NANCY

An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution [GA: 101096456]

Deliverable 1.9

Final Impact Creation Report

Programme: HORIZON-JU-SNS-2022-STREAM-A-01-06

Start Date: 01 January 2023

Duration: 36 Months

Document Control Page

Deliverable Name	Final Impact Creation Report
Deliverable Number	D1.9
Work Package	WP1 'Project, Innovation & Data Management'
Associated Task	T1.5 'Dissemination & Exploitation Activities'
Dissemination Level	Public
Due Date	31 December 2025 (M36)
Completion Date	30 December 2025
Submission Date	30 December 2025
Deliverable Lead Partner	DREVEN
Deliverable Author(s)	Alexios Chatzigoulas (DREVEN), Ioannis Batas (DREVEN), Nektarios Kokkovas (DREVEN), Panos Papadopoulos (DREVEN), Dimitrios Pliatsios (UOWM), Thomas Lagkas (UOWM), Panagiotis Sarigiannidis (UOWM), Athanasios Liatifis (UOWM), Chrysanthi Iakovidou (UOWM), Anna Triantafyllou (UOWM), Evanthia Ntina (UOWM), Thrasos Oikonomou (UOWM), Vasiliki Koutsioumpa (UOWM), Nikolaos Mitsiou (UOWM), Sotirios Tegos (UOWM), Nikolaos Papageorgiou (UOWM), Sotirios Tegos (UOWM), Pigi Papanikolaou (UOWM), Nikolaos Evgenidis (UOWM), Konstantinos Kyranou (SID), Georgia Venizelou (SID), Nikoleta Karditsioti (SID), Maria Tzana (SID), Stathis Mavridopoulos (MINDS), Giola Genni (MINDS), Nikolaos Ntampakis (MINDS), Pavlos Bouzinis (MINDS)
Version	1.0

Document History

Version	Date	Change History	Author(s)	Organisation
0.1	31/10/2025	Initial version	Alexios Chatzigoulas	DREVEN
0.2	3/12/2025	First draft	Alexios Chatzigoulas, Ioannis Batas, Nektarios Kokkovas, Panos Papadopoulos	DREVEN
0.3	5/12/2025	Inputs to Sections 3-5	Dimitrios Pliatsios, Thomas Lagkas, Panagiotis Sarigiannidis, Evanthia Ntina, Thrasos Oikonomou, Vasiliki Koutsioumpa, Nikolaos Mitsiou, Sotirios Tegos, Nikolaos Papageorgiou, Sotirios Tegos, Pigi Papanikolaou,	UOWM

			Nikolaos Evgenidis, Athanasios Liatifis, Chrysanthi Iakovidou	
0.4	7/12/2025	Inputs to Sections 3-5	Konstantinos Kyranou, Georgia Venizelou, Nikoleta Karditsioti, Maria Tzana	SID
0.5	8/12/2025	Inputs to Sections 3-5	Stathis Mavridopoulos, Giola Genni, Nikolaos Ntampakis, Pavlos Bouzinis	MINDS
0.6	12/12/2025	Second draft – Ready for internal review	Alexios Chatzigoulas, Ioannis Batas, Nektarios Kokkovas, Panos Papadopoulos	DREVEN
0.7	24/12/2025	Third draft – After revisions	Alexios Chatzigoulas, Ioannis Batas, Nektarios Kokkovas, Panos Papadopoulos	DREVEN
1.0	30/12/2025	Final version after quality revisions	Anna Triantafyllou, Dimitrios Pliatsios	UOWM

Internal Review History

Name	Organisation	Date
Antonella Clavenna	Italtel	18 December 2025
Alvise Rigo	VOS	18 December 2025

Quality Manager Revision

Name	Organisation	Date
Anna Triantafyllou, Dimitrios Pliatsios	UOWM	30 December 2025

Table of Contents

List of Figures

List of Tables

List of Acronyms

Acronym	Explanation
AI	Artificial Intelligence
B5G	Beyond 5G
B-RAN	Blockchain-Radio Access Network
CI/CD	Continuous Integration/Continuous Deployment
D	Deliverable
DCE	Dissemination, Communication, and Exploitation
ER	Exploitable Result
ETSI	European Telecommunications Standards Institute
GA	Grant Agreement
HRP	Horizon Results Platform
IPR	Intellectual Property Rights
KER	Key Exploitable Result
KPI	Key Performance Indicator
M	Month
MEC	Multi-Access Edge Computing
ML	Machine Learning
OER	Other Exploitable Result
O-RAN	Open Radio Access Network
PQC	Post-Quantum Cryptography
QKD	Quantum Key Distribution
SME	Small and Medium-sized Enterprise
SNS JU	Smart Networks and Services Joint Undertaking
SSI	Self-Sovereign Identity
TRL	Technology Readiness Level
WP	Work Package
XAI	Explainable Artificial Intelligence

Executive summary

D1.9 'Final Impact Creation Report' presents the complete set of dissemination, communication, and exploitation activities carried out by the NANCY project during its 36-month implementation period. It consolidates all actions undertaken to maximise the visibility, scientific reach, societal relevance, and long-term uptake of NANCY's results, and documents the project's contribution to the wider Smart Networks and Services Joint Undertaking ecosystem.

NANCY developed a secure, intelligent, and AI-driven Beyond 5G network architecture addressing critical challenges in trust, security, orchestration, energy efficiency, and quantum-resilience. The project produced major scientific, technical, and demonstration achievements, which were systematically communicated to diverse audiences through a coordinated DCE strategy established in D1.3 'Plans for Publicity, Dissemination and Exploitation' and refined in D1.6 'Initial Impact Creation Report'. This report details how the strategy evolved to match the increasing maturity of the project's results and how it aligned with key SNS JU visibility and branding requirements.

Across all dissemination activities, NANCY delivered an extensive body of high-quality scientific outputs, including **more than 80 conference/workshop papers and journal publications**, and multiple open-access datasets, tools, and software components shared via Zenodo and GitHub. The project successfully implemented **13 co-located workshops**, participated in major conferences (such as EuCNC & 6G Summit, IEEE GlobeCom, ICC, INFOCOM), and produced 9 **demonstrations and testbeds** validating core technologies, including quantum-safe mechanisms, explainable AI modules, blockchain-enabled trust frameworks, and self-healing network functionalities.

Communication activities ensured broad public visibility through the NANCY website, social media channels, YouTube multimedia content, newsletters, press releases, and public engagement events. The website attracted more than **2,700 unique visitors**, the project published **22 blog posts**, produced **27 videos**, released **19 newsletters**, achieved **hundreds of thousands of impressions** across LinkedIn/X/Facebook, and exceeded all KPIs for social media engagement, non-specialised outreach, and online visibility. NANCY's work was featured in **six external media outlets**, including Casadomo, Telecompaper, La Opinión de Murcia, and Free6GTraining, and highlighted in the **SNS JU Newsflash 15 times**, the SNS Standards Tracker, and three consecutive SNS Journals (2023–2025).

The project's public engagement activities reached thousands of citizens through the European Researchers' Night, Science and Technology Fairs, and open-access exhibitions. Additionally, NANCY achieved a strong presence in industrial and marketing events, including Infocom World, BEYOND Expo, Ericsson Innovation Days, and the Thessaloniki International Fair, surpassing all KPIs for trade fairs, exhibitions, and face-to-face outreach.

Exploitation efforts successfully identified and classified **28 Exploitable Results (ERs)** into Key Exploitable Results (KERs) and Other Exploitable Results (OERs). The methodology relied on the **final Exploitation Questionnaire**, with responses systematically mapped and consolidated into **28 detailed exploitation roadmaps** (ER1 to ER28). It provides a standardised breakdown of each result's profile across three major questionnaire sections: Partner info (Owner/Contributor), Exploitation (Value Proposition, Problem/Solution, Target Audience, Exploitation Type, Methods, tools and activities), and IPR Management & Ownership (Protection Form, Exclusive Status). The exploitation analysis reveals a portfolio split evenly between **Technological Solutions and Models/Algorithms**, with a strong focus on the **Industry and Private Sector**, delivering **15 commercial and 13 non-commercial** assets that advance **four strategic pillars**: Next-generation architecture, Future-proof security, Zero-touch intelligence, and Connectivity expansion. IPR protection is managed through patents, copyright, and

trade secrets, highlighted by **three registered patents and three applications currently under development**. Finally, **27 results were successfully published on the Horizon Results Platform** to maximise long-term visibility and market uptake.

The project contributed to standardisation activities through ETSI ISG PDL, O-RAN Alliance, and through technical inputs submitted to SNS JU working groups and white papers. A policy brief on quantum-resilience, identity management, and explainable AI—developed in collaboration with the SNS JU—will be included in the Annex to support long-term policy impact.

Stakeholder and community engagement were a defining feature of NANCY. The project collaborated with peer SNS projects in joint webinars, contributed to three SNS white papers, and aligned all DCE actions with the SNS JU's strategic communication and open-science principles. NANCY helped strengthen the visibility of European 6G initiatives by participating in the SNS Cluster activities, joint outreach campaigns, and shared communication channels.

Overall, NANCY met or exceeded nearly every KPI established in D1.3 and D1.6. The project achieved strong scientific impact, high international visibility, broad public engagement, and clear pathways for post-project exploitation. This deliverable concludes that NANCY's DCE activities substantially contributed to the dissemination of trustworthy, intelligent, and quantum-ready network architectures and created a solid foundation for continued research, standardisation, and innovation activities beyond the project's lifetime.

1. Introduction

The NANCY project aims to advance secure, intelligent, resilient, and quantum-ready Beyond 5G (B5G) network architectures by integrating cutting-edge technologies across quantum-resistant cryptography, explainable artificial intelligence (XAI), distributed security mechanisms, and multi-domain orchestration. As the project reached its final phase, the extensive dissemination, communication, and exploitation (DCE) activities undertaken by the consortium have played a pivotal role in ensuring that NANCY's technological outcomes, scientific contributions, and policy-relevant insights achieve broad visibility and long-term impact.

This Final Impact Creation Report (D1.9) consolidates the full scope of DCE activities conducted throughout the project's lifecycle and assesses their effectiveness against the established KPIs. It provides a comprehensive account of how NANCY has engaged scientific communities, industry stakeholders, policymakers, and the general public, and how these interactions have contributed to increasing the project's visibility, relevance, and uptake within the European 6G ecosystem.

The report also outlines the sustained collaboration with the Smart Networks and Services Joint Undertaking (SNS JU), including participation in cross-project activities, contributions to SNS working groups and white papers, and alignment with the programme's communication and visibility guidelines.

The following sections present the purpose of the deliverable, its relationship to the project work plan, and an overview of its structure.

1.1. Purpose of the Document

The purpose of this document is to present the final assessment of NANCY's dissemination, communication, and exploitation activities carried out over the full duration of the project (Months 1–36). Specifically, the document:

- Evaluates the effectiveness of the DCE strategy as defined in D1.3 'Plan for Impact Creation', taking into account the updated priorities, activities, and stakeholder interactions that emerged during the project.

- Reviews progress since D1.6 'Initial Impact Creation Report', highlighting the refinement of the strategy as the project matured, expanded its public profile, and delivered major technical outcomes.

- Assesses the achievement of the Key Performance Indicators (KPIs) related to scientific dissemination, media presence, digital engagement, industrial outreach, policy impact, and exploitation readiness.

- Documents the full range of activities undertaken, including publications, conference presentations, trade fair participation, testbed demonstrations, media features, videos, newsletters, webinars, social media engagement, and collaborations with SNS JU and sister projects.

- Identifies successful exploitation paths for the project's technical assets, including research outputs, demonstrators, software components, and strategic insights.

- Outlines the measures taken to ensure long-term sustainability and post-project visibility of NANCY's results.

- Provides evidence of compliance with EU and SNS JU communication rules, including branding, acknowledgements, open-access requirements, and responsible presentation of results.

Overall, the report serves as the definitive overview of NANCY's impact creation achievements, summarising how the project's results have been disseminated, communicated, positioned for exploitation, and aligned with European research priorities.

1.2. Relation to Project Objectives and Work Plan

This deliverable is part of Work Package 1 (WP1) 'Project, Innovation & Data Management' and Task 1.5 'Dissemination & Exploitation Activities', which oversees all activities related to dissemination, communication, exploitation, and stakeholder engagement. It directly relates to the project's overarching objectives by ensuring that NANCY's technological innovations—in security, quantum readiness, trustworthy AI, and network automation—are visible, usable, and positioned for long-term adoption.

Relation to D1.3 'Plan for Impact Creation'

D1.3 established the initial strategic framework for NANCY's DCE activities. It defined:

- The target audiences and stakeholder groups (scientific, industrial, regulatory, societal).

- The objectives, workflows, and responsibilities across consortium partners.

- The communication channels and formats (website, social media, press releases, videos, events).

- The expected KPIs for dissemination and communication.

- The exploitation roadmap for project assets.

The present deliverable builds directly on this plan, evaluating its implementation, documenting deviations or enhancements, and demonstrating the significant expansion of dissemination activities as the project evolved. In particular, several actions exceeded the originally planned KPIs, including the number of scientific publications, trade fair participations, social media interactions, and public-facing materials.

Relation to D1.6 'Initial Impact Creation Report'

D1.6 provided the first assessment and early achievements of the DCE strategy during the initial project phase (Months 1–12). It introduced early actions such as:

- Launch of the website and social media channels.

- Initial press releases, newsletters, and blog posts.

- First scientific publications.

- Early presence in SNS JU communication channels and events.

Since then, the project has significantly advanced its impact creation activities. The present deliverable documents:

- The expansion from initial activities to a comprehensive and sustained DCE effort.

- The execution of demonstrations and real-world testbed evaluations.

- The growth of scientific output, with more than 80 papers published across journals, conferences, and workshops.

- The development of explanatory videos, webinars, policy-oriented materials, and technical showcases.

- The preparation of a dedicated SNS JU policy brief on quantum security and explainable AI.

Alignment with NANCY Technical Objectives

The DCE activities directly support the project's core objectives, including:

- Promoting quantum-safe mechanisms and PQC/QKD readiness.

- Disseminating XAI methodologies for transparency and trust in network intelligence.

- Raising awareness of distributed blockchain-based security frameworks.

- Demonstrating self-healing and self-recovery mechanisms for resilient networks.

- Contributing to the European 6G research agenda through active collaboration within SNS JU.

Through these activities, NANCY's contributions extend beyond scientific excellence, supporting policy development, standardisation discussions, and industrial innovation.

1.3. Structure of the Document

The document is structured to provide a logical and comprehensive presentation of NANCY's impact creation activities:

1. **Introduction**
    1. **Purpose of the document** — scope and intended readership of D1.9.
    2. **Relation to project objectives and work plan** — how D1.9 maps to the project DoA, WP1 objectives, and to deliverables D1.3 and D1.6 (what changed by M36).
    3. **Structure of the document** — navigation map (this subsection).
2. **Objectives and Strategy**
    1. **Summary of the NANCY DCE strategy** — overview of the dissemination, communication, and exploitation approach established in D1.3 and refined in D1.6.
    2. **Evolution of the Strategy throughout the project** — Year-by-year (M1–M12, M13–M24, M25–M36) adjustments and triggers for change.
3. **Dissemination Activities**
    1. **Scientific Publications** — journals, conference papers, workshops, open access status, and publication KPIs, and Zenodo/GitHub deposits, FAIR compliance.

2. **Workshops, Conferences and Trade Fairs** — organised sessions, partner participations, keynote/technical talks, and trade fair attendances.
3. **Demonstrations and Testbeds** — in-lab and outdoor demonstrators, proof-of-concept scenarios, testbed descriptions, and validation KPIs (table of demonstrators).

4. **Communication Activities**
   1. **Overview of communication efforts** — audiences, channels, and strategic alignment with DCE objectives.
   2. **Website & Blog** — structure, content strategy, analytics, and linking to deliverables.
   3. **Social Media Engagement** — LinkedIn, X, Facebook: strategy, content calendar, growth, and analytics.
   4. **YouTube Videos and Multimedia Content** — video catalogue, formats, view statistics, and accessibility (subtitles).
   5. **Promotional Material** — branding, templates, and distribution.
   6. **Newsletters and News Alerts** — cadence, content pillars, and mailing list performance.
   7. **Media Outreach and Press Coverage** — press releases, partner articles, and external media mentions.
   8. **Public Engagement Activities** — exhibitions, Researchers' Night, free workshops, training sessions, and F2F interactions.
   9. **Marketing Events and Trade Fairs** — industry-facing activities and KPI alignment.

5. **Exploitation and Innovation Management**
   1. **Glossary:** Defines key terminology, including Exploitation mechanisms (Commercial vs. Non-Commercial), Result categorisation (KERs vs. OERs), and IPR Management (Background vs. Foreground IPR).
   2. **Methodology – Exploitation Questionnaire:** Explains the process for identifying the 28 Exploitable Results (ERs) and their classification into KERs and OERs.
   3. **Exploitation Roadmaps:** Presents the detailed tables for each result, summarising its full exploitation profile: Respondent Details, Result Characterisation, Market and Strategy, and IPR Management & Ownership.
   4. **Exploitation Analysis:** Provides the strategic breakdown of the result portfolio, covering: Categorisation of Results, Impact and Strategic Pillars, Stakeholder Targeting, Exploitation Type, IPR Management and Ownership (including Joint Exploitation constraints), and Contributions to Standardisation and Policy.
   5. **Horizon Results Platform (HRP):** Documents the use of the platform and the status of the 27 published results.

6. **Impact Assessment and KPIs** — Measurement against planned KPIs, quantitative and qualitative indicators, and Summary tables per KPI type.

7. **Supporting Europe's 6G ecosystem** — Interaction with the SNS JU community and other 6G projects, collaboration with external stakeholders, industry, and research clusters, citizen engagement and education activities — Researchers' Night, school/university outreach and training for non-specialists, and Policy engagement.

8. **Long-term sustainability and continuation of dissemination & exploitation** — maintenance of assets, handover, and follow-up activities.

9. **Conclusion** — High-level conclusions on the success of DCE activities, KPI summary, and the expected legacy of NANCY.

10. **ANNEX – NANCY Policy Brief** — The NANCY Policy Brief that will be disseminated through the SNS JU network in 2026.

This structure ensures coherence, completeness, and alignment with the requirements of the Grant Agreement and SNS JU guidelines.

2. Objectives and Strategy

2.1. Summary of the NANCY DCE Strategy

Over its three years, the NANCY DCE strategy matured from **strategic communication planning to practical impact creation**, achieving high visibility across Europe's research and innovation landscape. The coordinated approach ensured that communication, dissemination, and exploitation remained tightly connected to technical progress, fostering engagement with both expert and non-expert audiences and establishing a foundation for continued exploitation beyond the project's lifetime.

The DCE strategy of NANCY was designed to maximise the project's visibility, scientific impact, and uptake of results, while ensuring a coherent narrative connecting research, innovation, and societal benefit.

From the outset, the strategy was structured around three interlinked pillars:

- **Dissemination**: sharing technical and scientific results with the research and industrial communities to foster innovation uptake, stimulate collaboration, and strengthen NANCY's contribution to the 6G vision.
- **Communication**: raising awareness about NANCY's objectives, progress, and outcomes among wider audiences, including policymakers, citizens, and non-specialised stakeholders, while highlighting the project's European added value.
- **Exploitation**: ensuring that NANCY's key outcomes, including technological components, demonstrators, and methodologies, are adopted beyond the project lifetime, supporting commercial, academic, and standardisation activities.

The DCE strategy was mapped to a set of quantitative and qualitative KPIs defined in the **Grant Agreement** and refined in deliverables **D1.3 "Plans for Publicity, Dissemination and Exploitation"** and **D1.6 "Initial Impact Creation Report"**. These KPIs covered scientific dissemination (publications, open access compliance), communication (social media engagement, media coverage, public outreach), and exploitation readiness (identification of KERs/OERs, partner-level exploitation plans, and engagement in standardisation). These metrics ensured systematic monitoring and data-driven steering of the communication and exploitation activities.

The DCE strategy evolved dynamically throughout the project to adapt to emerging opportunities, new technological results, and the communication channels of the SNS JU ecosystem, ensuring consistency with the wider SNS JU narrative on secure, intelligent, and energy-efficient Beyond 5G/6G networks.

The DCE strategy also incorporated sustainability considerations from the early stages. Activities such as open-access repositories (public deliverables, datasets, and source code), publications, demonstration videos, and continued hosting of the NANCY website and YouTube channel ensure longevity and reuse of results beyond the project lifetime.

Exploitation

The NANCY exploitation strategy was integrated into the broader DCE framework from the outset, aiming to ensure the project's key outcomes are adopted beyond the project lifetime, supporting commercial, academic, and standardisation activities. This strategy was developed for Key Exploitable Results (KERs) and Other Exploitable Results (OERs), the development of partner-level exploitation plans, and active engagement in standardisation activities. The focus of the strategy evolved to align

results with the wider SNS JU's innovation clusters and incorporate long-term sustainability considerations, thereby establishing exploitation roadmaps for the continued commercial and non-commercial utilisation of NANCY's assets after the project's conclusion.

Strategic Objectives

The overarching objectives of the DCE strategy were to:

- **Ensure visibility and awareness** of NANCY's goals, achievements, and societal impact at the European and international levels.
- **Engage the scientific and industrial communities** through publications, presentations, and participation in high-level conferences and standardisation activities.
- **Reach general audiences and young people**, promoting understanding of how AI, blockchain, and quantum-safe technologies can make future networks more secure and sustainable.
- **Facilitate exploitation and sustainability** of project outcomes by defining exploitable assets, fostering collaboration among partners, and aligning with SNS JU's innovation clusters.
- **Promote European leadership in Beyond 5G and 6G technologies**, positioning NANCY as a reference project within the SNS JU portfolio.

Target Audiences

The DCE strategy defined differentiated communication pathways for the following stakeholder groups:

- **Scientific and research communities**: through journal and conference publications, open-access datasets, and participation in technical workshops.
- **Industry and SMEs**: through trade fairs, demonstrations, and technical collaborations.
- **Standardisation bodies and policy stakeholders**: via SNS JU working groups, white papers, and liaison activities.
- **General public and students**: through media outreach, public events (e.g., Researchers' Night), and online educational content.

Tools and Channels

NANCY employed a comprehensive toolkit to reach its audiences effectively:

- **Online presence**: Project website, social media (LinkedIn, X, YouTube), newsletters, and blog posts.
- **Scientific dissemination**: peer-reviewed publications, conference presentations, and open-access deliverables.
- **Media and outreach**: press releases, partner-produced articles, and external coverage in technology news outlets.
- **Events**: participation in and organisation of conferences, exhibitions, and public engagement activities.
- **Collaboration with SNS JU**: alignment with the joint branding, participation in SNS webinars, and contributions to the SNS Newsflash and Standardisation Tracker.

Strategic Evolution

Throughout the project, the DCE strategy evolved from **awareness-building** in the early phase (Year 1) to **evidence-based impact creation** in the later stages (Years 2-3).

- **Year 1 (Awareness and Positioning):** Launch of the website, visual identity, and social media channels; initial publications; introduction of NANCY within the SNS JU ecosystem.
- **Year 2 (Visibility and Engagement):** Focus on dissemination through conferences, publications, and demonstrator presentations; stronger partner-level communication efforts.
- **Year 3 (Validation and Impact):** Emphasis on integrated demonstrations, measurable KPIs, media coverage, and exploitation planning to ensure continuity beyond the project's lifetime.

2.2. Evolution of the Strategy throughout the Project

The NANCY DCE strategy evolved continuously throughout the project to reflect the maturity of the technical results, the growing visibility of the consortium within the **SNS JU** ecosystem, and the transition from **research and development** to **validation and demonstration** phases.

The evolution of the DCE strategy was supported by continuous monitoring of actions and KPIs, bimonthly WP1 meetings, and biannual plenary meetings. This ensured that communication and dissemination activities reflected real project progress rather than generic messaging. Moreover, a Google form was created for the reporting and monitoring of all D&C actions, e.g., publications, conference participations, workshop organization, etc. (Figure 1). All partners used this form for reporting their actions at any time, and monthly reminders were sent to ensure that the partners are timely in reporting their D&C actions.

Figure 1: A snapshot from the NANCY D&C monitoring file

This evolution was guided by the **three-stage dissemination framework** defined in D1.3 "Plans for Publicity, Dissemination and Exploitation" and D1.6 "Initial Impact Creation Report", consisting of:

- **Awareness and positioning** (M1–M12): This phase focused on building communication foundations and establishing the KPI baseline for measuring visibility, engagement, and exploitation readiness.

- **Engagement and collaboration** (M13–M24): This phase prioritised growth-oriented KPIs, such as publication volume, event participation, social media audiences, and collaboration outputs across SNS projects.
- **Validation and impact creation** (M25–M36): This phase targeted impact-oriented KPIs, including media coverage, tangible demonstration visibility, and exploitation milestones.

Each stage built upon the previous one, with increasing emphasis on scientific excellence, stakeholder engagement, and measurable impact.

Phase 1 – Awareness and Positioning (M1–M12)

During the first project year, activities focused on building NANCY's identity, presence, and recognition as a new SNS JU project. The primary objectives were to communicate the project's vision and relevance to the Beyond 5G (B5G) community and to establish the channels and materials that would sustain the DCE strategy throughout the project.

Key achievements during this phase included:

- Development of the **project's visual identity**, including logo, templates, and brand guidelines.
- Launch of the **official NANCY website** and **social media channels (LinkedIn, X, YouTube)**.
- Publication of the **communication kit (leaflet, poster, roll-up banner, and flyer)**, introducing the objectives and expected impacts.
- Participation in the **SNS JU introductory webinars**, helping position NANCY among peer projects.
- Preparation of the **Dissemination and Communication Plan (D1.3)** and **Initial Impact Creation Report (D1.6)**, establishing the KPI baseline.

This stage built initial awareness and credibility for NANCY, ensuring consistent branding and messaging across all communication activities.

Phase 2 – Engagement and Collaboration (M13–M24)

In the second year, the strategy evolved from establishing awareness to **actively engaging with technical, industrial, and academic stakeholders**. This phase coincided with the consolidation of NANCY's technical developments and early validation efforts.

Main focus areas:

- Dissemination of first **scientific results** through peer-reviewed publications and international conferences.
- Increased visibility through **joint SNS JU activities**, including the Lunchtime Webinar Series and contributions to the SNS Newsflash.
- Organization and participation in **workshops, conferences, and exhibitions**, including EuCNC & 6G Summit 2023 and Infocom World 2023.
- Release of multiple **blog posts and newsletters** describing progress in AI-driven network management, blockchain-based security, and quantum safety.
- Strengthening of **collaboration links** with other SNS JU projects, especially within Stream A on smart communication components, systems, and networks for 5G mid-term evolution systems.

- Initial identification of **exploitable assets** and start of the exploitation planning process among industrial partners.

By the end of this phase, NANCY had positioned itself as a recognised contributor to the European 6G research landscape, both through technical excellence and visible communication activities.

Phase 3 – Validation and Impact Creation (M25–M36)

The final phase of the project focused on demonstrating the **real-world applicability and impact** of NANCY's research results. As system integration and validation activities (WP6) began producing results, the DCE strategy shifted toward **evidence-based communication**, highlighting outcomes, demonstrations, and benefits for industry and society.

Key actions and achievements:

- Publication of **scientific papers** presenting mature results, including AI-driven network optimization, blockchain-radio access networks (B-RAN), and quantum key distribution experiments.
- Wide participation in **major events and exhibitions** such as EuCNC & 6G Summit 2024 and 2025, Thessaloniki International Fair, ETSI AI Conferences, and BEYOND Expo 2025.
- Release of **video content** highlighting partner contributions on the **NANCY YouTube channel**.
- Publication of **blog posts and newsletters** explaining complex technical topics in accessible language, making NANCY's innovations visible to broader audiences.
- Active presence in **public engagement events** (e.g., European Researchers' Night in Murcia and Science & Research Summit in Kozani), reaching non-specialised audiences and students.
- Consolidation of **media outreach**, including coverage in technology magazines and local newspapers, such as La Opinión de Murcia and Casadomo.
- **Six press releases** highlighting core developments.
- Continuous collaboration with the **SNS JU Office** for coordinated visibility and standardisation contributions.
- Identification of **28 Exploitable Results** (ERs), classified into KERs and OERs, complete with exploitable roadmaps.
- Analysis of the exploitable results portfolio, distinguishing between the **15 Commercial and 13 Non-Commercial exploitation** pathways and mapping contributions to the four **Strategic Pillars (Architecture, Security, Intelligence, Connectivity)**.
- Targeting of primary stakeholders, with the **Industry and Private Sector** confirmed as the main target audience for the majority of results.
- Successful **publication of 27 results to the Horizon Results Platform (HRP)** to ensure long-term visibility and market uptake among investors and policymakers.
- **Consolidation of the project's IPR strategy**, confirming the use of copyright, trade secrets, and **six patents (three registered and three under development)**, while assessing the constraints for formalising a Joint Exploitation plan post-project (after reaching higher TRLs).

This final stage successfully translated NANCY's technological developments into measurable impact (scientific, industrial, and societal) in line with the SNS JU's mission of advancing trustworthy, intelligent, and sustainable 6G networks (see below).

The transition across the three phases demonstrates that the DCE strategy was not static but adaptive, data-driven, and aligned with project maturity. Communication and dissemination evolved from introducing NANCY to establishing its relevance, and finally to demonstrating real-world impact and preparing exploitation continuity beyond the funding period.

3. Dissemination Activities

Dissemination has been one of the key pillars of NANCY's impact creation strategy, ensuring that the project's research results are communicated to the scientific community, industry stakeholders, and policy-makers in an open and structured way. The activities conducted under this pillar have contributed directly to NANCY's objective of promoting secure, intelligent, and trustworthy Beyond 5G network technologies at the European and global levels.

Throughout its three-year implementation, NANCY has pursued a **multi-channel dissemination approach**, balancing academic excellence with practical outreach. This approach was grounded in three main goals:

1. **Disseminate and validate research outcomes** through peer-reviewed publications and open-access scientific outputs.

2. **Engage the scientific and industrial communities** via workshops, conferences, and technical events.

3. **Create synergies** with ongoing European initiatives within the SNS JU ecosystem.

3.1. Scientific Publications

The dissemination of scientific results through peer-reviewed publications, conference proceedings, and the open sharing of datasets and source codes have been key enablers of transparency, reproducibility, and impact in the NANCY project. From the early stages, the consortium committed to Open Science principles, ensuring that all results, where feasible, are made publicly available through **open-access repositories**, **conference proceedings**, and **data-sharing platforms** aligned with the European Commission's guidelines.

Journal, Conference, and Workshop Publications

Throughout the project, partners published more than **80 scientific outputs**, surpassing the initial KPI target of **≥ 50 journal papers + ≥ 30 conference/workshop papers**. Although the distribution shifted slightly (41 journal articles, 45 conference/workshop papers, and 2 Books/Monographs chapters), the overall volume exceeded the expected threshold.

These publications cover NANCY's main innovation domains, including AI-driven orchestration, blockchain-enabled B-RAN security, self-sovereign identity, quantum-safe communication, and secure inter-operator service exchange. Results were disseminated in high-impact journals and conference venues, including IEEE Communications Magazine, IEEE Transactions, Elsevier Computer Networks, MDPI Sensors, IEEE GLOBECOM, IEEE ICC, and EuCNC & 6G Summit.

NANCY maintained a strong presence at international scientific and industrial events, resulting in **40+ oral presentations** across major 5G/6G forums and specialised workshops, including EuCNC & 6G Summit, ETSI AI Conference, IEEE World Forum on IoT, and ACM EdgeSys. This visibility significantly amplified the project's scientific footprint and reputation within the European 6G ecosystem.

By the project's conclusion, **all of NANCY's publications** were made available via **green or gold open access** pathways (Table 1). In the case of green access, the pre-prints were uploaded to **open-access**

repositories, primarily through **Zenodo, arXiv**, and **Institutional repositories** of partner universities and research centres.

Table 1: List of Scientific Publications.

1	**Title**	**'Localization as a key enabler of 6G wireless systems: A comprehensive survey and an outlook'**
	Abstract	'When fully implemented, sixth generation (6G) wireless systems will constitute intelligent wireless networks that enable not only ubiquitous communication but also high-accuracy localization services. They will be the driving force behind this transformation by introducing a new set of characteristics and service capabilities in which location will coexist with communication while sharing available resources. To that purpose, this survey investigates the envisioned applications and use cases of localization in future 6G wireless systems, while analyzing the impact of the major technology enablers. Afterwards, system models for millimeter wave, terahertz and visible light positioning that take into account both line-of-sight (LOS) and non-LOS channels are presented, while localization key performance indicators are revisited alongside mathematical definitions. Moreover, a detailed review of the state of the art conventional and learning-based localization techniques is conducted. Furthermore, the localization problem is formulated, the wireless system design is considered and the optimization of both is investigated. Finally, insights that arise from the presented analysis are summarized and used to highlight the most important future directions for localization in 6G wireless systems.'
	Partner(s)	UOWM, INNO
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2023.3324952
	Link	https://ieeexplore.ieee.org/abstract/document/10287134/
	Open Access	Yes
2	**Title**	**'Energy Efficient OFDM with Intelligent PAPR-aware Adaptive Modulation'**
	Abstract	'In this letter, we propose a novel peak-to-average power ratio (PAPR)-aware adaptive modulation scheme for Orthogonal Frequency Division Multiplexing (OFDM). The aim of the proposed PAPR-aware protocol is to maximize the energy efficiency of the OFDM transmission, where the energy efficiency is defined as the ratio of the OFDM throughput to the PA consumption, and is thus strongly affected by PAPR. For this purpose, we formulate the energy efficiency maximization problem with respect to power and adaptive modulation constraints per subcarrier. Due to the joint optimization of power allocation, adaptive modulation, and the non-convex terms introduced by PAPR, the problem cannot be solved by using convex optimization tools. Therefore, a solution based on online deep learning is proposed. Numerical results showcase that the energy efficiency of the proposed PAPR-aware protocol is greater up to 3-dB compared to the conventional PAPR-unaware protocol, while the PAPR is also reduced by 3-dB.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Communications Letters'
	DOI	10.1109/LCOMM.2023.3324137
	Link	https://ieeexplore.ieee.org/document/10283910

	Open Access	https://www.researchgate.net/publication/374688050_Energy_Efficient_OFDM_with_Intelligent_PAPR-aware_Adaptive_Modulation	
3	**Title**	**'Elevating 5G Network Security: A Profound Examination of Federated Learning Aggregation Strategies for Attack Detection'**	
	Abstract	'The popularity of 5G networks has resulted in significant advancement and opportunities in connectivity and reliability of communications, but, concurrently, it raised security challenges and privacy concerns due to the distributed and highly dynamic nature of these networks. In particular, while participating devices and nodes in a 5G network need to be resilient against cyber threats, most of them are not allowed to exchange their data, and, therefore, they are limited only to the corresponding patterns identified locally. To tackle this, this paper proposes a federated learning approach to enable different nodes to collaboratively train a unified intrusion detection system while avoiding the direct exchange of data. In our experiments, we tested a number of different federated learning strategies with two (2) base stations that serve as participating clients in a federated learning scheme, while a server orchestrates the training phase. In terms of evaluation, the proposed solution was tested against the 5G-NIDD dataset and produced a high detection rate of 97.89 % accuracy.'	
	Partner(s)	UOWM, MINDS, SID	
	Status	Presented in '2023 IEEE Future Networks World Forum (FNWF)'	
	DOI	10.1109/FNWF58287.2023.10520474	
	Link	https://ieeexplore.ieee.org/document/10520474	
	Open Access	https://zenodo.org/records/11510106	
4	**Title**	**'A Deep Learning Mobility Management Approach for RIS-Empowered Millimeter Wave Wireless Systems'**	
	Abstract	'This paper focuses on presenting a new deep learning (DL) mobility management approach for reconfigurable intelligent surface (RIS)-empowered millimeter wave wireless system. On the contrary to previously published contributions, we consider a new type of RIS that has a number of active elements capable of sensing the channel. These channel coefficients are fed to the DL algorithm that estimates the optimal phase shifts of all the RIS elements. Interestingly, the presented approach achieves similar results with the ideal case of perfect channel state information knowledge.'	
	Partner(s)	INNO	
	Status	Presented in '2023 IEEE Virtual Conference on Communications (VCC)'	
	DOI	10.1109/VCC60689.2023.10474939	
	Link	https://ieeexplore.ieee.org/document/10474939	
	Open Access	https://www.researchgate.net/profile/Alexandros-Apostolos-Boulogeorgos-2/publication/377206471_A_deep_learning_mobility_management_approach_for_RIS-empowered_millimeter_wave_wireless_systems/links/6599a5a50bb2c7472b3764eb/A-Deep-Learning-Mobility-Management-Approach-for-RIS-Empowered-Millimeter-Wave-Wireless-Systems.pdf	
5	**Title**	**'Feature Management for Machine Learning Operation Pipelines in AI Native Networks'**	
	Abstract	'Artificial intelligence (AI) has emerged as a key technology in various domains, including telecommunications. The use of AI in cellular networks has the potential to revolutionize the way we communicate by enabling new capabilities, improving network efficiency, and providing better user experiences. However, domain specific data transformations, pre-processing and management in modern data	

		driven pipelines is yet to be addressed. In this paper we perform a discuss Machine Learning Operations automation for with focus on feature management and feature store selection. The design of features and their subsequent management by specialized feature stores are one of the key components of successful infrastructure automation. We also study existing feature stores qualitatively and quantitatively.'
	Partner(s)	JSI
	Status	Presented in '2023 International Balkan Conference on Communications and Networking (BalkanCom)'
	DOI	10.1109/BalkanCom58402.2023.10167936
	Link	https://ieeexplore.ieee.org/document/10167936
	Open Access	https://www.researchgate.net/profile/Gregor-Cerar-2/publication/370772753_Feature_Management_for_Machine_Learning_Operation_Pipelines_in_AI_Native_Networks/links/6465f422702026631655a541/Feature-Management-for-Machine-Learning-Operation-Pipelines-in-AI-Native-Networks.pdf
6	Title	**'XAI for Self-supervised Clustering of Wireless Spectrum Activity'**
	Abstract	'The so-called black-box deep learning (DL) models are increasingly used in classification tasks across many scientific disciplines, including wireless communications domain. In this trend, supervised DL models appear as most commonly proposed solutions to domain-related classification problems. Although they are proven to have unmatched performance, the necessity for large labeled training data and their intractable reasoning, as two major drawbacks, are constraining their usage. The self-supervised architectures emerged as a promising solution that reduces the size of the needed labeled data, but the explainability problem remains. In this paper, we propose a methodology for explaining deep clustering, self-supervised learning architectures comprised of a representation learning part based on a Convolutional Neural Network (CNN) and a clustering part. For the state of the art representation learning part, our methodology employs Guided Backpropagation to interpret the regions of interest of the input data. For the clustering part, the methodology relies on Shallow Trees to explain the clustering result using optimized depth decision tree. Finally, a data-specific visualizations part enables connection for each of the clusters to the input data trough the relevant features. We explain on a use case of wireless spectrum activity clustering how the CNN-based, deep clustering architecture reasons.'
	Partner(s)	JSI
	Status	Presented in '2023 International Balkan Conference on Communications and Networking (BalkanCom)'
	DOI	10.1109/BalkanCom58402.2023.10167985
	Link	https://ieeexplore.ieee.org/document/10167985
	Open Access	https://www.researchgate.net/profile/Ljupcho-Milosheski-3/publication/370817797_XAI_for_Self-supervised_Clustering_of_Wireless_Spectrum_Activity/links/64648ab09533894cac75691c/XAI-for-Self-supervised-Clustering-of-Wireless-Spectrum-Activity.pdf
7	Title	**'Graph Neural Networks Based Anomalous RSSI Detection'**
	Abstract	'In today's world, modern infrastructures are being equipped with information and communication technologies to create large IoT networks. It is essential to monitor these networks to ensure smooth operations by detecting and correcting link failures or abnormal network behaviour proactively, which can otherwise cause interruptions in business operations. This paper presents a novel method

		for detecting anomalies in wireless links using graph neural networks. The proposed approach involves converting time series data into graphs and training a new graph neural network architecture based on graph attention networks that successfully detects anomalies at the level of individual measurements of the time series data. The model provides competitive results compared to the state of the art while being computationally more efficient with ≈171 times fewer trainable parameters.'
	Partner(s)	JSI
	Status	Presented in '2023 International Balkan Conference on Communications and Networking (BalkanCom)'
	DOI	10.1109/BalkanCom58402.2023.10167910
	Link	https://ieeexplore.ieee.org/document/10167910
	Open Access	https://arxiv.org/abs/2505.15847
8	**Title**	**'Machine Learning Operations Model Store: Optimizing Model Selection for AI as a Service'**
	Abstract	'With the emergence of Artificial Intelligence-as-a-Service (AIaaS), end users have access to an ever-growing number of pre-trained, fine-tuned, and evaluated Machine Learning (ML) models. These models are typically stored in a model store, an online repository that is part of Machine Learning Operations (MLOps) frameworks. Unfortunately, selecting the optimal ML model from a plethora of available options is challenging. The problem becomes even more pronounced when the micro-location of the user and the dynamic aspects of the environment are taken into account. To this end, we propose a dynamic approach for selecting the most appropriate ML model using Deep Reinforcement Learning (DRL). We demonstrate its effectiveness in a specific use case of energy consumption forecasting. We validate the proposed solution using the energy consumption dataset HUE and demonstrate that it outperforms heuristic methods for model selection by over ten percent while remaining cost-effective.'
	Partner(s)	JSI
	Status	Presented in '2023 International Balkan Conference on Communications and Networking (BalkanCom)'
	DOI	10.1109/BalkanCom58402.2023.10167931
	Link	https://ieeexplore.ieee.org/document/10167931
	Open Access	https://www.researchgate.net/profile/Gregor-Cerar-2/publication/370772679_Machine_Learning_Operations_Model_Store_Optimizing_Model_Selection_for_AI_as_a_Service/links/64628bfff43b8a29ba527198/Machine-Learning-Operations-Model-Store-Optimizing-Model-Selection-for-AI-as-a-Service.pdf
9	**Title**	**'Self-supervised Learning for Clustering of Wireless Spectrum Activity'**
	Abstract	'In recent years, much work has been done on processing of wireless spectrum data involving machine learning techniques in domain-related problems for cognitive radio networks, such as anomaly detection, modulation classification, technology classification and device fingerprinting. Most of the solutions are based on labeled data, created in a controlled manner and processed with supervised learning approaches. However, spectrum data measured in real-world environment is highly nondeterministic, making its labeling a laborious and expensive process, requiring domain expertise, thus being one of the main drawbacks of using supervised learning approaches in this domain. In this paper, we investigate the utilization of self-supervised learning (SSL) for exploring spectrum activities in a real-world unlabeled data. In particular, we assess the

		performance of SSL models, based on the reference DeepCluster architecture. We carefully consider the current state-of-the-art feature extractors, taking into account the performance and complexity trade-offs. Our findings demonstrate that SSL models achieve superior performance regarding the feature quality and clustering performance compared to baseline feature learning approaches. With SSL models we achieve significant reduction of the feature vectors size by two orders of magnitude, while improving the performance by a factor ranging from 2 to 2.5 across the evaluation metrics, supported by visual assessment. Furthermore, we showcase how adapting the reference SSL architecture to domain-specific data is followed by a substantial reduction in model complexity up to one order of magnitude, without compromising, and in some cases, even improving the clustering performance.'
	Partner(s)	JSI
	Status	Published in 'Computer Communications'
	DOI	10.1016/j.comcom.2023.10.009
	Link	https://www.sciencedirect.com/science/article/pii/S0140366423003729
	Open Access	Yes
10	**Title**	**'Deep Feature Learning for Wireless Spectrum Data'**
	Abstract	'In recent years, the traditional feature engineering process for training machine learning models is being automated by the feature extraction layers integrated in deep learning architectures. In wireless networks, many studies were conducted in automatic learning of feature representations for domain-related challenges. However, most of the existing works assume some supervision along the learning process by using labels to optimize the model. In this paper, we investigate an approach to learning feature representations for wireless transmission clustering in a completely unsupervised manner, i.e. requiring no labels in the process. We propose a model based on convolutional neural networks that automatically learns a reduced dimensionality representation of the input data with 99.3% less components compared to a baseline principal component analysis (PCA). We show that the automatic representation learning is able to extract fine-grained clusters containing the shapes of the wireless transmission bursts, while the baseline enables only general separability of the data based on the background noise.'
	Partner(s)	JSI
	Status	Presented in '2023 IEEE International Mediterranean Conference on Communications and Networking (MeditCom)'
	DOI	10.1109/MeditCom58224.2023.10266604
	Link	https://ieeexplore.ieee.org/document/10266604
	Open Access	https://arxiv.org/abs/2308.03530
11	**Title**	**'Private cloud as a didactic tool for effective research and teaching** *(translated from Slovenian)* **'**
	Abstract	'Recent technological innovations have revolutionized education, enhancing teaching and learning experiences. Among the available tools, Jupyter Notebooks stand out as a powerful didactic tool for interactive computing, programming, and data analysis. However, their use becomes challenging on large projects due to hardware constraints. Public cloud services offer alternatives, but they come with significant limitations. Private cloud solutions like ours address cost and security concerns while providing flexibility. We use Kubernetes technology as the

