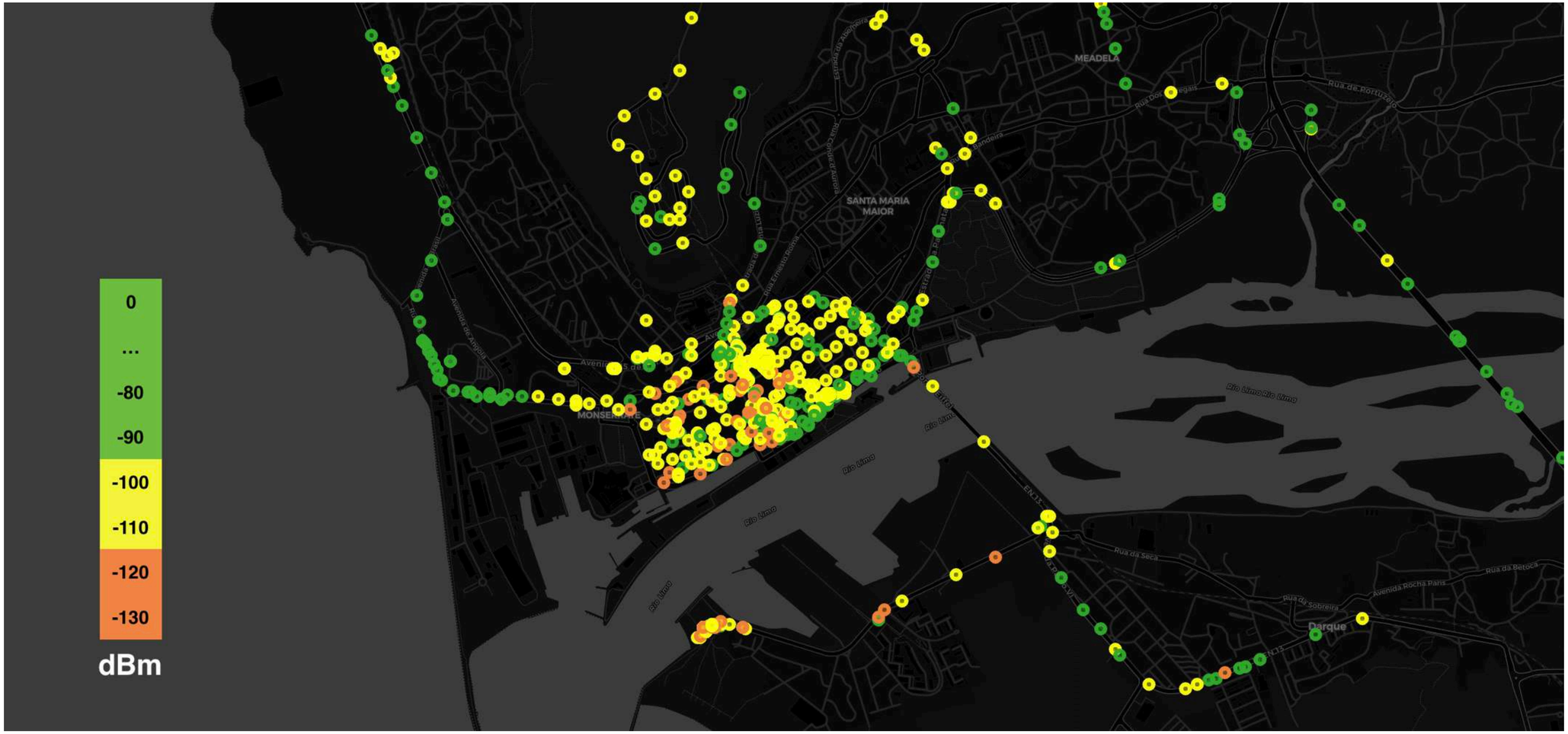
IPVC-S2C

LoRaWAN @ Viana do Castelo



Designing IoT-driven applications

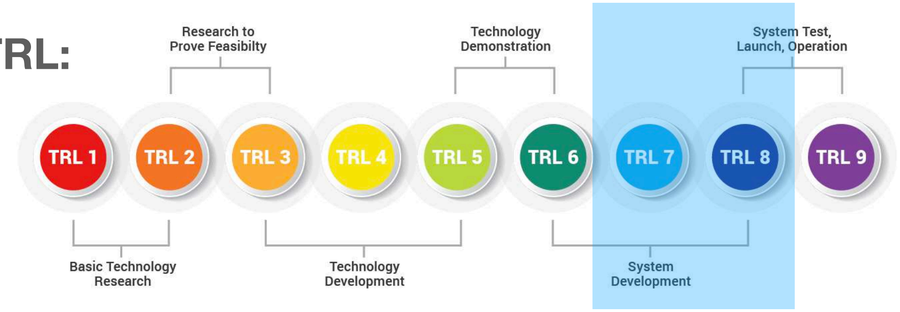
IPVC-S2C

Refill_H2O: Plastic Reduction on Campus

Instituto Politécnico de Viana do Castelo

SDGs:

TRL:



- **Facts**:
  - 51.000 bottles (500 ml) + 15.000 bottles (1500 ml), are consumed annually at the IPVC campus.
  - This is equivalent to 1215 kg of plastic
- **Goals**:
  - Stop selling disposable plastic water bottles on campus
  - Create awareness towards sustainable practices on campus
- **Funding**:

Iceland Liechtenstein Norway grants

EEA Grants Portugal

Mecanismo Financeiro do Espaço Económico Europeu
European Economic Area Financial Mechanism
Unidade Nacional de Gestão
National Focal Point

