A perspective on Next Generation IoT impact, success stories, and business modelling aspects

April 2023

Authors:
Rute C. Sofia, Manel Khelifi, Emilie Jakobson, Mirko Presser, John Soldatos, Lamprini Kolovou, Monique Calisti

The European IoT Hub
Growing a sustainable and comprehensive ecosystem for Next Generation Internet of Things

ngiot.eu

Table of Contents

Disclaimer

The information contained in this document is provided for informational purposes only and should not be construed as legal advice on any subject matter.
This information is:

- of a general nature only and is not intended to address the specific circumstances of any particular individual or entity
- not necessarily comprehensive, complete, accurate or up to date
- sometimes linked to external sites over which the authors services have no control and for which no responsibility is assumed
- not professional or legal advice (if you need specific advice, you should always consult a suitably qualified professional).

Grant Agreement N°: 956671

Topic: ICT-56-2020

Acronyms

3GPP	3rd Generation Partnership Project (3GPP)
5G-ACIA	5G Alliance for Connected Industries and Automation
5G-IA	5G Infrastructure Association
6G IA	6G Smart Networks and Services Industry Association
AB	Advisory Board
AI	Artificial Intelligence
AIoT	Artificial Intelligence of Things
AIOTI	Alliance for Internet of Things Innovation IVZW
BDVA	Bid Data Value Association
CB	Coordination Board
CCIS	Culture, Creativity, and Inclusive Society
CCS	Civil Security for Society
CEM	Climate, Energy, and Mobility
CENELEC	European Committee for Electrotechnical Standardisation
CTF	Coordination Task Force
DIS	Digital, Industry, Space
EC	European Commission
ETSI	European Telecommunications Standards Institute
EU	European Union
FAIR	Findable, Accessible, Interoperable, and Reusable
FBNRAE	Food, Bioeconomy, Natural, Resources, Agriculture, and Environment
FL	Federated Learning
Gaia-X	A federated data infrastructure for Europe
ICT	Information and Communication Technologies
IEEE	Institute of Electrical and Electronics Engineering
IETF	Internet Engineering Task Force
IoT	Internet of Things
IoT	Internet of Things
IP	Internet Protocol
IRTF	Internet Research Task Force
ISO	International organisation for standardisation
IT	Informational Technology
ITU-T	International Telecommunication Union
KER	Key Exploitable Result
KPI	Key Performance Indicator
KPI	Key Performance Indicator
MEC	Multi-access Edge Computing
ML	Machine Learning
NGIoT	Next Generation Internet of Things
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
RIA	Research and Innovation Action
SDG	Sustainability Development Goals
SDN	Software Defined Networking
SDO	Standards Development Organization
SMEs	Small and Medium Enterprises
TRL	Technology Readiness Level
WoT	Web of Things

EXECUTIVE SUMMARY

Having as scope the Next Generation IoT, the Cooperation and Support Action EU-IoT has developed between 2020 and 2023 an analysis of 6 flagship projects under the Horizon 2020 topic H2020-ICT-56-2020: Next Generation Internet of Things.

In this context, the projects have been researching and developing solutions integrating Internet of Things (IoT) technologies to leverage the European technological strength and leadership in the context of a next generation of IoT devices and systems, focusing on advanced topics such as beyond 5G, cyber-security, distributed computing, artificial intelligence (AI), Augmented Reality and tactile Internet.

This document provides an overview on the achieved impact, key research and innovation assets, lessons learned and success stories that have been collected in cooperation with the projects.

1 INTRODUCTION

The CSA EU-IoT has developed between 2020 and 2023 an impact assessment of the Next Generation IoT flagship *Research and Innovation Actions (RIAs)*, based on a series of analytical processes, the EU-IoT impact assessment framework (Deliverable D5.5, September 2021 [1]), in tight consultation with the RIAs.

By relying on the proposed tooling, EU-IoT has derived guidelines and lessons learned that benefit both ICT-56 projects and other projects with focus on IoT:

- Strengthen the focus towards the EU vision regarding SDG contributions.
- Identify relevant areas, groups, and entities such as Standards Developments Organizations and other audiences to further direct dissemination, communication, and exploitation.
- Identifying potential synergies between the participating projects.
- Provide an overview of the project's targeted or desired impacts.
- Provides success stories across different vertical domains, Energy, Manufacturing, Agriculture, among others.

1.1 EU-IoT Impact Assessment Framework Summary

The gathering of information and analysis derives from an iterative methodology conducted by EU-IoT between October 2020 and March 2023.

The methodology [1] derives from an effort involving the projects, the EU-IoT consortium, the RIAs, the Expert Group of EU-IoT. Joint workshops involving RIAs have assisted in further understanding the different project objectives and proposed assets, and initial exploitation proposals. Specific surveys (2021, 2022, 2023) have been shared with RIAs and assisted in collecting relevant input for both a qualitative and quantitative impact analysis. The survey's data collection has been complemented with one-to-one Web conferencing meetings with RIAs, to collect further data and eventually complement and correct previously the collected information. Then, results have been presented in different EU-IoT events such as dedicated sessions or workshops, to ignite awareness and to collect additional feedback.

The overall impact assessment has both a **qualitative** and a **quantitative** component. The **qualitative analysis** carried out in EU-IoT focuses on the contributions of the RIAs towards SDGs and the contributions towards the EU-IoT scope areas, by addressing impact on the six clusters that compose Horizon Europe's second Pillar, "Global Challenges and European Industrial Competitiveness" namely:

- Health.
- Culture, creativity, and Inclusive society.
- Civil Security for Society.
- Digital, industry, and Space.
- Climate Energy and Mobility.
- Food Bioeconomy, Natural Resources, Agriculture and Environment Impact.

The expected outcome of the projects in terms of technology, skills training, business exploitation, and standards, and policies assets have also been assessed in regard to the end-to-end vision of an IoT system abstraction reflected in the **the EU-IoT scope areas** [2]:

- **Human/ IoT interfaces** relates to topics such as intelligence, digital interfaces (e.g., virtual reality), sensing digital (e.g., tactile internet), and robotics.
- **Far Edge** relates to topics such as intelligence at the far edge, improving processing (e.g., low power devices), and context awareness.
- **Near Edge** relates to topics such as intelligence at the near edge and improving processing (e.g., virtualization- digital twins).
- **Infrastructure** relates to topics such as improving processing (e.g., network virtualization) and intelligent networks (e.g., time-sensitive networking, 5G).
- **Data spaces** relate to topics such as efficient and secure data spaces (e.g., plug & play models for autonomous applications) and managing data spaces (e.g., data governance).

The **quantitative analysis** component focuses on a collection of relevant research and development Key Performance Indicators (KPIs) to assist in an objective assessment of scientific and innovation impact; open calls impact; business exploitation impact. For this purpose, the following KPI guidelines have been considered:

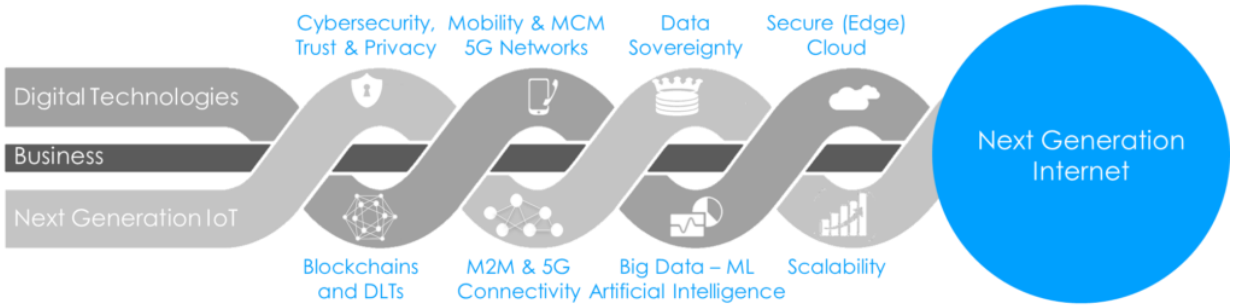
- For scientific excellence and innovation, EU-IoT adopts the guidelines of the OECD 2015 Frascati Manual for research and development indicators [8], in a way that components the proposed project indicators. Such KPIs are widely used across Europe for the purpose of assessing the impact of *R&D.*
- For use-case and business impact assessment, EU-IoT adopts common business KPIs in alignment with the CSA OpenDEI, input from the AB and from the Expert Group.