12		foundation of our private cloud solution, offering efficient application management, scalability, and resource flexibility.' *(translated from Slovenian)*
	Partner(s)	JSI
	Status	Presented in '32nd International Electrotechnical and Computer Science Conference'
	DOI	N/A (ISSN 2591-0442)
	Link	https://erk.fe.uni-lj.si/2023/papers/cerar(uporaba_zasebnega).pdf
	Open Access	Yes
	Title	**'Enhancing the Availability of Web Services in the IoT-to-Edge-to-Cloud Compute Continuum: A WordPress Case Study'**
	Abstract	'The IoT-to-Edge-to-Cloud compute continuum presents vast opportunities for innovative applications, including crowdsensing, which leverages interconnected devices to gather real-time data. In domains like autonomous driving, crowdsensing enables traffic information sharing through web services. In this context, web services, like those based on Content Management Systems (CMS), are often used by drivers and passengers to share data about user experience, traffic congestion, and high-definition maps. However, ensuring high availability becomes crucial to maintain accessibility and reliability against usage peaks. This paper proposes a modern WordPress deployment approach that takes advantage of cloud-based to realize a cost-effective horizontal scalable architecture, leveraging Amazon AWS. The architecture suggested was implemented to test the effectiveness and released as a set of architecture-ready-to-use templates. Experimental results are provided to measure per-request response times under different autoscaling policies and bootstrap times.'
	Partner(s)	SSS
	Status	Presented in '2023 26th Euromicro Conference on Digital System Design (DSD)'
	DOI	10.1109/DSD60849.2023.00088
	Link	https://ieeexplore.ieee.org/document/10456818
	Open Access	https://retis.santannapisa.it/~d.casini/papers/2025/TC2025/Timerlat_TC.pdf/~d.casini/papers/2023/DSD2023/Serra2023DSD.pdf
13	**Title**	**'Bounding the Data-Delivery Latency of DDS Messages in Real-Time Applications'**
	Abstract	'Many modern applications need to run on massively interconnected sets of heterogeneous nodes, ranging from IoT devices to edge nodes up to the Cloud. In this scenario, communication is often implemented using the publish-subscribe paradigm. The Data Distribution Service (DDS) is a popular middleware specification adopting such a paradigm. The DDS is becoming a key enabler for massively distributed real-time applications, with popular frameworks such as ROS 2 and AUTOSAR Adaptive building on it. However, no formal modeling and analysis of the timing properties of DDS has been provided to date. This paper fills this gap by providing an abstract model for DDS systems that can be generalized to any implementation compliant with the specification. A concrete instance of the generic DDS model is provided for the case of eProsima's FastDDS, which is eventually used to provide a real-time analysis that bounds the data-delivery latency of DDS messages. Finally, this paper reports on an evaluation based on a representative automotive application from the WATERS 2019 challenge by Bosch.'
	Partner(s)	SSS
	Status	Presented in '35th Euromicro Conference on Real-Time Systems (ECRTS 2023)'
	DOI	10.4230/LIPIcs.ECRTS.2023.9

	Link	https://drops.dagstuhl.de/entities/document/10.4230/LIPIcs.ECRTS.2023.10
	Open Access	Yes
14	Title	**'Virtual On-Board Unit Migration in a Multi-Access Smart-Campus 5G Architecture'**
	Abstract	'By embracing the next generation of network architectures, academic institutions are setting the scene to expand the research capabilities, enhance the learning experience of the students, and showcase how smart-city-like solutions can transform traditional educational environments into innovative platforms with state-of-the-art solutions. In this work, we present the University of Murcia's GAIA 5G multi-access smart-campus architecture as an enabler for research and experimentation in novel use cases related to Connected and Automated Mobility (CAM) scenarios. In this way, we demonstrate how a vehicular service that provides digital twins for on-board units with migration capabilities between virtualization domains has been integrated in an operational 5G environment. The experimental tests demonstrates the validity of the solution, which can be seamlessly deployed and operated in a real 5G network.'
	Partner(s)	UMU
	Status	Presented in '2023 IEEE Future Networks World Forum (FNWF)'
	DOI	10.1109/FNWF58287.2023.10520366
	Link	https://ieeexplore.ieee.org/document/10520366
	Open Access	https://zenodo.org/records/10625002
15	Title	**'Integrating Machine Learning models into the Linux Kernel: Opportunities and Challenges'**
	Abstract	'The advent of the next generation of communication networks demands deep changes within current infrastructures. In this regard, the softwarization of the network following the Software Defined Networking (SDN) and Network Function Virtualization (NFV) paradigms will be crucial to permit flexibility and programmability levels never seen before. This paper studies the opportunities that both the extended Berkeley Packet Filter (eBPF) and Machine Learning (ML) technologies bring to this field. Their convergence enables the integration of intelligent ML-powered programs into the Linux kernel hence permitting almost every device in the network to perform a plethora of tasks, e.g., traffic processing, security analysis, etc. However, this integration is not straight-forward and poses a series of challenges that are discussed and solved in this work. To this end, a methodology for integrating complex ML models within the Linux kernel is proposed introducing specific tools in its different phases. This integration paves the way for the development of diverse virtual network functions in commodity hardware in an efficient and secure way.'
	Partner(s)	UMU
	Status	Presented in 7th International Conference on Mobile Internet Security
	DOI	10.1007/978-981-97-4465-7_15
	Link	https://link.springer.com/chapter/10.1007/978-981-97-4465-7_15
	Open Access	https://zenodo.org/records/17182587
16	Title	**'Breaking Orthogonality in Uplink With Randomly Deployed Sources'**
	Abstract	'The requirement of the upcoming sixth-generation (6G) wireless communication systems to significantly elevate the services of enhanced mobile broadband (eMBB) and massive machine-type communications (mMTC) necessitates the design and investigation of appropriate multiple access schemes. This paper

		investigates the impact of random source deployment on the performance of uplink systems, emphasizing the implications of non-orthogonality in contention-free and contention-based access schemes. For the latter scheme, we combine the strengths of slotted ALOHA and successive interference cancellation. Considering the advantages of breaking orthogonality in scenarios with random source deployment, we propose distinct policies tailored for mMTC, eMBB, and hybrid mMTC-eMBB scenarios by splitting the cell into rings. Furthermore, we derive closed-form expressions for the outage probability, which play a pivotal role in extracting the throughput of the sources in the considered scenarios. The paper offers a comprehensive analysis of the proposed approach, corroborated through simulations, shedding light on the potential of such protocols in future 6G wireless communication systems.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2023.3349181
	Link	https://ieeexplore.ieee.org/document/10379479
	Open Access	Yes
17	Title	**'Delay Minimization for Hybrid Semantic-Shannon Communications'**
	Abstract	'Semantic communications offer a promising approach to decrease network congestion and improve reliability, leading to more sustainable and energy-efficient wireless networks. However, the design of semantic transceivers constrain their effectiveness. This paper introduces a novel multi-carrier system that combines both semantic and Shannon communications, with a focus on text transmission. We formulate an optimization problem that jointly selects the transmission method and allocates power to reduce the transmission delay. Despite the challenges of solving this non-convex problem, we employ alternating optimization techniques to address it and the closed-form solution of the power allocation is extracted. The simulation results verify that jointly selecting semantic and Shannon communications decreases the transmission delay compared to using only one of the schemes.'
	Partner(s)	UOWM
	Status	Presented in '2024 IEEE Wireless Communications and Networking Conference (WCNC)'
	DOI	10.1109/WCNC57260.2024.10571303
	Link	https://ieeexplore.ieee.org/document/10571303
	Open Access	https://www.researchgate.net/profile/Sotiris-Tegos-2/publication/381986511_Delay_Minimization_for_Hybrid_Semantic-Shannon_Communications/links/66d16fb3bd201736675fcd9f/Delay-Minimization-for-Hybrid-Semantic-Shannon-Communications.pdf
18	Title	**'Channel-Aware QUIC Control for Enhanced CAM Communications in C-V2X Deployments Over Aerial Base Stations'**
	Abstract	'The proliferation of vehicular ad hoc networks necessitates efficient data transfer protocols, particularly in the context of Cellular Vehicle-to-Everything (C-V2X) communications. This paper focuses on enhancing the performance of the Quick UDP Internet Connections (QUIC) protocol, focusing on cooperative vehicular networks supported by aerial drone relays. While QUIC outperforms traditional protocols, its default congestion and flow control mechanisms do not adequately address the unique challenges posed by volatile networks spanning the terrestrial and aerial domains, as they are characterized by frequent topology changes, and high propagation delay volatility. We analyze QUIC's congestion and flow control

		and propose enhancements to optimize its performance in such networks, specifically designed for C-V2X communications in Open Radio Access Networks (O-RAN). Our proposal adjusts connections' congestion window size and individual streams' flow control windows in a channel-aware manner. Simulation experiments assess the performance of our proposal, comparing it with QUIC's default mechanisms. Our proposal can be seamlessly integrated into existing implementations, making it a viable approach for improving performance and addressing the challenges specific to vehicle-to-drone communications. By addressing QUIC's limitations and optimizing its performance for C-V2X applications in O-RAN, our enhancement offers a valuable contribution towards enabling low-latency, and resource-aware vehicular communications for the realization of autonomous driving and advanced vehicular services.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Transactions on Vehicular Technology'
	DOI	10.1109/TVT.2024.3393614
	Link	https://ieeexplore.ieee.org/document/10508467
	Open Access	Yes
19	**Title**	**'Hybrid Semantic-Shannon Communications'**
	Abstract	'Semantic communications are considered a promising beyond-Shannon paradigm to reduce network traffic and increase reliability, thus making wireless networks more energy efficient, robust, and sustainable. However, the performance is limited by the efficiency of the semantic transceivers, i.e., the achievable "similarity" between the transmitted and received signals. Under strict similarity conditions, semantic transmission may not be applicable and Shannon communication is mandatory. In this paper, for the first time in the literature, we propose a multi-carrier Hybrid Semantic-Shannon communication system where, without loss of generality, the case of text transmission is investigated. To this end, a joint semantic-Shannon transmission selection and power allocation optimization problem is formulated, aiming to minimize two transmission delay metrics widely used in the literature, subject to strict similarity thresholds. Despite their non-convexity, both problems are decomposed into a convex and a mixed linear integer programming problem by using alternating optimization, both of which can be solved optimally. Furthermore, to improve the performance of the proposed hybrid schemes, a novel association of text sentences to subcarriers is proposed based on the data size of the sentences and the channel gains of the subcarriers. We show that the proposed association is optimal in terms of transmission delay. Numerical simulations verify the effectiveness of the proposed hybrid semantic-Shannon communication scheme and the derived sentence-to-subcarrier association, and provide useful insights into the design parameters of such systems.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Transactions on Wireless Communications'
	DOI	10.1109/TWC.2024.3376998
	Link	https://ieeexplore.ieee.org/document/10477313
	Open Access	https://arxiv.org/abs/2410.01379
20	**Title**	**'Quasi-Isolated Network Slicing for Multi-Access Edge Computing'**
	Abstract	'Network slicing via next-generation multiple access techniques and multi-access edge computing (MEC) are considered key enablers for meeting the heterogeneous quality of service requirements of the sixth-generation (6G)

		networks. Thus, in this work, we investigate the coexistence of further enhanced mobile broadband (feMBB) and ultra-massive machine-type communications (umMTC) devices in a quasi-isolated (QI) heterogeneous uplink MEC network, where users of both services share the same resources, interfering with each other. The feMBB users can partially offload their data to the MEC server utilizing the rate-splitting multiple access (RSMA) protocol, while the umMTC users perform only full offloading. We formulate and optimally solve the problem of maximizing the number of umMTC devices subject to data processing time and data rate constraints by adjusting both the decoding order of the users and the power splitting factor of the RSMA, while a closed-form expression for the optimal partial offloading factor of the feMBBs devices is derived. Simulation results verify that utilizing the RSMA protocol, the QI MEC network has the potential to support more umMTC devices compared to the isolated one.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Communications Letters'
	DOI	10.1109/LCOMM.2024.3374816
	Link	https://ieeexplore.ieee.org/document/10463044
	Open Access	https://www.researchgate.net/publication/378814572_Quasi-Isolated_Network_Slicing_for_Multi-Access_Edge_Computing
21	Title	**'CNN-Based Automatic Modulation Classification Under Phase Imperfections'**
	Abstract	'Dynamic spectrum allocation for diverse future applications is anticipated to be supported by sixth-generation (6G) wireless networks. Specifically, automatic modulation classification (AMC) has been highlighted as a technique to enhance spectral utilization. However, its accuracy is influenced not only by additive white Gaussian noise and channel fading but also by phase imperfections (PI) coming from unsynchronized local oscillators and imperfect channel state information (CSI), leading to degraded classification performance. To solve this problem, we propose a convolutional neural network (CNN)-based scheme that transforms the received data to improve the classification accuracy under generalized PI conditions. Moreover, we also modify the kernel dimensions of the CNN layers to further improve the performance based on the geometry of the modulated schemes after the proposed transformation is applied to the received data. Finally, through simulations, we verified the effectiveness of the method in elevating AMC accuracy, even in intense PI conditions.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Wireless Communications Letters'
	DOI	10.1109/LWC.2024.3379198
	Link	https://ieeexplore.ieee.org/document/10475703
	Open Access	https://geokarag.webpages.auth.gr/wp-content/papercite-data/pdf/j386.pdf
22	Title	**'Network Slicing for eMBB and mMTC with Finite Blocklength Codes'**
	Abstract	'Network slicing appears as a key enabler for next-generation wireless networks and together with multiple access schemes can meet the quality of service (QoS) requirements of various users and services. Thus, in this work, a heteroge-neous uplink network is investigated, where enhanced mobile broadband (eMBB) and massive machine-type communications (mMTC) users coexist and share the same resources. The problem of maximizing the sum-rate of eMBB users utilizing the rate-splitting multiple access (RSMA) protocol is formulated and optimally solved, whereas the optimal decoding order and power splitting factor are investigated. In addition, short packet communications are taken into account for the mMTC users and their optimal transmission power is derived in closed form. Simulation

		results verify the enhancement that the RSMA scheme provide compared to the NOMA counterpart.'
	Partner(s)	UOWM
	Status	Presented in '2024 13th International Conference on Modern Circuits and Systems Technologies (MOCAST)'
	DOI	10.1109/MOCAST61810.2024.10615386
	Link	https://ieeexplore.ieee.org/document/10615386
	Open Access	https://www.researchgate.net/profile/Sotiris-Tegos-2/publication/382929224_Network_Slicing_for_eMBB_and_mMTC_with_Finite_Blocklength_Codes/links/66d1707a64f7bf7b1948be11/Network-Slicing-for-eMBB-and-mMTC-with-Finite-Blocklength-Codes.pdf
23	**Title**	**'Waveform Design for Over-the-Air Computing under Sampling Error'**
	Abstract	'To accommodate the large number of devices expected to operate in next-generation networks, a paradigm shift toward over-the-air (OTA) computing has been proposed, which takes advantage of the superposition principle of multiple access channels aiming to achieve better resource management as it supports simultaneous transmission in time and frequency. However, related studies have focused on analog transmission schemes without considering the components of modern transceivers. Therefore, to facilitate the use of OTA computing in modern systems, we investigate the impact of different waveforms transmission in OTA computing by taking into account the sampling errors that occur at the receiver side due to synchronization problems. To this end, the average minimum square error (MSE), under time sampling error for any utilized waveform, is investigated. Then, the MSE minimization problem is formulated and solved using alternating optimization to extract an efficient power allocation scheme. Simulation results for the raised cosine (RC) and the better-than-raised-cosine (BTRC) waveforms validate the theoretical part of our work and illustrate the efficiency of the extracted power allocation scheme while also providing a fair comparison between the RC and the BTRC waveforms.'
	Partner(s)	UOWM
	Status	Presented in '2024 7th International Balkan Conference on Communications and Networking (BalkanCom)'
	DOI	10.1109/BalkanCom61808.2024.10557192
	Link	https://ieeexplore.ieee.org/document/10557192
	Open Access	https://www.researchgate.net/profile/Sotiris-Tegos-2/publication/381541936_Waveform_Design_for_Over-the-Air_Computing_under_Sampling_Error/links/66d17155b1606e24c2a8ab7f/Waveform-Design-for-Over-the-Air-Computing-under-Sampling-Error.pdf
24	**Title**	**'Breaking Orthogonality in Uplink With Heterogeneous Requirements and Randomly Deployed Sources'**
	Abstract	'In sixth-generation (6G) wireless communication systems, the coexistence of enhanced mobile broadband (eMBB) and massive machine-type communications (mMTC) services requires the investigation of appropriate multiple access schemes. In this direction, this paper delves into the hybrid eMBB-mMTC policy, focusing on the implications of non-orthogonality in contention-based access schemes and combining the strengths of slotted ALOHA and successive interference cancellation to address the challenges of this hybrid policy. Closed-form expressions for the outage probability, which are crucial for deriving the throughput of the sources, are presented and integrated into a comprehensive analysis. Finally, simulation results are used to validate the provided theoretical expressions, highlighting the effects of random source deployment within the

		hybrid eMBB-mMTC framework and highlighting the potential and challenges of this policy in shaping the future of 6G wireless communication systems.'
	Partner(s)	UOWM
	Status	Presented in '2024 IEEE Wireless Communications and Networking Conference (WCNC)'
	DOI	10.1109/WCNC57260.2024.10570690
	Link	https://ieeexplore.ieee.org/document/10570690
	Open Access	https://www.researchgate.net/profile/Sotiris-Tegos-2/publication/381982063_Breaking_Orthogonality_in_Uplink_With_Heterogeneous_Requirements_and_Randomly_Deployed_Sources/links/66d16f8df84dd1716c72d24c/Breaking-Orthogonality-in-Uplink-With-Heterogeneous-Requirements-and-Randomly-Deployed-Sources.pdf
25	Title	**'On the Performance of RIS-Assisted Networks with HQAM'**
	Abstract	'In this paper, we investigate the application of hexagonal quadrature amplitude modulation (HQAM) in reconfigurable intelligent surface (RIS)-assisted networks, specifically focusing on its efficiency in reducing the number of required reflecting elements. Specifically, we present analytical expressions for the average symbol error probability (ASEP) and propose a new metric for conditioned energy efficiency, which assesses the network's energy consumption while ensuring the ASEP remains below a certain threshold. Additionally, we introduce an innovative detection algorithm for HQAM constellations, which demonstrates a substantial reduction in computational complexity. Finally, our study reveals that HQAM significantly enhances both the ASEP and energy efficiency compared to traditional quadrature amplitude modulation (QAM) schemes.'
	Partner(s)	UOWM
	Status	Presented in '2024 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)'
	DOI	10.1109/EuCNC/6GSummit60053.2024.10597099
	Link	https://ieeexplore.ieee.org/document/10597099
	Open Access	https://www.researchgate.net/profile/Dimitrios-Tyrovolas-2/publication/380824833_On_the_Performance_of_RIS-assisted_Networks_with_HQAM/links/66504fbabc86444c72fd7d53/On-the-Performance-of-RIS-assisted-Networks-with-HQAM.pdf
26	Title	**'Larger-scale Nakamoto-style Blockchains Don't Necessarily Offer Better Security'**
	Abstract	'Extensive research on Nakamoto-style consensus protocols has shown that network delays degrade the security of these protocols. Established results indicate that, perhaps surprisingly, maximal security is achieved when the network is as small as two nodes due to increased delays in larger networks. This contradicts the very foundation of blockchains, namely that decentralization improves security. In this paper, we take a closer look at how the network scale affects security of Nakamoto-style blockchains. We argue that a crucial aspect has been neglected in existing security models: the larger the network, the harder it is for an attacker to control a significant amount of power. To this end, we introduce a probabilistic corruption model to express the increasing difficulty for an attacker to corrupt resources in larger networks. Based on our model, we analyze the impact of the number of nodes on the (maximum) network delay and the fraction of adversarial power. In particular, we show that (1) increasing the number of nodes eventually violates security, but (2) relying on a small number of nodes does not provide decent security provisions either. We then validate our analysis by means of an empirical evaluation emulating hundreds of thousands of

		nodes in deployments such as Bitcoin, Monero, Cardano, and Ethereum Classic. Based on our empirical analysis, we concretely analyze the impact of various real-world parameters and configurations on the consistency bounds in existing deployments and on the adversarial power that can be tolerated while providing security. As far as we are aware, this is the first work that analytically and empirically explores the real-world tradeoffs achieved by current popular Nakamoto-style deployments.'
	Partner(s)	NEC
	Status	Presented in 'IEEE Symposium on Security and Privacy (S&P)'
	DOI	10.1109/SP54263.2024.00227
	Link	https://www.computer.org/csdl/proceedings-article/sp/2024/313000a208/1WPcYAt0aze
	Open Access	https://arxiv.org/abs/2404.09895
27	**Title**	**'A Reinforcement Learning-Based Reverse Auction Enforcing Smart Pricing Policies towards B5G Offloading Strategies'**
	Abstract	'In this paper, we present our work on developing a Smart Pricing Policies module specifically designed for individual users and Mobile Network Operators (MNOs). Our framework will operate in a multi-MNO blockchain radio access network (B-RAN) and is tasked with determining prices for resource sharing among users and MNOs. Our sophisticated adaptive pricing system can adjust to situations where User Equipment (UE) shifts out of the coverage area of their MNO by immediately sealing a contract with a different MNO to cover the users' needs. This way, we aim to provide financial incentives to MNOs while ensuring continuous network optimization for all parties involved. Our system accomplishes that by utilizing deep reinforcement learning (DLR) to implement a reverse auction model. In our reinforcement learning scenario, the MNOs, acting as agents, enter a competition and try to bid the most appealing price based on the user's request, and based on the reward system, agents that do not win in the current round will adjust their strategies in an attempt to secure a win in subsequent rounds. The findings indicated that combining DRL with reverse auction theory offers a more appropriate method for addressing the pricing and bid challenges, and additionally, administrators can utilize this strategy to gain a notable edge by dynamically selecting and adjusting their methods according to the individual network conditions and requirements.'
	Partner(s)	8BELLS
	Status	Published in 'Electronics'
	DOI	10.3390/electronics13132488
	Link	https://www.mdpi.com/2079-9292/13/13/2488
	Open Access	Yes
28	**Title**	**'PHaul: A PPO-Based Forwarding Agent for Sub6 Enhanced Integrated Acess and Backhaul Networks'**
	Abstract	'3GPP Integrated Access and Backhaul (IAB) allows operators to deploy outdoor mm-wave access networks in a cost-efficient manner, by reusing the same spectrum in access and backhaul. In IAB networks the performance bottleneck is the wireless backhaul segment, where efficient forwarding strategies are needed to effectively use the available capacity. In addition, the performance of the mm-wave IAB backhaul segment is contingent on the availability of line of sight (LoS) conditions in the selected deployment sites. To mitigate LoS dependence, in this paper, we propose to complement the mm-wave backhaul segment of IAB

		networks with additional Sub6 backhaul links, which contribute to the capacity and robustness of the backhaul network. We refer to IAB networks combining Sub6 and mm-wave links in the backhaul as Sub6 enhanced IAB networks. In this context, the main contribution of this paper is PHaul, a forwarding engine for Sub6 enhanced IAB networks that accomodates different traffic engineering criteria, and combines an offline path selection heuristic with an online Deep Reinforcement Learning (DRL) agent based on Proximal Policy Optimization (PPO). By leveraging a network digital twin of the IAB wireless backhaul, PHaul periodically samples the input traffic of the backhaul network and updates flow to path mappings, with execution times below 10 seconds in realistic backhaul topologies. We present an exhaustive performance evaluation, where we demonstrate that PHaul can achieve gains of up to 36% in throughput efficiency and of up to 20% in fairness, when compared against two alternative heuristics in a wide range of network configurations. We also demonstrate that PHaul is robust to differences between the network topologies considered in the training and inference phases, which can occur in practice due to link failures.'
	Partner(s)	i2CAT
	Status	Published in 'IEEE Transactions on Network and Service Management (TNSM)'
	DOI	10.1109/TNSM.2024.3435505
	Link	https://ieeexplore.ieee.org/document/10614224
	Open Access	https://zenodo.org/records/17207399
29	Title	**'Semantic Communications for Image-Based Sign Language Transmission'**
	Abstract	'Semantic information representation in image-based communication often employs feature vectors, lacking interpretability and posing challenges for human comprehension. This paper addresses this challenge by exploring the reconstruction of original images in the context of American sign language (ASL) transmission. The conventional method involves decoding feature vectors through neural networks, introducing inefficiencies and complexities. To overcome these challenges, a novel system model for image-based semantic communications is presented, which utilizes a variant of the quadrature amplitude modulation (QAM) scheme, named 24-QAM. This modulation scheme is derived from the original 32-QAM constellation by removing 8 peripheral symbols and is proven capable of attaining superior error performance in ASL applications. Additionally, a semantic encoder based on a convolutional neural network (CNN) which effectively utilizes the ASL alphabet is presented. An original dataset is created by superimposing red-green-blue landmarks and key-points on top of the captured images; hence, enhancing the representation of hand posture. Finally, the training, testing, and communication performance of the proposed system is quantified through numerical results that highlight the achievable gains and trigger insightful discussions.'
	Partner(s)	INNO
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3360191
	Link	https://ieeexplore.ieee.org/document/10418996
	Open Access	Yes
30	Title	**'Toward Natively Intelligent Semantic Communications and Networking'**
	Abstract	'As the process of envisioning, researching, and strategizing for 6G communications has commenced, we present our vision on the role of semantic communications (SemCom) in the beyond 5G era. In the following discourse, we

		delve into the factors that may impede the progress of research and implementation of 6G with the objective of catering to the semantically enriched communication requirements of the 2030s. In addition, we proceed to establish the fundamental attributes of SemCom and engage in an examination of the requisite technological modalities. In order to bolster this overarching vision, we introduce a semantic networking architecture that encapsulates and characterizes various application scenarios of SemCom. Expanding on the concept of point-to-point SemCom systems the semantic networking architecture focuses on extracting and filtering goal specific semantic information at the source before transmitting signals. It also involves decoding and post processing semantics at the destination. What sets this networking architecture apart is its transformation into a multi-user distributed, edge-to-cloud network with deadline constraint traffic. Given its complexity, implementing such an architecture necessitates frameworks for extracting and representing knowledge theoretical models to predict and manage multiple time varying deadline/delay constrained traffic flows that may cause significant congestion in the network as well, as innovative metrics infused with semantics to measure performance while encapsulating its inherent relevance. Finally, we provide research considerations and future directions towards the integration of semantics in the forthcoming 6G wireless systems.'
	Partner(s)	INNO
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3371871
	Link	https://ieeexplore.ieee.org/document/10454584
	Open Access	Yes
31	Title	**'Rate-Splitting Multiple Access With Finite Blocklength and High Mobility for URLLC Transmissions'**
	Abstract	'In this letter, we investigate the ergodic performance of rate-splitting multiple access (RSMA) with finite blocklength (FBL) in high mobility communication systems to meet the ultra-reliable and low-latency (URLLC) requirements. Considering the imperfect channel state information at the transmitter (CSIT) originating from the high mobility of vehicles and the time delay of channel feedback, we analyze the statistical properties of signal-to-interference-plus-noise ratios (SINRs) for common and private streams at the desired vehicle. Next, we derive the closed-form expression for the ergodic sum-rate in FBL RSMA systems considering an arbitrary number of transmit antennas, number of vehicles, vehicle speeds, blocklengths, and block error rates (BLERs). Compared to other benchmarks, such as FBL non-orthogonal multiple access (NOMA) and space division multiple access (SDMA), the proposed scheme holds its optimum performance to meet the stringent BLER requirement while maintaining a prominent reduction in blocklength.'
	Partner(s)	INNO
	Status	Published in 'IEEE Wireless Communications Letters'
	DOI	10.1109/LWC.2024.3381154
	Link	https://ieeexplore.ieee.org/document/10478577
	Open Access	https://zenodo.org/records/17590782
32	Title	**'URLLC-Enabled Full-Duplex Cell-Free Massive MIMO Systems With Mobility'**
	Abstract	'In the rapidly evolving domain of intelligent vehicular systems, reliable and instantaneous communication is paramount. This paper delves into the robustness of an ultra-reliable low-latency communication (URLLC)-enabled full-

		duplex cell-free massive multiple-input multiple-output (FD-CFm-MIMO) system, considering the unique challenges presented by mobile vehicular networks. Recognizing the constraints of real-world fronthaul links, we focus on a uniform fronthaul quantization strategy. Our primary contribution is deriving the cumulative distribution function (CDF) of the signal-to-interference-plus-noise ratio (SINR) at each receiver. We utilize the Welch-Satterthwaite approximation, taking into account the effects of imperfect channel state information (CSI) and the inherent mobility of vehicle communication units (VCUs). Building upon this, we present closed-form expressions of outage probability for both infinite and finite block-length transmission models. A comparative study using Monte Carlo simulations validates our analytical derivations. We consider the half-duplex CFm-MIMO system as a benchmark scheme. Our results underscore the significant influence of several system parameters, such as transmit power, VCU mobility, CSI accuracy, fronthaul link quality, residual interference (RI), and quantization nuances, Doppler power spectra models, pilot contamination on overall system performance.'
	Partner(s)	INNO
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3398098
	Link	https://ieeexplore.ieee.org/document/10525063
	Open Access	Yes
33	Title	**'Visibility Graph Based Wireless Anomaly Detection for Digital Twin Edge Networks'**
	Abstract	'Network softwarization, which shifts hardware-centric functions to software implementations, is essential for enhancing the agility of cellular and non-cellular wireless networks. This change, while raising reliability concerns, also improves system monitoring through digital twins. One example is the Digital Twin Edge Networks (DITEN), which enhances real-time analysis and quick anomaly response in the unpredictable last-mile wireless edge network environment. Positioned close to the physical infrastructure, DITEN is effective in rapidly detecting and addressing network irregularities. This study presents an advanced anomaly detection method for DITEN, employing time-series data conversion to Visibility Graph (VG) and utilising Graph Neural Network (GNN), with a focus on addressing disruptions at the network's physical layer. Our proposed method outperforms the state-of-the-art time series Deep Learning (DL) classification architecture by 13 percentage points and achieves ≈110 times higher computational efficiency. Furthermore, our method surpasses the classical Machine Learning (ML) model Hive-Cote2 by 2.2 percentage points while maintaining ≈5.9 times better computational efficiency. The model also outperforms the current best state-of-art imaging model by up to 6 percentage points and the leading graph-based method by up to 10 percentage points, both with significantly lower Computational Complexity (CC) of ≈210-times and ≈4-times, respectively. Additionally, we show that when 1000 concurrent requests arrive, the proposed method achieves a mean response latency of less than or equal to 60 seconds across three setups. Finally, we demonstrate that the combination of Natural Visibility Graph (NVG) and the proposed GNN model provides interpretable insights by observing gradient changes.'
	Partner(s)	JSI
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3393853

	Link	https://ieeexplore.ieee.org/document/10508580
	Open Access	Yes
34	**Title**	**'Spectrum Sensing with Deep Clustering: Label-Free Radio Access Technology Recognition'**
	Abstract	'The growth of the number of connected devices and network densification is driving an increasing demand for radio network resources, particularly Radio Frequency (RF) spectrum. Given the dynamic and complex nature of contemporary wireless environments, characterized by a wide variety of devices and multiple RATs, spectrum sensing is envisioned to become a building component of future 6G, including as a components within O-RAN or digital twins. However, the current state-of-art research for RAT classification predominantly revolves around supervised Convolutional Neural Network (CNN)- based approach that require extensive labeled dataset. Due to this, it is unclear how existing models behave in environments for which training data is unavailable thus leaving open questions regarding their generalization capabilities. In this paper, we propose a new spectrum sensing workflow in which the model training does not require any prior knowledge of the RATs transmitting in that area (i.e., no labelled data) and the class assignment can be easily done through manual mapping. Furthermore, we adaptat a SSL deep clustering architecture capable of autonomously extracting spectrum features from raw 1D Fast Fourier Transform (FFT) data. We evaluate the proposed architecture on three real-world datasets from three European cities, in the 868 MHz, 2.4 GHz and 5.9 GHz bands containing over 10 RATs and show that the developed model achieves superior performance by up to 35 percentage points with 22% fewer trainable parameters and 50% less floating-point operations per second (FLOPS) compared to an state-of-art AE-based reference architecture.'
	Partner(s)	JSI
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3436601
	Link	https://ieeexplore.ieee.org/document/10623390
	Open Access	Yes
35	**Title**	**'Explainable semantic wireless anomaly characterization for digital twins'**
	Abstract	'The shift towards software-centric network infrastructures is driven by the increasing need for networks to be responsive, flexible, and scalable in the face of an expanding set of connected devices. The digital twin (DT) approach, mirroring physical entities in a digital format, has emerged as a key enabler of network reliability and availability. Incorporating artificial intelligence (AI) into DTs enhances the resilience of networks by providing in-depth analysis and increasingly automated mitigation strategies against operational disruptions. In this work, we propose a new AI-based information extraction module that is part of the DT Monitoring component able to process RSS data, extract and characterize abrupt anomalies. The output of this component is used to maintain an anomaly history in the Link Abstraction within the DT and subsequently inform possible automatic mitigation actions. We design the AI-based information extraction module to identify and characterize three types of RSS based anomalies. Our extensive performance analysis on 10 versions of the "You Only Look Once" architecture reveals that YOLOv8n produces a good tradeoff between performance and computational complexity. We show that our approach performs on par with the state of the art for anomaly detection, while enabling

		anomaly characterization by location, duration, and severity. By employing two state-of-art explainability algorithms, we also provide insights into the important regions of the input that trigger the selected model's classification and characterization decisions.'
	Partner(s)	JSI
	Status	Published in 'Computer Networks'
	DOI	10.1016/j.comnet.2024.110660
	Link	https://www.sciencedirect.com/science/article/pii/S1389128624004924
	Open Access	Yes
36	**Title**	**'Digital transformation with a lightweight on-premise PaaS'**
	Abstract	'The rise of cloud computing has been enabled by advances in virtualization and containerization technology. Over the past decade, the use of cloud computing has grown rapidly and has had a significant impact on digital transformation with many enterprises migrating to public clouds. While convenient and cost efficient, such approaches are prone to certain data privacy, compliance and security risks. The ongoing democratization of cloud technologies represented by the increasing number of open source projects, has enabled certain enterprises to easily develop their on-premise cloud infrastructure. However, these open source projects are largely enterprise level and still too complex for small and micro enterprises and academic environments. To further decrease the on-premise infrastructure deployment and management barrier, we first provide an analysis of the existing on-premises PaaS workflows and solutions, along with the complexity of their deployment models, and identify the requirements for simple PaaS solutions for small environments with limited resources. We then introduce Kubitect as an enabler of on-premises PaaS democratization and expedite digital transformation. Kubitect is a lightweight single file declarative infrastructure configuration solution for on-premises cluster definition, instantiation and update. Our qualitative and quantitative evaluation shows the advantage of Kubitect for small environments where simplicity is more important than deploy time, assuming the latter is relatively comparable with alternative solutions.'
	Partner(s)	JSI
	Status	Published in 'Future Generation Computer Systems'
	DOI	10.1016/j.future.2024.06.026
	Link	https://www.sciencedirect.com/science/article/pii/S0167739X24003261
	Open Access	Yes
37	**Title**	**'The MATERIAL framework: Modeling and AuTomatic code Generation of Edge Real-TIme AppLications under the QNX RTOS'**
	Abstract	'Modern edge real-time automotive applications are becoming more complex, dynamic, and distributed, moving away from conventional static operating environments to support advanced driving assistance and autonomous driving functionalities. This shift necessitates formulating more complex task models to represent the evolving nature of these applications aptly. Modeling of real-time automotive systems is typically performed leveraging Architectural Languages (ALs) such as Amalthea, which are commonly used by the industry to describe the characteristics of processing platforms, operating systems, and tasks. However, these architectural languages are originally derived for classical automotive applications and need to evolve to meet the needs of next-generation applications. This paper proposes an automatic framework for the modeling and automatic code generation of dynamic automotive applications under the QNX