Designing IoT-driven applications

IPVC-S2C

Refill_H2O: System Architecture

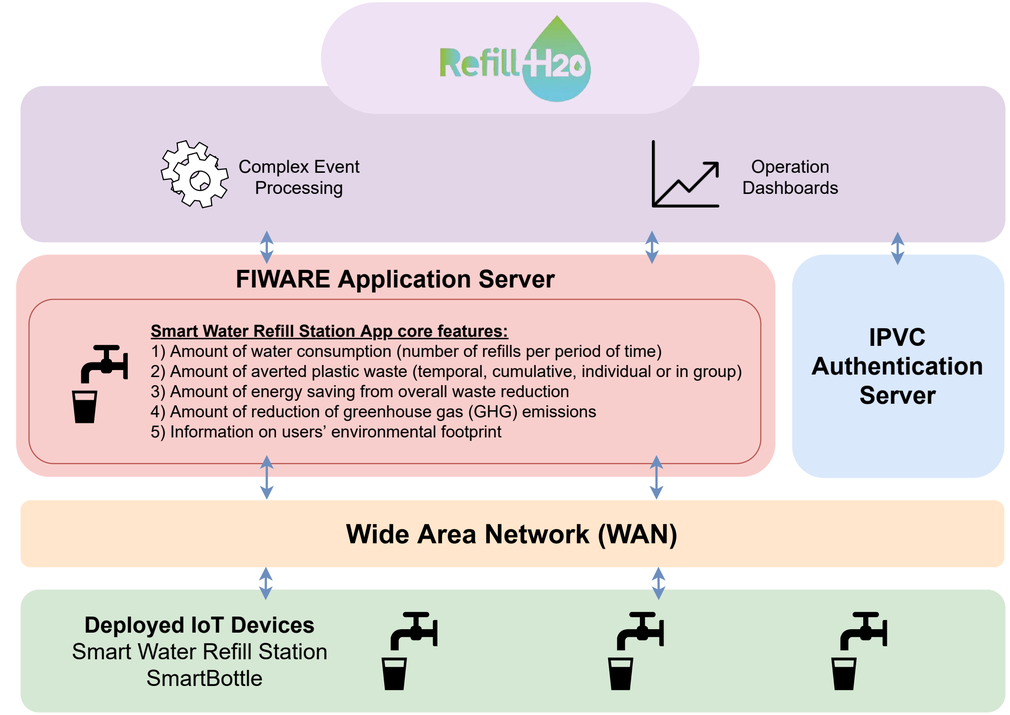
IoT Water Refill Station

Bottle Refill Zone

Display User Interface

ATM Payment

RFID Reader



IoT connected bottle

RFID Tag

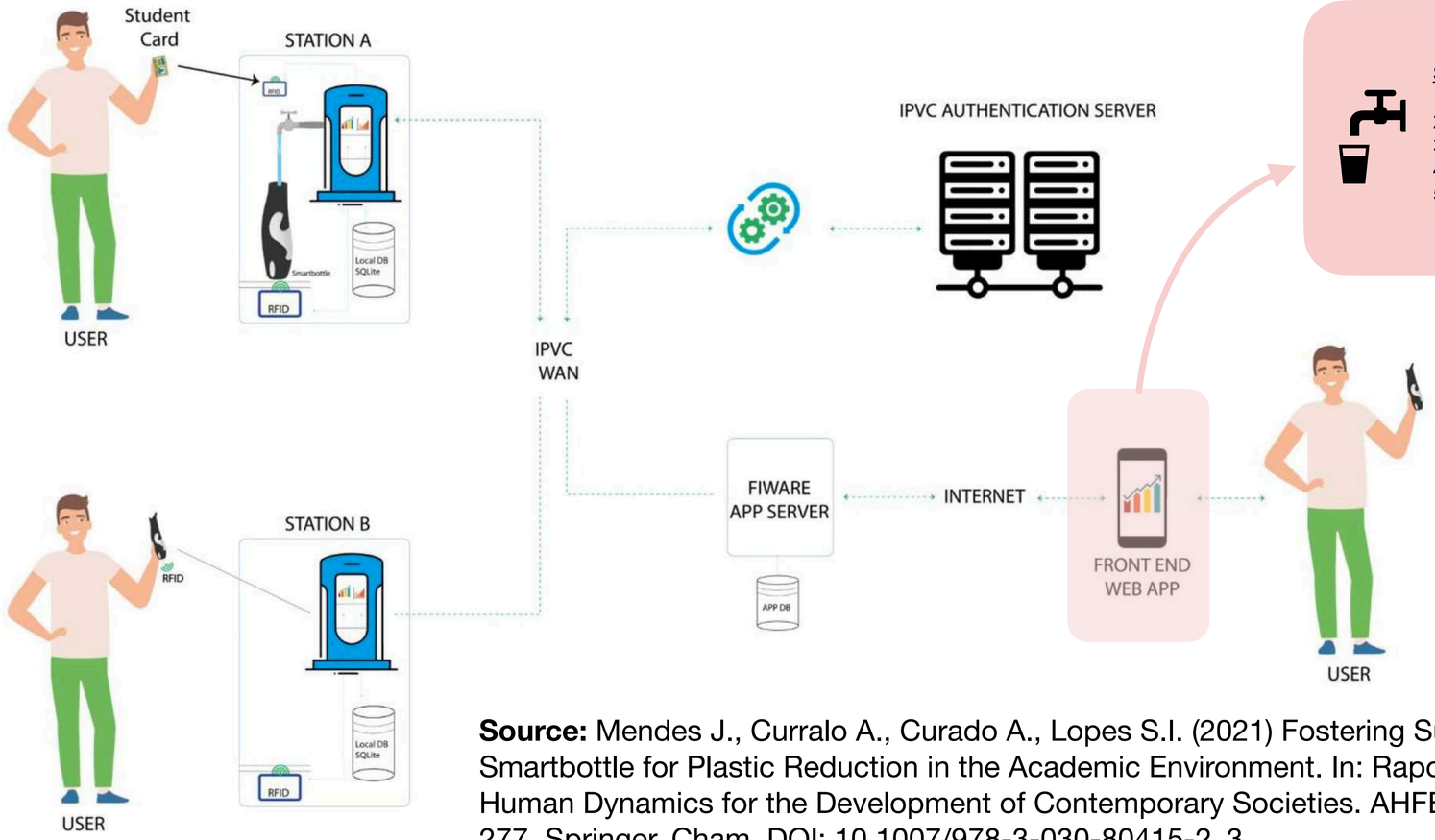
Reusable IPVC Smart Bottle

Source: Mendes J., Curralo A., Curado A., Lopes S.I. (2021) Fostering Sustainability on Campus: Design of an IoT-Enabled Smartbottle for Plastic Reduction in the Academic Environment. In: Raposo D., Martins N., Brandão D. (eds) Advances in Human Dynamics for the Development of Contemporary Societies. AHFE 2021. Lecture Notes in Networks and Systems, vol 277. Springer, Cham. DOI: 10.1007/978-3-030-80415-2_3

Designing IoT-driven applications

IPVC-S2C

Refill_H2O: How it Works



Smart Water Refill Station App core features:

1) Amount of water consumption (number of refills per period of time)
2) Amount of averted plastic waste (temporal, cumulative, individual or in group)
3) Amount of energy saving from overall waste reduction
4) Amount of reduction of greenhouse gas (GHG) emissions
5) Information on users' environmental footprint