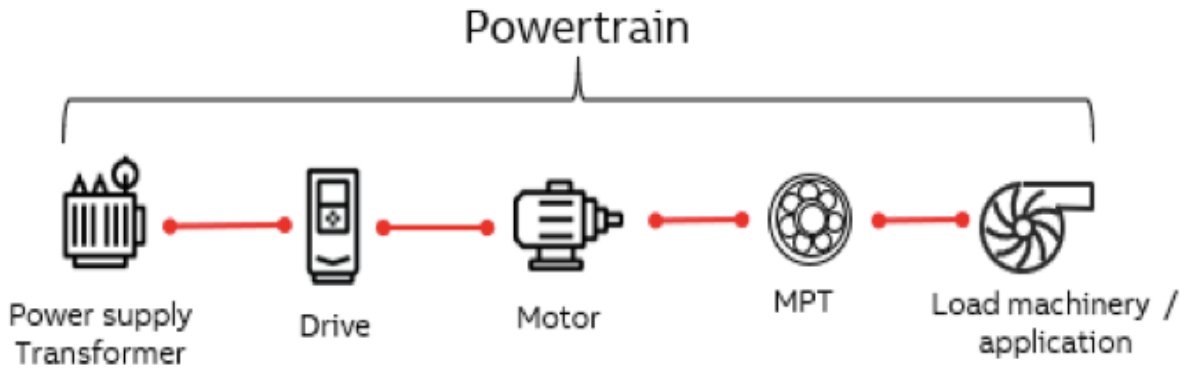
2 ICT-56 RIAS SUCCESS STORIES

2.1 IoT-NGIN:

Project title: IoT Engine
Duration: 01.11.2020- 31.10.2023
Website: https://iot-ngin.eu/

Internet of Things (IoT) is one of the next big concepts to support societal changes and economic growth, being one of the fastest growing ICT segments. A specific challenge is to leverage existing technology strengths to develop solutions that sustain the European industry and values. IoT-NGIN introduces novel research and innovation concepts, acting as the “IoT Engine” which will fuel the Next Generation of IoT as a part of the European Next Generation Internet. IoT-NGIN uncovers a pattern-based meta-architecture that encompasses evolving, legacy, and future IoT architectures. The project also optimizes IoT/M2M and 5G/MCM communications, including using secure-by-design micro-services to extend the edge cloud paradigm.Moreover, it enables IoT systems to be self-aware and autonomous through privacy-preserving federated ML and ambient intelligence with AR support for humans. Distributed IoT cybersecurity and privacy, for example, using Self-Sovereign Identities and interconnected DLTs to implement Meta-Level Digital Twins, are also among the main priorities of IoT-NGIN.





Digital powertrain and condition monitoring is another success story where the use case of an industrial partner is exploiting the contributions made by the IoT-NGIN project**.**

In the context of this use case, the term **powertrain** (rf. to Figure 18) is used to describe the equipment involved in transforming energy provided by a power source into useful work done by some machine. In industrial applications, such equipment typically includes an AC motor and a variable speed drive responsible for its control. Aside from direct process control, data gathered

in such powertrain applications is also used for higher-level supervisory tasks and condition monitoring. The goal in this use case is to leverage IoT-devices, 4G telecommunication and Cloud platforms to utilize novel ideas in data engineering, analytics, and condition monitoring.

This UC uses technologies developed by IoT-NGIN which include: IoT device discovery and indexing (target TRL 5) and Semantic Twins (target TRL 5).

The use-case is still under development, and the following preliminary results have been obtained:

- Powertrains are measured by modified IoT-panels and several other sensors so that data can be gathered flexibly and utilized by IoT-NGIN components.
- A raspberry PI gateway device has been prepared, which can process and then forward data to IoT-NGIN components, avoiding integration problems down the line.
- An initial twin document has been prepared describing data endpoints of a powertrain ensemble using the W3C WoT model.
- A condition monitoring SW has been developed to collect and visualize data from powertrains.

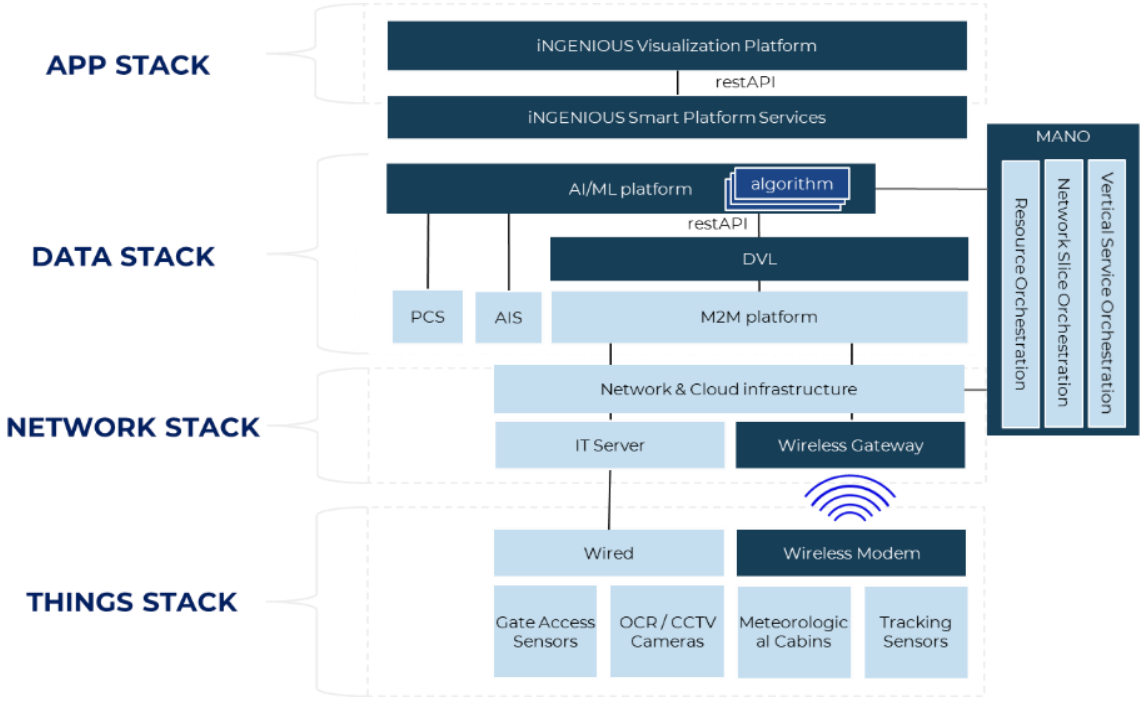
2.2 inGENIOUS

Project title: Next Generation IoT solutions for the universal supply chain

Duration: 01.10.2020-31.03.2023

Website: https://INGENIOUS-iot.eu/web/

An AI-based system for predicting port–city container traffic rates is the success story of INGENIOUS. A Cloud-based AI system was developed to predict vessel and truck traffic rates and turnaround times in sea ports. This capability is relevant e.g., for port and city traffic planning and hinterland logistics operators. The first components included in the solution are already offered as commercial services (TRL 8), while the system is deployed as an online demonstration (TRL 6) at the port of Valencia.



The developed system (rf. to Figure 17) comprises multiple ML-based prediction modules using data from heterogeneous IoT and operations planning systems in the port ecosystem. As part of the development, C-based ML operations infrastructure and services were set up to allow scalable and automated machine learning model training, and data integration services were developed to allow online demonstration of the system. The solution was integrated for demonstration as a Web application to a Cloud platform maintained by one of the project partners and is aimed to be piloted commercially using a *Software as a Service (SaaS)* licensing and delivery model after completion of the project.