		RTOS. To this end, we extend Amalthea to describe chains of communicating tasks with multiple operating modes and to consider the QNX's reservation-based scheduler, called APS, which allows providing temporal isolation between applications co-located on the same hardware platform. Finally, an evaluation is presented to compare different implementation alternatives under QNX that are automatically generated by our code generation framework.'
	Partner(s)	SSS
	Status	Published in 'Journal of Systems Architecture'
	DOI	10.1016/j.sysarc.2024.103219
	Link	https://www.sciencedirect.com/science/article/pii/S1383762124001565
	Open Access	Yes
38	Title	**'End-to-End Latency Optimization of Thread Chains Under the DDS Publish/Subscribe Middleware'**
	Abstract	'Modern autonomous systems integrate diverse soft-ware solutions to manage tightly communicating functionalities. These applications commonly communicate using frameworks implementing the publish/subscribe paradigm, such as the Data Distribution Service (DDS). However, these frameworks are real-ized with a multi-threaded software architecture and implement internal policies for message dispatching, posing additional chal-lenges for guaranteeing timing constraints. This work addresses the problem of optimizing a DDS-based interconnected real-time systems, proposing analysis-driven algorithms to set a vast range of parameters, ranging from classical thread priorities to other DDS-specific configurations. We evaluate our approaches on the Autoware Reference System, a realistic testbed from the Autoware autonomous driving framework.'
	Partner(s)	SSS
	Status	Presented in '2024 Design, Automation & Test in Europe Conference & Exhibition (DATE)'
	DOI	10.23919/DATE58400.2024.10546636
	Link	https://ieeexplore.ieee.org/document/10546636
	Open Access	https://retis.santannapisa.it/~a.biondi/papers/DATE24.pdf
39	Title	**'Fast Traffic Processing in Multi-Tenant 5G Environments: A Comparative Performance Evaluation of P4 and eBPF Technologies'**
	Abstract	'Although the softwarization of network infrastructures through the use of Software Defined Networking (SDN) and Network Function Virtualization (NFV) has set the foundations of future communication architectures, the efficient handling of high throughput traffic while maintaining latency requirements still remains a challenge. In this work, we explore two arising technologies that aim at reducing networking tasks' latency while dealing with high levels of traffic volume, namely, Programming Protocol-independent Packet Processors (P4) and the extended Berkeley Packet Filter (eBPF). We present a review of the latest advances in the use of both technologies and we provide a discussion on their advantages and disadvantages. As the main contribution of the paper, we showcase an extensive performance evaluation of these technologies under different traffic conditions. To do so, we implement a fast traffic processing network function operating in a real 5G Stand Alone (SA) network. Obtained results confirm, as expected, the high performance attained using dedicated hardware programmed by P4, in contrast to eBPF-based solution's poorer results while handling similar throughputs. Nevertheless, eBPF allows similar packet-processing times than P4, therefore qualifying it as a perfectly scalable solution

		on commodity hardware even as a virtual function, which paves the way for the realization of autonomous, flexible and cost-effective next-generation network infrastructures.'
	Partner(s)	UMU
	Status	Published in 'Engineering Science and Technology'
	DOI	10.1016/j.jestch.2024.101678
	Link	https://www.sciencedirect.com/science/article/pii/S2215098624000648
	Open Access	Yes
40	**Title**	**'Machine learning-powered traffic processing in commodity hardware with eBPF'**
	Abstract	'Network softwarization is paving the way for the design and development of Next-Generation Networks (NGNs), which are demanding profound improvements to existing communication infrastructures. Two of the fundamental pillars of NGNs are flexibility and intelligence to create elastic network functions capable of managing complex communication systems in an efficient and cost-effective way. In this sense, the extended Berkeley Packet Filter (eBPF) is a state-of-the-art solution that enables low-latency traffic processing within the Linux kernel in commodity hardware. When combined with Machine Learning (ML) algorithms, it becomes a promising enabler to perform smart monitoring and networking tasks at any required place of the fog-edge-cloud continuum. In this work, we present a solution that leverages eBPF to integrate ML-based intelligence with fast packet processing within the Linux kernel, enabling the execution of complex computational tasks in a flexible way, saving resources and reducing processing latencies. A real implementation and a series of experiments have been carried out in an Internet of Things (IoT) scenario to evaluate the performance of the solution to detect attacks in a 6LowPAN system. The performance of the in-kernel implementation shows a considerable reduction in the execution time (-97%) and CPU usage (-6%) of a Multi-Layer Perceptron (MLP) model in comparison with a user space development approach; thus positioning our proposal as a promising solution to embed ML-powered fast packet processing within the Linux kernel.'
	Partner(s)	UMU
	Status	Published in 'Computer Networks'
	DOI	10.1016/j.comnet.2024.110295
	Link	https://www.sciencedirect.com/science/article/pii/S1389128624001270
	Open Access	Yes
41	**Title**	**'Beyond 5G Networking: The Case of NANCY Project'**
	Abstract	'With the global deployment of the fifth-generation (5G) wireless networks, the exploration of Beyond 5G (B5G)/sixth-generation (6G) wireless communications has begun. It is foreseen that related technologies will exhibit superior characteristics compared to their predecessors, encompassing higher transfer speeds, expanded coverage, enhanced reliability, greater energy efficiency, reduced latency and, notably, an integrated "human-centric" network infrastructure driven by Artificial Intelligence (AI). This study underscores the imperative need for AI methodologies and security across various resources such as spectrum, computing and storage, provided by the advanced blockchain features in the forthcoming 6G era. Use cases posed by these B5G technologies aim to leverage its inherent features of decentralization, transparency, anonymity and resiliency, while blockchain can foster cooperative trust among disparate

		network entities. Furthermore, the paper elucidates insights into Blockchain Radio Access Networks (B-RANs) gleaned from the EU-funded research project NANCY whose pillars and architecture are highlighted, providing an overview of the core advancements it can offer.'
	Partner(s)	OTE
	Status	Published in 'Artificial Intelligence Applications and Innovations. AIAI 2024 IFIP WG 12.5 International Workshops'
	DOI	10.1007/978-3-031-63227-3_2
	Link	https://www.springerprofessional.de/en/beyond-5g-networking-the-case-of-nancy-project/27245858
	Open Access	N/A
42	**Title**	**'eBPF and XDP Technologies as Enablers for Ultra-Fast and Programmable Next-Gen Network Infrastructures'**
	Abstract	'Current and next-generation services present a challenging set of requirements that network infrastructures need to cope with. Although Software Defined Networking (SDN) and Network Function Virtualization (NFV) techniques have laid the foundations of future communication architectures by providing flexibility and robustness against operational changes, the reduction of the networking tasks' latency still remains as a challenge. This is specially crucial for enabling efficient resource management in fog/edge/cloud computing scenarios. In this line, the extended Berkeley Packet Filter (eBPF) has appeared as a promising solution to reduce these delays and to provide advanced programmability capabilities to the infrastructure. In this work, we explore eBPF and the eXpress Data Path (XDP) as key enablers for the design of next-generation networks as well as their advantages and limitations. Also, we present a case study in which an eBPF/XDP network function has been developed and integrated within a real 5G network adopting a Mobile Edge Computing (MEC) approach, with the aim of applying diverse Quality of Service (QoS) policies to different multi-tenant 5G traffic flows. The obtained results show how the proposed solution outperforms a baseline approach powered by iptables, achieving a reduction of around 40% in the packet processing time. The proposed solution paves the way for the development of novel virtual network and resource management functions.'
	Partner(s)	UMU
	Status	Book chapter in 'Resource Management in Distributed Systems'
	DOI	10.1007/978-981-97-2644-8_13
	Link	https://link.springer.com/chapter/10.1007/978-981-97-2644-8_13
	Open Access	https://zenodo.org/records/17182690
43	**Title**	**'Embedded Intelligence in Internet of Things Scenarios'**
	Abstract	'The emerging field of Tiny Machine Learning (TinyML) allows the deployment of Machine Learning (ML) models on resource-constrained devices. Besides, one of the most promising technologies for addressing the exponential growth of data traffic in Internet of Things (IoT) networks is extended Berkeley Packet Filter (eBPF), which enables the execution of sandboxed programs within the Linux kernel, without the need to modify the kernel's source code. This study presents significant progress in the implementation of complex ML models within the Linux kernel by leveraging the comprehensive capabilities provided by eBPF and TinyML technologies. Concretely, in the presented experimental validation, we show notable improvements in terms of execution time and CPU usage, when a Multi-Layer Perceptron (MLP) model is run within the kernel in comparison to its

		execution in user space. This achievement establishes a solid foundation for the direct integration of ML techniques within the IoT data plane.'
	Partner(s)	UMU
	Status	Book chapter in 'TinyML for Edge Intelligence in IoT and LPWAN Networks'
	DOI	10.1016/B978-0-44-322202-3.00021-X
	Link	https://www.sciencedirect.com/science/article/abs/pii/B978044322202300021X
	Open Access	https://zenodo.org/records/17182760
44	Title	**'Comparison of Swarm Intelligence Methods for Joint Resource Orchestration in Open Radio Access Network'**
	Abstract	'The radio access network (RAN) will be an integral part of the sixth generation (6G) of mobile networks. By using several advanced technologies (e.g., virtualization, cloud, and edge computing), it aims to address the stringent networking and computing requirements of new applications and offer high quality of service and experience levels to the consumers. However, the optimal allocation of computing and radio resources can be challenging due to the heterogeneity of the network and the stringent constraints imposed by the new application requirements. This work is focused on leveraging swarm intelligence methods in an Open RAN to offer a zero-touch management network architecture that autonomously orchestrates its resources taking into account several constraints. Specifically, three swarm intelligence methods are evaluated and compared, namely the Grey Wolf Optimizer, the Salp Swarm Algorithm, and the Particle Swarm Optimization. The results show that the Grey Wolf Optimizer features the best performance in solving the joint offloading and resource allocation problem in edge computing scenarios.'
	Partner(s)	UOWM
	Status	Presented at the '14th International Symposium on Communication Systems, Networks and Digital Signal Processing (CSNDSP 2024)'
	DOI	10.1109/CSNDSP60683.2024.10636586
	Link	https://ieeexplore.ieee.org/abstract/document/10636586
	Open Access	https://zenodo.org/records/13623403
45	Title	**'Period Estimation for Linux-based Edge Computing Virtualization with Strong Temporal Isolation'**
	Abstract	'Virtualization of edge nodes is paramount to avoid their under-exploitation, allowing applications from different tenants to share the underlying computing platform. Neverthe-less, enabling different applications to share the same hardware may expose them to uncontrolled mutual timing interference, as well as timing-related security attacks. Strong timing isolation through SCHED_DEADLINE reservations is an interesting solution to facilitate the safe and secure sharing of the processing platform: nevertheless, SCHED_DEADLINE reservations require proper parameter tuning that can be hard to achieve, especially in the case of highly dynamic environments, characterized by workloads that need to be served without knowing any accurate information about their timing. This paper presents an approach for estimating the periods of SCHED_DEADLINE reservations based on a spectral analysis of the activation pattern of the workload running in the reservation, which can be used to assign and refine reservation parameters in edge systems.'
	Partner(s)	SSS

	Status	Presented at '2024 IEEE 3rd Real-Time and Intelligent Edge Computing Workshop (RAGE)'
	DOI	10.1109/RAGE62451.2024.00013
	Link	https://ieeexplore.ieee.org/abstract/document/10628443
	Open Access	https://retis.santannapisa.it/~tommaso/publications/RAGE-2024.pdf
46	**Title**	**'Linux Kernel Traffic Processing with Machine Learning'** *(translated from Spanish)*
	Abstract	'Traffic processing using Machine Learning (ML)-based mechanisms has been gaining momentum in recent years due to the complexity of new communications systems and the need for advanced control of the flows they carry. Thus, new techniques and tools are emerging to enable the integration of intelligent algorithms in the end-to-end data path. One of them is the extended Berkeley Packet Filter (eBPF), which allows the execution of programs inside the Linux kernel without having to recompile it, enriching its functionality. In this work we take advantage of the options provided by eBPF to integrate a complex ML-based traffic analysis algorithm into the Linux kernel. This development strategy allows to significantly reduce processing latencies with respect to similar solutions implemented outside the kernel, in addition to allowing the deployment of advanced network functions in an agile way in devices not specialized in network management tasks.' *(translated from Spanish)*
	Partner(s)	UMU
	Status	Presented at 'XVI Jornadas de Ingeniería Telemática (JITEL 2023)'. Best paper award.
	DOI	N/A
	Link	https://web.salleurl.edu/docsmkt/JITEL/libro-actas-jitel.pdf
	Open Access	Yes
47	**Title**	**'DQN-based Intelligent Application Placement with Delay-Priority in Multi MEC Systems'**
	Abstract	'In 5G Multi-access Edge Computing (MEC) is critical to bring computing and processing closer to users and enable ultra-low latency communications. When instantiating an application, selecting the MEC host that minimizes the latency but still fulfills the application's requirements is critical. However, as future 6G networks are expected to become even more geo-distributed, and handled by multiple levels of management entities, this labor becomes extremely difficult and Machine Learning (ML) is meant to be a native part of this process. In this context, we propose a Reinforcement Learning model that selects the best possible host to instantiate a MEC application, looking to minimize the end-to-end delay while fulfilling the application requirements. The proposed ML method uses Deep Q-Learning through several stages of environment state, taking an action and rewarding the model when it chooses correctly and penalizing it otherwise. By modifying the reward incentives, we have successfully trained a model that chooses the best host possible delay-wise on a multi-level orchestration scenario, while meeting the applications' requirements. The results obtained via simulation over a series of MEC scenarios show a success rate of up to 96%, optimizing the delay in the long term.'
	Partner(s)	i2Cat
	Status	Presented at '2023 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)'
	DOI	10.1109/EuCNC/6GSummit58263.2023.10188300

	Link	https://ieeexplore.ieee.org/document/10188300/
	Open Access	https://zenodo.org/records/7891721
48	**Title**	**'Power-Optimal HARQ Protocol for Reliable Free Space Optical Communication'**
	Abstract	'In 5G Multi-access Edge Computing (MEC) is critical to bring computing and processing closer to users and enable ultra-low latency communications. When instantiating an application, selecting the MEC host that minimizes the latency but still fulfills the application's requirements is critical. However, as future 6G networks are expected to become even more geo-distributed, and handled by multiple levels of management entities, this labor becomes extremely difficult and Machine Learning (ML) is meant to be a native part of this process. In this context, we propose a Reinforcement Learning model that selects the best possible host to instantiate a MEC application, looking to minimize the end-to-end delay while fulfilling the application requirements. The proposed ML method uses Deep Q-Learning through several stages of environment state, taking an action and rewarding the model when it chooses correctly and penalizing it otherwise. By modifying the reward incentives, we have successfully trained a model that chooses the best host possible delay-wise on a multi-level orchestration scenario, while meeting the applications' requirements. The results obtained via simulation over a series of MEC scenarios show a success rate of up to 96%, optimizing the delay in the long term.'
	Partner(s)	UOWM
	Status	Presented at '2023 IEEE International Conference on Communications Workshops (ICC Workshops)'
	DOI	10.1109/ICCWorkshops57953.2023.10283668
	Link	https://ieeexplore.ieee.org/document/10283668
	Open Access	https://arxiv.org/abs/2303.17512
49	**Title**	**'Intelligible Protocol Learning for Resource Allocation in 6G O-RAN Slicing'**
	Abstract	'An adaptive standardized protocol is essential for addressing inter-slice resource contention and conflict in network slicing. Traditional protocol standardization is a cumbersome task that yields hardcoded predefined protocols, resulting in increased costs and delayed rollout. Going beyond these limitations, this article proposes a novel multi-agent deep reinforcement learning (MADRL) communication framework called standalone explainable protocol (STEP) for future sixth-generation (6G) open radio access network (O-RAN) slicing. As new conditions arise and affect network operation, resource orchestration agents adapt their communication messages to promote the emergence of a protocol on-the-fly, which enables the mitigation of conflict and resource contention between network slices. STEP weaves together the notion of information bottleneck (IB) theory with deep Q-network (DQN) learning concepts. By incorporating a stochastic bottleneck layer - inspired by variational autoencoders (VAEs) - STEP imposes an information-theoretic constraint for emergent inter-agent communication. This ensures that agents exchange concise and meaningful information, preventing resource waste and enhancing the overall system performance. The learned protocols enhance interpretability, laying a robust foundation for standardizing next-generation 6G networks. By considering an O-RAN compliant network slicing resource allocation problem, a conflict resolution protocol is developed. In particular, the results demonstrate that, on average, STEP reduces inter-slice conflicts by up to 6.06× compared to a predefined

		protocol method. Furthermore, in comparison with an MADRL baseline, STEP achieves 1.4× and 3.5× lower resource underutilization and latency, respectively.'
	Partner(s)	i2CAT
	Status	Published in 'IEEE Wireless Communications'
	DOI	10.1109/MWC.015.2300552
	Link	https://ieeexplore.ieee.org/document/10702574
	Open Access	https://zenodo.org/records/17086238
50	**Title**	**'AI-Driven Anomaly and Intrusion Detection in Energy Systems: Current Trends and Future Direction'**
	Abstract	'The growing digitalization and interconnection of energy infrastructures have improved operational efficiency but also heightened the risk of exposure to cyber threats. Traditional electrical power and energy systems encompass all infrastructure and processes for generating, transmitting, distributing, and consuming electricity. Conversely, the smart grid represents an advanced paradigm, integrating cyber-physical components to optimize efficiency, reliability, and sustainability. However, this paradigm shift renders the energy sector more susceptible to cyber threats and attacks, necessitating proactive identification and mitigation. This survey provides a comprehensive analysis of the current state of anomaly and intrusion detection systems specifically designed for the energy sector. We review recent advancements in detection methodologies, including machine learning, artificial intelligence, and hybrid techniques, highlighting their effectiveness in identifying potential threats.'
	Partner(s)	SID
	Status	Presented at '2024 IEEE International Conference on Cyber Security and Resilience (CSR)'
	DOI	10.1109/CSR61664.2024.10679380
	Link	https://ieeexplore.ieee.org/document/10679380
	Open Access	https://zenodo.org/records/17232782
51	**Title**	**'Toward Explainable Reasoning in 6G: A Proof of Concept Study on Radio Resource Allocation'**
	Abstract	'The move toward artificial intelligence (AI)-native sixth-generation (6G) networks has put more emphasis on the importance of explainability and trustworthiness in network management operations, especially for mission-critical use-cases. Such desired trust transcends traditional post-hoc explainable AI (XAI) methods to using contextual explanations for guiding the learning process in an in-hoc way. This paper proposes a novel graph reinforcement learning (GRL) framework named TANGO which relies on a symbolic subsystem. It consists of a Bayesian-graph neural network (GNN) Explainer, whose outputs, in terms of edge/node importance and uncertainty, are periodically translated to a logical GRL reward function. This adjustment is accomplished through defined symbolic reasoning rules within a Reasoner. Considering a real-world testbed proof-of-concept (PoC), a gNodeB (gNB) radio resource allocation problem is formulated, which aims to minimize under- and over-provisioning of physical resource blocks (PRBs) while penalizing decisions emanating from the uncertain and less important edge-nodes relations. Our findings reveal that the proposed in-hoc explainability solution significantly expedites convergence compared to standard GRL baseline and other benchmarks in the deep reinforcement learning (DRL) domain. The experiment evaluates performance in AI, complexity, energy consumption, robustness, network, scalability, and explainability metrics. Specifically, the results show that

		TANGO achieves a noteworthy accuracy of 96.39% in terms of optimal PRB allocation in inference phase, outperforming the baseline by 1.22× .'
	Partner(s)	i2CAT
	Status	Published in 'IEEE Open Journal of the Communications Society '
	DOI	10.1109/OJCOMS.2024.3466225
	Link	https://ieeexplore.ieee.org/document/10689363
	Open Access	Yes
52	**Title**	**'On the Design of Super Constellations'**
	Abstract	'In the evolving landscape of sixth-generation (6G) wireless networks that require ultra-high data rates, this study introduces the concept of super-constellation communications. We also introduce super amplitude phase shift keying (SAPSK), an innovative modulation technique designed to achieve these ultra-high data rate requirements. SAPSK is complemented by the generalized polar distance detector (GPD-D), which approximates the performance of Gaussian phase detector (GAP-D), which achieves equivalent performance to the maximum likelihood detector in channels with Gaussian phase noise (GPN). By utilizing the decision regions formulated by GPD-D, a tight closed-form approximation for the symbol error probability (SEP) of SAPSK constellations is derived, while a detection algorithm with O(1) time complexity is developed to ensure fast and efficient SAPSK symbol detection. Finally, the theoretical performance of SAPSK and the efficiency of the proposed O(1) algorithm are validated by numerical simulations, highlighting both its superiority in terms of SEP compared to various constellations and its practical advantages in terms of fast and accurate symbol detection.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3469553
	Link	https://ieeexplore.ieee.org/document/10689363
	Open Access	Yes
53	**Title**	**'Hierarchical Blockchain Radio Access Networks: Architecture, Modelling, and Performance Assessment'**
	Abstract	'Demands for secure, ubiquitous, and always-available connectivity have been identified as the pillar design parameters of the next generation radio access networks (RANs). Motivated by this, the current contribution introduces a network architecture that leverages blockchain technologies to augment security in RANs, while enabling dynamic coverage expansion through the use of intermediate commercial or private wireless nodes. To assess the efficiency and limitations of the architecture, we employ Markov chain theory in order to extract a theoretical model with increased engineering insights. Building upon this model, we quantify the latency as well as the security capabilities in terms of probability of successful attack, for three scenarios, namely fixed topology fronthaul network, advanced coverage expansion and advanced mobile node connectivity, which reveal the scalability of the blockchain-RAN architecture.'
	Partner(s)	InnoCube
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2025.3526421
	Link	https://ieeexplore.ieee.org/document/10829652
	Open Access	Yes

54	**Title**	**'Multi-Task Learning for Resource Allocation in Wireless Networks of Dynamic Dimensionality'**
	Abstract	'Deep neural networks (DNNs) have demonstrated their efficacy in delivering accurate solutions to a range of optimization problems. However, in the context of wireless communications, the size of these problems may vary across adjacent time slots, due to fast changes in the networks' architecture, e.g., the number of users. It is essential to note that this time-varying dimensionality of optimization problems in wireless networks necessitates adjustments in the DNN architecture, resulting in different numbers of input and output nodes. To address this challenge, in our paper, optimization problems of varying size are treated as distinct tasks. To tackle these tasks, a multi-task learning (MTL) approach based on modular sharing is proposed. The multi-task approach consists of a DNN, which is used to extract the solutions for all the optimization problems, and a router which manages which nodes and layers of the input and output layer of the DNN to be used during the forward propagation of each task. Consequently, all tasks share common parameters of the DNN, while the DNN dynamically adjusts to the number of nodes of its output and input layers. Numerical results demonstrate the superiority of the suggested approach over zero-padding, which is the current solution for handling resource allocation problems of varying size.'
	Partner(s)	InnoCube
	Status	Presented at '2024 IEEE 35th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)'
	DOI	10.1109/PIMRC59610.2024.10817307
	Link	https://ieeexplore.ieee.org/document/10817307
	Open Access	https://geokarag.webpages.auth.gr/wp-content/papercite-data/pdf/c256.pdf
55	**Title**	**'Explainable AI in 6G O-RAN: A Tutorial and Survey on Architecture, Use Cases, Challenges, and Future Research'**
	Abstract	'The recent O-RAN specifications promote the evolution of ranran architecture by function disaggregation, adoption of open interfaces, and instantiation of a hierarchical closed-loop control architecture managed by ric entities. This paves the road to novel data-driven network management approaches based on programmable logic. Aided by ai and ml, novel solutions targeting traditionally unsolved ran management issues can be devised. Nevertheless, the adoption of such smart and autonomous systems is limited by the current inability of human operators to understand the decision process of such ai/ml solutions, affecting their trust in such novel tools. xai aims at solving this issue, enabling human users to better understand and effectively manage the emerging generation of artificially intelligent schemes, reducing the human-to-machine barrier. In this survey, we provide a summary of the xai methods and metrics before studying their deployment over the o-ran Alliance ran architecture along with its main building blocks. We then present various use-cases and discuss the automation of xai pipelines for o-ran as well as the underlying security aspects. We also review some projects/standards that tackle this area. Finally, we identify different challenges and research directions that may arise from the heavy adoption of ai/ml decision entities in this context, focusing on how xai can help to interpret, understand, and improve trust in o-ran operational networks.'
	Partner(s)	i2CAT
	Status	Published in 'IEEE Communications Surveys & Tutorials'
	DOI	10.1109/COMST.2024.3510543
	Link	https://ieeexplore.ieee.org/document/10772472

56	**Open Access**	https://arxiv.org/abs/2307.00319v4
	Title	**'Cross-Compartment Virtio-Loopback: A Bare-Metal Virtualization Solution for the Edge'**
	Abstract	'With the evolution of 5G technologies and beyond, paradigms like the Mobile Edge Computing (MEC) mandate the deployment of services at the edge of the network and close to the users. Contributing to further reducing the latency and improving network performance, these paradigms are essential constituents of a networked infrastructure supporting ultra-reliable and low-latency services, as in the case of the recently emerging intelligent transportation services (ITS). With MEC being coupled with Network Functions Virtualization (NFV), these services are deployed upon the cellular V2X interface as Virtualized Network Functions (VNFs) across the various network domains, including the network edge. This paper proposes a virtualization solution suited for VNF deployments of these services at mixed-critical, embedded edge servers. The solution suggests that VNFs interfacing abstracted Virtio devices are hosted at individual and isolated bare-metal Operating Systems (OSes) or compartments, co-executing at the same hardware with different criticality. The current proof-of-concept targets ARMv8 embedded servers and introduces a split client-server Virtio design, extending an existing virtualization framework across bare-metal compartments. Finally, benchmarks on a virtualized embedded board show that the Cross-compartment Virtio-loopback design does not introduce extra overhead compared to the reference implementation.'
	Partner(s)	VOS
	Status	Presented at '2024 IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles & International Transportation Electrification Conference (ESARS-ITEC)'
	DOI	10.1109/ESARS-ITEC60450.2024.10819900
	Link	https://ieeexplore.ieee.org/document/10819900
	Open Access	https://zenodo.org/records/17249542
57	**Title**	**'Defying the Odds: Solana's Unexpected Resilience in Spite of the Security Challenges Faced by Developers'**
	Abstract	'Solana gained considerable attention as one of the most popular blockchain platforms for deploying decentralized applications. Compared to Ethereum, however, we observe a lack of research on how Solana smart contract developers handle security, what challenges they encounter, and how this affects the overall security of the ecosystem. To address this, we conducted the first comprehensive study on the Solana platform consisting of a 90-minute Solana smart contract code review task with 35 participants followed by interviews with a subset of seven participants. Our study shows, quite alarmingly, that none of the participants could detect all important security vulnerabilities in a code review task and that 83% of the participants are likely to release vulnerable smart contracts. Our study also sheds light on the root causes of developers' challenges with Solana smart contract development, suggesting the need for better security guidance and resources. In spite of these challenges, our automated analysis on currently deployed Solana smart contracts surprisingly suggests that the prevalence of vulnerabilities - especially those pointed out as the most challenging in our developer study - is below 0.3%. We explore the causes of this counter-intuitive resilience and show that frameworks, such as Anchor, are aiding Solana developers in deploying secure contracts.'

	Partner(s)	NEC
	Status	Presented at 'CCS '24: Proceedings of the 2024 on ACM SIGSAC Conference on Computer and Communications Security'
	DOI	10.1145/3658644.3670333
	Link	https://dl.acm.org/doi/10.1145/3658644.3670333
	Open Access	Yes
58	**Title**	**'vFFR: A Very Fast Failure Recovery Strategy Implemented in Devices With Programmable Data Plane'**
	Abstract	'The rapid emergence of new applications and services, and their increased demand for Quality of Service (QoS), have a significant impact on the development of today's communication networks. As a result, communication networks are constantly evolving towards new architectures, such as the 6th Generation (6G) of communication systems, currently being studied in academic and research environments. One of the most critical aspects of designing communication networks is meeting the restricted delay and packet loss requirements. In this context, although link failure recovery has been widely addressed in the literature, it remains one of the main causes of packet losses and delays in the network. The failure recovery time in currently deployed technologies is still far from the sub-millisecond delay required in 6G networks. The time required for distributed network architectures to converge to a common network state after a link failure is excessive. In contrast, centralized architectures such as Software-Defined Networking (SDN) solve this problem but still need to notify the failure to a centralized controller, which increases the recovery time. This paper proposes a very Fast Failure Recovery (vFFR) strategy that can recover from link failures in sub-millisecond timescales by reacting directly from the data plane of the network devices while maintaining a synchronized state with the centralized controller. We first analyze current failure recovery strategies and classify them according to the techniques used to optimize failure recovery time. Afterward, we describe the design of a vFFR strategy that combines three data plane recovery algorithms to reduce latency and packet loss under varying network conditions. Our vFFR strategy has been modeled in P4 language and tested on an emulation platform to validate the three data plane recovery algorithms under different conditions. The results show that latency varies according to the alternate path selected in the recovery.'
	Partner(s)	UPV/EHU
	Status	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2024.3493417
	Link	https://ieeexplore.ieee.org/document/10746495
	Open Access	Yes
59	**Title**	**'Managing real-time constraints through monitoring and analysis-driven edge orchestration'**
	Abstract	'The rapid emergence of new applications and services, and their increased demand for Quality of Service (QoS), have a significant impact on the development of today's communication networks. As a result, communication networks are constantly evolving towards new architectures, such as the 6th Generation (6G) of communication systems, currently being studied in academic and research environments. One of the most critical aspects of designing communication networks is meeting the restricted delay and packet loss requirements. In this context, although link failure recovery has been widely

		addressed in the literature, it remains one of the main causes of packet losses and delays in the network. The failure recovery time in currently deployed technologies is still far from the sub-millisecond delay required in 6G networks. The time required for distributed network architectures to converge to a common network state after a link failure is excessive. In contrast, centralized architectures such as Software-Defined Networking (SDN) solve this problem but still need to notify the failure to a centralized controller, which increases the recovery time. This paper proposes a very Fast Failure Recovery (vFFR) strategy that can recover from link failures in sub-millisecond timescales by reacting directly from the data plane of the network devices while maintaining a synchronized state with the centralized controller. We first analyze current failure recovery strategies and classify them according to the techniques used to optimize failure recovery time. Afterward, we describe the design of a vFFR strategy that combines three data plane recovery algorithms to reduce latency and packet loss under varying network conditions. Our vFFR strategy has been modeled in P4 language and tested on an emulation platform to validate the three data plane recovery algorithms under different conditions. The results show that latency varies according to the alternate path selected in the recovery.'
	Partner(s)	SSS
	Status	Published in 'Journal of Systems Architecture'
	DOI	10.1016/j.sysarc.2025.103403
	Link	https://www.sciencedirect.com/science/article/pii/S138376212500075X
	Open Access	Yes
60	Title	**'AdaLightLog: Enhancing Application Logs Anomaly Detection via Adaptive Federating Learning'**
	Abstract	'The role of anomaly detection systems in Critical Infrastructures (CIs) is critical due to the complexity of CIs and their control systems, which are usually implemented by computer-based controllers that constantly produce logs of their activities. Moreover, many CIs, located in different locations or even belonging to different companies, may share similar application software for controlling the CIs themselves. The goal of this work is to use such logs to perform automatic anomaly detection in a federated learning (FL) paradigm, which ensures that no data is exchanged between sites to train the anomaly detection models, but each learning agent learns on its own data, leveraging the knowledge acquired by the other agents. Our proposed approach - AdaLightLog - which implements a modified FL paradigm with adaptive loss functions at local servers side and weighted averaging of local server models, so to differentiate the quality of the different local servers' models in the global averaging, is tested against state-of-the-art methods and shows an improvement in performance in terms of accuracy, precision and recall with respect to the standard FL implementation (FedAvg). Furthermore, a comparison between different metrics for the adaptive loss functions and the dynamic weights is presented.'
	Partner(s)	CRAT
	Status	Presented at 'CRITIS: International Conference on Critical Information Infrastructures Security'
	DOI	10.1007/978-3-031-84260-3_17
	Link	https://link.springer.com/chapter/10.1007/978-3-031-84260-3_17
	Open Access	https://www.researchgate.net/profile/Emanuele-De-Santis/publication/389536107_AdaLightLog_Enhancing_Application_Logs_Anomaly_Detection_via_Adaptive_Federating_Learning/links/67d14c07bab3d32d844

		0fca6/AdaLightLog-Enhancing-Application-Logs-Anomaly-Detection-via-Adaptive-Federating-Learning.pdf?__cf_chl_tk=Pyn0_4sbrFMUZ7i9oshSJSZLjbPFHVrBgoEfI22xZyc-1760366942-1.0.1.1-3XkixlxBNx7ujzJ3q1KBUo8GwvgQwfcbV3xGnfXnD.E
61	**Title**	**'A Cooperative Feature Removal Mechanism for Cell Outage Detection in Wireless Telecommunication Networks'**
	Abstract	'In the domain of crisis management for telecommunications infrastructures, the autonomous detection of cell outages within cellular networks is of paramount importance for prompt identification and resolution in ensuring uninterrupted connectivity to users. Traditional methods usually involve data aggregation at the core network, which is responsible for identifying cell failures. Proposing a novel approach, we leverage a Machine Learning-based distributed and cooperative feature removal mechanism in order to preserve the privacy of data and avoid any degradation in classification performance. Simulations carried out on a dataset retrieved from a real 4G-LTE rollout demonstrate that the proposed approach, through a cooperation among agents, maintains or even slightly improves accuracy, precision, recall, and F1-score in outage prediction compared to other conventional methods, showcasing its efficacy for cell outage detection purposes while maintaining data privacy.'
	Partner(s)	CRAT
	Status	Presented at 'CRITIS: International Conference on Critical Information Infrastructures Security'
	DOI	10.1007/978-3-031-84260-3_5
	Link	https://link.springer.com/chapter/10.1007/978-3-031-84260-3_5
	Open Access	https://www.researchgate.net/profile/Emanuele-De-Santis/publication/389537784_A_Cooperative_Feature_Removal_Mechanism_for_Cell_Outage_Detection_in_Wireless_Telecommunication_Networks/links/67d14be1cc055043ce70bf23/A-Cooperative-Feature-Removal-Mechanism-for-Cell-Outage-Detection-in-Wireless-Telecommunication-Networks.pdf
62	**Title**	**'FraMark: A Blockchain Marketplace for a 5G Network Management using Fractional NFTs'**
	Abstract	'This paper presents FraMark, a blockchain-based framework for 5G network management that utilizes Hyperledger Fabric and fractional Non-Fungible Tokens (NFTs) to optimize resource allocation. We introduce a comprehensive system that fractionalizes digital assets to represent 5G network resources, enhancing efficiency and allocation flexibility. Our framework addresses the challenges of 5G network management by ensuring low latency, high transaction throughput, and secure resource trading. We conduct experiments to evaluate the performance of our approach, including CPU and memory utilization, latency analysis, and block size assessment. The results demonstrate the effectiveness of FraMark in improving network resource utilization and transaction efficiency, validating our framework's claims. By leveraging blockchain technology and innovative resource slicing techniques, FraMark paves the way for dynamic and efficient 5G network management.'
	Partner(s)	SID
	Status	Presented at '2024 7th World Symposium on Communication Engineering (WSCE)'
	DOI	10.1109/WSCE65107.2024.00009
	Link	https://ieeexplore.ieee.org/document/10945166
	Open Access	https://drive.google.com/file/d/1KJuv1cye3s5TgDePbP8OkkJCT3Tj-JA0/view

	Title	**'Practical Light Clients for Committee-Based Blockchains'**
63	Abstract	'Light clients are gaining increasing attention in the literature since they obviate the need for users to set up dedicated blockchain full nodes. While the literature features a number of light client instantiations, most light client protocols optimize for long offline phases and implicitly assume that the block headers to be verified are signed by highly dynamic validators.In this paper, we show that (i) most light clients are rarely offline for more than a week, and (ii) validators are unlikely to drastically change in most permissioned blockchains and in a number of permissionless blockchains, such as Cosmos and Polkadot. Motivated by these findings, we propose a novel practical system that optimizes for such realistic assumptions and achieves minimal communication and computational costs for light clients when compared to existing protocols. By means of a prototype implementation of our solution, we show that our protocol achieves a reduction by up to 90 and 40000× (respectively) in end-to-end latency and up to 1000 and 10000× (respectively) smaller proof size when compared to two state-of-the-art light client instantiations from the literature.'
	Partner(s)	NEC
	Status	Presented at '2024 Annual Computer Security Applications Conference (ACSAC)'
	DOI	10.1109/ACSAC63791.2024.00049
	Link	https://ieeexplore.ieee.org/document/10918256
	Open Access	https://arxiv.org/abs/2410.03347
	Title	**'Leveraging Blockchain technology for secure 5G offloading processes'**
64	Abstract	'This paper presents a secure 5G offloading mechanism leveraging Blockchain technology and Self-Sovereign Identity (SSI). The advent of 5G has significantly enhanced the capabilities of all sectors, enabling innovative applications and improving security and efficiency. However, challenges such as limited infrastructure, signal interference, and high upgrade costs persist. Offloading processes already address these issues but they require more transparency and security. This paper proposes a Blockchain-based marketplace using Hyperledger Fabric to optimize resource allocation and enhance security. This marketplace facilitates the exchange of services and resources among operators, promoting competition and flexibility. Additionally, the paper introduces an SSI-based authentication system to ensure privacy and security during the offloading process. The architecture and components of the marketplace and authentication system are detailed, along with their data models and operations. Performance evaluations indicate that the proposed solutions do not significantly degrade offloading times, making them suitable for everyday applications. As a result, the integration of Blockchain and SSI technologies enhances the security and efficiency of 5G offloading.'
	Partner(s)	TECNALIA
	Status	Published in Future Internet
	DOI	10.3390/fi17050197
	Link	https://www.mdpi.com/1999-5903/17/5/197
	Open Access	Yes
65	Title	**'Lyapunov-Based Stochastic Resource Allocation for Integrated Satellite-Terrestrial Networks'**
	Abstract	'The integration of a satellite network with a terrestrial network, supporting optimized network selection and service continuity, is essential to meet the requirements of sixth-generation (6 G) wireless networks. In a typical scenario

with both terrestrial and satellite services, a subset, referred to as terrestrial users (t-users), can communicate only with the terrestrial base station (BS), while dual users (d-users) can transmit information to both the BS and an available LEO satellite. Thus, we focus on an integrated satellite-terrestrial uplink network, assuming that non-orthogonal multiple access (NOMA) is used in the terrestrial sub-network, which is motivated by the existence of non-line-of-sight channels between the BS and the users. We also investigate the use of two communication protocols for the satellite sub-network, considering both orthogonal multiple access (OMA) and NOMA. We define a utility function based on the achievable rates of the users and formulate an optimization problem to maximize the long-term utility of the network, taking into account constraints on the maximum capacity of the BS and the LEO satellite, as well as short- and long-term power consumption. We apply Lyapunov theory to decompose it into multiple single-time slot sub-problems, and finally transform it into convex form and solve it effectively. The network selection by the d-users as well as the optimal resource allocation for all users are also investigated. The simulation results show that d-users prefer to communicate with the LEO satellite rather than the BS. The probability of this selection is strongly influenced by the chosen communication scheme and the trajectory of the LEO satellite. Furthermore, there is an improvement in utility when the LEO satellite is close to its zenith position, while users achieve higher utility when the NOMA protocol is used in the satellite sub-network compared to the OMA counterpart.'