Source: Mendes J., Curralo A., Curado A., Lopes S.I. (2021) Fostering Sustainability on Campus: Design of an IoT-Enabled Smartbottle for Plastic Reduction in the Academic Environment. In: Raposo D., Martins N., Brandão D. (eds) Advances in Human Dynamics for the Development of Contemporary Societies. AHFE 2021. Lecture Notes in Networks and Systems, vol 277. Springer, Cham. DOI: 10.1007/978-3-030-80415-2_3

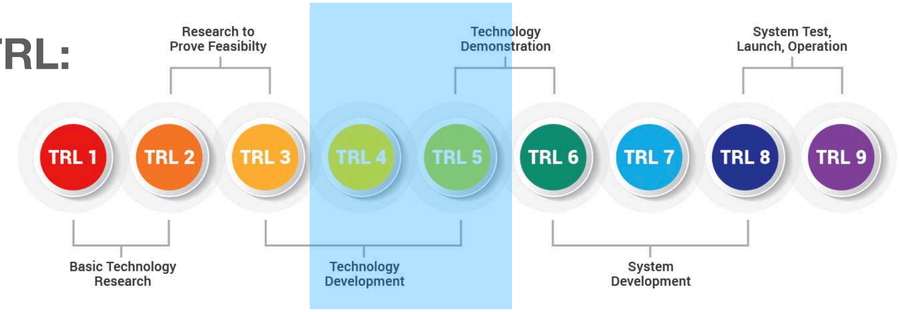
Designing IoT-driven applications

IPVC-S2C

BIRA Bicycle Real-Time Tracking

SDGs:

TRL:



ipvc

Instituto Politécnico de Viana do Castelo

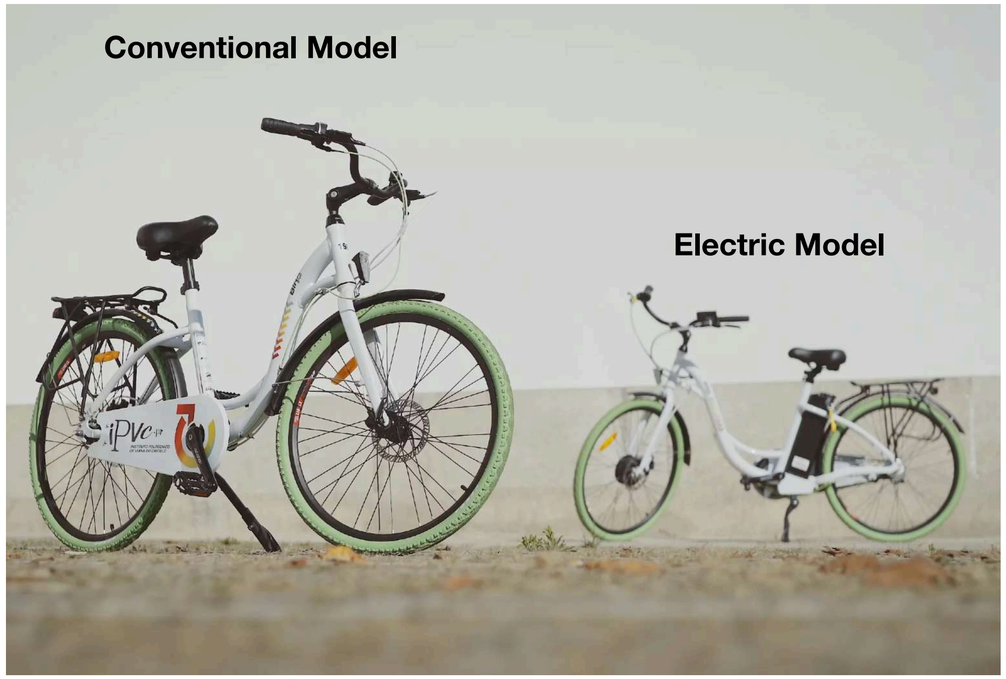
- **Facts**:
  - The BIRA Bicycle is accessible to the academic community (students, professors, staff, and researchers);
  - Bicycles are re-assigned annually to the users that have performed more Kms and thus contribute more to the reduction of CO2 Emissions.
- **Goals**:
  - Track Bicycles and effectively count user Kms;
  - Create awareness towards sustainable practices on campus:
- **Funding**:

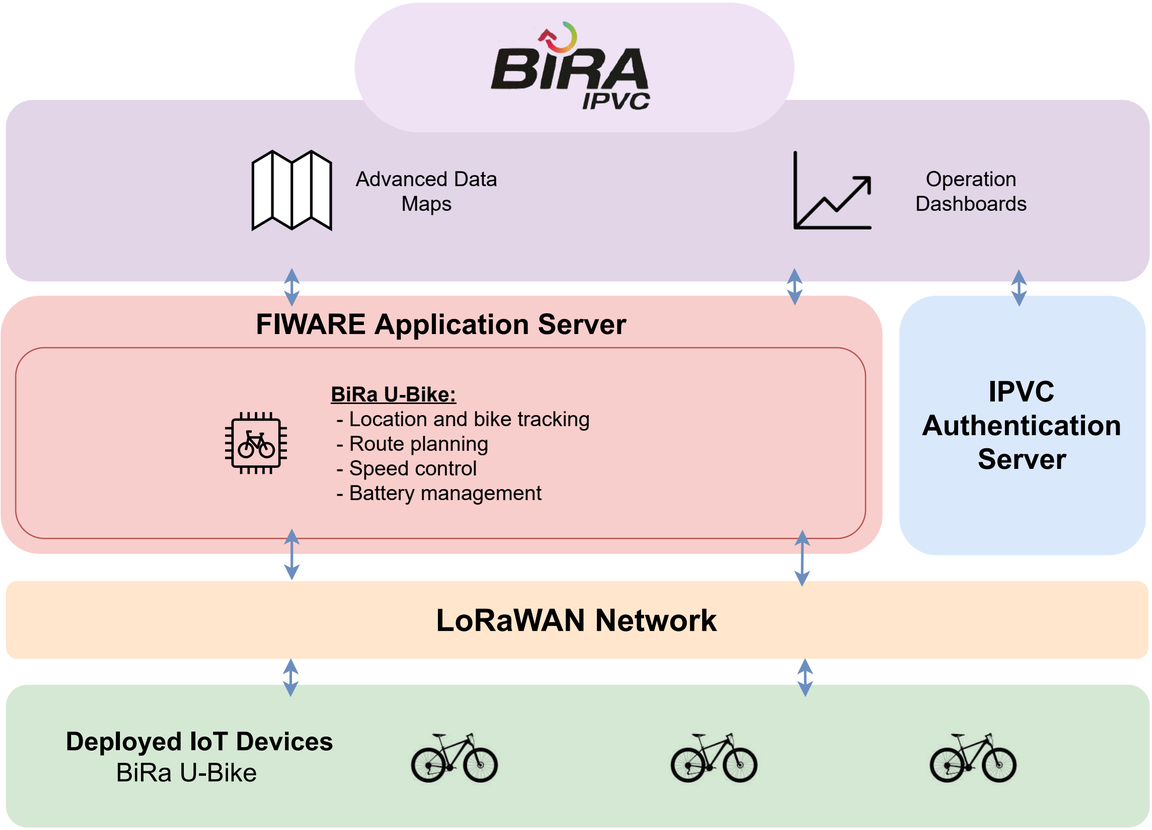
POSEUR PROGRAMA OPERACIONAL SUSTENTABILIDADE E EFICIÊNCIA NO USO DE RECURSOS 2014 20 · PORTUGAL 2020 · UNIÃO EUROPEIA Fundo de Coesão

Designing IoT-driven applications

IPVC-S2C

BIRA Bicycle Real-Time Tracking





Source: N. Torres, P. Martins, P. Pinto and S. I. Lopes, “Smart & Sustainable Mobility on Campus: A secure IoT tracking system for the BIRA Bicycle,” 2021 16th Iberian Conference on Information Systems and Technologies (CISTI), 2021, pp. 1-7, DOI: 10.23919/CISTI52073.2021.9476495.