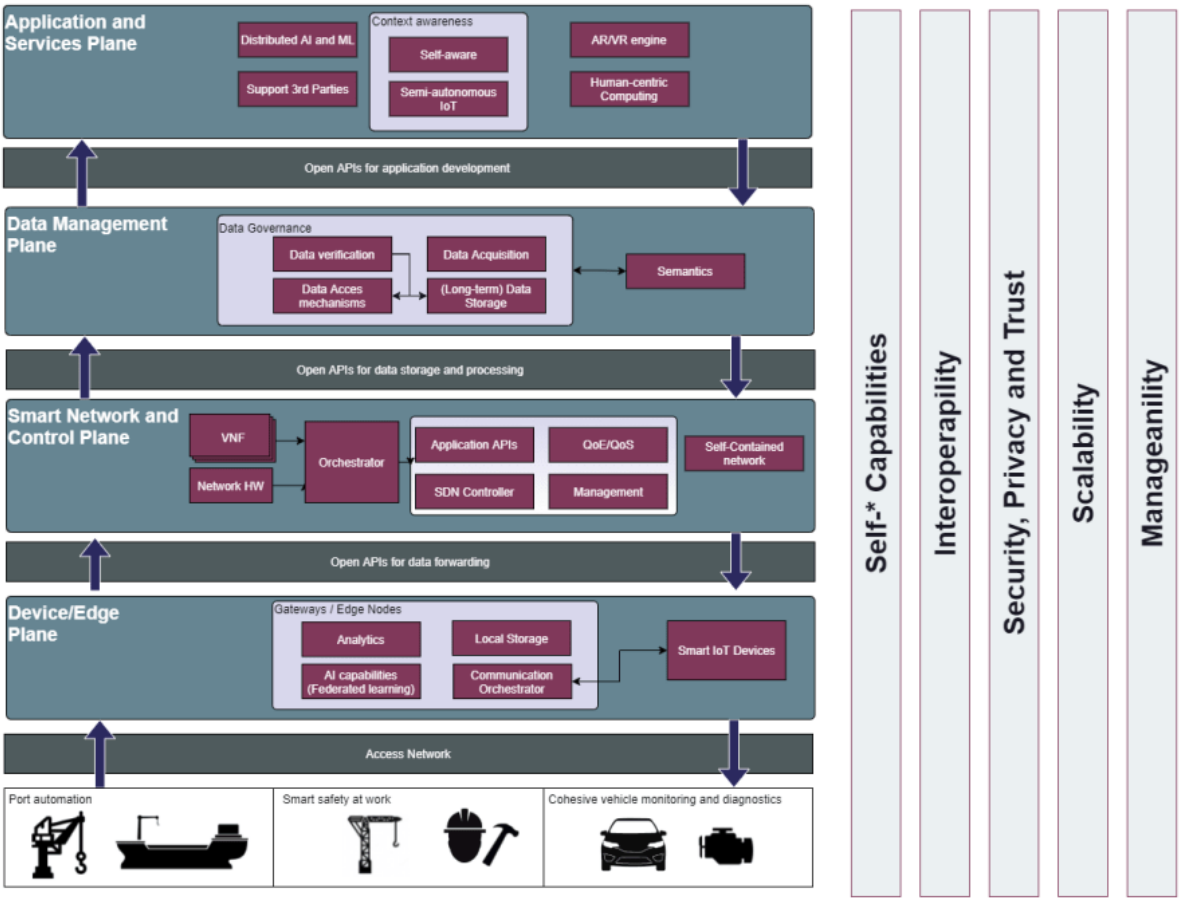
2.3 ASSIST-IoT

Project title: Architecture for Scalable, Self-*, human-centric, Intelligent, Secure, and Tactile next generation IoT

Duration: 01.11.2020 - 31.10.2023

Website: https://assist-iot.eu/

ASSIST-IoT aims at design, implementation, and validation of an open, decentralized reference architecture, associated enablers, services and tools, to assist human-centric applications in multiple verticals. Instances of the architecture will be supported by key enablers, like edge/fog computing, (semi-)autonomy, distributed AI, smart devices, interoperability, Distributed Ledger Technology (DLT) atop a smart network infrastructure, with low latency capabilities, allowing execution of context-aware applications with new interaction interfaces (e.g. AR/VR/MR), etc.



The ASSIST-IoT GWEN is a universal gateway with a modular design. GWEN relies on Edge AI, i.e., it has computational power to operate AI algorithms at the Edge, memory physical network interfaces, and Smart IoT device interfaces. GWEN is modular in the sense that a system on module (SOM) is used for the compute power which can be replaced by different versions with different memory sizes and different amount of CPU cores. An industry standardized SOM interface is used. This SOM is mounted at a carrier board. This carrier board has several fixed interfaces available, e.g., 1Gbps Ethernet, USB3, Wi-Fi 6, and 5G. Besides these fixed interfaces add-on modules can be plugged-in at the carrier board to implement dedicated interfaces, e.g., UWB for localization purposes. Linux is used as operating system with Docker as container runtime.

2.4 TERMINET

Project title: Next generation smart, interconnected IoT
Duration: 01.11.2020-31.10.2023
Website: https://TERMINET-h2020.eu/

The vision of TERMINET is to provide a novel next generation reference architecture based on cutting-edge technologies such as SDN, multiple-access edge computing, and virtualisation for next generation IoT, while introducing new, intelligent IoT devices for low-latency, market-oriented use cases.

A first innovation highlight concerns the TERMINET AR-assisted end-to-end smart precision and smart animal monitoring platform which includes an advanced data visualization dashboard that is intricately designed to aid the producer to keep track of field operations and status of their infrastructure while helping them achieve their production goals. This platform is utilized in

TERMINET UC1: User Centric Devices in Smart Farming, aiming to provide a complete solution for Smart Animal Husbandry capable of monitoring different kinds of productive animals such as cows, sheep, goats, and horses in real-time.

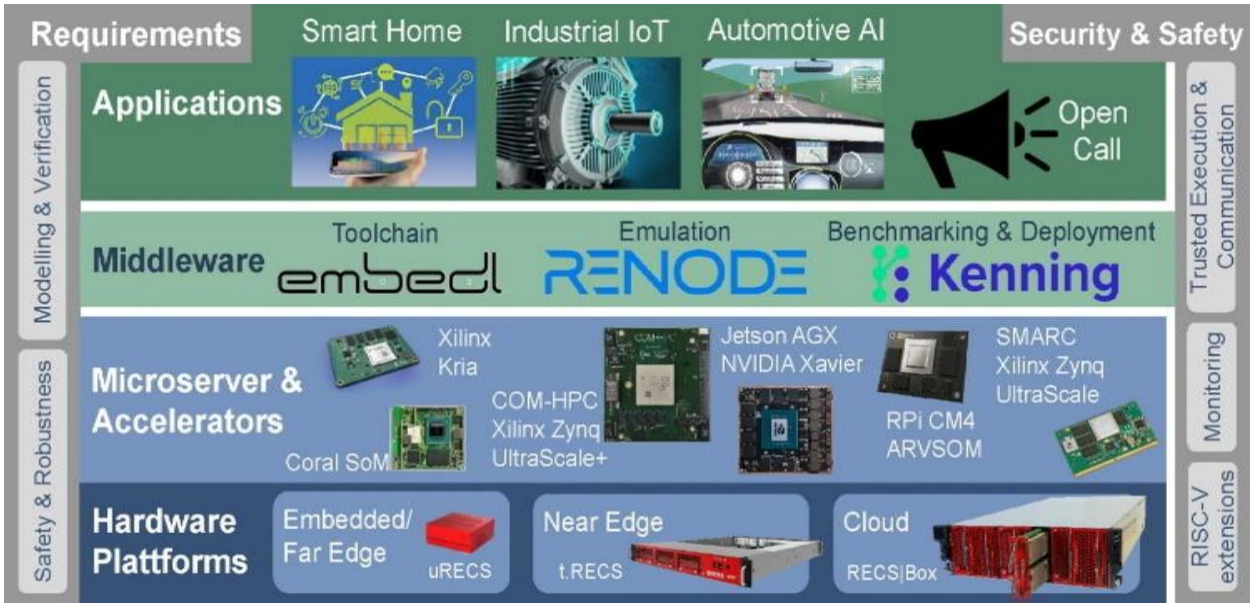
The TERMINET AR-assisted end-to-end smart precision and smart animal monitoring platform services include:

- Providing advice, suggestions, suggestions of good practices and climate change forecasts.
- Timely detection of abnormalities and diseases in real time.
- Real-time monitoring of arable land and agricultural land.
- Reduction of water used for irrigation.
- Reduction of fossil fuels used.
- Reduction of fertilizers used.
- Medicine cost reduction.
- Replacement of roughages for bovines.
- Measurement of distance travelled and grazing by each animal/welfare.
- The exact location of each animal using GPS.
- Physiology/ Zootechnical data of animals.
- Prediction of diseases based on real-time animal data & the movement pattern of each animal.
- Delineation of animals inside and outside virtual fences in real-time.
- Notification of theft or exit of animals outside virtual fences.
- Support real-time forecasts, warnings, and suggestions for changing weather conditions.

2.5 VEDLIoT

Project title: Very Efficient Deep Learning in IoT
Duration: 01.11.2020- 31.10.2023
Website: https://vedliot.eu/

Instead of traditional algorithms, artificial intelligence (AI) and deep learning (DL) are used to handle the large complexity. Due to the distributed approach, VEDLIoT allows dividing the application into smaller and more efficient components and work together in large collaborative systems in the Internet of Things (IoT), enabling AI-based algorithms that are distributed over IoT devices from edge to cloud. In terms of hardware, VEDLIoT offers a platform, the Cognitive IoT platform, leveraging European technology, which can be easily configured to be placed at any level of the compute continuum starting from the sensor nodes and then edge to cloud. Driven by use cases in the key sectors of automotive, industrial, and smart homes, the platform is supported by cross-cutting aspects satisfying security and robustness. Overall, VEDLIoT offers a framework for the Next Generation Internet based on IoT devices required for collaboratively solving complex DL applications across a distributed system.