	Partner(s)	UOWM
	Status	Published in 'IEEE Transactions on Vehicular Technology'
	DOI	10.1109/TVT.2025.3567144
	Link	https://ieeexplore.ieee.org/document/10988676
	Open Access	https://www.researchgate.net/publication/391471025_Lyapunov-Based_Stochastic_Resource_Allocation_for_Integrated_Satellite-Terrestrial_Networks
66	**Title**	**'A Reinforcement Learning-Based Reverse Auction Enforcing Smart Pricing Policies towards B5G Offloading Strategies'**
	Abstract	'The integration of a satellite network with a terrestrial network, supporting optimized network selection and service continuity, is essential to meet the requirements of sixth-generation (6 G) wireless networks. In a typical scenario with both terrestrial and satellite services, a subset, referred to as terrestrial users (t-users), can communicate only with the terrestrial base station (BS), while dual users (d-users) can transmit information to both the BS and an available LEO satellite. Thus, we focus on an integrated satellite-terrestrial uplink network, assuming that non-orthogonal multiple access (NOMA) is used in the terrestrial sub-network, which is motivated by the existence of non-line-of-sight channels between the BS and the users. We also investigate the use of two communication protocols for the satellite sub-network, considering both orthogonal multiple access (OMA) and NOMA. We define a utility function based on the achievable rates of the users and formulate an optimization problem to maximize the long-term utility of the network, taking into account constraints on the maximum capacity of the BS and the LEO satellite, as well as short- and long-term power consumption. We apply Lyapunov theory to decompose it into multiple single-time slot sub-problems, and finally transform it into convex form and solve it effectively. The network selection by the d-users as well as the optimal resource allocation for all users are also investigated. The simulation results show that d-users prefer to communicate with the LEO satellite rather than the BS. The

		probability of this selection is strongly influenced by the chosen communication scheme and the trajectory of the LEO satellite. Furthermore, there is an improvement in utility when the LEO satellite is close to its zenith position, while users achieve higher utility when the NOMA protocol is used in the satellite sub-network compared to the OMA counterpart.'
	Partner(s)	8Bells
	Status	Published in 'Electronics'
	DOI	10.3390/electronics13132488
	Link	https://www.mdpi.com/2079-9292/13/13/2488
	Open Access	Yes
67	**Title**	**'Timerlat: Real-time Linux Scheduling Latency Measurements, Tracing, and Analysis'**
	Abstract	'A trend in many embedded devices is the move from hardware-based to software-defined, such as software-defined networks and software-defined PLCs. This trend is motivated by multiple aspects, including the availability of complex software stacks and the consolidation of multiple devices into a single larger system. Due to its real-time capabilities and flexibility, Linux is the operating system of choice for many applications, including time-sensitive ones. However, assessing and debugging timing violations, especially those caused by scheduling latency, is challenging with the current state-of-the-art tools. This paper presents timerlat, a tool that integrates scheduling latency measurements, tracing, and analysis in an easy-to-use interface. Its output includes an auto-analysis, providing insightful details on the composition of the scheduling latency. Experimental results are reported, evaluating the effectiveness of timerlat in assessing the latencies, considering different setups and workloads.'
	Partner(s)	SSS
	Status	Published in 'IEEE Transactions on Computers'
	DOI	10.1109/TC.2025.3566908
	Link	https://ieeexplore.ieee.org/document/10985804
	Open Access	https://retis.santannapisa.it/~d.casini/papers/2025/TC2025/Timerlat_TC.pdf
68	**Title**	**'A DNN Framework on Waveform Design for Over-the-Air Computation'**
	Abstract	'One of the main applications expected to be enabled by next-generation networks is computing. The goal-oriented nature of computing allows the use of different implementation techniques, with over-the-air (OTA) computation being one of the main proposed schemes due to its effective resource management and computational efficiency. In this work, we aim at optimizing the waveform of the system in the presence of intersymbol interference (ISI) and sampling error. To this end, we propose a deep neural network (DNN) framework that generates an optimal waveform that minimizes the mean square error (MSE) of the OTA computation system. To ensure that the generated waveform exhibits the same behavior as other common waveforms, weighted energy and spectrum constraints are included in the loss function of the training phase. To better mitigate ISI, the spectrum constraint integrates the roll-off factor of the waveform, allowing for the generation of different waveforms. Simulation results verify that the desired constraints are met and show a significant performance gain over state-of-the-art waveforms.'
	Partner(s)	UOWM
	Status	Presented at '2025 IEEE Wireless Communications and Networking Conference (WCNC)'

	DOI	10.1109/WCNC61545.2025.10978310
	Link	https://ieeexplore.ieee.org/document/10978310
	Open Access	https://arxiv.org/abs/2405.20877
69	**Title**	**'A Novel Super Constellation Design Paradigm'**
	Abstract	'In the rapidly advancing field of sixth generation (6G) wireless networks, where the achievement of ultra-high data rates and energy efficiency is crucial, this study introduces the concept of super constellations as a solution to meet these pressing requirements. However, when higher-order modulations are employed, the system becomes increasingly susceptible to Gaussian phase noise (GPN), resulting in significant performance degradation. To address this issue, we propose a novel modulation scheme, called super amplitude phase shift keying (SAPSK), which is specifically designed to improve resilience against GPN. Furthermore, recognizing the critical need for efficient detection methods in high-order constellations, we present a detection framework that is not only capable of mitigating the detrimental effects of GPN, but also provides a foundation for the development of low-complexity detection algorithms. Specifically, we introduce the generalized polar distance detector (GPD-D), a detection metric that approximates maximum likelihood detection (MLD) in GPN-affected channels while introducing structured decision regions. Building on the GPD-D, SAPSK formulates a hexagonal lattice that provides improved energy efficiency and is further supported by a detection algorithm with $\acute{O}(1)$ complexity, ensuring fast and accurate symbol detection. Finally, the superiority of SAPSK is demonstrated through extensive numerical simulations, which show that SAPSK has significant advantages in terms of symbol error probability (SEP) over other conventional modulation schemes.'
	Partner(s)	UOWM
	Status	Presented at '2025 IEEE Wireless Communications and Networking Conference (WCNC)'
	DOI	10.1109/WCNC61545.2025.10978284
	Link	https://ieeexplore.ieee.org/document/10978284
	Open Access	https://arxiv.org/abs/2405.10695
70	**Title**	**'Dataset on personal mobility vehicle's regular riding and fall events'**
	Abstract	'Urban environments around the world are being highly populated by personal mobility vehicles, such as scooters or electric bicycles, which offer a new way to move around cities. Researchers from different disciplines are devoting efforts to integrate this novel vehicular paradigm into smart-city ecosystems given its advantages in terms of traffic sustainability, efficiency, and agility. However, the quick penetration of these vehicles also brings challenges and concerns related to their coexistence with other kinds of transportation systems or pedestrians, as well as the high number of accidents in which these vehicles are involved. When an accident happens, a fast and automatic detection is crucial to take quick measures, e.g., alerting emergency services. This is the main motivation of the dataset presented in this work, which provides the data captured by different sensors onboard an electric scooter under regular and accident conditions. A variety of accident kinds such as frontal collisions, lateral falls, etc. are considered, so the dataset may be valuable for the development of automatic engines to infer different riding situations.'
	Partner(s)	UMU
	Status	Published in 'Data in Brief'

	DOI	10.1016/j.dib.2025.111681
	Link	https://www.sciencedirect.com/science/article/pii/S2352340925004111
	Open Access	Yes
71	**Title**	**'Multi-Length CSI Feedback with Ordered Finite Scalar Quantization'**
	Abstract	'We propose a novel, lightweight, deep-learning based model, which enables fast, multi-length channel state information (CSI) feedback. The proposed method harnesses the advantages of finite scalar quantization and ordered representation learning, to create the ordered finite scalar quantization (OFSQ) scheme, which has a simple structure, with significantly reduced complexity, while demonstrating solid CSI reconstruction ability for any desired feedback bitstream length. Our method reshapes latent vectors into sub-vectors, applies a hyperparameter-based and bounded scalar quantization, while it integrates a nested dropout layer to prioritize sub-vectors based on their importance to CSI retrieval. Simulation results confirm that the proposed scheme significantly reduces the computational complexity, as it avoids to exhaustively search the quantization codebook, while it shows an improved CSI reconstruction ability compared to state-of-the-art multi-length CSI feedback models. Therefore, OFSQ is a promising plug-in architecture, which can be paired with any autoencoder for use in wireless communication systems.'
	Partner(s)	UOWM
	Status	Published in 'IEEE Communications Letters'
	DOI	10.1109/LCOMM.2025.3581951
	Link	https://ieeexplore.ieee.org/document/11045905
	Open Access	https://www.researchgate.net/publication/392949817_Multi-Length_CSI_Feedback_with_Ordered_Finite_Scalar_Quantization
72	**Title**	**'Delay Minimization of Task Offloading in O-RAN Architecture'**
	Abstract	'In this paper, we propose a heuristic algorithm for minimizing the delay of task offloading within the open radio access network (O-RAN) architecture. We model the O-RAN architecture using a directed graph connecting its various components. Assuming that frequency-division multiplexing (FDM) is used between all users sharing the same communication link, and applying the M/M/1 queueing model at the O-RAN central units (O-CUs), we update the graph weights and design a heuristic algorithm to provide delay-efficient routing for all users. Numerical results demonstrate the performance of the algorithm and provide insights into the O-RAN architecture.'
	Partner(s)	UOWM
	Status	Presented at '2024 IEEE Future Networks World Forum (FNWF)'
	DOI	10.1109/FNWF63303.2024.11028799
	Link	https://ieeexplore.ieee.org/document/11028799
	Open Access	https://www.researchgate.net/publication/392633564_Delay_Minimization_of_Task_Offloading_in_O-RAN_Architecture
73	**Title**	**'Enabling Containerisation of Distributed Applications with Real-Time Constraints'**
	Abstract	'Containerisation is becoming a cornerstone of modern distributed systems, thanks to their lightweight virtualisation, high portability, and seamless integration with orchestration tools such as Kubernetes. The usage of containers has also gained traction in real-time cyber-physical systems, such as software-defined vehicles, which are characterised by strict timing requirements to ensure safety and performance. Nevertheless, ensuring real-time execution of co-located containers is challenging because of mutual interference due to the sharing of the

		same processing hardware. Existing parallel computing frameworks such as Ray and its Kubernetes-enabled variant, KubeRay, excel in distributed computation but lack support for scheduling policies that allow guaranteeing real-time timing constraints and CPU resource isolation between containers, such as the SCHED_DEADLINE policy of Linux. To fill this gap, this paper extends Ray to support real-time containers that leverage SCHED_DEADLINE. To this end, we propose KubeDeadline, a novel, modular Kubernetes extension to support SCHED_DEADLINE. We evaluate our approach through extensive experiments, using synthetic workloads and a case study based on the MobileNet and EfficientNet deep neural networks. Our evaluation shows that KubeDeadline ensures deadline compliance in all synthetic workloads, adds minimal deployment overhead (in the order of milliseconds), and achieves lower worst-case response times, up to 4 times lower, than vanilla Kubernetes under background interference.'
	Partner(s)	SSS
	Status	Presented at '37th Euromicro Conference on Real-Time Systems (ECRTS 2025)'
	DOI	10.4230/LIPIcs.ECRTS.2025.3
	Link	https://drops.dagstuhl.de/entities/document/10.4230/LIPIcs.ECRTS.2025.3
	Open Access	Yes
74	Title	**'In Search of Butterflies: Exceedance Analysis for Real-Time Systems under Transient Overload'**
	Abstract	'In theory, real-time systems are provisioned based on provably sound worst-case execution times (WCETs), but in practice often only empirically derived, unsound execution-time estimates—i.e., nominal execution times (NETs)—are available since WCETs are difficult to obtain on modern hardware. NETs pose two significant challenges: First, since NETs may be exceeded at runtime, any response-time bounds derived from NETs are transitively unsound and may be violated. Second, even a minuscule NET violation can result in large, nonlinear response-time increases due to hard-to-predict, cascading scheduling effects. To explore the risk NET exceedance poses to a system's temporal correctness, this paper provides the first general, systematic, and explainable methodology for exceedance analysis. The proposed approach supports fixed-priority (FP), earliest-deadline first (EDF), and first-in first-out (FIFO) scheduling on a uniprocessor or within a partitioned multiprocessor platform, and the full spectrum of preemption models from fully preemptive to fully non-preemptive workloads. Additionally, it produces explainable evidence in the form of tunable example traces that engineers can adjust to take system-specific expertise into account. The proposed methodology is evaluated with synthetic task sets and workloads based on an automotive benchmark, and in a case study applied to parts of the WATERS'17 industrial challenge.'
	Partner(s)	SSS
	Status	Presented at '2024 IEEE Real-Time Systems Symposium (RTSS)'
	DOI	10.1109/RTSS62706.2024.00028
	Link	https://ieeexplore.ieee.org/document/10844716
	Open Access	https://retis.santannapisa.it/~a.biondi/papers/RTSS24.pdf
75	Title	**'Fully-Decentralized Consensus-Based Federated Learning for Cell Outage Detection in Cellular Networks'**
	Abstract	'Cell Outage Detection (COD) mechanisms in 5G and beyond cellular networks play an increasingly important role in ensuring uninterrupted services to end

		users by promptly identifying possible outages at the radio and cell levels. Traditionally, COD algorithms have used aggregated data at the core network level to detect anomalies, but there have been scalability and data confidentiality issues. This work proposes a novel fully-decentralized consensus-based Federated Learning approach. This approach utilizes Random Trees and federated feature removals to identify anomalies at the cell level. It is based only on data available locally at the Base Station (BS), but relies on knowledge acquired by all BSs participating in the federation. The approach is fully decentralized in the sense that it does not involve a central entity responsible for aggregating the knowledge of the learning agents. A set of simulations based on a dataset with real cell data has been employed to demonstrate the effectiveness of the proposed approach in comparison to other baseline approaches, even in the presence of malicious agents attempting to disrupt the learning process.'
	Partner(s)	CRAT
	Status	Presented at '2025 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)'
	DOI	10.1109/EuCNC/6GSummit63408.2025.11037088
	Link	https://ieeexplore.ieee.org/document/11037088
	Open Access	https://retis.santannapisa.it/~a.biondi/papers/RTSS24.pdf
76	**Title**	**'An overview and solution for democratizing AI workflows at the network edge'**
	Abstract	'With the process of democratization of the network edge, hardware and software for networks are becoming available to the public, overcoming the confines of traditional cloud providers and network operators. This trend, coupled with the increasing importance of AI in 6G and beyond cellular networks, presents opportunities for innovative AI applications and systems at the network edge. While AI models and services are well-managed in cloud systems, achieving similar maturity for serving network needs remains an open challenge. Existing open solutions are emerging and are yet to consider democratization requirements. In this work, we identify key requirements for democratization and propose NAOMI, a solution for democratizing AI/ML workflows at the network edge designed based on those requirements. Guided by the functionality and overlap analysis of the O-RAN AI/ML workflow architecture and MLOps systems, coupled with the survey of open-source AI/ML tools, we develop a modular, scalable, and distributed hardware architecture-independent solution. NAOMI leverages state-of-the-art open-source tools and can be deployed on distributed clusters of heterogeneous devices. The results show that NAOMI performs up to 40% better in deployment time and up to 73% faster in AI/ML workflow execution for larger datasets compared to AI/ML Framework, a representative open network access solution, while performing inference and utilizing resources on par with its counterpart.'
	Partner(s)	IJS
	Status	Published in 'Journal of Network and Computer Applications'
	DOI	10.1016/j.jnca.2025.104180
	Link	https://www.sciencedirect.com/science/article/pii/S1084804525000773
	Open Access	Yes
77	**Title**	**'Multi-Agent Reinforcement Learning-Based In-Place Scaling Engine for Edge-Cloud Systems'**

	Abstract	'Modern edge-cloud systems face challenges in ef-ficiently scaling resources to handle dynamic and unpredictable workloads. Traditional scaling approaches typically rely on static thresholds and predefined rules, which are often inadequate for optimizing resource utilization and maintaining performance in distributed and dynamic environments. This inefficiency hin-ders the adaptability and performance required in edge-cloud infrastructures, which can only be achieved through the newly proposed in-place scaling. To address this problem, we propose the Multi-Agent Reinforcement Learning-based In-place Scaling Engine (MARLISE) that enables seamless, dynamic, reactive control with in-place resource scaling. We develop our solution using two Deep Reinforcement Learning algorithms: Deep Q-Network (DQN), and Proximal Policy Optimization (PPO). We analyze each version of the proposed MARLISE solution using dynamic workloads, demonstrating their ability to ensure low response times of microservices and scalability. Our results show that MARLISE- based approaches outperform heuristic method in managing resource elasticity while maintaining microservice response times and achieving higher resource efficiency.'
	Partner(s)	IJS
	Status	Presented at '2025 IEEE 18th International Conference on Cloud Computing (CLOUD)'
	DOI	10.1109/CLOUD67622.2025.00014
	Link	https://www.computer.org/csdl/proceedings-article/cloud/2025/555700a032/29kKLFvuO2s
	Open Access	https://arxiv.org/abs/2507.07671
78	Title	**'Inter-AGV Scheduling and a Novel Multi-Agent Collaborative Protocol for Intra-AGV Resource Allocation in MEC-Enabled Multi-AGV Scenarios'**
	Abstract	'In modern novel collaborative multi-Automated Guided Vehicle (AGV) systems, vehicles are responsible for executing both mission-critical process-related operations and purely computational tasks, such as collision avoidance. This work investigates the problem of joint inter-AGV task placement and intra-AGV computational resource allocation in MEC-enabled multi-AGV environments. To address this challenge, a two-step strategy is proposed to maximize the number of scheduled and completed tasks across multiple AGVs while ensuring fair and efficient resource use within each AGV. The problem of inter-AGV task placement is solved by dynamically applying a catalog of deep reinforcement learning (DRL) models for varying numbers of AGVs. Training time for these models is reduced threefold by using datasets from existing optimization solvers. Transfer learning further reduces training times by up to 51%. Second, a multi-agent deep reinforcement learning (MADRL)-based collaborative protocol for dynamic intra-AGV resource allocation (MACP-DRA) is proposed, allowing AGVs to adjust computational resources dynamically. It incorporates a minimum guaranteed share strategy to ensure fair resource distribution while optimizing performance under dynamic workloads. Compared to existing MADRL approaches, MACP-DRA enhances conflict resolution efficiency while maintaining low computational cost. Evaluation results demonstrate that the proposed inter-AGV scheduling strategy approaches optimal performance while achieving a superior trade-off between decision time and task completion rates. Compared to a multi-agent DRL baseline, the proposed MACP-DRA models reduced resource conflicts by 54.9%, task processing delays by 35.7%, and resource underutilization by 9.93%, while maintaining minimal computational and energy consumption overhead.'
	Partner(s)	i2CAT

79	**Status**	Published in 'IEEE Open Journal of the Communications Society'
	DOI	10.1109/OJCOMS.2025.3567585
	Link	https://ieeexplore.ieee.org/document/10990154/
	Open Access	Yes
	Title	**'High-Fidelity Coherent-One-Way QKD Simulation Framework for 6G Networks: Bridging Theory and Reality'**
	Abstract	'Quantum key distribution (QKD) has emerged as a promising solution for guaranteeing information-theoretic security. Inspired by this, a great amount of research effort has been recently put on designing and testing QKD systems as well as articulating preliminary application scenarios. However, due to the considerable high-cost of QKD equipment, a lack of QKD communication system design tools, wide deployment of such systems and networks is challenging. Motivated by this, this paper introduces a QKD communication system design tool. First we articulate key operation elements of the QKD, and explain the feasibility and applicability of coherent-one-way (COW) QKD solutions. Next, we focus on documenting the corresponding simulation framework as well as defining the key performance metrics, i.e., quantum bit error rate (QBER), and secrecy key rate. To verify the accuracy of the simulation framework, we design and deploy a real-world QKD setup. We perform extensive experiments for three deployments of diverse transmission distance in the presence or absence of a QKD eavesdropper. The results reveal an acceptable match between simulations and experiments rendering the simulation framework a suitable tool for QKD communication system design.'
	Partner(s)	TECNALIA, INNO, UOWM
	Status	Published in 'IEEE Transactions on Network and Service Management'
	DOI	10.1109/TNSM.2025.3619551
	Link	https://ieeexplore.ieee.org/document/11197320
	Open Access	Yes
80	**Title**	**'Sustainable Development in the Era of 6G'**
	Abstract	'The concept of sustainable development is at the forefront of the global agenda in intensifying the demand for groundbreaking technological advancements that will form sustainable mobile communications, both technologically and societally. This article presents an in-depth analysis of sustainable use cases of Beyond 5G (B5G) and 6G wireless communication systems, highlighting the critical need for environmentally friendly and energy-efficient networks. It begins by establishing the broader context and significance of the study, emphasizing the mobile technology development and the trifold dimension of sustainability. Finally, the paper elucidates insights into pillars and use cases gleaned from the EU-funded research project NANCY [1], providing an overview of how they could contribute to a more sustainable future.'
	Partner(s)	OTE, INNO
	Status	Presented at 'Artificial Intelligence Applications and Innovations. AIAI 2025 IFIP WG 12.5 International Workshops'
	DOI	10.1007/978-3-031-97317-8_18
	Link	https://link.springer.com/chapter/10.1007/978-3-031-97317-8_18
	Open Access	No

81	**Title**	**'Spiking Neural Networks for Resource Allocation in UAV-Enabled Wireless Networks'**
	Abstract	'This work presents a new spiking neural network (SNN)-based approach for user equipment-base station (UE-BS) association in non-terrestrial networks (NTNs). With the introduction of UAV's in wireless networks, the system architecture becomes heterogeneous, resulting in the need for dynamic and efficient management to avoid congestion and sustain overall performance. The presented framework compares two SNN-based optimization strategies. Specifically, a top-down centralized approach with complete network visibility and a bottom-up distributed approach for individual network nodes. The SNN is based on leak integrate-and-fire neurons with temporal components, which can perform fast and efficient event-driven inference. Realistic ray-tracing simulations are conducted, which showcase that the bottom-up model attains over 90\% accuracy, while the top-down model maintains 80-100\% accuracy. Both approaches reveal a trade-off between individually optimal solutions and UE-BS association feasibility, thus revealing the effectiveness of both approaches depending on deployment scenarios.'
	Partner(s)	INNO
	Status	Presented in a Conference Proceedings
	DOI	To be published
	Link	https://arxiv.org/abs/2508.03279
	Open Access	Yes
82	**Title**	**'Adapting communication networks to the quantum safe era: lessons learned in the coexistence of polarization-entangled QKD and classical channels'**
	Abstract	'The growth of communication networks and the innovation in technology have driven a rising need for advanced security solutions. With the rise of quantum technologies, traditional communication networks could potentially become vulnerable, posing challenges for academia, research, and industry. Quantum Key Distribution (QKD) has emerged as a promising quantum-safe solution, but its integration into existing infrastructures requires extensive study due to challenges in real-world scenarios. This paper presents an innovative quantum-safe infrastructure deployment and an in-depth analysis of co-propagation, using polarization-entangled QKD in the C-band, coexisting with classical data at 100 Gbps via Dense Wavelength Division Multiplexing (DWDM), and employing production-ready equipment within a real infrastructure. Results validate the coexistence of data and quantum channels within the same fibers, demonstrating the adaptability of traditional networks toward future quantum-safe ecosystems. In addition, the paper provides insights and lessons learned for similar deployments.'
	Partner(s)	UPV/EHU
	Status	Presented at '2025 International Conference on Quantum Communications, Networking, and Computing (QCNC)'
	DOI	10.1109/QCNC64685.2025.00025
	Link	https://ieeexplore.ieee.org/abstract/document/11000237
	Open Access	Yes
83	**Title**	**'Authentication of the QKD classical channel through Post-Quantum Cryptography in a multi-site 5G/6G quantum-safe communication network'**
	Abstract	'Breakthroughs in the field of quantum computing are forcing society to adapt the systems it employs to future threats. Telecommunications networks are no

		exception, and technologies such as Quantum Key Distribution (QKD) have been developed to establish secure and confidential mechanisms for quantum-safe key distribution. However, the lack of flexibility and scalability of this technology hinders its implementation in 5G/6G networks. In this context, this paper presents the design and development of a QKD classical channel authentication system based on Post-Quantum Cryptography (PQC) algorithms for securing multi-site 5G/6G networks. It also presents the deployment in an experimental infrastructure with a 5G core securization use case, and a comprehensive validation and performance evaluation, measuring key parameters such as protocol timing, error rate, and keyrate. Results show that the PQC authentication offers a similar performance compared to the inflexible, vendor-specific authentication mechanism, obtaining Quantum Bit Error Rate (QBER) measurements ranging from 2.5% to 3.5% in both cases, while only reducing the keyrate 4.53% (from 525.27 bps to 501.44 bps).'
	Partner(s)	UPV/EHU
	Status	Presented at '2025 International Conference on Quantum Communications, Networking, and Computing (QCNC)'
	DOI	10.1109/QCNC64685.2025.00108
	Link	https://ieeexplore.ieee.org/abstract/document/11000183
	Open Access	Yes
84	Title	**'A Representation Learning Approach to Feature Drift Detection in Wireless Networks'**
	Abstract	'AI is foreseen to be a centerpiece in next generation wireless networks enabling enabling ubiquitous communication as well as new services. However, in real deployment, feature distribution changes may degrade the performance of AI models and lead to undesired behaviors. To counter for undetected model degradation, we propose ALERT; a method that can detect feature distribution changes and trigger model re-training that works well on two wireless network use cases: wireless fingerprinting and link anomaly detection. ALERT includes three components: representation learning, statistical testing and utility assessment. We rely on MLP for designing the representation learning component, on Kolmogorov-Smirnov and Population Stability Index tests for designing the statistical testing and a new function for utility assessment. We show the superiority of the proposed method against ten standard drift detection methods available in the literature on two wireless network use cases.'
	Partner(s)	JSI, BI2S, UOWM
	Status	To be published in Journal
	DOI	To be published
	Link	https://arxiv.org/abs/2505.10325
	Open Access	Yes
85	Title	**'Towards Reliable AI in 6G: Detecting Concept Drift in Wireless Network'**
	Abstract	'AI-native 6G networks promise unprecedented automation and performance by embedding machine-learning models throughout the radio access and core segments of the network. However, the non-stationary nature of wireless environments due to infrastructure changes, user mobility, and emerging traffic patterns, induces concept drifts that can quickly degrade these model accuracies. Existing methods in general are very domain specific, or struggle with certain type of concept drift. In this paper, we introduce two unsupervised, model-agnostic, batch concept drift detectors. Both methods compute an expected-utility score

		to decide when concept drift occurred and if model retraining is warranted, without requiring ground-truth labels after deployment. We validate our framework on two real-world wireless use cases in outdoor fingerprinting for localization and for link-anomaly detection, and demonstrate that both methods are outperforming classical detectors such as ADWIN, DDM, CUSUM by 20-40 percentage points. Additionally, they achieve an F1-score of 0.94 and 1.00 in correctly triggering retraining alarm, thus reducing the false alarm rate by up to 20 percentage points compared to the best classical detectors.'
	Partner(s)	BI2S, JSI, UOWM
	Status	To be published in Journal
	DOI	To be published
	Link	https://arxiv.org/abs/2508.00042
	Open Access	Yes
86	**Title**	**'Real-Time Resource Scaling and Service Allocation for Mobile Devices in Edge-Cloud Continuum'**
	Abstract	'This work presents a new spiking neural network (SNN)-based approach for user equipment-base station (UE-BS) association in non-terrestrial networks (NTNs). With the introduction of UAV's in wireless networks, the system architecture becomes heterogeneous, resulting in the need for dynamic and efficient management to avoid congestion and sustain overall performance. The presented framework compares two SNN-based optimization strategies. Specifically, a top-down centralized approach with complete network visibility and a bottom-up distributed approach for individual network nodes. The SNN is based on leak integrate-and-fire neurons with temporal components, which can perform fast and efficient event-driven inference. Realistic ray-tracing simulations are conducted, which showcase that the bottom-up model attains over 90\% accuracy, while the top-down model maintains 80-100\% accuracy. Both approaches reveal a trade-off between individually optimal solutions and UE-BS association feasibility, thus revealing the effectiveness of both approaches depending on deployment scenarios.'
	Partner(s)	SSS
	Status	Presented in '33rd International Conference on Real-Time Networks and Systems (RTNS 2025)'
	DOI	To be published
	Link	N/A
	Open Access	Yes
87	**Title**	**'Secure the Core: A Novel Approach for Secure and Efficient Communication in Service-Based Architectures and 6G'**
	Abstract	'Security in Service-Based Architectures (SBA) is often overlooked, as it is an optional feature within Public Land Mobile Networks (PLMN) and Non-Public Networks (NPNs). The prevailing operational approach in 5G and future 6G core network communications prioritizes performance over security to attain specific attributes like ultra-low latency or reliability. Nonetheless, one of the primary objectives of upcoming mobile networks is to establish secure communications using APIs, TLS authentication, and OAuth 2.0 authorization, even though these might be seen as heavy protocols involving numerous messages between Network Functions (NFs) and the Network Repository Function (NRF). This paper presents an innovative technique, compatible with current standards, for authenticating the consumer NF and performing the service request while

		reducing the authentication time by more than 30%. The proposed mechanism builds on the TLS session resumption mechanism (0-RTT resumption for TLS 1.3), resuming a previously established session to improve performance. It proposes employing the NRF as both an authentication server and a storage for TLS sessions with each NF. The NRF is tasked with setting up TLS sessions with NFs beforehand and preserving them in a secure local repository, later delegating these sessions to the originating NFs (consumers) who establish secure communications in 0-RTT. Results show that the service discovery and service request times can be 15.01% and 65.97% faster respectively, demonstrating the clear enhancement to the performance of the security mechanisms in SBA and core networks.'
	Partner(s)	UPV/EHU
	Status	To be published in a Journal
	DOI	To be published
	Link	https://ssrn.com/abstract=5189628
	Open Access	Yes
88	Title	**'End-To-end response-time analysis of DDS-based real-time applications'**
	Abstract	'The Data Distribution Service (DDS) is established as a middleware communication standard based on a data-centric publish-subscribe protocol. This standard is pivotal for applications in autonomous driving, smart cities, and Industry 4.0, facilitating communication among diverse devices across the IoT-to-Edge-to-Cloud continuum. Particularly in the automotive industry, modern autonomous systems, built on top of frameworks like ROS 2 and Autoware, heavily rely on DDS for real-time data exchange across distributed software components. The DDS is however typically implemented with a multithreaded software structure and leverages middleware-specific policies for message dispatching, posing considerable challenges in guaranteeing timing constraints. This paper fills significant gaps in the current understanding of DDS's real-time performance. We introduce a comprehensive DDS model that includes both synchronous and asynchronous communication under various dispatching policies. The model is then used to derive a holistic response-time analysis capable of bounding the end-to-end latency of DDS-enabled real-time applications. Furthermore, we integrate our analysis with a state-of-the-art executor-based analysis for ROS2-based systems. The effectiveness of our approach is validated through experiments on a real platform using FastDDS, a popular DDS implementation, and a modern automotive testbed taken from the WATERS 2019 Industrial Challenge by Bosch. Finally, our analysis method is evaluated with both a ROS2 case-study application and the Autoware reference system, a realistic testbed from the open-source Autoware.Auto framework for autonomous driving.'
	Partner(s)	SSS
	Status	Published in 'Internet of Things'
	DOI	10.1016/j.iot.2025.101853
	Link	https://www.sciencedirect.com/science/article/pii/S2542660525003671
	Open Access	Yes

Datasets, Source Code, and Software

Open data and source code contributions have been central to NANCY's commitment to reproducible research and long-term impact. In line with our initial expected targets of **≥ 10 open datasets and ≥ 30 open-source codes**, NANCY delivered **11 datasets and 17 ML models and other source codes**, particularly in the context of AI training, blockchain validation, and network orchestration testing. In Table 2 and Table 3, the list of NANCY Datasets and NANCY Source Codes, and Software is presented.

All datasets comply with the **FAIR (Findable, Accessible, Interoperable, Reusable)** principles, ensuring their long-term usability and interoperability with other SNS JU projects.

<div align="center">Table 2: List of Datasets</div>

1	**Title**	**'Multiple Blockchain Consensus Performance Evaluation'**
	Abstract	'A comparison of four blockchain consensus protocols was conducted, based on two frameworks. Hyperledger Besu was evaluated with IBFT and QBFT, while Hyperledger Fabric was tested with SBFT and RAFT. For the analysis, Hyperledger Caliper has been utilised, running tests to create (register data on the ledger) and query a sample (retrieve data from the ledger). The Fabcar smart contract was employed, with tests performed using varying worker counts (1 and 10). Each test (create/query) included 150 iterations per worker, totaling 300 results per worker.'
	Partner(s)	SID
	Status	Published
	DOI	-
	Link	https://zenodo.org/records/17672004
	Open Access	Yes
2	**Title**	**'American Sign Language dataset for semantic communications'**
	Abstract	'The dataset was developed as part of the NANCY project (https://nancy-project.eu/) to support tasks in the computer vision area. It is specifically designed for sign language recognition, focusing on representing joints and finger positions. The dataset comprises images of hands that represent the alphabet in American Sign Language (ASL), with the exception of the letters "J" and "Z," as these involve motion, and the dataset is limited to static images. A significant feature of the dataset is the use of color-coding, where each finger is associated with a distinct color. This approach enhances the ability to extract features and distinguish between different fingers, offering significant advantages over traditional grayscale datasets like MNIST. The dataset consists of RGB images, which enhance the recognition process and support more effective learning, achieving high performance even with a relatively modest amount of training data. This format improves the ability to discriminate and extract features compared to grayscale images. Although the use of RGB images introduces additional complexity, such as increased data representation and storage requirements, the advantages in accuracy and feature extraction make it a valuable choice. The dataset is well-suited for applications involving gesture recognition, sign language interpretation, and other tasks requiring detailed analysis of joint and finger positions. '
	Partner(s)	INNO
	Status	Published in IEEE Dataport
	DOI	10.21227/2c1z-8j21
	Link	https://zenodo.org/records/14635573

	Open Access	Yes	
3	**Title**	**'Dataset on personal mobility vehicle's regular riding and fall events'**	
	Abstract	'Urban environments around the world are being highly populated by personal mobility vehicles, such as scooters or electric bicycles, which offer a new way to move around cities. Researchers from different disciplines are devoting efforts to integrate this novel vehicular paradigm into smart-city ecosystems given its advantages in terms of traffic sustainability, efficiency, and agility. However, the quick penetration of these vehicles also brings challenges and concerns related to their coexistence with other kinds of transportation systems or pedestrians, as well as the high number of accidents in which these vehicles are involved. When an accident happens, a fast and automatic detection is crucial to take quick measures, e.g., alerting emergency services. This is the main motivation of the dataset presented in this work, which provides the data captured by different sensors onboard an electric scooter under regular and accident conditions. A variety of accident kinds such as frontal collisions, lateral falls, etc. are considered, so the dataset may be valuable for the development of automatic engines to infer different riding situations.'	
	Partner(s)	UMU	
	Status	Published in Data in Brief	
	DOI	10.1016/j.dib.2025.111681	
	Link	https://zenodo.org/records/14887437	
	Open Access	Yes	
4	**Title**	**'Multi-perspective Traffic Video Recording'**	
	Abstract	'This dataset was produced as part of the NANCY project (https://nancy-project.eu/), with the aim of using it in the fields of communication and computer vision. Within the dataset are contained three different scenarios, each of which has three videos. All three videos were captured by different devices; a vehicle-mounted unit, a roadside unit (RSU), and a drone. These devices were placed at different locations, with different angles and heights but all facing the same area of interest, providing multiple different views of the desired location. The present architecture offers the integration of complementary data, offering a richer and more comprehensive understanding of the observed area. Additionally, the dataset was tailored made for use in semantic communications (SemCom). By using SemCom the above dataset provides a more precise and enriched understanding of the area of interest. This is achieved by transmitting only meaningful and context-aware information rather than raw data, significantly reducing data traffic while at the same time enhancing the quality of insights.'	
	Partner(s)	UMU, INNO	
	Status	Published in IEEE Dataport	
	DOI	10.21227/he66-fa61	
	Link	https://ieee-dataport.org/documents/multi-perspective-traffic-video-recording#files	
	Open Access	Yes	
5	**Title**	**'5G traffic trace under mobility conditions'**	
	Abstract	Dataset gathering 5G radio and traffic metrics collected from the University of Murcia's 5G deployment.	
	Partner(s)	UMU	
	Status	Published	

	DOI	10.5281/zenodo.15516876	
	Link	https://zenodo.org/records/15516876	
	Open Access	Yes	
6	**Title**	**'NANCY SNS JU Project - VR Video Streaming & iPerf3 on O-RAN 5G Testbed Dataset'**	
	Abstract	'This dataset was developed in the context of the NANCY project and it is the output of the experiments involving streaming a virtual reality (VR) video in a 5G coverage expansion scenario. Additionally, iPerf3 experiments in both TCP and UDP modes were carried out. The coverage expansion scenario involves a main operator and a micro-operator which extends the main operator's coverage and can also provide additional services. The dataset includes network traffic, which was captured and stored in a .pcap files, as well as various performance metrics that were collected by an xApp running in the near-real-time Radio Access Network Intelligent Controller.'	
	Partner(s)	UOWM	
	Status	Published in IEEE Dataport	
	DOI	10.21227/j56t-ww52	
	Link	https://zenodo.org/records/13863832	
	Open Access	Yes	
7	**Title**	**'NANCY SNS JU Project - Cyberattacks on O-RAN 5G Testbed Dataset'**	
	Abstract	'This dataset was developed in the context of the NANCY project and it is the output of the experiments involving cyberattacks against services that are running in a 5G coverage expansion scenario. The coverage expansion scenario involves a main operator and a micro-operator which extends the main operator's coverage and can also provide additional services, such as Artificial Intelligence-based cyberattack detection. The dataset includes both network traffic which was captured and stored in a .pcap file, as well as an annotated .csv file. The annotated .csv file was generated by parsing the .pcap file through CICFlowMeter to extract the network flows. It was manually annotated based on the timeline of the cyberattacks that were carried out.'	
	Partner(s)	UOWM, MINDS, SID	
	Status	Published in IEEE Dataport	
	DOI	10.21227/vjf4-y322	
	Link	https://zenodo.org/records/14811122	
	Open Access	Yes	
8	**Title**	**'NANCY SNS JU Project - 5G Coverage Expansion Dataset 1'**	
	Abstract	'This dataset was developed in the context of the NANCY project and it is the output of the experiments involving cyberattacks against services that are running in a 5G coverage expansion scenario. The coverage expansion scenario involves a main operator and a micro-operator which extends the main operator's coverage and can also provide additional services, such as Artificial Intelligence-based cyberattack detection. The dataset includes both network traffic which was captured and stored in a .pcap file, as well as an annotated .csv file. The annotated .csv file was generated by parsing the .pcap file through CICFlowMeter to extract the network flows. It was manually annotated based on the timeline of the cyberattacks that were carried out.'	