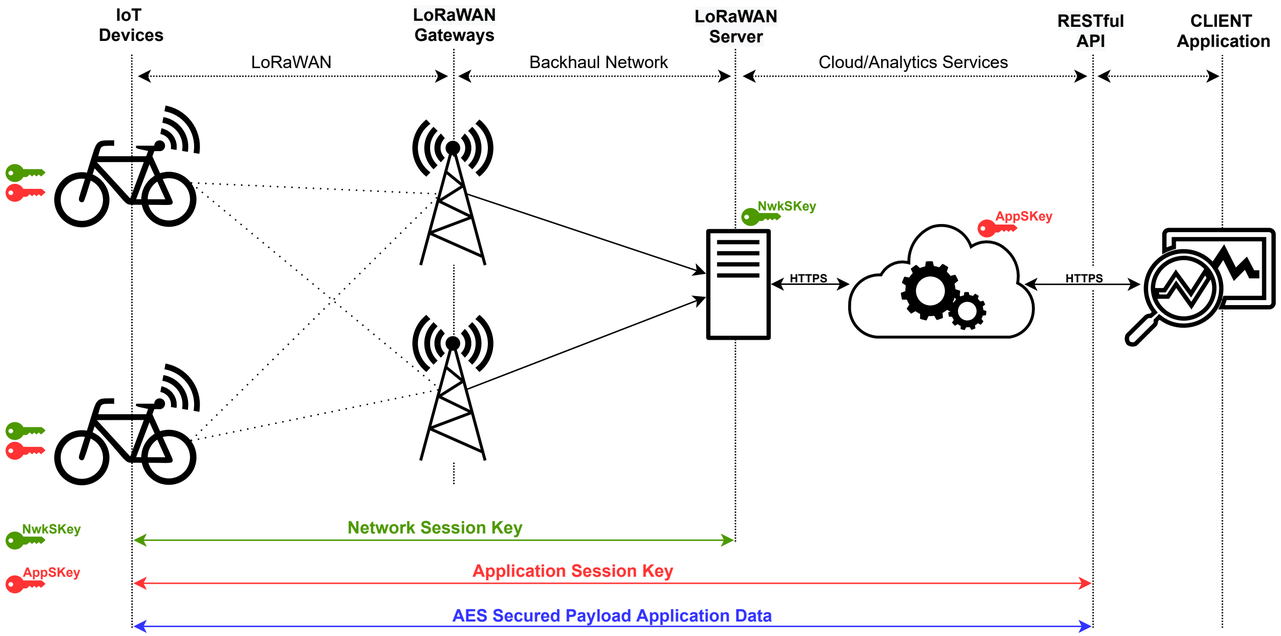
Designing IoT-driven applications

IPVC-S2C

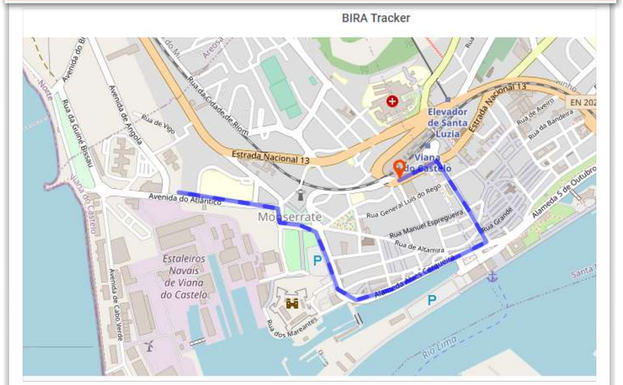
BIRA Bicycle Real-Time Tracking

IoT-Tracker with LoRAWAN Connectivity

IoT-Enabled BiRa Bicycle



BiRa U-Bike:
- Location and bike tracking
- Route planning
- Speed control
- Battery management



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Final Remarks

- The **digital age presents challenging yet promising opportunities for sustainable innovation** in diverse sectors;
- **Multidisciplinary environments are essential drivers of sustainable innovation** in the digital age, e.g. STEAM (Science, Technology, Engineering, Arts, and Mathematics);
- **Policymakers hold a critical position in establishing an enabling environment that fosters sustainable innovation** (e.g., government, city council, rectory, etc.);
- The **digital age enables the democratization of innovation by leveraging open-source platforms and encouraging citizen participation**;
- To **achieve successful implementations of sustainable innovation**, a holistic approach is imperative, considering its **technological**, **social**, **economic**, and **environmental** dimensions.

Department of Information Engineering
University of Padua - UNIPD, ITALY
9 April 2024

Thank you!

Grazie!

Sérgio Ivan Lopes (sil@estg.ipvc.pt)

Assistant Professor, Instituto Politécnico de Viana do Castelo, Portugal
Researcher, Instituto de Telecomunicações, Aveiro, Portugal
Director-General, CiTin - Centro de Interface Tecnológico Industrial
IEEE Senior Member, Professional Activities Appointed Officer - Portuguese Section

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