The **VEDLIoT hardware platform** (TRL 6) provides a modular, scalable hardware platform for heterogeneous computing on the cognitive compute continuum, from embedded via Edge to the Cloud. Unlike other solutions, it covers the complete spectrum of heterogeneous computing, integrating x86_64, ARM64, RISC-V, workstation and embedded GPUs, FPGA, and specialized accelerators in standardized computer-on-module form factors like COM-HPC. In addition, it integrates a sophisticated, multi-level communication and monitoring infrastructure. In this way, the VEDLIoT hardware platform can be used to provide a tailored hardware solution for a wide range of use cases, providing optimal performance and energy efficiency.

The platform is currently at a prototype level and is being used on VEDLIoT use-cases and open calls.

2.6 IntellIoT

Project title: Very Efficient Deep Learning in IoT
Duration: 01.10.2020- 30.09.2023
Website: https://INTELLIOT.eu/

The IntellIoT project mainly focuses on three research aspects and associated next-generation IoT capability component areas, namely collaborative intelligent systems (IoT), human interaction with the intelligent systems and that all these activities are performed in a trustworthy and secure way. These aspects result in three pillars along with IntellIoT's dynamically managed network and compute infrastructure.

Semi-autonomous agricultural vehicle (TRL 5-6) is one of the most relevant highlights for INTELLIoT.

The solution incorporates the human-in-the-loop in the intelligent IoT environment of a semi-autonomous agricultural vehicle, while improving safety, reliability, and security. Human intervention is then needed in uncertain situations, and it is especially valuable in the initial deployments of smart farming.

The INTELLIOT semi-autonomous agricultural vehicle system incorporates six software components from IntellIoT's focus areas, prototypes, and one demonstrator in the agricultural use-case. Most components, which includes software development, will be provided open source at the end of the project.

3 QUALITATIVE PERSPECTIVE ON ICT-56 IMPACT

3.1 Key Contributions Towards SDGs

Overall, the ICT-56 project contributions are well aligned with the nature of the ICT-56 program, as corroborated in Figure 4. The six projects propose relevant contributions across the six impact categories.

All projects expect highly relevant contributions to the impact category **Digital, industry, and Space**, which aligns with the call description, regarding digitization and emerging technologies as well as data privacy and security contributions.

Significant contributions are also expected in terms of **Climate, Energy, and Mobility**, where IoT-NGIN, INGENIOUS, INTELLIOT, and VEDLIoT contribute to transport and environmentally friendly mobility as well as to intelligent automation management. TERMINET targets smart energy by transforming buildings into smart structures and optimizing their energy consumption and harvesting, using distributed AI techniques. ASSIST-IoT targets fleet management considering energy efficiency (reducing environmental impact) while optimizing engine parameters in a user-centric way.

In the Health category, TERMINET and INTELLIOT rely on federated learning to improve remote monitoring of patients and have an open call on Health. TERMINET applies ML to support training and personalization of treatments. Then, ASSIST-IoT is developing a pilot for safety at work integrating Edge computing and addressing integration across low latency networks. VEDLIoT has a smart mirror use-case and is focusing on its use for feedback to support aspects such as the elderly and their daily living based on real-time abnormal pattern detection. VEDLIoT focuses on the ML to hardware integration aspects as well.

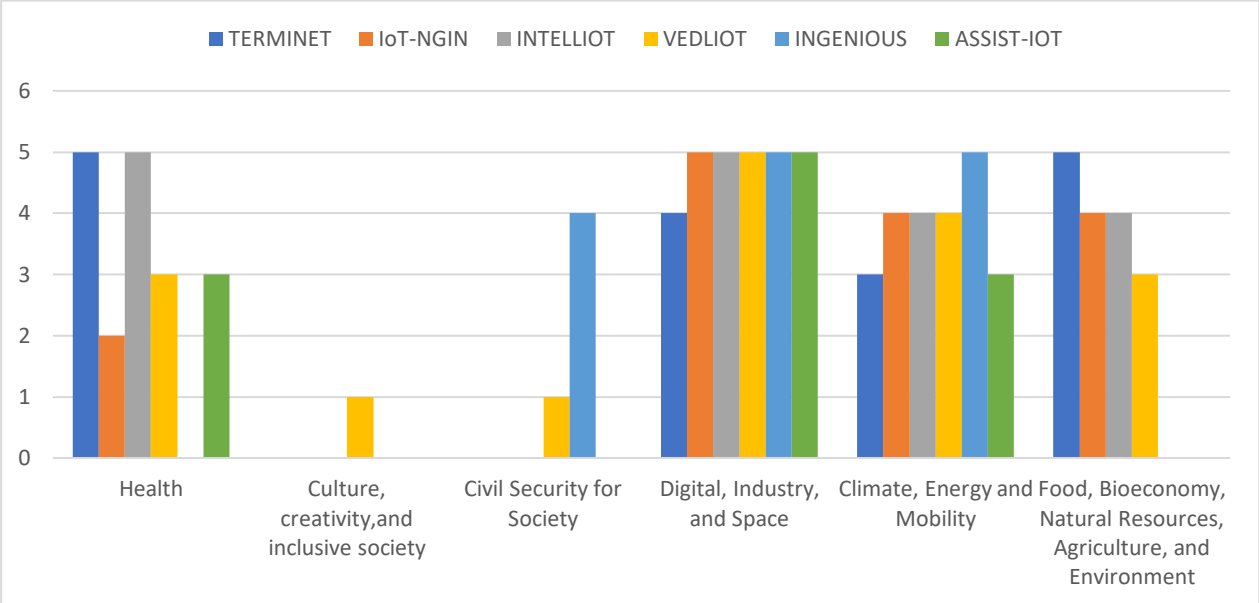


Figure 1: ICT-56 RIAs contributions to SDG impact categories, ranked 1 (not so relevant) to 5 (highly relevant); 0 (no contributions expected).

The expected contributions towards **Food, Bioeconomy, Natural Resources, Agriculture, and Environment** reflect the application of technology in Agriculture use-cases. There is a good overlap in terms of smart farming solutions across the projects proposing contributions. In addition to Agriculture, VEDLIoT has a use-case added via an open call concerning AIoT Pollen Analysis

for the honey industry, and the use of AI/ML for automated Harvesting System for Mushrooms. TERMINET, IoT-NGIN as well as IntellIoT provide contributions towards this pillar.

While societal impact is not a key driver of the ICT-56 projects, they are all addressing inclusiveness aspects (e.g., VEDLIoT) and security aspects towards **Civil Security for society** (INGENIOUS). Specific aspects that relate with societal impact, e.g., data privacy and trustworthiness, are visible across all projects.

3.2 Key Contributions Towards EU-IoT Scope Areas

Most projects tend to focus on the far Edge, near Edge, and Human/IoT interfaces. Infrastructure is the area that ranks next. Followed by Data Spaces, where two projects fit best. Overall, al projects provide good coverage across all EU-IoT scope areas, and they have renewed their operation, solutions, and services towards different sectors to be aligned with the EU vision.