	Partner(s)	UOWM, MINDS, SID
	Status	Published in IEEE Dataport
	DOI	10.21227/vm3z-ww28
	Link	https://zenodo.org/records/10442969
	Open Access	Yes
9	**Title**	**'NANCY SNS-JU project "Italian in-lab testbed dataset 1"'**
	Abstract	'This Dataset provides input data for the development of the B-RAN and attacks models for the NANCY framework, to model training and model inference functions. The data collected plays the role of ML algorithm-specific data preparation. The dataset contains time-series, collected transmitting a video content through the Italtel "VTU - video streaming and transcoding application", that can convert audio and video streams from one format to another, at multiple encodings schemes, changing resolution, bitrate, and video parameters. The data collected are related to the observation of some of the resources involved in the Usage Scenario: "Fronthaul network of fixed topology – Direct Connectivity". In the Italtel Italian in-lab testbed, a MEC assisted 5G network scenario with a video streaming application for generating traffic is provided. Two different scenarios were set-up, related to downstream and upstream video flows. The variety of collected features ranges from radio front-end metrics to physical server operating system and network function metrics. The dataset consists of raw network traffic and extracted flow-based data captured in separate files. Each file captured is associated to a 10min video streaming of the "Big Buck Bunny" video. This video was transmitted on two different bands, N3 and N78, with different resolutions, 480p, 720p, 1080p; both in uplink (UL) and in downlink (DL); the type of protocol monitored is "HTTP protocol"; in case of N78 band, data related to the resource usage were also captured, for a total of more that 100 data files. The collected dataset is representative resource-intensive video traffic that has the greatest impact on 5G/B5G network planning and provisioning. The video streaming dataset includes data directly measured while watching the video on the mobile devices and data directly measured while generating downstream video stream traversing the gNB (i.e., downstream scenario), and vice versa (i.e., upstream scenario). In each experiment, we fixed the location of the UE and the gNB.'
	Partner(s)	ITL
	Status	Published in IEEE Dataport
	DOI	10.21227/y6ah-j205
	Link	https://zenodo.org/records/10489608
	Open Access	Yes
10	**Title**	**'NANCY SNS-JU project "Italtel Italian in-lab testbed - Latency metrics"'**
	Abstract	'This Dataset provides input data for the development of the B-RAN and attacks models for the NANCY framework, to model training and model inference functions. The data collected plays the role of ML algorithm-specific data preparation. The dataset contains time-series, collected transmitting a video content through the Italtel "VTU - video streaming and transcoding application", that can convert audio and video streams from one format to another, at multiple encodings schemes, changing resolution, bitrate, and video parameters. The data collected are related to the observation of some of the resources involved in the Usage Scenario: "Fronthaul network of fixed topology – Direct Connectivity/CoMP Connectivity". In the Italtel Italian in-lab testbed, a MEC assisted 5G network

		scenario with a video streaming application for generating traffic is provided. Two different scenarios were set-up, related to downstream and upstream video flows. Each file captured is associated to a 10min video streaming of the "Big Buck Bunny" video. This video was transmitted with different resolutions, 480p, 720p, 1080p, 2160p; both in uplink (UL) and in downlink (DL); the type of metrics monitored is RTT (Round Trip Time).'
	Partner(s)	ITL
	Status	Published in IEEE Dataport
	DOI	10.21227/1ts7-c931
	Link	https://zenodo.org/records/11047037
	Open Access	Yes
11	**Title**	**'NANCY SNS-JU project "Italtel Italian in-lab testbed dataset 2"'**
	Abstract	'This Dataset provides input data for the development of the B-RAN and attacks models for the NANCY framework, to model training and model inference functions. The data collected in the Italian in-lab testbed, namely "dataset 2", focus on the Edge segment of the network and consider the presence of some of the NANCY components, to assess their impact with respect to the baseline defined through the first collected dataset (D6.6 "Italian in-lab testbed dataset 1"), assessment that will be carried out and completed, together with the technology evaluation, in subsequent project activities. More specifically, the data collected in the Italtel Italian in-lab testbed, where a MEC assisted 5G network scenario with a video streaming application for generating traffic is provided, consider an Edge server based on ARMv8 CPU architecture, and some components specifically developed by the Partners for the NANCY project; these components are integrated in the Italtel environment and are part of the testbed topology set-up: ·　　the "Anomaly detection application module", provided by CRAT partner (Consortium for Research in Automation and Telecommunications) and focusing on detecting anomalous utilization of computing and network resources ·　　the" VOSySmonitor and vManager", provided by VOS (Virtual Open Systems), a novel virtualization technology, designed by NANCY, to host offloaded VNFs, which can be deployed in a bare-metal fashion ensuring "application isolation" ·　　"Malicious traffic generation application" and "PAPI extension for ARM performance counter interaction", provided by SSS (Sant'Anna Higher School of Pisa) for the technology validation in the context of the Italian testbed set-up ·　　"Italtel VTU application", provided by ITL, which can convert audio and video streams from one format to another, at multiple encodings schemes, changing resolution, bitrate, and video parameters. The dataset contains time series, collected by transmitting video content through the Italtel VTU application. The collected dataset is representative resource-intensive video traffic that has the greatest impact on 5G/B5G network planning and provisioning. The video streaming dataset includes data directly measured while watching the video on the mobile devices and data directly measured while generating downstream video stream traversing the gNB (i.e., downstream scenario), and vice versa (i.e., upstream scenario). In each experiment, we fixed the location of the UE and the gNB.'
	Partner(s)	ITL
	Status	Published in IEEE Dataport
	DOI	10.21227/v3q2-b941
	Link	https://zenodo.org/records/15189242

	Open Access	Yes

Table 3: List of Source Codes and Software.

Partner	Brief Description	Repository URL
MINDS	Intrusion Detection System for Network Attacks trained with Federated Learning	
MINDS	Explainable system for Intrusion Detection Models	https://github.com/Sidroco-Holdings-Ltd/NANCY_Explainable_AI_Toolbox
MINDS	Explainable system for Outage Prediction	https://github.com/Sidroco-Holdings-Ltd/NANCY_Explainable_AI_Toolbox
SID	LLM for explanation of XAI models	https://github.com/Sidroco-Holdings-Ltd/NANCY_Explainable_AI_Toolbox
TECNALIA	Blockchain based marketplace for the selection of available services	https://github.com/NANCY-PROJECT/wp5_nancy_marketplace
TECNALIA	Oracles sed by the marketplace to interact with SP and DAC NANCY components	https://github.com/NANCY-PROJECT/wp5_nancy_marketplace
SSS	RT Resource Driver for Dynamic Resource Allocation (RT-DRA)	https://gitlab.retis.santannapisa.it/dra-rt/dra-rt-driver
IJS	Models as a Service - Model Deployment with FastAPI and Uvicorn on Docker/Kubernetes	https://github.com/sensorlab/SL-MaaS
IJS	NAOMI: Network AI Workflow Democratization	https://github.com/sensorlab/NAOMI
IJS	Multi Agent Reinforcement Learning-based In-place Scaling Engine (MARLISE)	https://github.com/sensorlab/agent-edgeautoscaling
IJS	UMU Localization Services	https://github.com/sensorlab/umu-localization-service
IJS	SPIRE Self-suPervIsed SpectRum ClusteRing	https://github.com/sensorlab/spire
IJS	Model as a Service - Spectrum Sensing deployment with FastAPI and Uvicorn on Docker/Kubernetes	https://github.com/sensorlab/SpectrumSensingMaaS
IJS	Development scripts for Self-supervised	https://github.com/sensorlab/self-supervised-spectrum-sensing

	spectrum sensing models	
8BELLS	NANCY Smart pricing component	https://github.com/Eight-Bells-Ltd/Smart_Pricing_MARL_NANCY
8BELLS	NANCY Smart pricing RL model	https://github.com/Eight-Bells-Ltd/Smart_Pricing_MARL_NANCY/tree/RLlib/models/test
i2CAT	Deep Reinforcement Learning Agent that produces the optimal flow allocations for Integrated Access Backhaul networks. (d4.2)	https://github.com/Fundacio-i2CAT/phaul

Open access and FAIR data

NANCY publications complied with **Horizon Europe Open Access mandates**. When gold OA was not available, a green OA route was followed by depositing preprints in public repositories such as **arXiv, TechRxiv, Zenodo, and institutional archives**.

To reinforce FAIR principles, the consortium uploaded datasets linked to NANCY peer-reviewed publications to Zenodo; released ML models, algorithms, and orchestration components via open-source repositories on **GitHub**; and provided documentation to enable reuse by external researchers.

These actions directly support open science reuse, as several datasets and code repositories have already been downloaded, cited, or forked by external users across the AI and networking communities.

3.2. Workshops, Conferences, and Trade Fairs

Participation in scientific and technical events has been one of the primary dissemination mechanisms for the NANCY consortium. These events provided opportunities to present intermediate and final research results, exchange knowledge with peers, and align developments with the broader 6G community.

Between M1 and M36, NANCY partners **actively contributed to** the organization of 13 Workshops, Special Sessions, and Events (Table 4), exceeding by far the KPI target "Number of workshops organised (3+/at least one per-year)". Moreover, NANCY participated in 7 Trade Fairs and Exhibitions (Table 5), achieving the KPI target "Number of trade fairs/exhibitions (≥2)". Finally, NANCY participated in 21 other Workshops, Special Sessions, and Events (Table 6), showcasing the project's solutions and demonstrating its technological innovation to the scientific community and incentivising their transition from research to innovation and, finally, the industrial world.

The consortium's sustained visibility at these events demonstrates its commitment to promoting European leadership in **secure, intelligent, and quantum-ready networks**.

NANCY's participation in conferences and events was guided by the following objectives:

- **Disseminate scientific and technical results** from the project's work packages to specialised and multidisciplinary audiences.

- **Promote collaboration and synergy** with other SNS JU and Horizon Europe projects in the same research domain.

- **Engage with industry and standardisation bodies** to support the uptake of NANCY's technologies and concepts.

- **Enhance the project's visibility** through participation in flagship 6G and ICT conferences and exhibitions.

These participations were planned according to the technical progress of each Work Package and coordinated through the D&C management structure to ensure coherent messaging and brand visibility.

Table 4: List of Workshops, Special Sessions, and Events Supported by NANCY

1	**Title**	**'Real-time And intelliGent Edge computing workshop (RAGE) 2023'**
	Description	Organization of the "Real-time And intelliGent Edge computing workshop" (RAGE) at the Cyber-Physical Systems and Internet-of-Things Week (CPS-IoT Week) 2023. Location: San Antonio, Texas, United States Date: 9 May 2023
	Partner(s)	SSS
	Link	https://rage-workshop.github.io/2023/
2	**Title**	**'Workshop on Scalable and Trustworthy AI for 6G Wireless Networks (6GSTRAIN)'**
	Description	Organization of the Workshop named "Scalable and Trustworthy AI for 6G Wireless Networks (6GSTRAIN)" at the IEEE International Conference on Communications (ICC) 2023. Location: Rome, Italy Date: 28 May - 01 June 2023
	Partner(s)	i2CAT
	Link	https://icc2023.ieee-icc.org/workshop/ws-20-workshop-scalable-and-trustworthy-ai-6g-wireless-networks-6gstrain
3	**Title**	**'Training Session Organization'**
	Description	Organization of a training session focused on NANCY's key technologies. Location: Rome, Italy Date: 13 November 2023
	Partner(s)	CRAT
	Link	N/A
4	**Title**	**'AI Empowered Cellular Communication and Computing Service Management'**
	Description	Organization of the Special Session "AI Empowered Cellular Communication and Computing Service Management" at the Sixth International Balkan Conference on Communications and Networking (BalkanCom) 2023. Location: Istanbul, Türkiye Date: 5-8 June 2023
	Partner(s)	IJS, UOWM
	Link	https://www.balkancom.info/2023/cfp-special-04.html
5	**Title**	**'HSTIEC: Hardware, Software, and Tools for the IoT-to-Edge-to-Cloud Continuum 2023'**

	Description	Organization of the Special Session "HSTIEC: Hardware, Software, and Tools for the IoT-to-Edge-to-Cloud Continuum" at the 26th Euromicro Conference Series on Digital System Design and 49th Euromicro Conference Series on Software Engineering and Advanced Applications - DSD/SEAA 2023. Location: Durres, Albania Date: 6-8 September 2023
	Partner(s)	SSS, UOWM
	Link	https://dsd-seaa2023.com/hstiec/
6	**Title**	**'NANCY Project Session at 25th Infocom World 2023'**
	Description	Organization of a session at Infocom World 2023 dedicated to the NANCY project.
	Partner(s)	UOWM, OTE, INNO, 8BELLS, INTRA
	Link	https://infocomworld.gr/en/
7	**Title**	**'3rd Real-time And intelliGent Edge computing workshop (RAGE) 2024'**
	Description	Organization of the "Real-time And intelliGent Edge computing workshop" (RAGE) at the Cyber-Physical Systems and Internet-of-Things Week (CPS-IoT Week) 2024. Location: Hong Kong, China Date: 13 May 2024
	Partner(s)	UOWM, SSS
	Link	https://rage-workshop.github.io/2024/
8	**Title**	**'1st International Workshop on Explainable and Responsible AI/GenAI for 6G Networks (6GBRAIN)'**
	Description	Organization of the "1st International Workshop on Explainable and Responsible AI/GenAI for 6G Networks (6GBRAIN)" at the IEEE International Mediterranean Conference on Communications and Networking (MeditCom) 2024. Location: Madrid, Spain Date: 8-11 July 2024
	Partner(s)	i2CAT
	Link	https://meditcom2024.ieee-meditcom.org/workshop/ws-05-1st-international-workshop-explainable-and-responsible-aigenai-6g-networks-6gbrain
9	**Title**	**'HSTIEC: Hardware, Software, and Tools for the IoT-to-Edge-to-Cloud Continuum 2024'**
	Description	Organization of the Special Session "HSTIEC: Hardware, Software, and Tools for the IoT-to-Edge-to-Cloud Continuum 2023" at the 27th Euromicro Conference Series on Digital System Design and 50th Euromicro Conference Series on Software Engineering and Advanced Applications - DSD/SEAA 2024. Location: Paris, France Date: 28-30 August 2024
	Partner(s)	SSS
	Link	https://dsd-seaa.com/dsd_2024_hstiec/
10	**Title**	**'Open-RAN for Intelligent B5G and 6G Wireless Networks: Emerging Trends and Recent Developments'**
	Description	Organization of session Open-RAN for Intelligent B5G and 6G Wireless Networks: Emerging Trends and Recent Developments. Location: Ljubljana, Slovenia Date: 3-6 June 2024
	Partner(s)	UOWM
	Link	https://www.balkancom.info/2024/ss-open-ran-for-intelligent-b5g-and-6g-wireless-networks.html
11	**Title**	**'4th Real-time And intelliGent Edge computing workshop (RAGE) 2025'**

	Description	Organization of Workshop: Organization of the RAGE Real-time And intelliGent Edge Computing Workshop at CPS-IoT-Week 2025. Location: Irvine, CA, USA Date: 6 May 2025
	Partner(s)	SSS
	Link	https://rage-workshop.github.io/2025/
12	**Title**	**'Network Softwarization technology enablers for Trust and Security in B5G and 6G Networks'**
	Description	Special session at the EuCNC & 6G Summit 2025, jointly organized with the PRIVATEER and RIGOROUS SNS JU projects. Location: Poznan, Poland Date: 4 June 2025
	Partner(s)	UOWM
	Link	https://www.eucnc.eu/programme/special-sessions/special-session-16/
13	**Title**	**'Murcia's Artificial Intelligence and Cybersecurity Summit (AICS)'**
	Description	UMU organized a workshop on the use of advanced AI techniques to orchestrate B5G networks and their cybersecurity. The workshop hosted 30 technical experts from the industry enrolled in our workshop. Location: Murcia, Spain Date: 1-2 October 2025
	Partner(s)	UMU
	Link	https://aicsrm.es/

Table 5: Participation in Trade Fairs and Exhibitions.

1	**Title**	**'EuCNC & 6G Summit 2023'**
	Description	Exhibition booth at the EuCNC & 6G Summit 2023, presenting the vision and objectives of the NANCY project. Location: Gothenburg, Sweden Date: 6-9 June 2023
	Partner(s)	OTE, UOWM, SID, MINDS
	Link	https://rage-workshop.github.io/2023/
2	**Title**	**'ETSI AI Conference'**
	Description	Demonstration of an AI-based cyberattack detection in the Greek in-lab testbed at the ETSI AI Conference. Location: Sophia Antipolis, France Date: 5-7 February 2024
	Partner(s)	UOWM, MINDS
	Link	https://icc2023.ieee-icc.org/workshop/ws-20-workshop-scalable-and-trustworthy-ai-6g-wireless-networks-6gstrain
3	**Title**	**'EuCNC & 6G Summit 2024'**
	Description	Demonstration of an AI-based cyberattack detection enhanced by explainable AI capabilities in the Greek in-lab testbed at EuCNC & 6G Summit 2024. The conference had about 1000 participants over three days. Over 150 leaflets/flyers were distributed. Location: Antwerp, Belgium Date: 3-6 June 2024
	Partner(s)	UOWM, SID, MINDS
	Link	N/A
4	**Title**	**'ETSI Conference: Software and Standards for Smart Networks and Services Conference & Hackfests'**

4	**Description**	Presentation of the NANCY project and demonstration of the Greek in-lab testbed. Free of Charge. Location: Sophia Antipolis, France Date: 12-14 November 2024
	Partner(s)	UOWM
	Link	https://www.balkancom.info/2023/cfp-special-04.html
5	**Title**	**'88th Thessaloniki International Fair 2024'**
	Description	Presentation of the NANCY project's developments at the 88th Thessaloniki International Fair 2024. Location: Thessaloniki, Greece Date: 7-15 September 2024
	Partner(s)	UOWM
	Link	https://dsd-seaa2023.com/hstiec/
6	**Title**	**'BEYOND 2025 exhibition '**
	Description	NANCY was hosted in the University of Western Macedonia (UOWM) booth in the BEYOND 2025 exhibition, which took place in Athens, Greece, from 4 to 6 April 2025. A live demonstration of UOWM's 5G testbed attracted significant interest from multiple stakeholders, including public authorities, investors, and industry leaders. Location: Athens, Greece Date: 4-6 April, 2025
	Partner(s)	UOWM
	Link	https://www.beyond-expo.gr/
7	**Title**	**'EuCNC & 6G Summit 2025 '**
	Description	Exhibition booth featuring the project & joint organization of a special session (see Table 4). Location: Poznan, Poland Date: 3-6 June 2025
	Partner(s)	UOWM, SID
	Link	https://rage-workshop.github.io/2024/

Table 6: Participation in Workshops, Special Sessions, and Events.

1	**Title**	**'Ericsson R&D Italy Innovation Day 2023'**
	Description	Presentation of the NANCY project in Innovation Day 2023, organized by Ericsson. Location: Genoa, Italy Date: 14-15 November 2023
	Partner(s)	TEI
	Link	https://foryou.ericsson.com/rd-italy-innovation-day-2023-registration.html
2	**Title**	**Participation in 'ERK 2023 Slovenia'**
	Description	Knowledge Transfer, Networking at the ERK 2023, Slovenia. Location: Portorož, Slovenia Date: 28 - 29 September 2023
	Partner(s)	IJS
	Link	https://erk.fe.uni-lj.si/2023/program.php
3	**Title**	**Project Presentation in Corporate Event**
	Description	Presentation of NANCY in ITL's corporate event.
	Partner(s)	ITL
	Link	N/A
4	**Title**	**Presentation at 'SNS JU 6G Architecture Working Group'**

	Description	Presentation of the NANCY project at the SNS JU 6G Architecture Working Group meeting.
	Partner(s)	UOWM
	Link	N/A
5	**Title**	**Presentation at 'SNS JU 6G Reliable Software Network Working Group'**
	Description	Presentation of the NANCY project at the SNS JU Reliable Software Network Working Group meeting.
	Partner(s)	UOWM
	Link	N/A
6	**Title**	**'9ᵗʰ Italian Workshop on Embedded Systems (IWES 2024)'**
	Description	Presentation of "Real-Time Scheduling and Orchestration of Edge Devices in NANCY: an approach based on SCHED_DEADLINE". Location: Catania, Italy Date: 19-20 September 2024
	Partner(s)	SSS
	Link	https://eascitech.eu.org/iwes/2024
7	**Title**	**'Ericsson R&D Italy Innovation Day 2024'**
	Description	Presentation of the NANCY project in Innovation Day 2024, organized by Ericsson. Location: Genoa, Italy Date: 12-13 November 2024
	Partner(s)	TEI
	Link	https://foryou.ericsson.com/rd-italy-innovation-day-2024-registration.html
8	**Title**	**'ETSI Security Conference'**
	Description	Presentation called "Enhancing B5G/6G Network Security with Federated Learning in O-RAN". Location: Sophia Antipolis, France Date: 14-17 October, 2024
	Partner(s)	MINDS
	Link	https://www.etsi.org/events/2445-etsi-security-conference-2024
9	**Title**	**'6G and Chips workshop'**
	Description	Presentation of the NANCY project and the Greek in-lab testbed technologies in an online workshop. Location: Online Date: 20 November 2024
	Partner(s)	UOWM, INNO, INTRA
	Link	https://6g-workshop.com/
10	**Title**	**'European Night of Researchers in Murcia 2024'**
	Description	Presentation of the NANCY project's development in the European Researchers' Night'24 event in Murcia, Spain. Location: Murcia, Spain Date: 26 September 2024
	Partner(s)	UMU
	Link	https://www.um.es/web/ucc/proyectos/la-noche-de-los-investigadores
11	**Title**	**'Science and Technology Week '24 in Murcia'**
	Description	Presentation of the NANCY project's developments at the Murcia Week of Science and Technology fair 2024. Location: Murcia, Spain Date: 25-27 September 2024
	Partner(s)	UMU

	Link	https://fseneca.es/secyt24/cartel/
12	Title	**'Science and Research Summit in Kozani 2024'**
	Description	Presentation of the NANCY project's developments in the Science and Research Summit in Kozani 2024. Location: Kozani, Greece Date: 18 October 2024
	Partner(s)	UOWM
	Link	https://www.uowm.gr/ekdilosi/imera-epistimis-kai-ereynas-sto-panepistimio-dytikis-makedonias-2/
13	Title	**'IEEE Future Networks World Forum 2025'**
	Description	Presentation of "A Proposed Architecture for C-V2X-Based Mesh Networking in Infrastructure-Less Environments" (to be published) Location: Bangalore, India Date: 10-12 November 2025
	Partner(s)	UVP/EHU
	Link	https://fnwf2025.ieee.org/
14	Title	**'DATAMITE Project Meetup'**
	Description	NANCY joined the DATAMITE Project Meetup event in Athens, Greece, hosted by our partner OTE Group of Companies (HTO) IT Innovation Center. The event brought together 65 EU-funded projects and 400+ attendees to foster collaboration between research and industry. Location: Athens, Greece Date: 6 February 2025
	Partner(s)	OTE
	Link	https://datamite-horizon.eu/2025/01/27/save-the-date-datamite-meet-up-event/
15	Title	**'2nd Research Symposium organized by the University of Western Macedonia'**
	Description	The vision and latest developments of the NANCY project were presented during the 2nd Research Symposium, which was organized and hosted in the University of Western Macedonia premises. The symposium had over 100 participants, including researchers and representatives from industry organizations and local authorities. Location: Kozani, Greece Date: 12-13 June 2025
	Partner(s)	UOWM
	Link	https://www.uowm.gr/en/news/2nd-research-symposium-the-university-of-western-macedonia-s-dynamic-presence-on-the-academic-map/
16	Title	**'4th International Workshop on Real-Time and Cyber-Physical Cloud (RT-Cloud 2025)'**
	Description	Invited talk: Daniel Casini, "Virtualization at the Edge with Strong Temporal Isolation: What's Next?" Location: Brussels, Belgium Date: 8 July 2025
	Partner(s)	SSS
	Link	https://www.ecrts.org/rt-cloud-2025/
17	Title	**'Murcia's European Researchers Night 2025'**
	Description	UMU had a booth in which we exhibited different equipment, and communications/AI developments to families and a non-expert audience. Location: Murcia, Spain

		Date: 26 September 2025
	Partner(s)	UMU
	Link	https://www.um.es/web/ucc/proyectos/la-noche-de-los-investigadores
18	**Title**	**'10th Italian Workshop on Embedded Systems (IWES 2025)'**
	Description	Presentation of "Temporal Isolation and Adaptive Scheduling for Containerized Edge Workloads", related to NANCY. Location: Modena, Italy Date: 18 September 2025
	Partner(s)	SSS
	Link	https://eascitech.eu.org/iwes/2025
19	**Title**	**'Joint SNS JU Webinar — Security & Trust in Multi-Domain 6G Networks'**
	Description	The SNS JU projects ACROSS, NANCY, RIGOROUS, and 6G-PATH co-organized a joint webinar dedicated to strengthening security and trust across next-generation 6G networks. Location: online Date: 2 December 2025
	Partner(s)	UOWM
	Link	https://nancy-project.eu/joint-sns-ju-webinar-security-trust-in-multi-domain-6g-networks/
20	**Title**	**'IEEE Conference on Network Function Virtualization and Software Defined Networks'**
	Description	In this conference, the NANCY project maintained high visibility through a dedicated roll-up display and a video presentation that showcased its innovative contributions to the field. Location: Athens, Greece Date: 10-12 November 2025
	Partner(s)	OTE
	Link	https://nfvsdn2025.ieee-nfvsdn.org/
21	**Title**	**'27th Infocom World 2025'**
	Description	In this event, the NANCY project gained significant visibility through a dedicated project roll-up and an engaging video presentation that showcased its latest innovations. Location: Athens, Greece Date: 26 November 2025
	Partner(s)	OTE
	Link	https://infocomworld.gr/en/

In conclusion, NANCY's active engagement in scientific and technical events ensured that its innovations reached both specialised and general audiences, supporting the broader objective of promoting secure, intelligent, and trustworthy European network infrastructures beyond 5G.

3.3. Demonstrations and Testbeds

Demonstrations and testbed deployments constituted one of NANCY's most concrete and externally visible dissemination instruments, enabling the consortium to present validated technical results in operational and public-facing settings. Rather than remaining confined to academic dissemination, these activities translated NANCY's research outputs into tangible implementations that could be experienced by scientific peers, industry stakeholders, policymakers, and citizens.

By Month 36, NANCY delivered **nine documented demonstrations and public showcases** (coming close to the KPI target of at least 10 demonstrations) directly linked to testbed operation and system validation, many of which were embedded in major international conferences, exhibitions, and public engagement events. Several of these demonstrations were also carried out within **trade fairs and exhibitions**, thereby strengthening the project's visibility beyond the research community.

The demonstrations served a dual role: (i) **technical validation** of NANCY components in controlled and real-world environments, and (ii) **dissemination and engagement**, allowing non-consortium stakeholders to directly observe, discuss, and assess the project's outcomes. A list of the demonstrations at various events is provided in Table 7.

In-Lab Demonstrators

A significant part of the demonstration effort focused on the **in-lab testbeds**, which acted as a controlled environment for validating mature NANCY components before and alongside field exposure. Across these in-lab demonstrations, evaluation focused on measurable indicators such as detection accuracy, response time, explainability outputs, and system adaptability under changing conditions, providing evidence of technical maturity.

Public and Exhibition-Based Demonstrators

NANCY results were also disseminated through **public exhibitions and institutional events**, where demonstrations were adapted to non-specialist audiences while preserving technical credibility. These activities strengthened NANCY's positioning within the European digital innovation ecosystem and enabled direct interaction with decision-makers and technology adopters.

Public Engagement and Outreach Demonstrators

In parallel with technical and industrial events, NANCY placed strong emphasis on **citizen-oriented demonstrations**, particularly through the Spanish partners at UMU. These activities contributed directly to KPIs on **free-access exhibitions, face-to-face interaction with local communities, and science education**, reaching thousands of visitors over the two years.

Rather than isolated showcases, these demonstrations collectively illustrated the **end-to-end applicability of NANCY technologies**, from laboratory validation to public and industrial dissemination, confirming their relevance for future secure and intelligent Beyond-5G networks.

Table 7: Demonstrations and Testbeds

1	**Demonstration / Event Name**	**Demonstration at the 'ETSI AI Conference'**
	Description, Location, and Date	Demonstration of an AI-based cyberattack detection scenario in the Greek in-lab testbed. Location: Sophia Antipolis, France Date: 5 -7 February 2024
	Partner(s)	UOWM, MINDS, SID
	Link	N/A
2	**Demonstration / Event Name**	**Demonstration at 'EuCNC & 6G Summit 2024'**
	Description, Location, and Date	Demonstration of an AI-based cyberattack detection enhanced by explainable AI capabilities in the Greek in-lab testbed. Location: Antwerp, Belgium Date:3 – 6 June 2024
	Partner(s)	UOWM, SID, MINDS
3	**Demonstration / Event Name**	**'Thessaloniki International Fair 2024'**
	Description, Location, and Date	UOWM had a booth in the Thessaloniki International Fair 2024, where the NANCY project and the activities associated with the Greek in-lab testbed were presented. Location: Thessaloniki, Greece Date: 7-15 September 2024
	Partner(s)	UOWM
4	**Demonstration / Event Name**	**'Science and Research Day at the University of Western Macedonia'**
	Description, Location, and Date	NANCY was featured in the Science and Research Summit that was organized by the University of Western Macedonia. Also, the Greek in-lab testbed was demonstrated to local stakeholders and public authorities. Notably, Mr. Margaritis Schinas, vice-president of the European Commission, was the official guest of the event.
	Partner(s)	UOWM
5	**Demonstration / Event Name**	**International Exhibition of Digital Technology and Innovation "Beyond2025"**
	Description, Location, and Date	UOWM had a booth in the Beyond 2025 exhibition, where the NANCY project and the activities associated with the Greek in-lab testbed were presented. Location: Athens, Greece Date: 4-6 April 2025
	Partner(s)	UOWM
6	**Demonstration / Event Name**	**Demonstration at 'EuCNC & 6G Summit 2025'**
	Description, Location, and Date	Demonstrated the capabilities of the Greek in-lab testbed in expanding the network coverage. Also, an explainable AI scenario was showcased, which was expanded with large language model interpretation. Location: Poznan, Poland Date: 3-6 June 2025
	Partner(s)	UOWM, MINDS, SID
7	**Demonstration / Event Name**	**'European Researchers' Night 2024'**

	Description, Location, and Date	UMU partners demonstrated the NANCY project's development in the European Researchers' Night 24 event in Murcia, Spain. Location: Murcia, Spain Date: 27 September 2024
	Partner(s)	UMU
8	**Demonstration / Event Name**	**'Murcia's Science and Technology Week 2024'**
	Description, Location, and Date	UMU researchers engaged visitors with hands-on presentations and simplified explanations on edge computing and dynamic resource management, focusing on how secure networks support everyday digital life. Location: Murcia, Spain Date: 25 - 27 October. 2024
	Partner(s)	UMU
9	**Demonstration / Event Name**	**'European Researchers' Night 2025'**
	Description, Location, and Date	UMU had a booth in which we exhibited different equipment, and communications/AI developments to families and a non-expert audience. Location: Murcia, Spain Date: 26 September 2025
	Partner(s)	UMU

4. Communication Activities

4.1. Overview of Communication Activities

Communication has been a central pillar of NANCY's impact creation framework, ensuring that the project's objectives, progress, and results were conveyed clearly and consistently to audiences beyond the core scientific community. The communication strategy implemented throughout the project was grounded in accessibility, transparency, and value creation, designed to reflect Europe's ambition for secure, intelligent, and energy-efficient Beyond 5G networks. All communication efforts were fully aligned with the DCE strategy described in Deliverables D1.3 and D1.6, and implemented in accordance with the SNS JU communication and visibility guidelines.

The overarching goal of communication activities was to raise awareness, build trust, and foster understanding of NANCY's innovations. To achieve this, complex technological concepts—such as AI-driven orchestration, blockchain-based security, and quantum-safe communications—were translated into clear and engaging messages tailored to diverse stakeholder groups.

Target Audiences

NANCY's communication targeted a variety of audiences through tailored channels and messages:

- **The general public and citizens**, to increase their understanding of emerging technologies and their benefits in daily life.

- **Scientific and academic communities**, to strengthen visibility and attract collaboration opportunities.

- **Industry and SMEs**, to stimulate innovation uptake and potential exploitation pathways.

- **Policy makers and public authorities**, to inform them about technological advancements aligned with EU digital strategies.

- **Younger audiences and students**, to foster interest in AI, cybersecurity, and 6G-related research.

Communication Channels

A diverse set of communication tools and channels was maintained throughout the project to ensure broad reach and continuous visibility:

- The **NANCY website** served as the primary information hub, hosting news, blog posts, publications, and open-access materials.

- **Social media platforms (LinkedIn, X/Twitter, and Facebook)** were used for continuous engagement, announcements, and event promotion.

- The **YouTube channel** hosted partner videos, offering an accessible visual gateway to NANCY's results.

- **Newsletters** provided periodic summaries of project milestones, scientific results, and partner contributions.

- **Press releases and media outreach** enhanced visibility beyond the consortium, connecting NANCY with broader European and international audiences.

- **Printed and digital promotional materials** (brochures, posters, flyers) were used at events, exhibitions, and fairs.

Strategic Alignment

The communication strategy evolved in close alignment with the project's dissemination and exploitation efforts, ensuring consistency in key messages and timing of outputs. Communication actions were synchronised with project milestones, such as major deliverables, publications, and demonstration phases, to amplify impact.

Moreover, NANCY adhered to **SNS JU's communication and visibility requirements**, including:

- Use of the official EU and SNS JU logos and funding statements on all materials.

- Active contribution to SNS JU newsletters, newsflashes, and online presence.

- Participation in SNS JU joint outreach activities, webinars, and cross-project events.

This integrated approach ensured that NANCY's communication efforts contributed not only to awareness but also to the project's scientific, societal, and technological impact, bridging the gap between high-level research and public understanding.

4.2. Website & Blog

The **NANCY website** (www.nancy-project.eu) has served as the project's central communication and dissemination hub, designed to ensure open access to information, enhance transparency, and engage diverse audiences throughout the project's lifetime. Developed and maintained by the dissemination and communication team, the website was continuously updated with content contributions from all partners, reflecting the progression of technical work and milestones.

Website Structure and Content

The website's structure was carefully designed to reflect the breadth of NANCY's activities and to provide intuitive navigation for both specialized and non-specialized visitors. The website structure is presented in Table 8.

Table 8: The NANCY website structure

Main Page Subpage	Link To Page	Brief description
Home Page	https://nancy-project.eu/	Introductory page with basic information on NANCY.
The Project	https://nancy-project.eu/about/	NANCY's vision, objectives, and pillars.

	Consortium	https://nancy-project.eu/consortium/	Expertise and roles of each participating organization
Results			
	Publications	https://nancy-project.eu/category/dissemination/publications/	NANCY's peer-reviewed journal publications and conference proceedings.
	Deliverables	https://nancy-project.eu/results/deliverables/	NANCY public deliverables.
Media			
	Videos	https://nancy-project.eu/category/videos/	NANCY videos.
	Newsletters	https://nancy-project.eu/category/dissemination/newsletters/	NANCY newsletters.
	Press Releases	https://nancy-project.eu/category/dissemination/press-releases/	NANCY Press Releases.
	Communication Kit	https://nancy-project.eu/communication-kit/	NANCY leaflet, flyer, roll-up banner, poster, and infographic
Blog		https://nancy-project.eu/category/blog/	NANCY blog posts.
News		https://nancy-project.eu/category/news/	NANCY news featuring conference and workshop participations, announcements for videos, blog posts, press releases, publications, deliverables, and other results
Contact		https://nancy-project.eu/contact/	Contact page with the e-mails of the Project Coordinator, Technical Manager, and Communication Manager

The site complies with the SNS JU branding and EU visibility requirements, displaying the EU emblem, the SNS JU logo, and the funding acknowledgment on the footer in all pages and in all downloadable materials.

On the footer, the NANCY social media accounts are also available for cross-platform interaction, along with a sign-up form for the NANCY newsletter.

Website Analytics

Since its launch in late 2023, the website has maintained steady and growing engagement. Analytics were monitored throughout Google Analytics. In total, by M35, **2,963 unique users** visited the website, with **5,916 user engagements** and **10,393 page views**, primarily from the United States, Greece, Italy, and Spain (Figure 2).
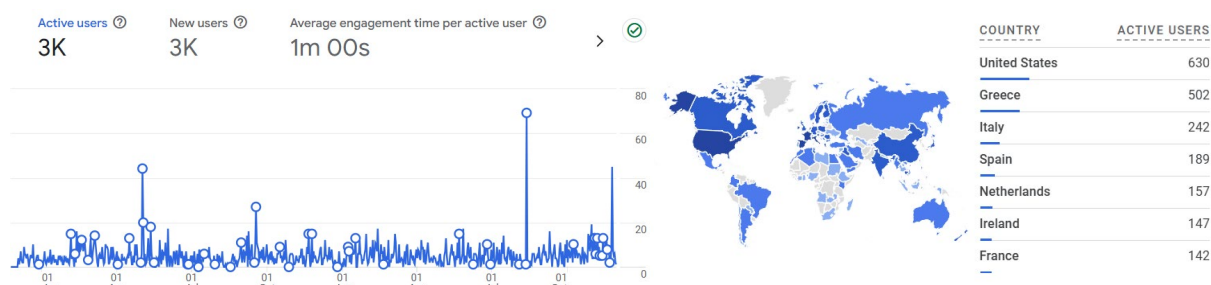

Figure 2: Website statistics and distribution of viewers' countries

Blog Content Strategy

The NANCY blog has been a tool for connecting with both technical and general audiences, offering posts written by partners and curated by the communication team. The strategy followed three main objectives:

1. **Technical insights**: posts highlighting NANCY's AI, blockchain, and quantum-safe research innovations (e.g., *"How NAOMI Makes ML Operations Simple"*).

2. **Project storytelling**: updates on progress, demonstrators, and human-interest stories showing the collaborative nature of European research (e.g., *"Building Self-Healing Networks Beyond 5G"*).

3. **Accessible outreach**: simplified articles explaining the societal relevance of secure and intelligent connectivity, targeting non-specialized readers and policy-oriented audiences.

Each post was complemented with visuals and embedded links to related publications and deliverables, creating a dynamic connection between research outputs and public communication.

Each Partner published a blog post, having **22 blog posts** in total, outperforming the initial KPI of **15 blog posts** (≥ 5 publications per year) (see also the Media Outreach and Press Coverage section for external publications in online magazines, newspapers, blogs). Moreover, these blog posts assembled **814 views** by M35, outperforming the KPI for more than 500 views.

To organize this initiative, we created a monthly calendar, where each partner was scheduled to write a blog post in a specific month (Figure 3). The blog posts are listed in Table 9.

Info	M25-jan	M26-feb	M27-mar	M28-apr	M29-may	M30-jun	M31-jul	M32-aug	M33-sep	M33-sep2	M34-oct
Year 3											
Partner responsible	NEC	Bi2S	CERTH	TDIS		SID	SSS	UBI	JSI	CRAT	TEI
Thematic Area (if existing: Milestone/ Deliverable/ etc.)	5.2	T4.1	Throughput Forecasting/ Outage Probability	T5.1&5.2:Post-Quantum Cryptography		Bridging the Gap: How LLMs and SHAP Values are Transforming Explainable AI	Temporal Guarantees in Virtualized Edge Applications in NANCY	T6.1		5.3	T6.8
Status (i.e. to be contacted, contacted, pending, posted)	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted		Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted
Title (to be provided once the blog post is ready)	Enhancing Privacy in B5G Blockchain Radio Access Networks with Self-Sovereign Identity	Reducing AI energy consumption with NANCY's data drift detection framework	Network availability and throughput: in 5G and beyond!	From Blockchain to 5G—Post-Quantum Cryptography Is the Key to Long-Term Trust		Bridging the Gap: How LLMs and SHAP Values are Transforming Explainable AI	Temporal Guarantees in Virtualized Edge Applications in NANCY	Maestro in NANCY — orchestrating B-RAN across edge, cloud, and legacy 5G	How NAOMI Makes ML Operations on Network Systems Simple?	Building Self-Healing Networks Beyond 5G	Final Demonstration of NANCY Results in Real 5G Infrastructure
URL (to be added once it is published)	https://nancy-project.eu/enhancing-privacy-in-b5g-blockchain-radio-access-networks-with-self-sovereign-identity/	https://nancy-project.eu/reducing-ai-energy-consumption-with-nancys-data-drift-detection-framework/	https://nancy-project.eu/network-availability-and-throughput-in-5g-and-beyond/	https://nancy-project.eu/quantum-resilient-security-for-next-gen-networks/		https://nancy-project.eu/bridging-the-gap-how-llms-and-shap-values-are-transforming-explainable-ai/	https://nancy-project.eu/temporal-guarantees-in-virtualized-edge-applications-in-nancy/	https://nancy-project.eu/maestro-in-nancy-orchestrating-b-ran-across-edge-cloud-and-legacy-5g/	https://nancy-project.eu/how-naomi-makes-ml-operations-on-network-systems-simple/	https://nancy-project.eu/building-self-healing-networks-beyond-5g/	https://nancy-project.eu/final-demonstration-of-nancy-results-in-real-5g-infrastructure/

Figure 3: Snapshot of the blog post calendar

Table 9: The NANCY Blog posts

Partner	Title and Website link	Views
UOWM	One year into the NANCY Project	146
MINDS	Facing the Security and Privacy Challenges of 5G and B5G Networks Utilizing Federated Learning	48
INNOCUBE	The Future of Communications: A Deep Dive into 6G and Semantic Communications	196
VOS	Edge Virtualization in the Era of 5G: Exploring Alternative Solutions	23
ITALTEL	A First Look at NANCY's System Integration and Validation: Deep Dive into Italian in-lab testbed	121
INTRA	NANCY CI/CD system	25
DRAXIS	The Digital Contract Creator	10
TECNALIA	Enabling unconditional security in B5G network backbone communications	9
UMU	Task offloading in NANCY	26
i2CAT	AI Virtualizer: Multi-Agent Emerging Communication for Efficient Inter-Slice Resource Management in 6G	43
8BELLS	Smart Pricing Module: AI-Powered Pricing Optimization for Beyond-5G Networks	28
NEC	Enhancing Privacy in B5G Blockchain Radio Access Networks with Self-Sovereign Identity	16
Bi2S	Reducing AI energy consumption with NANCY's data drift detection framework	19
CERTH	Network Availability and Throughput: in 5G and Beyond!	16
THALES	Engineering Quantum-Resilient Security for Next-Gen Networks	12
SIDROCO	Bridging the Gap: How LLMs and SHAP Values are Transforming Explainable AI	29
SSS	Temporal Guarantees in Virtualized Edge Applications in NANCY	11
CRAT	Building Self-Healing Networks Beyond 5G	14
JSI	How NAOMI Makes ML Operations on Network Systems Simple?	10
UBITECH	Maestro in NANCY — orchestrating B-RAN across edge, cloud, and legacy 5G	7
ERICSSON	Final Demonstration of NANCY Results in Real 5G Infrastructure	7
EHU	Advanced Connectivity on Mobile Nodes: restore communication when it's needed the most	4
Total Views		**820**

4.3. Social Media Engagement

Social media has been a cornerstone of NANCY's communication and visibility strategy, enabling continuous, accessible, and wide-reaching engagement with diverse audiences. Through **LinkedIn**, **X (Twitter)**, **Facebook**, and **YouTube** channels, the project established an active digital presence, regularly sharing milestones, publications, videos, and events. These platforms played a key role in amplifying NANCY's visibility within both the research community and the general public, supporting the SNS JU's wider communication ecosystem.

Strategy for Maintaining an Active Presence

From the outset, NANCY adopted a structured social media strategy designed around three key principles:

1. **Consistency** – ensuring frequent posting around project milestones, publications, events, and partner news. Initially, we published a social media post biweekly, but towards the second half of the project, when the results of the project increased, the social media post frequency increased to one per week.

2. **Accessibility** – presenting complex scientific results in clear, engaging language, without jargon, supported by visuals.

3. **Collaboration** – encouraging partners to contribute content and amplify posts through their institutional channels, ensuring a multiplier effect across networks.

The communication team coordinated with the SNS JU communication unit to ensure cross-promotion through official SNS channels, especially during key project moments such as the SNS JU LinkedIn and X(Twitter), and SNS JU NewFlash.

All posts consistently applied hashtags relevant to NANCY's domains, including #NANCYproject, #wireless, #network, #5G, #blockchain, #research, #innovation, #security, #privacy, #architecture, #technology, #SNSJU, #6G, #B5G, and #InfoComWorld to maximise reach and visibility within the European digital innovation ecosystem (Figure 4).
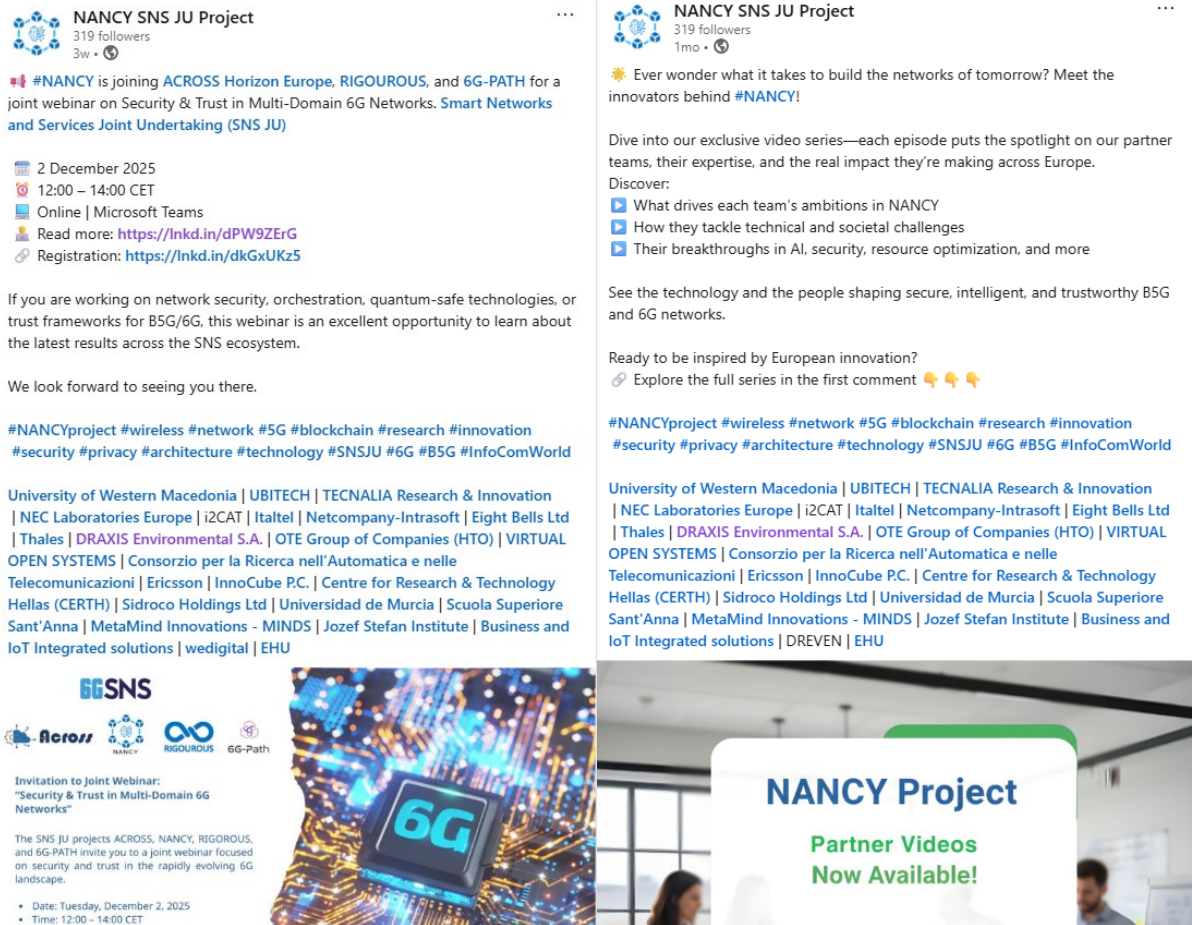
Figure 4: Example NANCY LinkedIn posts

Growth and Analytics

Over the course of the project, NANCY's social media channels achieved steady and meaningful growth, reflecting sustained interest in its activities and displaying a professional engagement with researchers, industry representatives, and policymakers.

In total, we created more than 100 posts in the social media accounts, exceeding by a factor the initial KPI "Number of NANCY posts (≥10)", and hosted 27 videos on YouTube, contributing to greater accessibility for non-specialised audiences (more information in the YouTube Videos and Multimedia Content section).

In all platforms, by M35, we had a total of 556 followers (319 LinkedIn, 186 X, 37 Facebook, 14 YouTube), again exceeding the initial KPI "Number of contacts (≥100)".

On average, a post received ~30 reactions in LinkedIn, ~15 reactions in X, and ~10 reactions in Facebook, achieving the initial KPI "Number of likes (≥ 50 likes / share)".

Only on LinkedIn, between M24-M35, NANCY received 24,592 impressions and 1,586 reactions (Figure 5).

Highlights

Data for 12/1/2024 - 11/30/2025

24,592	1,586	38	10
Impressions	Reactions	Comments	Reposts

Metrics

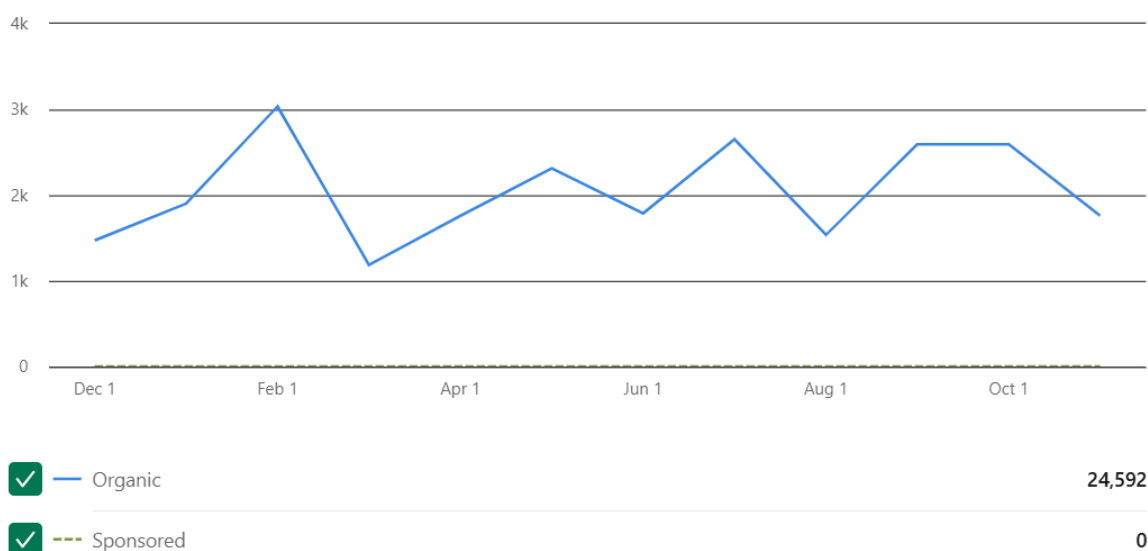|		
✓ — Organic		24,592
✓ --- Sponsored		0

Figure 5: The NANCY LinkedIn statistics during M24-M35 (12 months)

4.4. YouTube Videos and Multimedia Content

The **NANCY YouTube channel** provided a visual and accessible medium to explain technical concepts, highlight partner contributions, and showcase results to both expert and non-specialized audiences. It complemented written dissemination and social media outreach by transforming complex scientific work into engaging audiovisual content, thereby increasing public understanding and long-term visibility of the project's outcomes.

Overview and Objectives

Launched in March 2025, the **NANCY YouTube channel** (Figure 6) was created with the following objectives:

- To **increase public visibility** of NANCY's research and innovations through audiovisual storytelling.

- To **highlight partner contributions** and strengthen the project's collaborative identity.

- To **support open science and accessibility**, offering content understandable to audiences without a technical background.

- To **serve as a long-term repository** of visual materials, ensuring the project's outcomes remain visible beyond its official duration.

All videos adhere to Horizon Europe and SNS JU visibility requirements, featuring the EU emblem, SNS JU logo, and the appropriate funding acknowledgement.
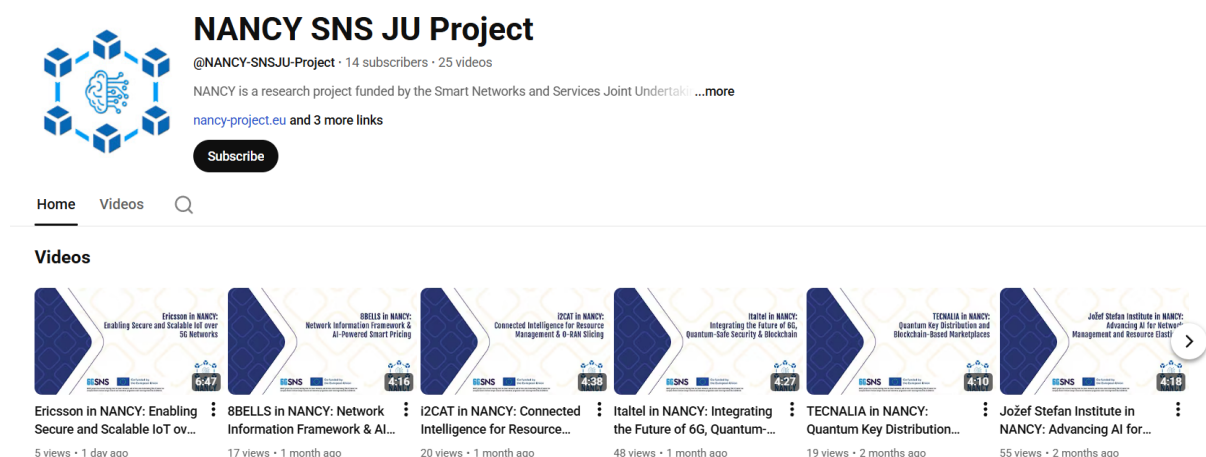

Figure 6: The NANCY YouTube channel

Content Formats and Topics

By Month 36, the project successfully executed its video dissemination strategy, publishing a total of **27 videos**, fully meeting NANCY's initial communication KPI target for **24 videos**. This initiative was organized using a dedicated monthly production calendar (see Figure 7), assigning specific creation and publication deadlines to each partner. A list of all NANCY videos is available on the NANCY Video page and in Table 10.

The 27 videos were produced collaboratively by the consortium and were strategically categorized into four main content types to ensure comprehensive coverage:

- **Initial Project Overview (UOWM):** One video, produced by the Project Coordinator, introducing NANCY's core objectives, organizational structure, and expected societal and technological impact.

- **Technical Deep Dive (INNOCUBE):** One video produced by the Technical Coordinator, detailing the practical implementation of key technologies, such as AI, blockchain, quantum-safe mechanisms, and orchestration systems.

- **24 Partner videos:** Dedicated videos (one per consortium member) allowing each partner to introduce their specific expertise, role, and contribution to the project.

- **Final Outcomes Summary (UOWM):** One concluding video, produced by the Project Coordinator, summarizing NANCY's final achievements and outcomes**.**

To ensure consistency across the 24 partner videos, creators followed a structured briefing template responding to the following questions:

1. What are the main goals and objectives of [partner] in the NANCY project?

2. What are the specific challenges and opportunities you have identified?
3. How is [partner] contributing to the NANCY project, and what expertise do they bring? Can you highlight some activities already implemented?

All videos include English subtitles to support accessibility, ease of distribution, and broader community engagement. A complete list of multimedia content is presented in Table 10 and available on the NANCY Video webpage.

Info	M27 - Mar vid1	M27 - Mar vid2	M28 - Apr vid1	M28 - Apr2 vid1	M28 - Apr3 vid1	M29 - May vid1	M29 - May vid2	M29 - May vid3	M30 - Jun vid1	M30 - Jun vid2	M30 - Jun vid3	M31 - Jul vid1
Partner responsible	UOWM	InnoCube	DREVEN	INTRA	OTE	InnoCube	Draxis	SID	VOS	UOWM	UBI	UMU
Thematic area	1 video by the project coordinator's organisation that will briefly describe the project	1 video by the project technical coordinator's organisation that will explain NANCY's technical advances	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project	1 video by each partner, that will detail their role and expertise in the project
Status (i.e. to be contacted, contacted, pending, posted)	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted	Submitted / Posted
URL (to be added once it is published)	https://www.youtube.com/watch?v=YAARatRadIU&t	https://www.youtube.com/watch?v=hqt6BuBYpU4	https://www.youtube.com/watch?v=iVj_9B-Mp8c	https://www.youtube.com/watch?v=Qw5RHiXdwWA	https://www.youtube.com/watch?v=zi6q36irPpl	https://www.youtube.com/watch?v=EGZRdb29Q58	https://www.youtube.com/watch?v=9BCyhv62qwE	https://www.youtube.com/watch?v=ANSY_LFeCa8	https://www.youtube.com/watch?v=AjinwDFcGo	https://www.youtube.com/watch?v=pfcb94LMjAew	https://www.youtube.com/watch?v=MKz_4xZ4QSU	https://www.youtube.com/watch?v=LdFAtolQmY0

Figure 7: Snapshot of the video calendar

Table 10: NANCY Videos on YouTube

Partner	Title and YouTube link
UOWM	Introduction to the NANCY Project
INNOCUBE	NANCY Technical Overview
DRAXIS	DRAXIS in NANCY: Smart Contracts Made Easy with DAC
INNOCUBE	InnoCube in NANCY: Blockchain, QKD, Semantic Communications & Network Simulation
INTRA	Netcompany-Intrasoft in NANCY: Driving Integration and Automation
SIDROCO	Sidroco in NANCY: AI, Blockchain & Data Management for Secure B5G Networks
UBITECH	UBITECH in NANCY: Orchestrating Beyond-5G Services with Maestro
WEDIGITAL	DREVEN in NANCY: Bringing NANCY to the World
VOS	VOS in NANCY: Virtualization & Secure Edge Solutions for Beyond-5G Networks
UOWM	UOWM in NANCY: Coordinating the Project and Investigating Micro-Operator Scenarios
MINDS	MetaMind Innovations in NANCY: AI-Powered Security & Explainability for Future Networks
UMU	The University of Murcia in NANCY: Dynamic Resource Management in B5G Infrastructures
OTE	OTE in NANCY: Leading the Greek Outdoor Demonstrator for Beyond-5G
Bi2S	Bi2S in NANCY: Advancing AI for Smart, Sustainable Beyond-5G Networks
NEC	NEC in NANCY: Using Blockchain and SSI to improve integrity and privacy in B5G networks
SSS	Scuola Superiore Sant'Anna in NANCY: Virtualization at the Edge with Strong Temporal Isolation
CRAT	CRAT in NANCY: Advancing Self-Healing and Resilient Beyond-5G Networks
THALES	THALES in NANCY: Engineering Quantum-Resilient Security for Next-Gen Networks
CERTH	CERTH in NANCY: Advancing AI Tools for Smarter, More Reliable B5G Networks
JSI	Jožef Stefan Institute in NANCY: Advancing AI for Network Management and Resource Elasticity
TECNALIA	TECNALIA in NANCY: Quantum Key Distribution and Blockchain-Based Marketplaces
ITALTEL	Italtel in NANCY: Integrating the Future of 6G, Quantum-Safe Security & Blockchain

i2CAT	i2CAT in NANCY: Connected Intelligence for Resource Management & O-RAN Slicing
8BELLS	8BELLS in NANCY: Network Information Framework & AI-Powered Smart Pricing
ERICSSON	Ericsson in NANCY: Enabling Secure and Scalable IoT over 5G Networks
EHU	UPV/EHU in NANCY: Advanced Connectivity on Mobile Nodes
UOWM	NANCY Project Final Outcomes: Secure, Intelligent & Quantum-Ready Beyond 5G Networks

Audience Engagement and Analytics

The NANCY YouTube channel achieved consistent growth over the project's lifetime, with 729 total view counts by M35, and steady engagement across all videos (Figure 8).
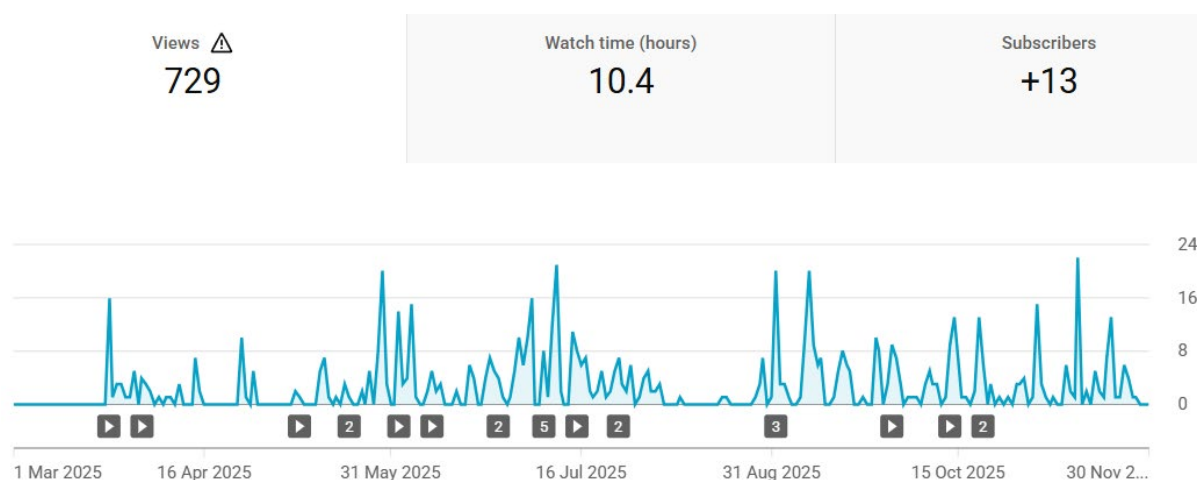
Figure 8: The NANCY YouTube view statistics until M35

Future Multimedia Plans

Although NANCY will conclude at the end of 2025, the YouTube channel will remain accessible, continuing to serve as a long-term reference for researchers, a dissemination resource for educators and students, and a visibility asset for industrial and public stakeholders exploring secure 6G technologies.

Through this multimedia approach, NANCY has succeeded in making advanced research tangible, engaging, and accessible — turning scientific innovation into visual storytelling that resonates across the European digital landscape.

4.5. Promotional Material

Throughout the project, **NANCY developed a coherent and recognisable visual identity** to ensure consistent, professional, and appealing communication across all materials and channels. This identity served as a unifying element across the consortium and reinforced the project's visibility at European and international levels.

Visual Identity and Templates

The project's visual identity was established at the beginning of the project (Month 3) and documented in *Deliverable D1.3: Plans for Publicity, Dissemination, and Exploitation*. It included:

- The **NANCY logo**, designed to represent innovation, intelligence, and connectivity.

- A unified **colour palette** and **typography set** applied consistently across online and printed materials.

- **Templates** for PowerPoint presentations, Word documents, and deliverable covers, ensuring uniform branding.

- **Poster and factsheet layouts** to visually summarise project objectives, consortium composition, and key results.

These materials comply with the **European Commission's visibility requirements**, displaying the Horizon Europe and **SNS JU logos**, as well as the EU funding disclaimer on all communication outputs.

Promotional Materials and Dissemination Assets

To support visibility at major conferences, exhibitions, and stakeholder events, the project developed a diverse and periodically updated set of five promotional materials throughout its duration. These core communication assets were designed to summarize NANCY's consortium structure, objectives, technical pillars, use cases, and key achievements:

- **Print and Digital Assets:** A comprehensive suite of materials, including a leaflet (trifold), flyer, poster, and roll-up banner, was created for both physical and virtual distribution (Figure 9).

- **Infographic:** A dedicated infographic was utilized as a dynamic tool, providing visual summaries of key data and progress. This asset was proactively **updated monthly** until the end of the project to reflect the latest achievements (Figure 10).

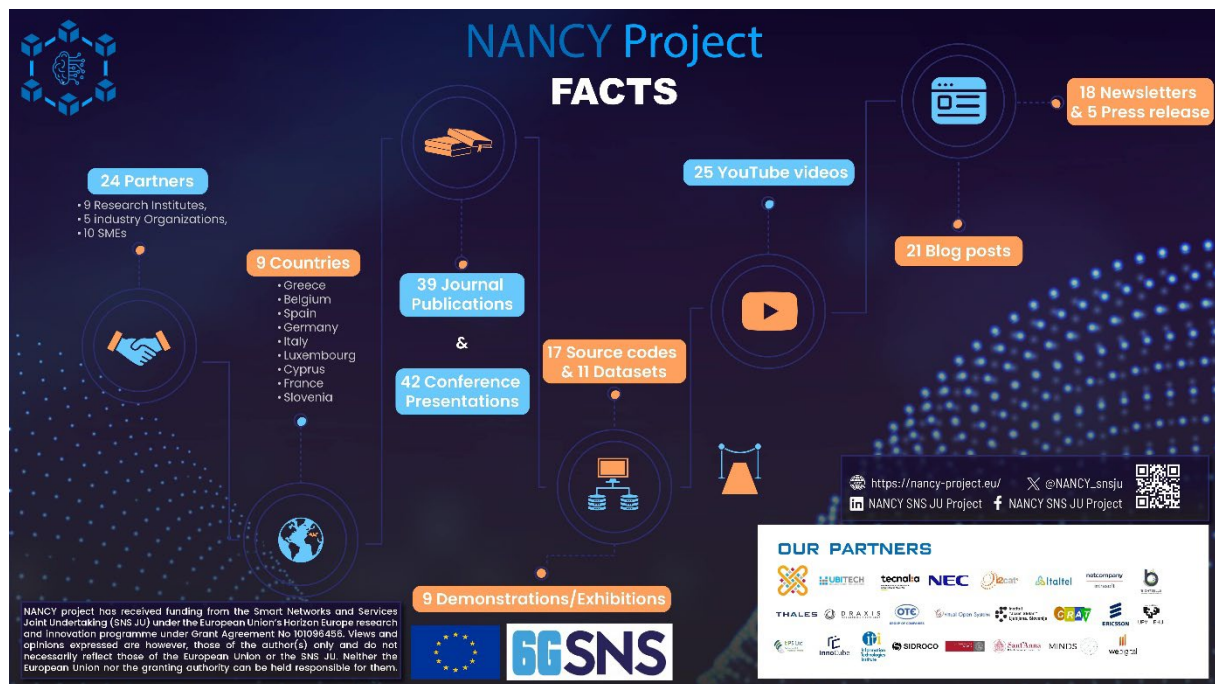Figure 9: The NANCY leaflet (trifold), flyer, poster, and roll-up banner

Figure 10: NANCY infographic

Commitment to Accessibility and Open Communication

To ensure effective engagement beyond the research community, all communication materials were tailored to everyone, from **technical experts** to **non-specialized audiences and the general public**. This strategic approach involved:

1. **Plain Language:** Ensuring all content was written in accessible, plain language.

2. **Visual Explanations:** Accompanying text with clear visual explanations of core NANCY technologies.

This inclusive communication strategy ensured that NANCY remained fully compliant with the **Horizon Europe "open science and open communication" principles**, maximizing project reach and impact across all stakeholder groups.

All materials were produced in both **digital and print formats**, allowing for flexible distribution during both physical and virtual events.

Distribution Strategy

Promotional materials were distributed strategically to ensure maximum visibility and audience reach. The distribution strategy combined **targeted physical dissemination** with **broad digital reach**:

- **At events and conferences**: Flyers, brochures, and roll-ups were distributed at major industry and academic gatherings, including EuCNC & 6G Summit, ETSI AI Conference, BEYOND Expo, and Infocom World.

- **Through the project website**: Digital versions of all materials are uploaded on the NANCY Communication Kit webpage.

- **Within partner networks**: Consortium partners disseminated materials through institutional communication channels, amplifying NANCY's visibility at national and regional levels.

Overall, the promotional material strategy succeeded in creating a strong and recognisable brand identity for NANCY, ensuring coherent, engaging, and compliant communication across all channels. This visual consistency strengthened public recognition and supported NANCY's positioning as a key European project driving the development of secure and intelligent Beyond 5G networks.

4.6.   Newsletters and News Alerts

The **NANCY newsletters and news alerts** were designed to ensure regular visibility of project outcomes, updates, and partner activities to both specialised and non-specialised audiences. These publications served to maintain engagement with stakeholders, promote new scientific and technical results, and support outreach towards a broader public audience, including young professionals and citizens interested in technology and digital innovation. For permanent and easy access, all published newsletters and alerts were archived on the NANCY Newsletter page.

The project launched its external dissemination strategy with the first **Newsletter published in April 2024 (M16)**, providing a comprehensive summary of the overall progress during the first year. Subsequent issues were strategically adapted into concise **news alerts** to provide timely updates on activities. As the project entered its third year and the volume of results matured, the publication frequency was heightened, shifting to a **monthly basis** to ensure efficient dissemination of technical and scientific outputs. By Month 36, NANCY had successfully published a total of **18 Newsletters**, thereby **achieving the KPI target of 18** required for the project, **expecting another one in January 2026** that includes the NANCY news for December 2025 (Table 11).

Structure, Content, and Milestones

The NANCY consortium adopted a milestone-based publication model, ensuring releases were strategically aligned with major project achievements, such as the release of public deliverables, participation in international conferences, and the launch of new videos or demonstrators.

Each newsletter followed a clear and consistent structure to present both high-level summaries and detailed results efficiently (Figure 11). The content showcased the full spectrum of NANCY's activities, which included:

- **Headline Section:** Highlighting recent project milestones.

- **Scientific Dissemination:** Summaries of public deliverables and new scientific results and open-access outputs available on platforms like IEEE Xplore and ScienceDirect.

- **Multimedia Promotion:** Features promoting engaging content such as blog posts, press releases, and partner videos from NANCY's YouTube channel, highlighting integration, cybersecurity, and quantum-safe technologies.

- **Events & Outreach:** Event Highlights summarising participation in leading venues such as EuCNC & 6G Summit, ETSI AI Conference, BEYOND Expo, and IWES 2025.

- **Stay Connected Section:** Directing readers to the website, YouTube channel, and social media for further information.

Each issue was accompanied by visuals and links to ensure an appealing and engaging reading experience.

Figure 11: Snapshot of the NANCY October 2025 Newsletter

Table 11: The NANCY Newsletters

Date	Title and Website link
April 2024	NANCY Project: Celebrating a Year of Innovation and Progress
May 2024	CALL for PAPERS for RTCloud 2024 and for HSTIEC 2024
June 2024	NANCY at EUCNC 6G Summit Antwerp, Belgium 3-6 June 2024
August 2024	Pushing the Frontiers of Beyond-5G: Highlights from NANCY Project
September 2024	Submission of Key Deliverables
November 2024	Key Events Showcasing Innovation
December 2024	From Lab to Publication: Recent Achievements Across the NANCY Project
February 2025	Key Deliverables Submitted & Successful Plenary Meeting in Murcia!
March 2025	NANCY Project Achievements and Engagements
April 2025	NANCY Project: Recent Milestones and Achievements
May 2025	NANCY Project: MAY 2025
June 2025	New Deliverables, Publications, Videos, and Event Highlights
July 2025	New Deliverables, Breakthrough Publications & Cutting-Edge Demos
August 2025	Pushing the Boundaries of Beyond-5G Innovation
September 2025	NANCY Highlights New Videos, Press Release, and 6th Plenary Meeting
October 2025	NANCY Highlights Advances and Updates for September 2025
November 2025	NANCY October 2025: Demonstrations, Breakthrough Research, and Quantum-Ready Innovations
December 2025	NANCY November 2025: Advancing Live Trials, Security Innovation, and Quantum-Safe Networking

Overall, the NANCY newsletters and news alerts successfully combined informative scientific updates with accessible, audience-friendly storytelling. This approach ensured that project outcomes reached both the technical community and the broader public, strengthening the project's visibility and reinforcing its contribution to the European R&I landscape in secure, intelligent Beyond 5G networks.

4.7. Media Outreach and Press Coverage

Media and online outreach ensured that the project's results, milestones, and societal relevance reached both specialised and general audiences across Europe. Through coordinated press releases, media appearances, and features in technology outlets, NANCY effectively increased its visibility within the broader research, innovation, and digital transformation communities.

Press Releases

NANCY implemented a structured press release plan focused on major milestones and technical achievements. **Six press releases** were produced, each highlighting core developments from the main conceptual and technical Work Packages (WP2–WP6), concluding with a final summary of the project's overall impact (Table 12). The NANCY Press Releases are also available on the NANCY Press Release page.

Each release was written in accessible, non-technical language to make advanced topics relatable to policymakers, journalists, and the general public. Partners were encouraged to republish the releases on their own websites and channels, amplifying visibility and ensuring consistency across communications.

Table 12: NANCY Press Releases

Concept	Title and Website link
WP2	NANCY Delivers Trustworthy AI-Driven B5G Networks
WP3	NANCY Unveils AI-Driven Architecture for Secure, High-Performance Beyond-5G Networks
WP4	NANCY Advances Smart Resource Management and Dynamic Pricing in Beyond 5G Networks
WP5	NANCY Introduces Quantum-Resilient, Privacy-First Marketplace for Beyond-5G Networks
WP6	NANCY Begins Real-World Proof-of-Concept: Smarter, Safer Networks Put to the Test
WP1-WP6t	NANCY Successfully Completes the Development of a Secure and Intelligent Beyond 5G Network Architecture

Partner and Institutional Coverage

Project partners actively contributed to NANCY's visibility through dedicated articles and announcements on their institutional websites. These publications highlighted NANCY's technical advances in areas such as post-quantum cryptography, blockchain-based trust, and edge intelligence, as well as partner roles in demonstrations, testbeds, and standardisation activities. A full list of institutional publications is provided in Table 13.

Table 13: Partner and Institutional Coverage

Partner	Title and Website link
8BELLS	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
CERTH	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
CERTH (M4D)	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
CERTH (MKLab)	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
COSMOTE	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
DRAXIS	'A secure and intelligent architecture for the beyond the fifth generation (B5G) wireless network'
EHU	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
i2CAT	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
ITALTEL	'Italtel at the 6th Plenary Meeting of the European NANCY Project in Thessaloniki'
ITALTEL	'The NANCY Project: Innovation and Advanced Testing towards the future Beyond 5G and 6G networks'
ITALTEL	'European NANCY project: blockchain and post-quantum cryptography for secure Beyond-5G networks'
MINDS	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
SIDROCO	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
SSS	'Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
THALES	'Engineering Quantum-Resilient Security for Next-Gen Networks'
UBITECH	'UBITECH participates at the SNS JU Research and Innovation Action NANCY on a secure and intelligent architecture for the beyond the fifth generation wireless networks'
UMU	'The UMU 'NANCY' project promotes intelligent resource management and dynamic pricing in networks beyond 5G'
UMU	'The University of Murcia completes the installation of its own 5G network on campus and tests the improvement of application performance in moving vehicles'
UOWM	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'
VOS	'An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution'

VOS	'Research Outcomes from NANCY SNS EU project'
VOS	'A bare-metal virtualization solution for the edge'

Media Coverage and Features in Online Magazines, Blogs, and Technology Portals

NANCY's results and milestones were highlighted in a range of **online magazines, blogs, and digital technology outlets** beyond the traditional scientific community, allowing the project to engage non-specialized audiences through accessible and informative articles. This strategy has strengthened NANCY's online visibility and supported its goal of explaining complex technological advances in simple, relatable terms. Notable examples include:

- **Free6GTraining** is a platform providing educational and training resources focused on the development and implementation of **6G mobile communication technologies**. **Free6GTraining** published two articles of explanatory articles about NANCY's objectives, the importance of secure and intelligent 6G architectures, and the role of the SNS JU initiative in advancing European research.

  - Maximizing the Impact of European 6G Research through Standardization
  - 6G Smart Networks and Services Joint Undertaking (SNS JU) Phase 1 Projects

- **Casadomo** is a specialized Spanish-language publication and portal dedicated to news, trends, and technology concerning **home automation and smart building systems (domotics)**. **Casadomo** featured NANCY's work on AI-driven network architecture for improved security and performance beyond 5G.

  - The architecture of the NANCY project will improve the security and efficiency of Beyond 5G wireless networks

- **La Opinión de Murcia** is a major Spanish daily regional newspaper that provides comprehensive news coverage for the **Region of Murcia, Spain**. **La Opinión de Murcia** reported on UMU's leadership in building a 5G campus network as part of NANCY, highlighting the project's societal relevance and local impact.

  - Nancy, a project that will revolutionize wireless connectivity in Europe

  - Achieving total immunity to blackouts in mobile networks is complicated

- **Telecompaper** is a Dutch-based international market intelligence and news service specializing in providing **data, analysis, and news coverage of the global telecommunications industry**. **Telecompaper** covered NANCY's selection among leading European 6G initiatives, further increasing awareness among the telecommunications sector.

  - EU selects 35 projects in EUR 250 mln 6G research call

Although external platforms do not publicly disclose viewership analytics, all media channels exhibit high reader traffic and are considered relevant dissemination vectors for digital transformation and communications system innovation.

These publications complemented the project's official press releases and partner-driven news, bringing research outcomes to audiences more familiar with digital transformation, connected cities, and consumer technology trends rather than pure academic research.

Coordination with SNS JU Channels

To maximise impact and ensure alignment with the broader European 6G communication ecosystem, NANCY maintained **close coordination with the SNS JU** communication team. The project achieved:

- **15 appearances in the monthly SNS JU Newsflash**, showcasing major updates, events, and results.

- **Inclusion in the Smart Networks portal** as part of the SNS Phase 1 project portfolio.

- **Feature participation in the SNS JU Lunchtime Webinar #2**, which introduced NANCY's objectives and results to a pan-European audience.

- **Contributions to the SNS JU Standards Tracker**, highlighting NANCY's technical input to ongoing standardisation efforts.

This collaboration reinforced NANCY's positioning within the SNS JU ecosystem and helped disseminate results to a wide European audience of researchers, industry experts, and policymakers.

In summary, the media and online communication activities carried out throughout the NANCY project successfully fulfilled and, in many cases, exceeded the **KPIs**. Under **media outreach**, NANCY published six press releases covering the project's main technical milestones (from WP2 to WP6 and the final validation phase) and achieved extensive coverage through 21 media pieces produced by partners and six external outlets. The project was also repeatedly featured in the SNS JU Newsflash, the Smart Networks portal, and related EU communication channels. Overall, NANCY met or surpassed all communication KPIs related to "Media outreach (Press releases (6/), media produced by partners / coverage in industry magazines / promo on TV / radio (5+))" and "Participation in media (TV, newspapers, radio) events in order to communicate NANCY results of the project and explain its benefits to EU citizens, industry etc)".

4.8. Public Engagement Activities

Public engagement aimed to bring advanced research on B5G and AI-driven network technologies closer to citizens, students, and local communities. These activities contribute directly to the project's KPIs on **exhibitions with free access**, **face-to-face (F2F) interactions with local audiences**, and **training sessions for non-specialized participants**.

Exhibitions, Workshops, and Public Engagement Events

NANCY partners participated in a series of high-impact, open-access science events that attracted thousands of visitors and provided opportunities for dialogue between researchers and the public. These included:

- **European Researchers' Night (Murcia, 2024 & 2025)** – Through an interactive booth (UMU), families, students, and citizens explored AI, blockchain, and cybersecurity demonstrations that illustrated how next-generation networks can become more intelligent, resilient, and energy-efficient.

- **Science and Technology Week 2024 (Murcia)** – UMU researchers engaged visitors with hands-on presentations and simplified explanations on edge computing and dynamic resource management, focusing on how secure networks support everyday digital life.

- **Science and Research Summit 2024 (Kozani, Greece)** – UOWM presented NANCY's concepts on secure connectivity, smart orchestration, and blockchain-enabled networking. Demonstrations were tailored for a broad audience, with students, researchers, and local community members participating.

- **2nd Research Symposium of the University of Western Macedonia (2024)** – UOWM organised sessions showcasing NANCY's contributions to the European 6G research landscape, focusing on collaboration between academia and industry.

- **88th Thessaloniki International Fair 2024:** NANCY was showcased within the UOWM technology exhibitions, presenting the project's developments to a broad audience, including citizens, policymakers, and industrial stakeholders. The activity served as a powerful platform for public visibility and engagement.