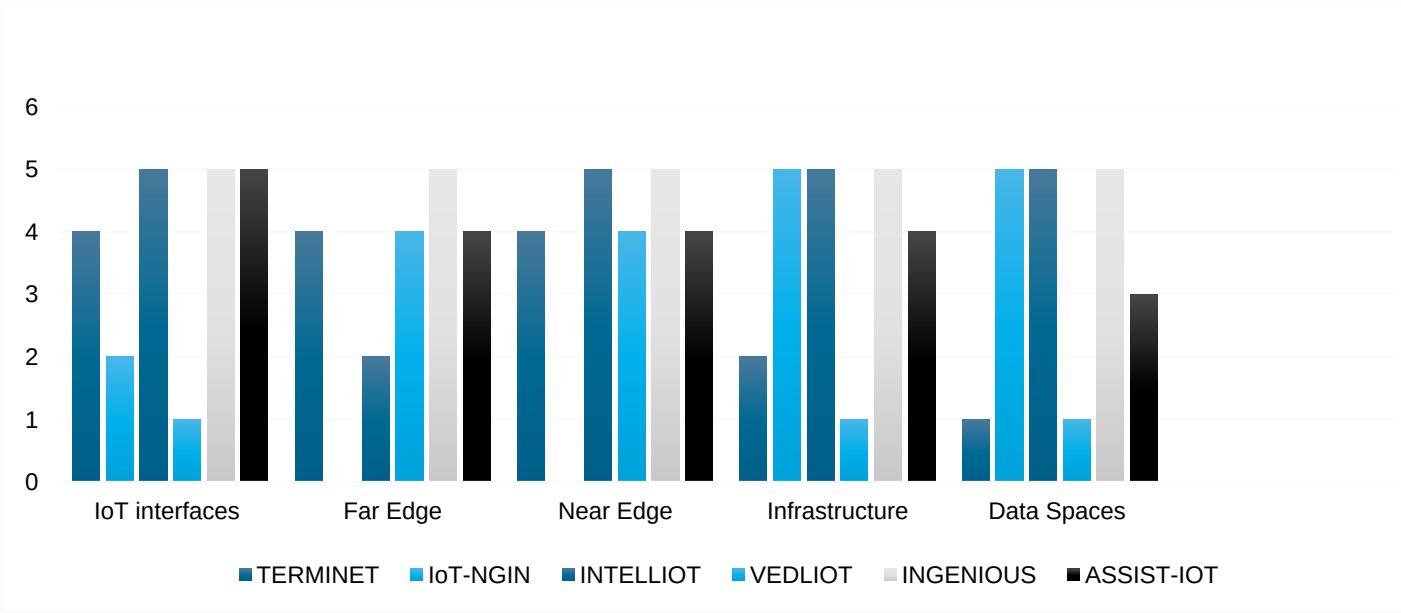


Figure 2: Contributions of projects towards EU-IoT scope areas, ranked 1 (not relevant) to 5 (highly relevant).

3.3 Contribution towards Ethical Aspects

Identifying the potential ethical impact categories tackled by the RIAs, involves identifying the potential issues that may arise from the different ethical aspects such as privacy and data governance, transparency, technical robustness, and safety, etc. This analysis helps to understand and describe the tackled categories as well as assessing the impact on broader ethical principles and values to the impact of developed technologies and assets by the ICT-56 RIAs. This, in turn, helps to promote trust, fairness, and to avoid potential harm or negative impacts. Thus, developing technologies that address the ethical issues identified in the analysis. This may involve developing guidelines to mitigate the potential harm or ensure ethical principles are upheld. As summarized in Table 14 and illustrated in Figure 6, different ethical aspects and topics were actively tackled by the RIAs especially in terms of privacy and data governance as well towards technical robustness, safety and legal issues.

3.4 Cooperation Dimension

ICT-56 projects to show-case efforts aimed at establishing collaboration between them in different areas. This collaboration can be organized through joint publications, events such as Hackathons, workshops, conferences, etc. Mostly, the organization of collaborative events can contribute to knowledge sharing and the implementation of joint initiatives. Hence, several initiatives have been launched by the EU-IoT to consolidate this cooperation, and others have been initiated by the ICT-56 projects. For instance, several NGIoT events were organized such as EU-IoT IDEAthon/Hackathon 2021/22, and the international CONANSENSE 2022 / EU-IoT Hackathon, organized in July 2022 by FOR with the support of EU-IoT and of the ICT-56 RIAs, along with other RIAs.

These events assist ICT-56 projects, developers, scientists, and researchers to present the latest advances and use-cases related to different projects to facilitate the development of new applications or services that benefit from the strengths of the technology of every project.

Similarly, EU-IoT has organized several workshops like EU-IoT Training Workshops Series (4 events) to facilitate discussions on interoperability challenges and solutions.

4 QUANTITATIVE PERSPECTIVE ON IMPACT

4.1 R&D Impact

Overall, there is an excellent level of R&D contributions. In terms of **Scientific Publications (A),** the projects have provided already 162 peer-reviewed international publications, out of which 59 were accepted in excellent international venues (international journals SJR Q1/Q2 or conferences CORE Rank A*/A/B). A particularly good level of scientific event organization has been reached by projects that have a stronger research orientation, e.g., TERMINET, INTELLIOT. **Organization of Events (B)** provides a good number of contributions, where some activities are already being jointly pursued by projects. Another relevant success area concerns **Advanced Training (C)** with 139 contributions, out of which 51 reflect active PhDs, 45 concern concluded MScs. Lectures and seminars amount to a total of 25, showing a good transfer from research towards educational products. In terms of **Knowledge and Technology transfer (D),** the contributions are extremely balanced across the different sub-indicators, e.g., talks and Webinars to industry, and invited talks and keynote speeches.As for Research **Demonstrators and Testbeds (E),** most contributions already have a TRL4-5.

In terms of scientific impact (rf. to Figure 10), the ICT-56 projects show an excellent impact via relevant tooling, such as an excellent level of relevant open access scientific publications, a very good level of mature knowledge, and technology transfer contributions.

Aspects that can be further worked on to strengthen the overall scientific impact in ICT-56 relate to the development of cross fertilization aspects, such as joint book development and joint event development, e.g., winter or spring schools. The strong level of active PhD students and the high number of concluded MSc theses are relevant aspects in the articulation of joint scientific events, with the assistance of EU-IoT.

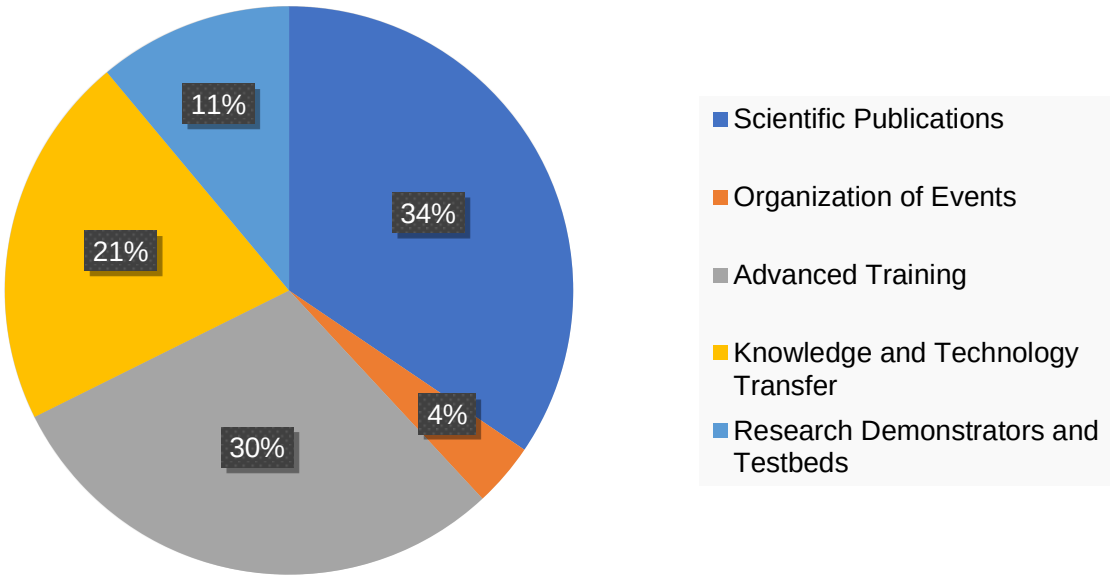


Figure 3: Relative R&D impact perspective of ICT-56 RIAs.

4.2 Standardization Impact

This section provides input concerning the contributions that projects are developing toward *Standards Development Organizations (SDOs)*[1]. The contributions are split into two categories:

- **monitoring**, where projects attend specific SDO events and discussions, but are not directly contributing to specific outcome under development in an SDO;
- **contributions**, where projects are effectively contributing to an SDO via white papers, reports, presentations, demonstrations, and other material.

Table 18 provides the summary of **SDO monitoring contributions** provided by the six RAIs, where the activity is measured via a grading of 0 (low activity) to 3 (high activity), while *Table 19* provides similar content concerning **SDO contributions** by RIAs.

Regarding **monitoring**, most projects exhibit a good level of monitoring activities across a broad range of relevant SDOs. Monitoring contributions require a significant level of staff involvement and are time consuming. The current monitoring level is therefore too high in terms of potential impact. For instance, two projects (TERMINET and ASSIST-IoT) rely on a more selective monitoring methodology, where they focus on specific SDOs, e.g., IEEE.

The projects have also established remarkably interesting effort towards other SDOs that have been considered in EU-IoT (under WP3).

As shown in Figure 11, most projects are actively monitoring relevant SDOs such as IEEE, IETF, ITU-T. ETSI, ISO, CEN-CENELEC.