- **BEYOND 2025 Exhibition:** NANCY was hosted at the UOWM booth, where a live demonstration of UOWM's 5G testbed captured strong interest from public authorities, investors, industry leaders, and innovation communities. This demonstration presented real-time AI-driven resource management and secure service delivery across testbed components.

Through these combined actions, NANCY achieved **7** exhibitions and public workshops engaging **thousands of non-specialized attendees** and contributing to the KPIs for free-access exhibitions, F2F interaction with local audiences, and free trials for general public.

Free Trials and Open Demonstrations

Public demonstrations and testbed showcases provided accessible ways for citizens to see NANCY technologies in action. Simplified versions of AI-driven orchestration and blockchain-enabled authentication were presented at university campuses and fairs, while video explainers on the NANCY YouTube channel extended this access to online audiences. Together, these activities supported the KPI on "free trials and open demonstrations," by providing tangible, real-world insights into secure Beyond 5G systems.

4.9.   Marketing Events and Trade Fairs

Participation in major **marketing events and trade fairs** provided high-visibility opportunities to present project outcomes, engage with industrial stakeholders, and demonstrate the practical value of NANCY technologies within Europe's 6G and digital innovation landscape.

Participation in Major Marketing and Industry Events

Throughout the project, NANCY partners showcased results at **6 major marketing events**, meeting and exceeding the KPI target of at least three events ("≥1 in Year 2 and ≥2 in Year 3"). Each participation helped bridge research and market adoption by engaging audiences across academia, industry, and public sectors.

Key participations included:

- **Infocom World 2023 &2025 (UOWM, OTE, INNO, 8BELLS, INTRA):** The leading ICT and telecommunications event in Greece, where partners presented NANCY's advances in AI-driven orchestration, network automation, and blockchain-based trust models to telecom professionals and researchers.

- **Ericsson R&D Italy Innovation Days 2023 & 2024 (TEI):** Industrial innovation events where NANCY's progress in quantum-safe security, blockchain integration, and AI-enhanced orchestration was presented to key industrial stakeholders and research collaborators.

- **Project Presentation at Corporate Event (ITL):** Italtel highlighted NANCY's integration and validation role, connecting research outcomes with real-world deployment strategies.

- **DATAMITE Project Meetup (OTE):** Participation in this collaborative EU project event showcased how NANCY's data management and AI-driven decision-making complement Europe's broader innovation ecosystem.

These events (Figure 12) not only promoted technical outcomes but also positioned NANCY as a reference for secure and intelligent B5G solutions, encouraging dialogue with industry actors on future applications and commercialization paths.

Figure 12: Social Media images highlighting the NANCY participation in the "Infocom World 2023", "Ericsson R&D Italy Innovation Days 2024", and "DATAMITE Project Meetup" events

Integration of Communication and Dissemination Objectives

NANCY's representation at these events went beyond technical demonstrations — it also served as a communication channel to **promote the project's vision, mission, and societal impact**. Posters, roll-ups, and videos were used to attract non-specialized audiences and policymakers, while dedicated presentations and discussions targeted the expert community.

By aligning on-site promotion with online visibility, NANCY ensured that each event amplified its outreach efforts. Event participation was systematically covered through the **project website**, **social media**, and **newsletters**, maximizing audience engagement before, during, and after each exhibition.

5. Exploitation and Innovation Management

The NANCY consortium has developed an exploitation strategy to identify, manage, and accelerate the project's innovations, categorising **28 exploitable results** into Key and Other Exploitable Results. Through a dedicated questionnaire, these results, split evenly between technological solutions and theoretical models, are detailed in individual roadmaps that include their value propositions, target audience (stakeholders), and early adopters / end-users. The exploitation analysis highlights a strong industrial focus with **15 commercial** and **13 non-commercial** results, impacting four strategic pillars: Next-generation architecture, future-proof security, Zero-touch intelligence, and connectivity expansion. To ensure long-term sustainability, the consortium employs a multi-layered IPR strategy involving **patents (three registered and three under development)** and copyrights, primarily under exclusive ownership, and has **successfully published 27 results on the Horizon Results Platform** to maximise visibility among investors and policymakers.

5.1. Glossary

According to GA Article 16.2, a "**result**" encompasses any tangible or intangible effect of an action, including data, knowledge, and information, regardless of its form or nature, or whether it is protected by intellectual property rights.

Exploitation is defined by the European Commission as the active utilisation of project results in research and innovation activities beyond the scope of the original project. The strategic emphasis on exploitation aims to maximise the utility of these results, thereby ensuring they transform research into tangible societal value. Successful exploitation may lead to new legislative frameworks, resolve specific technical or societal problems, and address existing needs, ultimately creating lasting impacts across the economy and the innovation landscape.[1]

The project identifies two distinct categories of results defined as follows:

- **Key Exploitable Results (KERs)**: They represent the primary outputs identified at the project's inception and explicitly outlined in the Grant Agreement (GA). These results are selected and prioritised due to their substantial potential for downstream exploitation, whether through integration into commercial value chains, contribution to policy frameworks, or the advancement of educational and research initiatives.

- **Other Exploitable Results (OERs)**: They encompass assets that were not originally foreseen during the planning phase but emerged during the project's implementation. Despite not being initially planned, these results demonstrate significant exploitation potential, ranging from commercial applications to academic and societal contributions.

The project utilises two primary mechanisms for leveraging project results (Commercial and Non-commercial exploitation)[2]:

- **Commercial exploitation**: This approach focuses on generating financial value from the project's IP and outcomes. It relies on market transactions—such as product sales and licensing agreements—to deliver goods and services to customers, thereby providing a financial return

---

[1] Webinar session: Dissemination & Exploitation in Horizon Europe (9 June 2021)
[2] https://www.wipo.int/edocs/pubdocs/en/wipo-pub-855-22-en-collective-management-of-copyright-and-related-rights.pdf

to the implementing organisations. This pathway is typically employed by private companies to convert knowledge into economic benefits.

- **Non-commercial exploitation**: Conversely, this mechanism involves utilising results for purposes unrelated to direct financial gain. Key activities in this category include knowledge transfer, the promotion of public welfare, educational support, policy influence, and the advancement of scientific research outside the project.

IPR management entails the deliberate and organised administration of intellectual property assets within a corporate or project environment. Intellectual Property Rights (IPR) are defined as private legal rights that protect creations of the human mind, including inventions, literary and artistic works, as well as symbols, names, images, and designs utilised in commerce.

Effective Intellectual Property Rights management relies on a precise understanding of the specific legal mechanisms used to protect knowledge. Before proceeding with the detailed analysis of the NANCY results, the following key terms are defined in accordance with European Union guidelines[3]:

- *A patent* is an exclusive right granted for the protection of inventions (products or processes) offering a new technical solution or facilitating a new way of doing something.

- *Copyright (or author's right)* is the term used to describe the rights that creators have over their literary, scientific, and artistic works.

- *A utility model* is an exclusive right granted for an invention, which allows its owner to prevent others from commercially using the protected invention, without their authorisation, for a limited period of time.

- *A trademark* is an exclusive right over the use of a sign in relation to the goods and services for which it is registered.

- *A trade secrets* agreement offers rights holders protection when it comes to confidential information that can be sold or licensed.

- *A sui generis protection* protects the content of a database, preventing the extraction and/or reuse of the whole or substantial part of its content when the structure of a database is not an original creation.

Furthermore, the IPR management strategy establishes a clear distinction between pre-existing assets and novel results, adhering to the following definitions derived from the Grant Agreement:

- **Background IPR**: According to the GA Article 16.1, 'Background' refers to any data, know-how or information - whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights - that is: (a) held by the beneficiaries before they acceded to the Agreement and (b) needed to implement the action or exploit the results. If the background is subject to the rights of a third party, the beneficiary concerned must ensure that it is able to comply with its obligations under the Agreement.

- **Foreground IPR**: According to the GA "Impact" Section, 'Foreground' refers to knowledge that is generated during the course of the project. It includes any new data, knowledge, or information that is developed or discovered during the project.

---

[3] https://op.europa.eu/en/publication-detail/-/publication/ddf8fb93-ec0e-11e9-9c4e-01aa75ed71a1/language-en

5.2. Methodology - Exploitation Questionnaire

The data and analysis presented in this chapter of the deliverable are directly derived from the responses gathered through the final Exploitation Questionnaire completed by all consortium partners. This questionnaire was designed to map every project's exploitable result, estimate its exploitation potential, and design appropriate future pathways.

To provide a cohesive and detailed characterisation of the project's innovation potential, the responses have been consolidated into a unified table format for each identified result. The structure of this table directly mirrors the three core sections of the exploitation questionnaire used for data collection:

- **Partner info (Section 1 of the Exploitation Questionnaire):** This initial section of the questionnaire identifies the partner organisation responsible for the data provided. In the consolidated table, this maps to the **Owner / Contributor** field, ensuring that every result is clearly attributed to a specific beneficiary (e.g., *Organisation Name, Name and Surname, E-mail*) to establish accountability and a contact point for future exploitation inquiries.

- **Exploitation (Section 2 of the Exploitation Questionnaire):** This segment defines the core attributes and exploitation planning of the result. It includes the **Category of Result** (KER# or OER#) and the **Type of Result** (Technological Solutions, Methods, Models and Algorithms, Skills and Know-how, Guidelines and Recommendations, Plans and Strategies, Data, Standards). The **Short Description** and **Value Proposition** are extracted from the partners' detailed descriptions of features and benefits. Additionally, the **Problem / Solution** field combines answers regarding the specific challenges addressed and the technical solutions proposed. It also identifies the **Target Audience** (Industry, Researchers, Public Sector, Civil Society, Policy makers and Public Authorities, Other) and descriptions of **Early Adopters/End-users**. It further specifies the **Exploitation Type** (Commercial, Non-Commercial, Other) and outlines the planned **Methods, Tools, & Activities**, which capture the partners' roadmaps for market analysis, partnerships, and development timelines.

- **IPR management & Ownership (Section 3 of the Exploitation Questionnaire):** This section details **IPR** considerations by synthesising responses regarding Background and Foreground IP, specifically indicating the protection form (Patents, Copyright and related rights, Trademarks, Trade secrets, Utility model, Sui generis protection). It also maps the **Exclusive Ownership** status (Yes, No). If shared, partners are identified alongside a description of how they have contributed to the development of the exploitable result.

Based on the exploitation questionnaire input, a total of **28 exploitable results (ERs)** were identified. Table 14 and Table 15 provide an overview, listing all KERs and OERs by their R number(s), title, and respective owners. These are followed by 28 detailed tables (ER1 to ER28) that offer a standardised breakdown of their exploitation profiles, including short description, type of result, problem/solution, value proposition, target audience, early adopters / end-users, exploitation type, method, tools and activities, IPR management, and ownership.

Table 14: List of Key Exploitable Results

KER#	R#	KER Title	Owner(s)
KER1	ER1	'NANCY architecture and approach'	SSS
KER2	-	'Novel trustworthy grant/cell-free cooperative access mechanisms'	-
KER3	ER2,ER3, ER4	'A novel security and privacy toolbox'	TDIS, NEC, TEI
KER4	ER5	'Realistic blockchain and attacks models'	INNO
KER5	ER6	'Quantum safety mechanisms to boost end-user privacy'	INNO
KER6	-	'AI-based B-RAN orchestration with slicer instantiator'	-
KER7	ER7	'A novel AI virtualiser for underutilized computational & communication resource exploitation'	i2CAT
KER8	ER8,ER9	'Novel self-evolving AI model repository'	IJS, CERTH
KER9	ER10	'Semantic & goal-oriented communication schemes for beyond Shannon performance '	INNO
KER10	ER11	'NANCY Explainable AI Toolbox'	MINDS
KER11	ER12	'Next-generation SDN-enabled MEC for autonomous anomaly detection, self-healing and self-recovery'	CRAT
KER12	ER13, ER14	'A computational offloading mechanism with novel resource-aware/ provision scaling mechanisms and novel battery as well as computational-capabilities aware offloading policies' (VOS, UBITECH)	VOS, UBITECH
KER13	-	'User-centric caching mechanisms'	-

Table 15: List of Other Exploitable Results

OER #	R#	OER Title	Owner(s)
OER1	ER15	Smart Contracts	DRAXIS
OER2	ER16	Machine learning models for decision-making	Bi2S (UMU, IJS)
OER3	ER17	Market place	TECNALIA (NEC)
OER4	ER18	MultiRAT-Nomadic Connectivity Provider	UMU
OER5	ER19	Micro-Operator Deployment for Network Coverage Expansion	UOWM
OER6	ER20	Exploitation of Blockchain technology powered by AI/ML algorithms in the field of 5G and Edge Computing	OTE
OER7	ER21	Throughput Forecasting Service	CERTH
OER8	ER22	Smart Pricing Policies	8BELLS
OER9	ER23	Big Data Platform for self-healing and self-recovery	TEI
OER10	ER24	A framework for data and concept drift detection in 6G networks	Bi2S
OER11	ER25	Multi-hop V2X solution for coverage extension	EHU (UMU and IJS)
OER12	ER26	Multi-hop 5G solution for coverage extension	EHU (UMU and IJS)
OER13	ER27	PQC-Enabled B-RAN: System Integration Across Heterogeneous Edge Platforms	ITL
OER14	ER28	Central Management Domain Deployment & Orchestration	INTRA (UBI)

Note: In this project, KERs serve as strategic thematic groupings aligned with the GA, rather than implying joint ownership. Consequently, a single KER often encompasses multiple exploitable results (e.g., KER3 includes ER2, ER3, and ER4) that maintain separate owners and independent exploitation paths. It is also noted that three KERs were not addressed. OERs, conversely, refer to single results that emerged during the project and were not initially foreseen in the Grant Agreement.

5.3. Exploitation Roadmaps

ER1	Hierarchical SCHED_DEADLINE with Kubernetes integration
Owner / Contributor	SSS
Category of Result	KER1 - NANCY Architecture and Approach
Type of Result	Technological Solutions
Short Description	The main feature of the Hierarchical SCHED_DEADLINE scheduling policy is its capability to enforce the maximum CPU time granted to each reservation to reduce the noisy neighbours' issue. This problem reduces the execution time predictability of containers hosted on shared physical cores. It impacts the guarantees that can be provided on the application running in a container and is typically solved by overprovisioning. The proposed solution increases the isolation among co-hosted containers at the kernel level and allows guaranteed lower latencies, better exploiting underlying computational resources. It also presents a simple API that allows changing the allocated slice at runtime, thus supporting adapting it to mutated requirements or incoming workload variations. The API can be exploited for seamless integration in frameworks like Kubernetes, mapping its parameters in higher-level configurations like ETSI MANO descriptors.
Problem / Solution	Problem: To improve isolation and reduce interference among co-hosted containers. Solution: Improve isolation at the kernel level on Linux and provide an API to easily set reservation parameters.
Value Proposition	Ensures predictable, low-latency container performance by eliminating noisy-neighbour effects, with dynamic CPU reservations and easy integration into orchestration frameworks.
Target Audience	Industry
Early Adopters / End-users	The goal would be the publication of this novel scheduler as open source and the submission for integration within the relevant open-source projects (mainly Linux kernel and Kubernetes). This has already happened in the past with other proposed features and is based on a collaboration with many mainline developers established over the years and fostered by several workshops SSS organised with them.
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Concerning the patchset to extend SCHED_DEADLINE with the Hierarchical Constant Bandwidth Server support: - The design and initial implementation have been discussed in March (M27), at the OSPM summit [https://lwn.net/Articles/1021332/]; - The first RFC for the first part of the patchset was sent at the beginning of June (M30) [https://lkml.org/lkml/2025/6/5/227]; - SSS will send the RFC v2 at the end of July (M31); - After that, the requests from the maintainers will be addressed (M33-M36).

	Regarding Kubernetes, the contributions have been implemented as a standalone plugin to facilitate its adoption and simplify maintenance for compatibility with future Kubernetes releases. A paper presenting the contribution has been accepted and presented in July (M31) at the 37th Euromicro Conference on Real-Time Systems [https://doi.org/10.4230/LIPIcs.ECRTS.2025.3] The codebase has been made publicly available on SSS's public GitLab server (M30) [https://gitlab.retis.santannapisa.it/dra-rt]
IPR (Background / Foreground)	None
Exclusive Ownership	Yes

ER2	PQC Signature Solution
Owner / Contributor	TDIS
Category of Result	KER3 - A novel security and privacy toolbox
Type of Result	Technological Solutions
Short Description	Main features: TDIS is developing a Digital Signature Solution composed of: 1. A TDIS PQC Signature Token: it consists in a smart card integrating a quantum resistant digital signature algorithm. 2. A TDIS PQC Signature Driver: This driver provides the minimal services to the applications for interfacing with the Token. The published set of API will be based on the PKCS #11 standard and will be used for digital signature purposes. Objectives: This Solution can be used for public key infrastructure (PKI) applications such as identity cards and corporate security (closed user groups). This feature can be used to ensure the integrity and authentication of any data files. Advantages: Support of a hybrid PKI concept (hybrid=classic+post-quantum cryptography) as well as Crypto Agility. What is new: Post-Quantum cryptography and Crypto Agility on smartcard devices. Why is it important: major security agencies in the US and Europe are recommending industry stakeholders to anticipate for post-quantum area for all technologies based on public key cryptography.
Problem / Solution	Problem: To bring resilience of the actual PKI system towards new threats from quantum computing Solution: All Thales smartcard products from all TDIS's business segments (Identity cards, SIM cards, bank cards) will benefit from this technology
Value Proposition	To provide a smart card based PKI solution, anticipating the transition to the post quantum area

Target Audience	Public Sector (TDIS provides ID cards, ePAssports, eDriving Licences, eHealthcare cards)
Early Adopters / End Users	TDIS is providing awareness sessions about the post-quantum rationale with the help of functional demonstrators. Some existing legacy customers are starting to be interested to migrate on PQC. However, they will get PQC products only when it will be totally qualified and industrialised.
Exploitation Type	Commercial
Methods, Tools & Activities	There is no specific method for this product. The commercialisation will go through the Thales DIS traditional sales channels. Timeline: Product end of certification & industrialisation: end 2025
IPR (Background / Foreground)	None
Exclusive Ownership	Yes

ER3	Blockchain wallet with SSI and PQC capabilities
Owner / Contributor	NEC (TDIS)
Category of Result	KER3 - A novel security and privacy toolbox
Type of Result	Technological Solutions
Short Description	Main features: A wallet for blockchain clients that has SSI and PQC capabilities. Objectives: Improve privacy and security. What is new: both SSI and PQC are recent technologies that are still in progress. Incorporating them into a wallet solution is beyond the state of the art.
Problem / Solution	An SSI and PQC-capable blockchain wallet tackles several problems: 1) Centralised Identity: Centralised identity providers (like Google, Facebook, banks) control user identities, often leading to privacy loss, data breaches, and a lack of user control. A blockchain wallet with SSI lets users authenticate, sign transactions, or access services without revealing more information than needed (zero-knowledge). 2) Quantum Threats: Current cryptographic algorithms (RSA, ECDSA) used in blockchain wallets and identity schemes are vulnerable to quantum computers, which could break them in the next decade. NEC's wallet combines next-gen crypto with identity—preventing attackers from forging identity credentials or stealing funds using quantum capabilities. 3) Fragmentation: users need multiple apps for identity (e.g., ID wallets) and assets (e.g., crypto wallets). 4) Legacy solutions lack portability and privacy across countries and sectors. NEC's wallet supports W3C Verifiable Credentials and Decentralised Identifiers for interoperability, while PQC ensures long-term compliance with evolving standards (e.g., NIST).

Value Proposition	PQC will shortly become one of the main cryptography standards. While quantum-secure wallets and SSI wallets have seen progress, a unified, production-grade wallet combining both SSI and PQC is still emerging. So far, a fully integrated PQC-able and SSI-able blockchain wallet solution does not exist.
Target Audience	Private sector (This solution will be tested in a permissioned blockchain, hence the private sector is the main stakeholder)
Early Adopters / End Users	NEC has a longstanding relationship with the public and private sectors. Still no early adopters since this result cannot be released on its own, but as part of a more mature system
Exploitation Type	Commercial
Methods, Tools & Activities	Pitch meetings with NEC Corp. in Japan
IPR (Background / Foreground)	Background (Previous knowledge about Blockchain and SSI - Protected with Patent)
Exclusive Ownership	No. TDIS's efforts concentrate on delivering the PQC capabilities for signature that the wallet would use through an SW adaptor (done by TDIS). Still, an SSI-enabled wallet would be a KER in itself

ER4	**Post Quantum Cryptography secure communication**
Owner / Contributor	TEI
Category of Result	KER3 - A novel security and privacy toolbox
Type of Result	Models and Algorithms, Skills and know-how
Short Description	Main features: PQC communication in a 5G massive IoT scenario. Objectives: Provide Post Quantum assurance to device communication. Advantages: To be secure against the potential threat posed by quantum computers. What is new: PQC prototyping and algorithms comparison in 5G scenario, integrating PQC digital signature Token. Why is it important: To improve the security of communication can be a reputational advantage for the organisation.
Problem / Solution	Problem: Secure communication against the potential threat posed by both quantum and classical computers Solution: Integrating PQC in a 5G scenario using a digital signature token
Value Proposition	Improve communication protection.
Target Audience	Industry (Transition to PQC will be a normative requirement)
Early Adopters / End Users	Since the PQC is not yet completely validated, the adopters should not be involved in the evaluation.

Exploitation Type	Commercial
Methods, Tools & Activities	Not applicable. Waiting for the complete standard definition and interest from early adopters. TEI currently does not have an exploitation timeline, as commercial exploitation will take place after the end of the project.
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER5	B-RAN Theoretical Framework
Owner / Contributor	INNO
Category of Result	KER4 - Realistic blockchain and attacks models
Type of Result	Models and Algorithms
Short Description	Main features: Models the performance of the B-RAN in various scenarios Objectives: Accurately model and estimate the achievable performance of B-RAN. Advantages: Customised development of B-RAN based on the client's needs. What is new: Novel framework. Why is it important: Reduces development and deployment costs.
Problem / Solution	Problem: Reduces development and deployment costs. Solution: Accurately model and estimate the achievable performance of B-RAN.
Value Proposition	Conduct pre-deployment evaluation and design of B-RAN.
Target Audience	Industry & Public sector (Interesting technology for any stakeholder trying to deploy private or public B-RAN)
Early Adopters / End Users	Researchers
Exploitation Type	Commercial
Methods, Tools & Activities	Theoretical modelling based on queueing theory and Markov chains, as well as AI and ML, too Timeline: - M1-M24: Development and Refinement - M24-M36: Identification of key stakeholders - M36+: Market analysis
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER6	QKD Simulation Framework
Owner / Contributor	INNO
Category of Result	KER5 - A novel quantum key distribution mechanism
Type of Result	Models and Algorithms
Short Description	Main features: Simulates the performance of QKD communications without the need for equipment. Objectives: Achieve close to real-life performance. Advantages: No need for expensive QKD equipment. What is new: The component will be compared to actual experiments during the duration of the project. Why is it important: Highly reduced costs compared to the actual equipment.
Problem / Solution	Problem: Achieve close to real-life performance. Plan and/or estimate the performance of QKD communications without the need for expensive QKD equipment. Solution: Simulates the performance of QKD communications without the need for equipment.
Value Proposition	Plan and/or estimate the performance of QKD communications.
Target Audience	Industry & Public sector (Interesting technology for any stakeholder trying to deploy QKD solutions)
Early Adopters / End Users	Researchers
Exploitation Type	Commercial
Methods, Tools & Activities	QKD communications without the need of actual equipment. Timeline: - M1-M24: Development and Refinement - M24-M36: Identification of key stakeholders - M36+: Market analysis
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER7	A novel AI virtualiser for underutilised computational & communication resource exploitation
Owner / Contributor	i2CAT

Category of Result	KER7 - A novel AI virtualiser for underutilised computational & communication resource exploitation
Type of Result	Models and Algorithms
Short Description	Main features: Inter-slice conflict and underutilization mitigation Objectives: Efficient resource exploitation in the RAN-Edge-Cloud continuum What is new: protocol learning as a basis
Problem / Solution	Problem: Inter-slice resource conflict and underutilization. Solution: develop a multi-agent communication protocol, learning to establish collaboration between concurrent slices.
Value Proposition	Efficient use of resources to maximise the return from leasing the infrastructure to multiple tenants
Target Audience	Industry
Early Adopters / End Users	Not reported
Exploitation Type	Commercial
Methods, Tools & Activities	Multi-agent communication, Pytorch, Docker, Kubernetes. Timeline: - M6-M9: Design of the AI virtualiser - M10-M12: Implementation of the AI virtualiser in simulation - M13-M16 Dockerisation of the AI virtualiser - M16-M19: Integration with the slice manager - M20-M24: Testbed validation
IPR (Background / Foreground)	Background (Slice Manager protected with License)
Exclusive Ownership	Yes

ER8	Automatic Machine Learning Model Development and Management
Owner / Contributor	IJS
Category of Result	KER8 - Novel self-evolving AI model Repository
Type of Result	Technological Solutions
Short Description	Main features: Pipeline with data and model versioning, as well as automatic training and management. Objectives: Aligned with the AIMLFW specification of O-RAN, realised with state-of-the-art cloud-negative technologies. Advantages: Zero-touch, like model training and management.

	What is new: Such a system for cellular networks
	Why is it important: Applicable for the core network and also in different verticals: IoT, vehicular communications, smart cities, etc.
Problem / Solution	Problem: Increased need for AI and intelligence in networks
	Solution: The Automatic Machine Learning Model Development and Management will make it easier to add such intelligence
Value Proposition	Support for intelligence in 5G and beyond networks.
Target Audience	Researchers
Early Adopters / End Users	Integration and use of the implemented asset in the research activities of IJS's research group.
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Result refinement, Partnerships and Collaborations, and Continuous monitoring and improvement. Timeline: - M24: Finished development - M24-M36: Partnerships and Collaborations, and Continuous monitoring and improvement
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER9	**AI Network Quality Module (AINQM)**
Owner / Contributor	CERTH
Category of Result	KER8 - Novel self-evolving AI model Repository
Type of Result	Models and algorithms
Short Description	Main features: Advanced predictive machine learning algorithms that utilise historical data and specific features, so as to train models, where the probability of outage/availability is predicted in a 5G/B5G network. Objectives: Enhance network reliability and availability, Support network administrators for decision making for signal processing. Advantages: Building a network information framework that accurately estimates the outage probability to achieve proactive compensation of network downtime. This can assist decision makers in allocating network resources more effectively. What is new: Mitigation of performance degradation and proactive decision-making.

	Why is it important: Detection of network outage/availability assists in efficient resource management.
Problem / Solution	Problem: Low network availability in terms of 5G network service requirements and poor QoS. Solution: Predicting outages will assist decision makers to allocate the resources more efficiently; in particular, ensuring network services reliability and QoS demand for network users
Value Proposition	Accurate prediction of network outages
Target Audience	Industry (Telecom equipment vendors and network technology providers can benefit significantly from the outage probability prediction module, providing assistance with spectrum management and network design relevant to resource management. IoT operators and smart cities can optimise their infrastructure to satisfy connectivity demands and enhance network outage anticipation. Moreover, outage probability prediction services guarantee dependable and quick connectivity for all customers.
Early Adopters / End Users	Potential early adopters include telecommunications providers, mobile network operators, as well as academia and research institutions.
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Relative to the AINQM module for predicting upcoming rate outage events, CERTH has also and will continue to refine model accuracy through expanded datasets, to support operational decision-making by highlighting the drivers behind high-risk and performance degradation events. Outage predictions have been and will be directly connected to network operation tools, allowing the promotion of proactive interventions while testing performance in Open RAN scenarios. CERTH has monitored and assessed systematically market trends and conditions; moreover, CERTH's research efforts will continue, potentially leading to market launch, given an appropriate legal form. Having initially defined a) Qualcomm and Nokia Bells, b) Hewlett Packard, c) Nokia, and d) Huawei as key service providers, the market analysis will continue based on the piloting results beyond the end of the project, and an updated view of the provider ecosystem will be built to ensure ongoing model relevance.
IPR (Background / Foreground)	Background (The predictive analytics and forecasting framework has been developed in the course of previous research activities under different domains focused on crime risk projection. This framework has been extended and adapted properly to cover different needs, such as cyberattack prediction. In NANCY, this framework will be used, and it will be adapted properly to cover the needs of the project. It is protected by Copyright.)
Exclusive Ownership	Yes

ER10	Semantic Communications Framework
Owner / Contributor	INNO

Category of Result	KER9 - Semantic & goal-oriented communication schemes for beyond Shannon performance
Type of Result	Models and Algorithms
Short Description	Main features: Next-gen energy and data efficient communications. Objectives: Intelligently reduce the amount of data transferred in the network. Advantages: Increase energy and data efficiency. What is new: Novel framework based on AI and conventional techniques. Why is it important: Pushes the current SoTA of the networks towards sustainability.
Problem / Solution	Problem: Increase energy and data efficiency, and pushes the current SoTA of the networks towards sustainability. Solution: Intelligently reduce the amount of data transferred in the network.
Value Proposition	Increase energy and data efficiency.
Target Audience	Industry & Public sector (Interesting technology for any stakeholder trying to reduce network traffic and/or improve energy efficiency in communication/networking tasks.)
Early Adopters / End Users	Researchers
Exploitation Type	Commercial
Methods, Tools & Activities	Novel semantic communications framework based on AI and conventional techniques. Timeline: - M1-M24: Development and Refinement - M24-M36: Identification of key stakeholders - M36+: Market analysis
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER11	**NANCY Explainable AI Toolbox**
Owner / Contributor	MINDS (SID and INNO)
Category of Result	KER10 - An explainable AI Framework – MINDS
Type of Result	Models and Algorithms
Short Description	"NANCY Explainable AI Toolbox" presents the overall architecture, functionalities and components of the explainable Artificial Intelligence (XAI) Toolbox. It provides an overview of the methodologies and tools that support transparency and interpretability for decision-making beyond 5G (B5G)

	network functions. The main components of the NANCY XAI Toolbox (https://github.com/Sidroco-Holdings-Ltd/NANCY_Explainable_AI_Toolbox) are (i) the anomaly detection XAI Component, (ii) the outage prediction XAI Component and (iii) the semantic communications XAI Component. Furthermore, the deliverable presents the implementation of the centralised XAI dashboard, which provides access to global and local model explanations through visual and interactive interfaces.

The integration of a Large Language Model (LLM)-Powered Analysis Component is introduced as a Dashboard's sub-component, which facilitates the transformation of technical outputs into natural language for better usability by non-experts. Additionally, the deliverable provides a comprehensive description of the optimisation strategies that support stability and scalability. Overall, this deliverable contributes towards a trustworthy and understandable AI, addressing the needs of end-users in network management. |
| **Problem / Solution** | Problem: The low clarity and understandability of AI-enabled components' decisions pose significant challenges in various domains. When AI systems make decisions, especially in complex tasks or critical contexts, the lack of clarity can impede trust, comprehension, and accountability. This opacity may stem from the intricate inner workings of deep learning models, the black-box nature of certain algorithms, or the absence of transparent decision-making processes. The integration of plain language is essential for decision-making using explainability reports.

Solution: The aforementioned problem can be addressed by providing easy-to-understand visualisation of the main findings and insights of the XAI algorithms in order non-expert personnel to be able to benefit from them, integrating plain language explanations. |
Value Proposition	Increase energy and data efficiency.
Target Audience	Industry
Early Adopters / End Users	Not reported
Exploitation Type	Commercial
Methods, Tools & Activities	1. Thorough Analysis of the needs of the market / 2. First Results published / 3. Collaboration with project partners leveraging their expertise and experience / 4. Possible IPR Protection / 5. Dissemination and Improvements / 6. Long-term market launch

Timeline:
1. M01-M36 / 2. M09-M12 / 3. M01-M36 / 4. M27-after / 5. M27-36 / 6. M36-after |
| **IPR (Background / Foreground)** | No |
| **Exclusive Ownership** | No. MINDS, SID, INNO |

MINDS implementation:
(i) the anomaly detection XAI Component
(ii) the outage prediction XAI Component
(iii) LLMs functionalities
SID implementation:
(i) the XAI dashboard with LLM integration
INNO implementation:
(iii) the semantic communications XAI Component

ER12	Anomaly Detection and Self Healing via Federated Learning
Owner / Contributor	CRAT
Category of Result	KER11 - Next-generation SDN-enabled MEC for autonomous anomaly detection, self-healing and self-recovery
Type of Result	Models and Algorithms
Short Description	Main features: Anomaly Detection in 5G and Beyond radio access networks, core network and MEC, proactive and reactive Self Healing and Recovery to restore QoS levels, federated learning architecture to preserve users' privacy and operators' data. Objectives: Provide an automatic framework that detects anomalies (with possible anomaly diagnosis), provides an automatic response or proactively monitors QoS/QoE levels to adapt network configuration or to perform load balancing among edge servers. Advantages: One of the key strengths of this approach lies in its ability to preserve privacy by design. By leveraging federated learning, the system ensures that raw user or operator data never leaves its source, mitigating regulatory risks and fostering trust among stakeholders. At the same time, it enables a high degree of generalisation, as local models benefit from diverse operational conditions without requiring centralised data aggregation. The architecture is inherently scalable and suited for geographically distributed deployments, as it avoids single points of failure or bottlenecks. Furthermore, the system responds in real time, enabling swift identification and resolution of issues as they arise. Its adaptability to both routine fluctuations and rare faults enhances the network's resilience and positions it for long-term sustainability in increasingly dynamic environments. What is new: This approach uniquely integrates federated anomaly detection with closed-loop self-healing at both the RAN and edge layers. It combines proactive QoS monitoring with AI-driven corrective actions, embedding intelligence into the infrastructure while maintaining strict data boundaries between stakeholders. Why is it important: As 5G networks grow in complexity and edge computing becomes central to service delivery, traditional monitoring systems fall short. Manual fault management is no longer viable at scale. This framework

	addresses a critical need for autonomy and adaptability, ensuring networks can self-manage and evolve without compromising privacy or reliability.
Problem / Solution	Problem: The proposed output addresses the growing need for automated, real-time monitoring and management of network and edge computing infrastructures. It detects anomalies affecting QoS and QoE, either at the RAN, core, or edge level, and triggers proactive or reactive self-healing mechanisms. The system minimises downtime, reduces the need for manual intervention, and maintains service continuity, even under dynamic or unpredictable conditions. By integrating federated learning, it also ensures privacy while enabling distributed intelligence, making it suitable for large-scale, privacy-sensitive telecom environments. Solution: CRAT plans to address this problem by developing a federated learning-based framework that enables distributed anomaly detection and self-healing across network and edge layers. The system continuously monitors QoS and QoE metrics, detects deviations from expected behaviour, and triggers appropriate recovery actions—either reactively, after a fault, or proactively, based on predicted degradations. By training models locally and sharing only model updates, CRAT preserves data privacy while still enabling collaborative learning. The solution is designed to be modular, scalable, and adaptable to diverse deployment environments and operator-specific requirements.
Value Proposition	The solution reduces operational expenditures (OPEX) by minimising manual interventions, improves user experience by ensuring uninterrupted service, and enhances resilience in increasingly complex, decentralised network topologies. By using federated learning, it also guarantees regulatory compliance and data confidentiality, which are critical concerns for telecom providers.
Target Audience	Researchers
Early Adopters / End Users	As CRAT is a consortium with the University of Rome "La Sapienza", Politechnic University of Bari, University of Sannio, Thales Alenia Space Italy and TopNetwork, CRAT has established relationships both with academia and industry. Some researchers of the aforementioned Universities are preliminarily interested in the results to be used for publications and future research projects
Exploitation Type	Non-Commercial
Methods, Tools & Activities	CRAT will adopt a combination of AI/ML-based anomaly detection, federated learning techniques, and QoS/QoE monitoring methods. Tools will include simulation environments (e.g., NS-3, Mininet), edge computing platforms (e.g., OpenNESS, Kubernetes), and FL frameworks (e.g., TensorFlow Federated, Flower). Key activities involve model development, network emulation, privacy assessment, integration with self-healing modules, and validation in real-world-like testbeds. Timeline: M1–M6: Requirements analysis, use case definition, testbed design M6–M12: Baseline anomaly detection and QoS/QoE monitoring model development

	M12–M18: Federated learning framework implementation and integration
	M18–M24: Development of proactive and reactive self-healing modules
	M24–M30: System validation, fine-tuning, and scalability testing
	M30–M36: Demonstration in pilot deployments, preparation for exploitation (e.g., technical documentation, standardisation contributions, stakeholder
IPR (Background / Foreground)	Foreground (Patent)
Exclusive Ownership	Yes

ER13	Virtio-based cross-world transport layer
Owner / Contributor	VOS
Category of Result	KER12 - A novel security and privacy toolbox
Type of Result	Technological Solutions
Short Description	Main features: Virtio transport layer that allows configuring virtio backend and frontend in different worlds of a TrustZone-enabled ARM system. For instance, this result would enable running the backend of a virtio device in the secure world while the frontend is in the non-secure world.

Objectives: Provide extreme flexibility when the execution of multiple operating systems on the same platform is required. In these cases, the multiplexing of physical resources must be performed in an extremely efficient way, and this result is a key component to achieving that.

Advantages: This virtio-based transport layer does not rely on a type-1 or type-2 hypervisor, thus involving less virtualisation overhead, making it suitable for embedded use-cases where careful handling of the available resources is needed. Additionally, this technology can have a great impact on all those systems that do not have multiple independent video/graphic pipelines. With the virtio-based cross-world transport layer, it is possible to allow the two worlds to render to the same screen, keeping the contact surface as narrow as possible.

What is new: The specific way in which virtio is used in a non-virtualised environment

Why is it important: Paired with VOSyS' VOSySmontior partitioning technology, it can constitute the foundation for software stacks in various embedded market segments as an alternative to highly priced and locked-in commercial solutions. |
| **Problem / Solution** | Problem: Nowadays, there are not so many options when it comes to realising a software stack where multiple operating systems are co-intelligently reducing the amount of data transferred in the network, executing on the same platform, most of the time with addressing tasks of diverse criticalities. In these cases, the company, usually the system integrator, is forced to look at very expensive virtualisation solutions that come already with a variety of black-box software and tools that are |

	effectively locking in the implementor. For this reason, the software stack will be designed around the purchased virtualisation solution, instead of being tailored specifically to one use case. The virtio-based technology with VOS' VOSySmonitor would offer a more flexible alternative, made even more appealing by the extremely flexible business model that can adapt to the interested customers. Solution: VOS will provide development services to tailor its technologies around the specific needs of the customer, with the final objective of providing what the customer needs instead of an all-inclusive, black-box solution.
Value Proposition	This result enables the implementation of powerful software stacks for ARM systems featuring the TrustZone extension that can rely on different operating systems to address tasks of diverse criticalities, all sharing a set of resources in an efficient way.
Target Audience	Industry (Industrial stakeholders can benefit from this exploitable result to realise commercial software stacks)
Early Adopters / End Users	In the second half of 2025, the pool of possible stakeholders has increased due to some new developments on VOS' virito-based transport layer. Specifically, VOS was successful in running virtio-gpu on top of virtio-loopback, unlocking interesting new possibilities and stakeholders for the virtio-based transport layer.
Exploitation Type	Commercial
Methods, Tools & Activities	Partnerships and Collaborations: VOS has started some discussions with possible industrial partners that are willing to share the costs to be sustained to enrich the technology offer. Sales and price strategy: VOS has a flexible marketing strategy that does not enforce a specific business model, but rather tailors it to the customer.
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER14	AI-based Energy-Efficient RAN Orchestration Solution
Owner / Contributor	UBI
Category of Result	KER12 - A novel security and privacy toolbox
Type of Result	Technological Solutions
Short Description	Main features: - Utilises artificial intelligence algorithms for efficient radio access network (RAN) orchestration. - Enhances security and privacy measures within RAN operations. - Targets both public and private sectors for implementation.