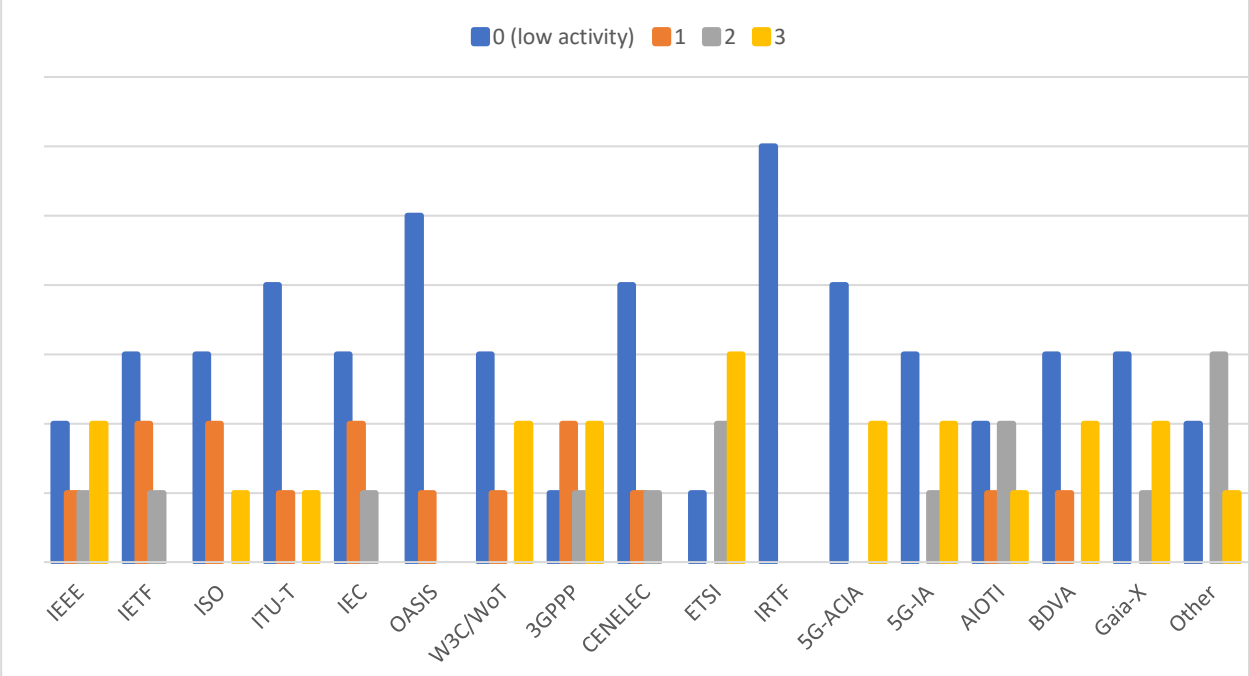


Figure 4 : Monitoring contributions towards key SDOs, by ICT-56 projects

In what concerns contributions to SDOs, Figure 12 provides aggregate results across a relevant set of SDOs. A good level of contributions (impact level 3) is being provided across most relevant SDOs, namely, IEEE, ISO, ITU-T, W3C/WoT, ETSI, etc.

[1] In EU-IoT, the term SDO refers to entities that develop standards and pre-standardisation entities as well as consortia that assist in the adoption of standards across different vertical domains.

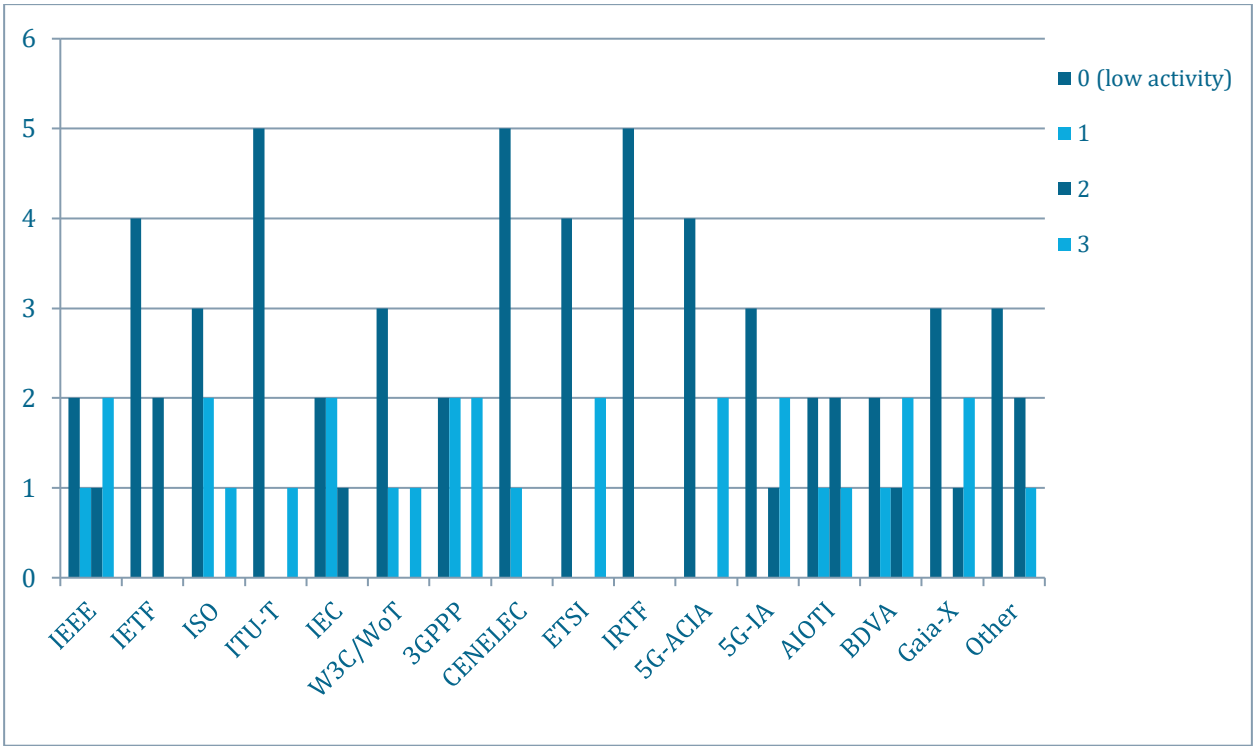


Figure 5: SDO contribution incidence by ICT-56 projects.

4.3 Open-Source Contributions

Table 14 provides an overview of the projects' open-source contributions. Three projects have open repositories via GitLab, Docker Hub, or GitHub. Then, ASSIST-IoT has a private repository, and TERMINET is also developing a software repository, not public. The licensing (open, open source) has not yet been clearly defined, apart from the assets developed by VEDLIoT. In addition, projects such as INGENIOUS and VEDLIoT are also providing open hardware solutions.

In terms of repositories, there is some fragmentation which may hinder impact and dissemination. Specifically, most projects have individual repositories related to each asset under the git of a partner, or multiple partners. IoT-NGIN has opted to create an open repository common to the project. A suggestion would be to follow this approach: individual partners can work on their own assets, and later push to the main, common repository of the project.

Table 14: OSS contributions by ICT-56 RIAs.

Project	Repository/Asset(s)	URL
IoT-NGIN	• GitLab • Docker Hub	• https://gitlab.com/h2020-iot-ngin • https://hub.docker.com/u/iotngin

Project	Repository/Asset(s)	URL
INGENIOUS	• Software: M3 operating system • Hardware: Trusted Communication Unit (TCU), Network-on-Chip (NoC)	• https://github.com/Barkhausen-Institut/M3 • https://github.com/Barkhausen-Institut/M3-hardware
ASSIST-IoT	Not public	• https://assist-iot-enablersdocumentation.readthedocs.io/en/latest/index.html
TERMINET	Under development, not public	-
VEDLIoT	• Renode • Kenning • Twine: An Embedded Trusted Runtime for WebAssembly • PMP: Cost-Effective Forced Execution with Probabilistic Memory Pre-Planning • Gradsec • Renode-verilator-integration • Sire • WaTZ	• https://github.com/antmicro/renode-verilator-integration • https://github.com/antmicro/kenning • https://github.com/JamesMenetrey/unine-twine • https://github.com/JamesMenetrey/unine-watz • https://github.com/lindemer/pmp • https://github.com/aghiles-ait/Static_GradSec/tree/master • https://github.com/antmicro/renode-verilator-integration/ https://vedliot.eu/open-source-software/renode-verilator-integration/ • https://github.com/tiagorncarvalho/SIRE • https://vedliot.eu/open-source-software/watz/

Project	Repository/Asset(s)	URL
INTELLIOT	• Hypermedia Multi-agent System (HyperMAS) that manages available artifacts and agents along with available procedural knowledge (i.e., agent plans). - HyperMAS - Examples of thing descriptions (TDs). • 5G Technology – OpenAirInterface (https://openairinterface.org/) technology based on the OpenAirInterface Software Alliance (OSA) license (like Apache 2.0) - 5G RAN. - 5G Core - Mosaic5G • IAKM – A repository for AI models (Apache 2.0 license)	• https://github.com/Interactions-HSG/yggdrasil • https://github.com/Interactions-HSG/example-tds • https://gitlab.eurecom.fr/oai/openairinterface5g/ • https://gitlab.eurecom.fr/oai/cn5g • https://gitlab.eurecom.fr/mosaic5g • https://gitlab.eurecom.fr/intelliot/iakm

4.4 Open Calls

Out of the six projects, all have open calls, except for INGENIOUS. Therefore, Table *15* The overall analysis of open calls is, in EU-IoT, coordinated by WP2. The numbers collected and presented in this section aim at providing a summarized quantitative perspective of the overall outreach and benefits that open calls have had so far for the ICT-56 projects.

Out of the six projects, all have open calls, except for INGENIOUS. Therefore, Table 21 summarizes the analysed items for all projects, except INGENIOUS. In addition, two projects have two open calls, VEDLIoT and IoT-NGIN. The KPIs in the table, therefore, provide an aggregate perspective, to assess the overall impact of the open calls, independently of the number of run open calls. However, we also highlight that the two second calls of VEDLIoT and IoT-NGIN are still open.

The open calls have been defined and counted in all projects with most project partners, an aspect that is relevant to ensure adequate future exploitation of assets and better integration of services or other assets, derived from third parties running to the open calls.

Table 21: Quantitative perspective on open calls KPIs.

	TERMINET	VEDLIoT	IoT-NGIN	INTELLIOT	ASSIST-IoT	Total
Call 1 details (dates)	01.08.2022-31.10.2023	01.03.2022-08.05.2022	1.10.2021 - 30.12.2021	01.09.2021 - 30.09.2022	01.07.2022-14.10.2022	
Call 2 details (dates)	24.11.2022 31.01.2023	01.07.2022 - 30.06.2023	01.07.2022– 30.09.2022	01.10.2022 - 31.08.2023	01.09.2022-15.01.2023	
Number of involved partners	5	0	12	13	15	45
Number of involved components/products/services	0	7	22	19	40	88
Number of users experimenting the project solutions via open calls (entities)	0	12	15	20	20	67
Number of projects that expressed interest in the open calls.	0	30	95	370	70	565
Number of selected projects	0	10	15	10	7	42
Number of active projects	0	10	15	4	7	36
Total cascading funding (EU and percentage of budget)	400,000 Euros. 5%	840,000 Euros, 10.5%	750,000 Euros, (1st Open Call; 450,000 expected via the 2nd Open Call), 15% in total for both	860,000 Euros, 11%	900.000 Euros, 11.38%	
Sub-Projects						
New applications	0	10	5	6	7	28
Testing and validation of components or services	0	8	5	4	7	24
Usability of components or services	0	8	0	0	7	15
Skills training of components or services	0	0	0	0	-	0

5 IOT/EDGE BUSINESS MODELLING

The activities of the EU-IoT project to provide Success stories and best practice use cases (and Business models and acceleration support is based on the ICT-56 RIA projects but extends further into the European IoT ecosystem and include also stakeholders from complementary RIAs, CSAs, and other relevant European initiatives (such as NGIoT, OPEN DEI, AIOTI, IoTAC, ACTIVAGE, Startup3, DIATOMIC, Eclipse Foundation, LoRa Alliance, The Things Network, MERMISS/MEREFF, Nordic IoT Center. The Danish Industry Foundation and The IoT Next Club.

By funnelling a wider group of relevant stakeholders that are active in IoT business model innovation, we aim to ensure the application of IoT use cases and IoT business models beyond the ICT-56 projects and to facilitate synergies in the board European community of innovators and learners in academia as well as in industry.

5.1 Use cases // The IoT use case catalogue

A use case catalogue has been developed with the aim to inspire industry, innovators, IoT learners and policy makers by demonstrating best practices for developing and/or deploying IoT solutions. The use case catalogue consists of 30 use cases, each documented in a unique story that articulates the IoT success achieved by the specific company. The stories are presented in an online catalogue where they exemplify relatable best practices for practitioners to gain insight into how success with IoT can be achieved.

The use case catalogue is made available as an online resource on the official Website of EU-IoT / NGIoT[2].

The 30 IoT success stories in the catalogue represent the seven key domains Agri-Food, Energy & Utility Health & Care, Manufacturing, Mobility & Transportation, Smart Cities & Communities, and Other (e.g., cyber-security and network infrastructure), and the use cases are explored across 12 diverse national origins, and across more than 20 IoT-related technologies.

Among the success stories are for example *ASM Terni*, a company that uses digitalised metering to enable energy management and flexibility in Smart Grids, and *Fauna Smart Technologies*, that has developed an intelligent platform for pest and disease management supporting the transition to greener, healthier, and more efficient farming practices, and *Veoneer*, that uses Distributed Ledger Technology to enable vehicular collective perception towards fully automated driving.

[2] https://www.ngiot.eu/use-cases/.

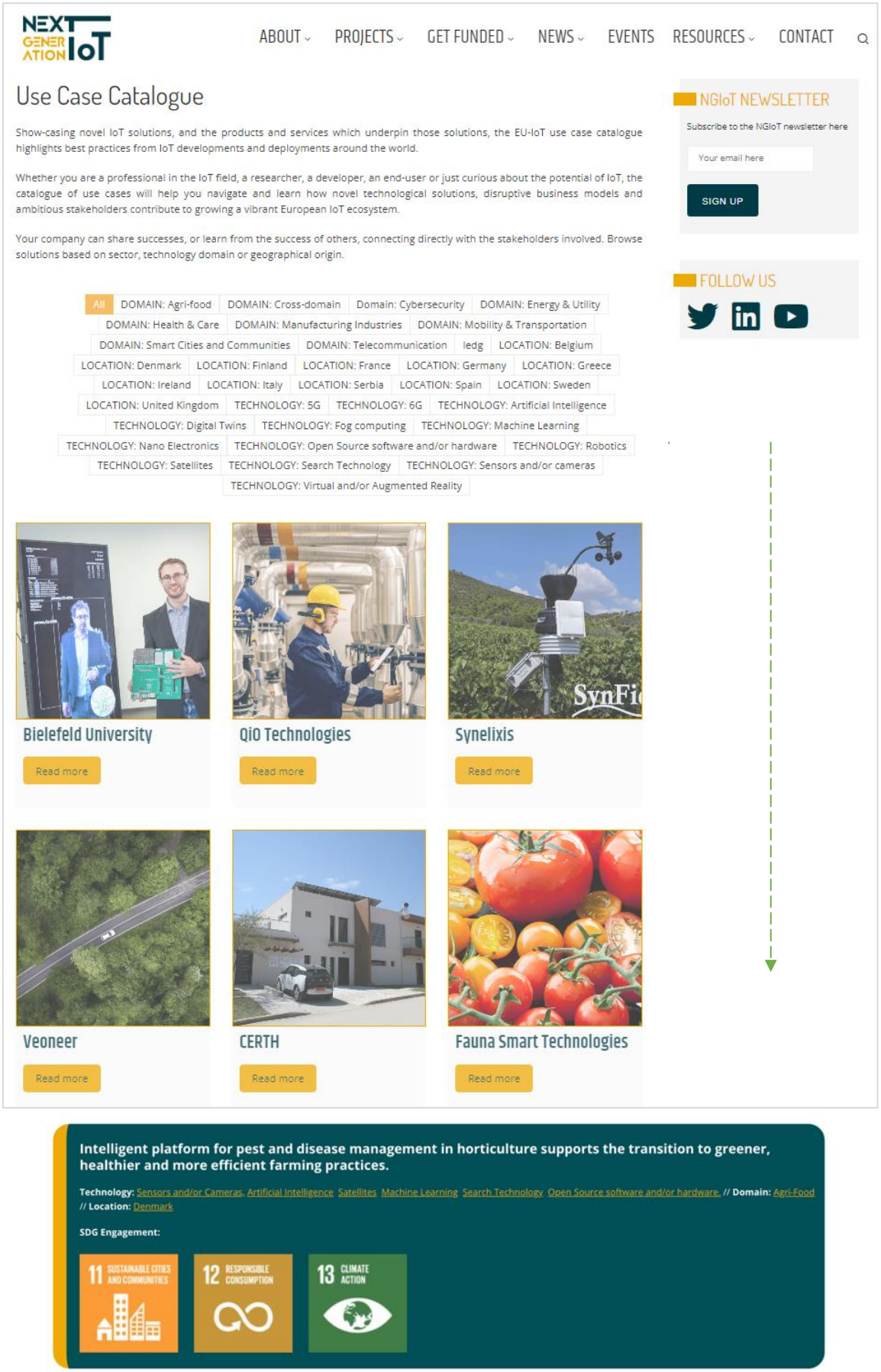


Figure 6: The IoT use case catalogue.

Along with the collection of the use cases, a study across the cases was conducted, generating new knowledge on patterns in business dynamics and technological dynamics of relevance to IoT success. The insights are useful for innovators and learners as a point of reference for conceptualising successful IoT BMs, and as a framework to perform BM self-evaluation prior to initiating an IoT BMI process. Results of the use case study are made available in deliverable D4.2 [3], along with a full presentation of the use case catalogue.

The practical examples offered by the IoT use case catalogue lower the barriers for adopting IoT technologies, eventually helping practitioners to understand how they can create the most optimal premises for themselves and for the ecosystem to succeed with IoT. The relatable stories of the IoT use case catalogue are valuable in illustrating IoT business models through best practice examples. Hence, the success stories have valuable impact to demonstrate theoretical application in a real-world scenario. This is helpful to support practitioners in successfully adopting best practices for building novel and disruptive business models that enable them to achieve success in the IoT area.

5.2 Business models // E-learning platform (ELP) for digital business development

An e-learning platform for digital business development has been developed to facilitate knowledge on best practices for IoT business model innovation, and for providing the assets that enable innovators and learners to adopt these best practices and build successful IoT BMs accordingly.

The ELP for digital business development is made available as an online resource on the official website of EU-IoT / NGIoT[3].

The platform assembles a toolbox and appertaining recommendations with the ambition to support practitioners through the entire BMI process while building up the skills for optimal utilisation of novel IoT technologies. The platform targets industry stakeholders and projects, and address both innovators that are active users of IoT technology already, but also learners that are late bloomers in leveraging the potential of digital technology. The contents to support and accelerate IoT BMI consist of 1) a toolbox that provides tools, templates and methods that support practitioners in building novel and disruptive business models for next generation IoT applications, and 2) rrecommendations that provide guidance that supports practitioners to adopt best practices in the innovation process.

The contents of the platform are structured into 12 learning modules that support the entire BMI process. Each learning module treats one distinctive step in the BMI process and build the related distinctive skills. Hence, this modular composition of the ELP helps innovators and learners to build or enhance their BMs one step at a time. Going through all the modules, practitioners will find themselves closer towards adopting IoT and unlocking the success of a novel and disruptive IoT business model.

[3] https://www.ngiot.eu/business-development/

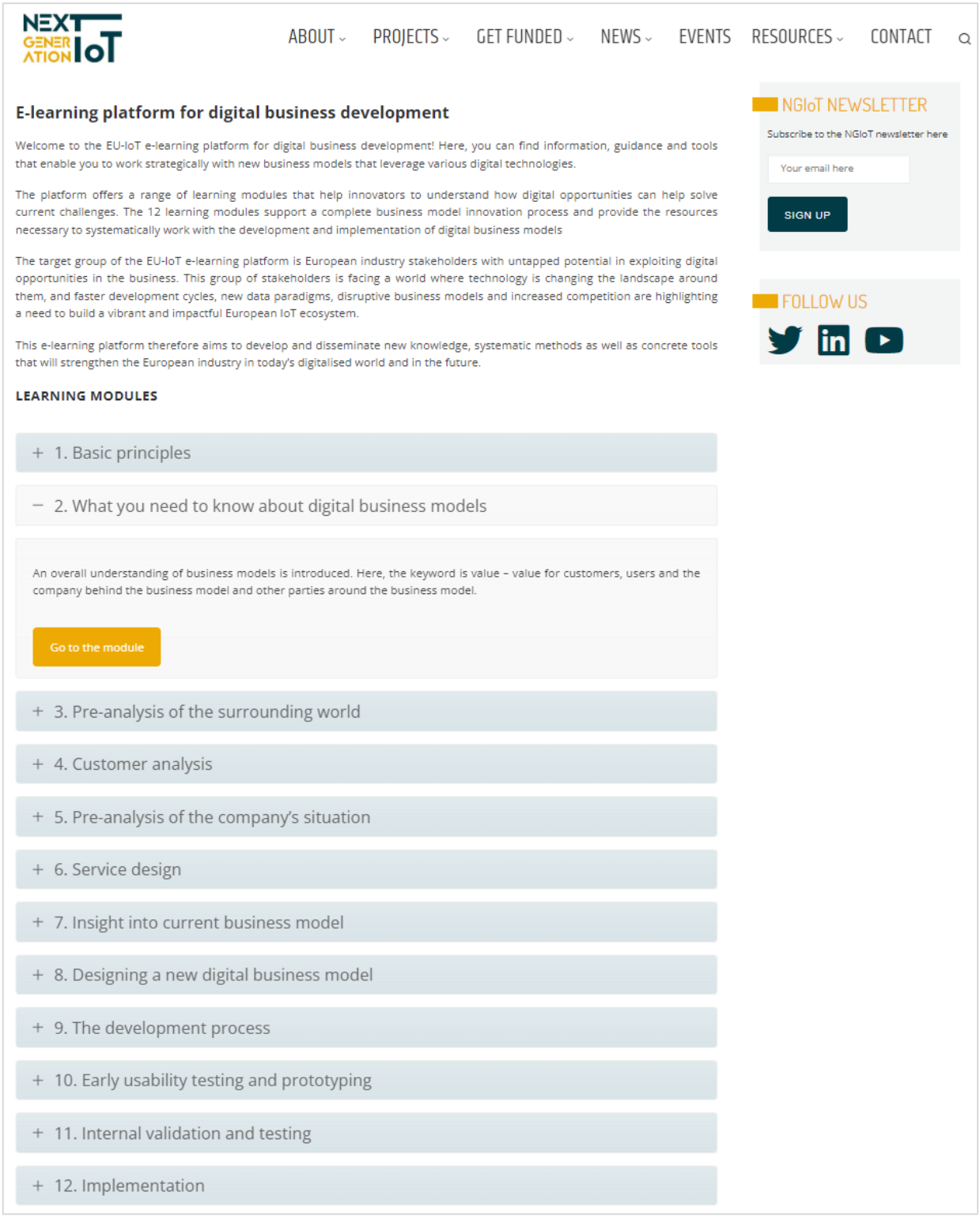


Figure 7: The e-learning platform for digital business development

The ELP translates knowledge on best practices for IoT business model innovation into action by providing the toolbox needed for innovators and learners to adopt these best practices and build novel and disruptive business models accordingly. The platform is easy to access, easy to use and easy to custom to various levels of innovation and technological novelty, as well as to diverse complexities of ecosystems, compositions of BM elements and the products and services within them. The strategic considerations and process of developing the ELP for digital business development are made available in deliverable D4.6 [4], released in September 2022, and

deliverable D4.7 [5], released In March 2023, along with accounts for testing and validation activities and impact assessment of platform analytics.

The ELP is essentially an asset that will educate practitioners in leveraging the innovation potential of digital technologies. Tools, templates and methods that support practitioners through the entire BMI process are made available along with appertaining recommendations that build up their skills for optimal utilisation of novel IoT technologies.

6 REFERENCES

[1] N. Bnouhanna, R. C. Sofia, EU-IoT Deliverable D5.5 – EU-IoT Impact Assessment Framework. September 2021. Available at: https://www.ngiot.eu/download/d5-5/?wpdmdl=4038&masterkey=615c4cb4b2dda

[2] M. Khelifi. Rute C. Sofia, E. Jakobson, J. Soldatos. EU-IoT D5.6: Impact assessment – Guidelines for IoT Collaboration Sustainability.

[3] M. Calisti, L. Kolovou, B. Browan, R. Covaci. EU-IoT Deliverable D2.1 – Towards a Vibrant IoT Ecosystem. March 2021. Available at: file:///home/sofia/Downloads/D2.1-Towards-a_vibrant_European_IoT_ecosystem_v1.0.pdf

[4] E. Jakobson, M. Presser. J. Soldatos, R. C. Sofia, L. Kolovou, EU-IoT Deliverable D4.2: Report on best practices for IoT use cases. Sep 2022.

[5] E. Jakobson, M. Presser,A. Skou, J. Soldatos, L. Kolovou. EU-IoT Deliverable D4.6: Report on IoT business model innovation patterns and acceleration support activities. Sep 2022.

[6] E. Jakobson, M. Presser,A. Skou, J. Soldatos, L. Kolovou. EU-IoT Deliverable D4.7: Report on IoT business model innovation patterns and acceleration support activities Version 2. Mar 2023.

The European IoT Hub

Growing a sustainable and comprehensive ecosystem
for Next Generation Internet of Things

FOLLOW US

WWW.NGIOT.EU

The EU-IoT work is partly supported by the European Union's Horizon 2020
Research and Innovation Programme (Grant Agreement no 956671).
Special thanks to all partners from the EU-IoT consortium and
to the EU-IoT Expert Group for valuable contributions.