	Objectives: - Reinforce UBITECH's portfolio by leveraging acquired knowledge and technological advancements. - Increase competitiveness in the market, particularly in the domains of AI, cybersecurity, and radio access networks. - Identify opportunities for technology transfer and future collaborations with industrial partners. Advantages: - Increases competitiveness by offering cutting-edge AI-based solutions. - Enhances efficiency and reduces energy consumption in RAN orchestration. - Strengthens security and privacy measures, ensuring robust network operations. - Facilitates technology transfer and future collaborations with industrial partners. What is new: - Integration of artificial intelligence into RAN orchestration for energy efficiency. - Focus on improving security and privacy within RAN operations. - Emphasis on collaboration and technology transfer opportunities with industrial partners. Why is it important: - Addresses the growing demand for energy-efficient solutions in telecommunications. - Mitigates security and privacy risks in radio access network operations. - Enhances UBITECH's competitiveness in the market and fosters future collaborations with industry partners.
Problem / Solution	Problem: - Energy Inefficiency: Traditional radio access network (RAN) orchestration methods may lead to inefficiencies in energy usage, contributing to increased operational costs and environmental impact. The AI-based solution seeks to optimise energy consumption, reducing both costs and environmental footprint. - Security and Privacy Concerns: With the increasing complexity of telecommunications networks, ensuring robust security and privacy measures is crucial. The solution integrates advanced security and privacy features to mitigate risks associated with unauthorised access, data breaches, and privacy violations. - Competitiveness in the Market: In a rapidly evolving technological landscape, companies need to stay ahead of the competition by offering innovative solutions. The AI-based RAN orchestration solution enhances UBITECH's competitiveness by providing cutting-edge technology that addresses critical industry challenges, such as energy efficiency and security. Solution: - Advanced Technology Integration: UBITECH can leverage its expertise in telecommunications to integrate advanced AI algorithms into the RAN orchestration process. By consuming machine learning and optimisation

techniques, the solution can dynamically adjust network parameters to maximise energy efficiency while maintaining optimal performance.
- Enhanced Security and Privacy Measures: UBITECH can integrate NANCY's robust security and privacy features into the solution, such as encryption protocols, access controls, and anomaly detection mechanisms. By implementing these measures at the service and network orchestration level, UBITECH can mitigate security risks and ensure compliance with regulatory requirements, thus safeguarding sensitive data and protecting user privacy.
- Collaboration and Technology Transfer: UBITECH can collaborate with industrial partners, vendors, manufacturers, and network operators to identify opportunities for technology transfer and future collaborations. By leveraging its extensive network and expertise, UBITECH can explore synergies with partners to enhance the scalability, interoperability, and commercial viability of the solution, thereby accelerating its adoption in the market.
- Customisation and Tailored Solutions: UBITECH can offer customizable solutions tailored to the specific needs and requirements of its clients in both the public and private sectors. By understanding the unique challenges and constraints faced by different organisations, UBITECH can tailor NANCY's AI-based RAN orchestration solution to optimise energy efficiency, enhance security, and improve overall network performance, thus delivering maximum value to its clients.

Value Proposition	- Provides an advanced solution for optimising energy efficiency in RAN orchestration. - Enhances security and privacy measures, addressing critical concerns in network operations. - Offers a competitive advantage to UBITECH and its partners in the public and private sectors.
Target Audience	Industry
Early Adopters / End Users	Other HEU projects
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Partnerships and Collaborations
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER15	Smart Contract Creator
Owner / Contributor	DRAXIS
Category of Result	OER1 - Smart Contract Creator
Type of Result	Technological Solutions
Short Description	Main features: Automation in creating, compiling, simulating and deploying a Smart Contract (SC).

	Objectives: To develop a software component for addressing the above (under the scope of the NANCY project) Value proposition: The value proposition of a smart contract lies in its ability to automate and enforce the execution of an agreement or contract without the need for intermediaries. Advantages: The smart contracts will enable the secure relay of data among users while limiting data access only to the authorised user(s). What is new: The smart contract will be used to explain the radio access network (RAN) users' needs and to enforce the service level agreement (SLA). Why is it important: To help promote and build confidence in open markets, NANCY will incorporate blockchain and smart contract technologies into the O-RAN medium access control (MAC) layer, which provides immutable and permanent records that can be audited by interested parties.
Problem / Solution	Problem: 1. Automation and Efficiency: Smart contracts eliminate the need for intermediaries and streamline the contract execution process, reducing delays, errors, and manual processes involved in traditional agreements. 2. Trust and Transparency: Smart contracts operate on decentralised blockchain platforms, ensuring transparency and immutability. All parties involved can verify and trust the terms and conditions encoded in the contract, reducing the risk of disputes." Solution: By using Docker container technology for creating, compiling, simulating, deploying and monitoring the smart contracts. In the context of automation, Docker containers can be used to create self-contained and isolated environments for running automated tests or processes. These containers can be easily created, updated, and destroyed as needed, providing a consistent and predictable environment for automation tasks.
Value Proposition	- Provides an advanced solution for optimising energy efficiency in RAN orchestration. - Enhances security and privacy measures, addressing critical concerns in network operations. - Offers a competitive advantage to UBITECH and its partners in the public and private sectors.
Target Audience	Private sector
Early Adopters / End Users	Not-reported
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Partnerships and Collaborations & Continuous Monitoring and Improvement
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER16	Machine learning models for decision-making
Owner / Contributor	Bi2S (UMU and IJS)
Category of Result	OER2 - Machine learning models for decision-making
Type of Result	Models and algorithms
Short Description	Main features: AI training framework, novel AI model architecture, Deep Neural Network models, machine learning algorithms, and innovative reinforcement learning approach. Objectives: To improve the State-of-the-art in the corresponding domains, to increase the efficiency of ML models, and to achieve near-optimal performance in computational offloading tasks in next generation 5G/6G networks. Advantages: Real-time service migration. Beyond SotA policy selection for computational offloading tasks. Consideration of multiple factors for the decision-making process. Reduced AI model training time. What is new: Existing AI models/methodologies consider only a few factors to perform policy optimisation for computation offloading. NANCY's machine learning models consider a significant amount of parameters to do so, and thus, they manage to properly select the optimal policies. To accomplish this, SotA reinforcement learning AI techniques are leveraged, and novel AI training methods are employed. Why is it important: This exploitable result does not only advances the state-of-the-art of the AI models for computational offloading, but also provides a real solution for next generation 5G/6G networks. The algorithms are designed to achieve near-optimal performance in real-world scenarios with real-world data.
Problem / Solution	Problem: Telecommunication service providers: NANCY's "Machine learning models for decision-making" solve the issues of computational offloading in Edge ecosystems. The main problem is the optimal use of Edge computational resources that maximise the Quality of Service and reduce the computational complexity for each end user. Telecommunication Infrastructure providers: The main problem that NANCY's "Machine learning models for decision-making" solves is the reduction of computational resources required for AI model training." Solution: The proposed "Machine learning models for decision-making" adopts novel approaches to optimise the computational resource utilisation of the Edge with respect to the Quality of Service of the network. To achieve this, NANCY employs an AI approach which makes on-the-fly decisions on what type of services to offload to the Edge of the network. This decision-making process is conducted while taking into account several network parameters. A novel machine learning training framework guarantees the minimisation of computational requirements of the models during the AI training process.

Value Proposition	Increased Quality of Service within the network, increased computational distribution between Cloud and Edge, Real-time adaptation, computational offloading provisioning under diverse operating scenarios.
Target Audience	Industry
Early Adopters / End Users	Bi2S has initiated contact with partners from the Industry (telecommunications and Cloud providers) in order to formulate the requirements for the machine learning models. Through this process (bilateral online calls and email exchange), Bi2S has gathered information on what type of data should the components use, how much resources should utilise, how fast should the decision-making process be conducted, what is an acceptable machine learning accuracy score in commercial applications, what are the specific needs for these sectors and what type of solutions/algorithms are being used to address those needs at the moment.
Exploitation Type	Commercial
Methods, Tools & Activities	Solution (continuous development), Partnerships, Market analysis. Timeline: - M18-M22: Market analysis - M19-M36: Forging partnerships - M18-M36: Continuous development - M36-3 years after NANCY ends: Continuous development / Continuous integration
IPR (Background / Foreground)	Background (Reinforcement learning AI models and AI training framework.)
Exclusive Ownership	No. UMU and IJS, as WP Leaders, are also contributing to this result as it is part of larger components of the NANCY architecture. UMU and IJS provide data and develop guidelines on how smaller software components should communicate and coordinate with each other.

ER17	Marketplace
Owner / Contributor	TECNALIA (NEC)
Category of Result	OER3 - Marketplace
Type of Result	Technological Solutions
Short Description	The main objective of the marketplace is to provide an accessible platform for users to access 5G resources anytime and anywhere. Marketplace publishes a list of service providers together with services they can provide (with given performance indicators), plus minimum and maximum prices (for said services and indicators), plus the service providers' reputation. This platform is able to register all requests from different operators, both to publish or request resources and generate an SLA before establishing the contract. After signing the contract, the marketplace supports the management of these contracts between providers and consumers.
Problem / Solution	Problem:

	To obtain in a single point all the offers from different operators and support the process to agree on the signing of the contracts. Solution: Create a central platform based on blockchain technology that facilitates the requests (publish or request) from different operators.
Value Proposition	The decentralised, blockchain-based marketplace enables operators to register, discover, and select high-quality workload offloading services without intermediaries. This empowers service providers to offer scalable, reliable solutions while giving operators seamless access to verified, optimised services—driving innovation and efficiency in distributed computing.
Target Audience	Industry
Early Adopters / End Users	Other research projects and telecommunications operators
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Result refinement and partnerships, and collaboration. Timeline: - M30-M36 Refinement based on UOWM testbed. - After the end of the project: Partnerships and collaboration
IPR (Background / Foreground)	Background (Previous knowledge on Blockchain) Foreground (Copyright)
Exclusive Ownership	No. In order to use this Market place is required to use a BC infrastructure. In this project, this infrastructure is provided by NEC.

ER18	MultiRAT-Nomadic Connectivity Provider
Owner / Contributor	UMU
Category of Result	OER4 - MultiRAT-Nomadic Connectivity Provider
Type of Result	Technological Solutions
Short Description	Main features: Portable device providing dynamic access to the 5G infrastructure. Objectives: Extend 5G connectivity through 5G and non-5G access technologies. Advantages: Any device with or without a 5G interface will access the 5G infrastructure. What is new: MultiRAT extension of 5G coverage. Why is it important: applicable in different verticals: IoT, vehicular communications, smart cities, etc.
Problem / Solution	Problem: Limited 5G coverage in certain scenarios. Solution:

	The device will provide connectivity through different radio interfaces to offer access to the 5G infrastructure
Value Proposition	A low-cost and portable device will provide extended coverage for a 5G network.
Target Audience	Researchers
Early Adopters / End Users	Integration and use of the implemented asset in the research activities of our research group.
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Result refinement, Partnerships and Collaborations, and Continuous monitoring and improvement. Timeline: M12-M24: Result refinement M12-M36: Partnerships and Collaborations M24-M36: Continuous monitoring and improvement
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER19	**Micro-Operator Deployment for Network Coverage Expansion**
Owner / Contributor	UOWM
Category of Result	OER5 - Micro-Operator Deployment for Network Coverage Expansion
Type of Result	Other (Testbed)
Short Description	Main features: The testbed leverages Ettus Research USRP devices to deploy 5G base stations. The srsRAN software is used to manage the USRP devices, while the Open5GS software provides 5G Core Network functionalities. Moreover, the near-real-time RAN intelligent controller from the O-RAN Software Community is deployed to manage the RAN. The testbed is fully compliant with the Open-RAN specifications. Objectives: The testbed aims to investigate scenarios where small-scale operators (i.e., micro-operators) can deploy 5G base stations to serve the particular needs of their consumers, while also serving as neutral hosts for the other operators' customers. Advantages/What is new: Apart from extending network coverage, services such as cyberattack detection can be added, serving as an extra security layer. Moreover, offloading of services (e.g., a video streaming service) from the main operator to the micro operator can be realised, thereby reducing the consumption and load of the main operator. Why is it important: The testbed investigates a new paradigm, where services among different large-scale and small-scale operators can be exchanged through an inter-operator marketplace.

Problem / Solution	Problem: Network densification is a key approach to satisfy the increasing requirements of future mobile networks in terms of network capacity and coverage. However, the network densification (e.g., deployment of additional base stations) can increase the capital and operating expenses of the operators, while the respective return on investment may be low. Solution: The neutral hosting paradigm can alleviate the required expenses and provide increased network capacity and coverage. In this respect, the testbed investigates a scenario where a micro-operator can expand the network coverage and also provide extra services in order to alleviate the large-scale operators' load.
Value Proposition	The aforementioned scenarios can potentially lead to new business models, both for the large-scale operators and small-scale operators.
Target Audience	Researchers and Industry
Early Adopters / End Users	Through its participation in European and national research projects, UOWM has built relationships with other universities, research institutions, SMEs, and industrial organisations. The testbed can be utilised by the NANCY consortium partners, as well as external stakeholders.
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Timeline: M30-M36+: Result refinement, Partnerships and Collaborations, and Continuous Monitoring and Improvement
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER20	Exploitation of Blockchain technology powered by AI/ML algorithms in the field of 5G and Edge computing
Owner / Contributor	OTE
Category of Result	OER6 - Exploitation of Blockchain technology powered by AI/ML algorithms in the field of 5G and Edge computing
Type of Result	Technological Solutions
Short Description	Main features: Artificial Intelligence, Machine Learning, Blockchain Objectives: Integration of blockchain and AI/ML algorithms in 5G networks and beyond. Advantages: The integration of these technologies will support the development of new services and business models, positioning OTE at the forefront of next-generation network transformation. What is new: B-RAN.

	Why is it important: OTE's exploitation goal aims to demonstrate how blockchain and B-RAN architecture have the ability to drive innovation in B5G mobile networks by enabling dynamic network scalability, while simultaneously enhancing trust, security, and privacy.
Problem / Solution	Problem: By leveraging blockchain, network decentralisation is enhanced in parallel with trust and security. Moreover, AI/ML algorithms enable intelligent, real-time orchestration, optimising resource allocation and improving energy efficiency. Solution: Enhancing security and trust, protecting data and resources.
Value Proposition	OTE aims to exploit the outcomes of the NANCY project by integrating blockchain powered by AI/ML algorithms into 5G and edge computing environments, with a focus on evaluating their efficiency and by testing overall network performance.
Target Audience	Not reported
Early Adopters / End Users	Not reported
Exploitation Type	Commercial
Methods, Tools & Activities	Not reported
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER21	Throughput Forecasting Service
Owner / Contributor	CERTH
Category of Result	OER7 - Throughput Forecasting Service
Type of Result	Models and algorithms
Short Description	Main features: Advanced predictive analytics algorithms that analyse historical data, current trends to accurately forecast throughput in a 5G network. Objectives: Enhance overall operational efficiency, reduce downtime, and boost resource allocation. Advantages: Ensuring adaptability in nowadays fast-paced environment of wireless networks. The service is vital for stakeholders who seek to streamline operations, reduce costs, and enhance overall productivity. What is new: Proactive decision-making. Why is it important: Allowing for the allocation of resources efficiently.

Problem / Solution	Problem: Low QoS of the system. Solution: Enhancing QoS by predicting Throughput in a 5G Network. In particular, tracking an optimal path, considering various user activities such as walking, driving, etc.
Value Proposition	Improve Performance via Accurate Forecasting.
Target Audience	Industry (Telecom vendors can benefit significantly from the throughput forecasting service, providing assistance with spectrum management and network design. IoT operators and smart cities can optimise their infrastructure to satisfy connectivity demands. In addition, the throughput forecasting service can be utilised by corporations to establish their private networks and streamline their supply chains. Moreover, throughput forecasting services guarantee dependable and quick connectivity for all customers, allowing end users to enjoy higher-quality services.)
Early Adopters / End Users	Potential early adopters include telecommunications providers, mobile network operators, as well as academia and research institutions.
Exploitation Type	Non-Commercial
Methods, Tools & Activities	Relative to Throughput, CERTH will also continue to refine model accuracy through expanded datasets to support operational decision-making by highlighting the drivers behind high-risk and performance degradation events. Throughput predictions have been and will also be directly connected to network operation tools, allowing the promotion of proactive interventions while testing performance in Open RAN scenarios. These activities have also been based on the expected TRL of the totality of NANCY tools. CERTH has monitored and systematically assessed market trends and conditions; moreover, CERTH's research efforts will continue, potentially leading to market launch, given an appropriate legal form. Having initially defined a) Qualcomm and Nokia Bells, b) Hewlett Packard, c) Nokia, and d) Huawei as key service providers, the market analysis will continue based on the piloting results beyond the end of the project, and an updated view of the provider ecosystem will be built to ensure ongoing model relevance.
IPR (Background / Foreground)	Background (The predictive analytics and forecasting framework has been developed in the course of previous research activities under different domains focused on crime risk projection. This framework has been extended and adapted properly to cover different needs, such as cyberattack prediction. In NANCY, this framework will be used, and it will be adapted properly to cover the needs of the project. It is protected by Copyright.)
Exclusive Ownership	Yes

ER22	Smart Pricing Policies
Owner / Contributor	8BELLS
Category of Result	OER8 - Smart Pricing Policies

Type of Result	Models and algorithms
Short Description	Main features: A smart pricing module integrated into NANCY's architecture. Objectives: To dynamically determine optimal pricing for provided services. Advantages: Optimised and dynamic pricing. What is new: Integrating auction and game theoretic methods into the pricing model. Why is it important: Creation of new monetary incentives for providers and users.
Problem / Solution	Problem: The shift toward decentralised B5G/6G networks creates environments where multiple providers must share resources dynamically, but existing pricing models cannot keep up with rapid fluctuations in demand. Static or centrally controlled pricing leads to inefficiencies, unfairness, and bottlenecks, especially when many independent actors are competing to offer similar services. Solution: The problem is addressed by implementing smart pricing schemes that introduce financial incentives for UEs and providers. These mechanisms promote dynamic cooperation and resource sharing across different network operators.
Value Proposition	The determined price is tailored to the specific service, aiming to maximise revenue while minimising potential profit loss.
Target Audience	Private sector and Researchers
Early Adopters / End Users	• Mobile Network Operators • Private Network Operators • Research Testbeds • Researchers
Exploitation Type	Commercial
Methods, Tools & Activities	Detailed Market Analysis, Intellectual Property Protection, Continuous Monitoring and Improvement. Timeline: - M11-M36: Detailed Market Analysis. - M11-M36: Continuous Monitoring and Improvement.
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER23	Big Data Platform for self-healing and self-recovery
Owner / Contributor	TEI
Category of Result	OER9 - Big Data Platform for self-healing and self-recovery

Type of Result	Models and algorithms and Skills and know-how
Short Description	Main features: Management of the data needed by self healing and self recovery algorithms. Objectives: Implement the necessary big data management mechanisms to allow to scale up to extreme data volumes. Advantages: Improve reliability and availability of 5G networks. What is new: A multi-broker approach to implement federated learning algorithms. Why is it important: To improve the availability of Service Level Objectives.
Problem / Solution	Problem: Ensure the robustness and reliability of the 5G network. Solution: Implementing a Big Data Platform for self-healing and self-recovery utilising advanced technologies and techniques, scaling up to extreme data volumes.
Value Proposition	Ensure the management of a large amount of data to improve the network with self-healing techniques.
Target Audience	Industry / Telecom Operator
Early Adopters / End Users	A big data platform in 5G network node management will be evaluated to be integrated in a commercial solution, so it is too early to propose a prototype to telecom operators early adopters.
Exploitation Type	Commercial
Methods, Tools & Activities	Not reported
IPR (Background / Foreground)	No
Exclusive Ownership	Yes

ER24	A framework for data and concept drift detection in 6G networks
Owner / Contributor	Bi2S (UMU, IJS)
Category of Result	OER10 - A framework for data and concept drift detection in 6G networks
Type of Result	Models and algorithms
Short Description	Main features: End-to-end machine learning pipeline, data processing components, and machine learning algorithms. Objectives: To improve the State-of-the-art in the corresponding domains, to increase the efficiency of ML models, to achieve near-optimal performance in data/concept drift detection tasks, in next generation 6G networks.

	Advantages: Real-time decision-making on whether an AI model should be retrained or not. Beyond SotA performance. Consideration of multiple factors for the decision-making process. Reduced AI model training time. What is new: Existing methodologies consider only a few factors to assess whether an AI model should be retrained or not, given new input data. NANCY's data drift and concept drift detectors employ a complex yet highly computationally efficient mechanism to integrate several parameters into the mix. This highly increases the assessment accuracy and perfectly situates the result under investigation to be used in production environments. Why is it important: This exploitable result does not only advances the state-of-the-art of the AI models for data drift and concept drift detection, but also provides a real solution for next generation 5G/6G networks. The algorithms are designed to achieve near-optimal performance in real-world scenarios with real-world data.
Problem / Solution	Problem: Telecommunication service providers: NANCY's "Machine learning models for time series prediction" solves the issues of data offloading in Edge ecosystems. The main problem is the optimal use of Edge storage resources that maximise the Quality of Service and minimise latency for each end user. Telecommunication Infrastructure providers: The main problem that NANCY's "Machine learning models for time series prediction" solves is the reduction of computational resources required for AI model training. Also, they optimise the Edge storage resource utilisation efficiency. Solution: The proposed data/drift detection models introduce two unsupervised methods that use model-agnostic batch concept drift detectors. Both methods compute an expected-utility score to decide when concept drift occurred and if model retraining is warranted, without requiring ground-truth labels after deployment. We validated our approach using real-world datasets, stemming from NANCY's data repositories.
Value Proposition	Increased Quality of Service within the network, high energy efficiency when AI models are retrained, real-time adaptation, increased AI model quality, and framework generalisability to other verticals.
Target Audience	Industry
Early Adopters / End Users	Bi2S has initiated contact with partners from the Industry (telecommunications and Cloud providers) in order to formulate the requirements for the machine learning models. Through this process (bilateral online calls and email exchange), Bi2S has gathered information on what type of data should the components use, how much resources should utilise, how fast should the decision-making process be conducted, what is an acceptable machine learning accuracy score in commercial applications, what are the specific needs for these sectors and what type of solutions/algorithms are being used to address those needs at the moment.
Exploitation Type	Commercial

Methods, Tools & Activities	Solution (continuous development), Partnerships, Market analysis. Timeline: - M18-M22: Market analysis - M19-M36: Forging partnerships - M18-M36: Continuous development - M36-3 years after NANCY ends: Continuous development / Continuous integration
IPR (Background / Foreground)	Background (Reinforcement learning AI models and AI training framework.)
Exclusive Ownership	No. UMU and IJS, as WP Leaders, are also contributing to this result as it is part of larger components of the NANCY architecture. UMU and IJS provide data and develop guidelines on how smaller software components should communicate and coordinate with each other.

ER25	Multi-hop V2X solution for coverage extension
Owner / Contributor	EHU (UMU and IJS)
Category of Result	OER11 - Multi-hop V2X solution for coverage extension
Type of Result	Technological Solutions
Short Description	It implements a multi-hop network based on C-V2X technologies, with the objective of providing connectivity in remote areas or disaster zones in a flexible and fast way. Each node in the multi-hop network is implemented by a drone carrying a C-V2X module to transmit traffic. The solution supports the transmission of any application traffic and traffic routing by means of a Layer 2 retransmission mechanism. It allows container-based application deployment through the Slice Manager. The solution supports data rates up to 5 Mbps. The main advantages of this solution are: (1) the capacity to reach long coverage areas, thanks to the extended coverage of the C-V2X modules with reduced weight and low energy consumption. This allows for the nodes to be easily deployed using drones. (2) The capacity to transmit any type of application data (not limited to V2X messages). (3) The flexibility to deploy containerised applications in any of the nodes through the Maestro framework.
Problem / Solution	Problem: Lack of coverage in remote areas or in case of disaster, where no network infrastructure is available. Solution: The solution is based on the use of drones to provide connectivity on demand in an agile and fast way, without the need to deploy infrastructure. Each drone is equipped with a V2X module that enables extensive coverage with reduced weight and low power consumption. The solution includes a level 2 multi-hop routing mechanism for establishing routes between drones.

Value Proposition	1. The capacity to reach long coverage areas, thanks to the extended coverage of the C-V2X modules with reduced weight and low energy consumption. This allows for the nodes to be easily deployed using drones. 2. The capacity to transmit any type of application data (not limited to V2X messages). 3. The flexibility to deploy containerised applications in any of the nodes through the Maestro framework.
Target Audience	Researchers
Early Adopters / End Users	Not reported
Exploitation Type	Non-Commercial
Methods, Tools & Activities	This exploitable result was developed within the project up to a prototype implementation in order to showcase its potential. EHU will continue to refine and improve it after the project ends. It will be exploited in further research projects as a knowledge asset and also in scientific publications. Timeline: - M30-M36: finish development, prototype implementation and showcasing. - After the end of the project: Partnerships and collaborations.
IPR (Background / Foreground)	Not reported
Exclusive Ownership	No. UMU and IJS, as WP Leaders, are also contributing to this result as it is part of larger components of the NANCY architecture. UMU and IJS provide data and develop guidelines on how smaller software components should communicate and coordinate with each other.

ER26	Multi-hop 5G solution for coverage extension
Owner / Contributor	EHU (UMU and IJS)
Category of Result	OER12 - Multi-hop 5G solution for coverage extension
Type of Result	Technological Solutions
Short Description	It implements a multi-hop network based on 5G, where each node implements a whole 5G Core. The objective is to extend 5G coverage to underserved areas, guaranteeing the high throughput provided by 5G technologies. Each of the nodes in the multi-hop solution includes a significant amount of hardware and computing resources, which cannot be onboarded in conventional drones. Therefore, nodes should be deployed statically, either using cars, boats, street furniture, hot air balloons, etc. The solution provides higher throughput than the Multi-hop V2X solution for coverage extension, but at the expense of higher energy consumption and computing resources. The solution allows container-based application deployment through the Maestro framework. The main advantages of this solution are: (1) Capacity to provide 5G network connectivity in underserved areas. (2) Support for high data throughput. (3)

	Flexibility to deploy containerised applications in any of the nodes through the maestro framework.
Problem / Solution	Problem: Extension of 5G coverage to specific underserved points with high throughput requirements. Solution: Implementation of a multi-hop 5G network solution, where each node implements a whole 5G-Core.
Value Proposition	1. Capacity to provide 5G network connectivity in underserved areas. 2. Support for high data throughput. 3. Flexibility to deploy containerised applications in any of the nodes through the Maestro framework.
Target Audience	Researchers
Early Adopters / End Users	Not reported
Exploitation Type	Non-Commercial
Methods, Tools & Activities	This exploitable result will be developed within the project up to a prototype implementation in order to showcase its potential. We will continue to refine and improve it after the project ends. It will be exploited in further research projects as a knowledge asset and also in scientific publications. Timeline: - M30-M36: finish development, prototype implementation and showcasing. - After the end of the project: Partnerships and collaborations.
IPR (Background / Foreground)	Not reported
Exclusive Ownership	Not reported UMU and IJS, as WP Leaders, are also contributing to this result as it is part of larger components of the NANCY architecture. UMU and IJS provide data and develop guidelines on how smaller software components should communicate and coordinate with each other.

ER27	**PQC-Enabled B-RAN: System Integration Across Heterogeneous Edge Platforms**
Owner / Contributor	ITL
Category of Result	OER13 - System integration on different Edge platform architectures
Type of Result	Other (Any solutions derived from NANCY)
Short Description	Main features: Experimenting with Blockchain on O-RAN architecture together with PQC (to sign to Blockchain) at the Edge.

	Objectives: Considering that systems integration is one of ITL's core activities, Blockchain on O-RAN architecture together with PQC (to sign to Blockchain when the UE fall under the coverage of both the two different operators, thus to provide access to two different types of Edge servers, either based on Arm or Intel architecture, and even when belonging to two different operators, assuming an agreement has been signed between them) solutions, derived from NANCY could be conveyed in the integration activities performed by ITL. Advantages: The ITL testbed is presented to potential customers, enriched with features designed to facilitate resource sharing, trusted interaction, etc. What is new: Experimenting with Blockchain on O-RAN architecture together with PQC (to sign to Blockchain) at the Edge. Why is it important: protecting against Quantum attacks, future-proofing security, and considering different Edge environments.
Problem / Solution	Problem: Maintaining trust and integrity, future-proofing security, and protecting critical infrastructure. Solution: Through the validation of the NANCY technologies, B.RAN architecture and PQC to sign to Blockchain, considering different Edge environments.
Value Proposition	To enhance ITL system integration capabilities and to showcase NANCY B-RAN architecture as a new paradigm towards 6G to enable cooperative trust among separate network entities at the Edge.
Target Audience	Private sector (The outcomes of the technologies' validation tests conducted in the Italian in-lab testbed will provide useful results that can be leveraged by larger-scale experiments. This can be presented to potential customers to highlight ITALTEL's integration capabilities.)
Early Adopters / End Users	Not reported
Exploitation Type	Other (The outcomes of the technologies' validation tests conducted in the Italian in-lab testbed will provide useful results that can be leveraged by larger-scale experiments. This can be presented to potential customers to highlight ITALTEL's integration capabilities.)
Methods, Tools & Activities	Not reported
IPR (Background / Foreground)	No
Exclusive Ownership	Not reported

ER28	Central Management Domain Deployment & Orchestration
Owner / Contributor	INTRA (UBI)

Category of Result	OER14 - Central Management Domain Deployment & Orchestration
Type of Result	Technological Solutions
Short Description	Main features: A suite of technical tools to automate and simplify integration, testing, deployment and orchestration among NANCY components; Objectives: The NANCY Central Management Domain incorporates Continuous Integration and Continuous Deployment, coupled with a service Orchestrator to support the efficient central management of NANCY component deployments.
	Advantages: The main advantages are reduction in development time, simplified code management, automated testing, improved orchestration and deployment. In cases of bugs and failures the use of a CI/CD pipeline can lead to shorter time to recovery (MTTR) and allow easier tracking of bugs.
	What is new: Cloud service and microservice integration, security upgrades.
	Why is it important: CI/CD is important because its features allow an organisation to achieve better performance and faster operations. CI/CD has been linked with reductions to an organisation's OPEX (operational expenditures) https://www.testevolve.com/blog/benefits-of-implementing-a-cicd-pipeline.
Problem / Solution	Problem: Reduction of operational expenditures, Resource utilisation optimisation and faster time-to-fix/time-to-recovery in case of a bug or incident.
	Solution: CI/CD automates testing, makes it easier to manage code versions, and in general streamlines code delivery to be faster, more efficient and less error prone
Value Proposition	The INTRA CI/CD pipeline is used to help organisations consistently deliver code that meets high quality standards. UBI's Maestro service orchestrator deals with the deployment and orchestration of services. The Orchestration and CI/CD system services are hosted in the central NANCY Kubernetes cluster, which serves a dual purpose: (a)To establish a common development and testing environment for containerized NANCY components, aiming to verify their functionalities and ensure integration among various components and services prior to deployment in operational settings (separate Kubernetes clusters at NANCY testbeds/demonstrators), (b) To host NANCY Management domain services, which include as mentioned above orchestration services that are accessible across different operational environments via secure VPN tunnels. The CI/CD Platform provides DevOps automation capabilities through the configuration of software build, testing and deployment pipelines for the different NANCY components and services. The NANCY CI/CD system is connected to the central NANCY Kubernetes cluster, supporting the development and testing of NANCY components. The CI/CD system services are also securely connected to the Kubernetes environments of the different NANCY testbeds and demonstrators to control the deployments of NANCY containerised components and services either directly through the CI server or through the Maestro service orchestrator. Maestro is a cloud-native service orchestrator designed to manage the

	lifecycle of end-to-end services across geo-distributed infrastructures. It facilitates automated deployment, scaling, and lifecycle management of microservices-based applications. Maestro integrates with Kubernetes and OpenStack environments to deploy services via containers or virtual machines. Maestro operates in environments involving Kubernetes clusters and integrates with edge and core infrastructures. It uses Kubernetes-as-a-Service (K8s-aaS) for resource orchestration. Container images and Helm charts are managed in the NANCY Harbor container registry, ensuring smooth retrieval of artefacts during deployment. Service providers onboard containerised services, which are subsequently deployed via Kubernetes.
Target Audience	Multiple types of organisations can benefit. The tools are geared towards organisations that develop, maintain and deploy code in their (or their clients') operations.
Early Adopters / End Users	As a software company, Netcompany Intrasoft offers CI/CD solutions both in research projects and as a commercial offering
Exploitation Type	Commercial
Methods, Tools & Activities	Detailed market analysis, a technical roadmap of new AI-driven features, an effective marketing campaign, and proof of concept demonstrations to potential clients. Within the lifetime of the project, Netcompany will maintain the CI/CD pipeline and improve the security and performance aspects. After the end of the project, we expect to start developing additional features, such as introducing an AI architecture for code monitoring and management, along with the existing CI/CD stack.
IPR (Background / Foreground)	Background (Maestro is IP protected under copyright, but it will become open source in the future.) Foreground (In terms of the CI/CD platform, INTRA utilises copyright and trade secrets agreements.)
Exclusive Ownership	No - Netcompany SEE & EUI owns the IPR for the CI/CD pipeline, UBI owns the IPR regarding the Maestro Orchestrator. The two exploitable assets (CI/CD and Maestro) can be utilised as standalone software, but have been integrated in the NANCY Kubernetes cluster to form the Central management domain Integration, Testing, Deployment and Orchestration services

5.4. Exploitation Analysis

This section provides a strategic analysis of the project's entire portfolio of exploitable results, covering their technological categorisation, impact and value proposition, stakeholder and end user targeting, commercial and non-commercial exploitation strategies, and the underlying IPR management and ownership framework.

5.4.1.Type of Results

The project's results are evenly distributed between technological solutions and theoretical or algorithmic models.

Technological Solutions (13 Results)

This category represents **13 results** that have been developed into concrete software platforms, hardware components, or integrated systems ready for deployment or demonstration. The core infrastructure is defined by **ER1**, the project's primary architecture, supported by **ER13** and **ER14**, which provide specialised transport layers and orchestration solutions for energy-efficient network management. A strong cluster of security and operational tools includes **ER2**, **ER3**, and **ER20**, which deliver tangible products such as PQC smart cards, blockchain wallets, and AI-powered blockchain integrations. For service and application delivery, the project offers **ER8**, **ER15**, and **ER17** (Marketplace), enabling automated and decentralised service exchanges. Finally, connectivity and hardware prototypes are represented by **ER18**, **ER25**, **ER26**, and **ER28**, which provide physical and software-defined solutions for extending network coverage and managing central domains. The high number of Technological Solutions highlights the consortium's focus on prototyping and system integration. Unlike purely academic projects, NANCY has moved significantly towards commercialisation, creating functional assets that can be immediately adopted by industrial partners.

Models and Algorithms (13 Results)

Also comprising **13 results**, this category focuses on novel logic, mathematical frameworks, and artificial intelligence models that drive the technological solutions. The theoretical foundation is laid by **ER5**, **ER6**, and **ER9**, which provide the necessary modelling for B-RAN, Quantum Key Distribution, and semantic communications. The largest concentration here is on AI and Machine Learning innovation, with **ER7**, **ER10**, **ER11**, **ER12**, **ER16**, and **ER24** delivering specialised algorithms for virtualisation, explainability, anomaly detection, and concept drift in dynamic networks. Additionally, **ER4** and **ER23** combine algorithms with specialised know-how to address security and big data self-healing, while **ER21** and **ER22** offer predictive models for throughput forecasting and game-theoretic pricing. This category represents the innovation engine of the project. While these results may not always take the form of a standalone commercial product, they are the critical differentiators that power the "Technological Solutions".

Other (2 Results)

The final category contains **2 results** that serve as enablers for validation and integration rather than direct end-products. **ER19** provides a specialised laboratory testbed specifically designed for investigating inter-operator service exchanges, acting as a crucial sandbox for verifying the project's theoretical claims. **ER27** is classified as a system integration result, focusing on the capability to deploy and validate these technologies across different Edge platform architectures.

5.4.2. Impact and Value Proposition

The NANCY project delivers a comprehensive ecosystem of technological innovations designed to reshape the 5G and 6G landscape. By addressing critical challenges in network architectural flexibility, security, and intelligence, the project's 28 exploitable results offer significant value to telecom operators, vertical industries, and the research community. The impact of these results is categorised into four strategic pillars:

Next-generation architecture & orchestration (efficiency & flexibility)

At the core of the NANCY value proposition is the ability to manage complex, disaggregated networks with unprecedented efficiency and flexibility.

- **ER1** revolutionises container isolation at the kernel level. Its value lies in ensuring predictable, low-latency performance for co-hosted applications, effectively eliminating "noisy neighbour" issues in cloud-native environments.

- **ER13** and **ER27** unlock extreme flexibility and efficiency for embedded systems. ER13 provides a cost-effective alternative to expensive hypervisors by enabling secure, efficient resource sharing between different operating worlds (e.g., secure vs. non-secure) on ARM platforms.

- **ER14** and **ER7** directly target Operational Expenditure (OPEX) reduction. ER14 optimises energy consumption through intelligent orchestration, while ER7 mitigates inter-slice resource conflicts to maximise infrastructure return on investment.

- **ER28** and **ER15** streamline operations through automation. ER28 integrates CI/CD pipelines with the Maestro orchestrator to reduce the Mean Time To Recovery (MTTR) and automate deployments. ER15 removes intermediaries from Service Level Agreements (SLAs), using blockchain to automatically enforce contract terms, thereby increasing trust and reducing administrative overhead.

Future-proof security & trust (quantum & blockchain)

NANCY proactively addresses the security threats of the post-quantum era, offering a robust shield for future networks.

- **ER2**, **ER3,** and **ER4** collectively provide a "Secure-by-Design" framework. ER2 and ER4 secure identity and communications against quantum computing threats, essential for long-term government and critical infrastructure protection. ER3 combines Self-Sovereign Identity (SSI) with Post-Quantum Cryptography (PQC), offering the private sector a unique wallet solution that ensures user privacy and asset security against future attacks.

- **ER5** and **ER6** lower the barriers to adopting advanced security. ER6 allows stakeholders to estimate Quantum Key Distribution performance without expensive hardware, while ER5 reduces development costs for Blockchain-RAN deployments by providing accurate pre-deployment modelling.

- **ER20** further enhances trust by integrating AI to secure edge computing environments, enabling dynamic scalability without compromising data integrity.

Zero-touch network intelligence (AI/ML & analytics)

The project enables the transition to autonomous, "Zero-Touch" networks through a suite of advanced AI and data tools.

- **ER11** and **ER24** address the "Black Box" problem in AI. ER11 builds trust by making AI decisions transparent and understandable for network operators, while ER24 ensures long-term reliability by detecting when AI models become inaccurate due to changing data patterns (concept drift).

- **ER8**, **ER16**, and **ER23** provide the operational engine for intelligence. ER23 scales to handle extreme data volumes for self-healing, ER8 automates the lifecycle of AI models to support rapid deployment, and ER16 optimises edge offloading decisions in real-time to maximise Quality of Service (QoS).

- **ER9, ER10,** and **ER21** drive efficiency. ER10 introduces semantic strategies to intelligently reduce data traffic, while ER9 and ER21 utilise predictive analytics to forecast outages and throughput, allowing operators to proactively allocate resources and prevent downtime.

Connectivity expansion & new business models

Finally, NANCY extends the reach of 5G/6G networks and enables new monetisation strategies.

- **ER25** and **ER26** provide critical solutions for coverage extension. Using drones and static nodes, these results offer rapid, on-demand connectivity for disaster zones or underserved areas, ensuring high throughput where infrastructure is absent.

- **ER18** and **ER19** facilitate flexible access. ER18 allows non-5G devices to access 5G infrastructure, democratizing connectivity. ER19 validates "micro-operator" models, where small players can deploy base stations to serve local needs or offload traffic from major operators.

- **ER17** and **ER22** create the economic layer for these interactions. ER17 establishes a decentralised platform for trading 5G resources, while ER22 introduces game-theoretic pricing to dynamically maximise revenue for providers and incentivise resource sharing among users.

- **ER12** complements this by ensuring that, as networks expand, they remain resilient through autonomous anomaly detection and self-healing.

Together, these 28 results move beyond theoretical advancements to deliver tangible tools—ranging from hardware prototypes and secure wallets to sophisticated AI frameworks. They solve the trilemma of **efficiency** (via AI orchestration), **security** (via PQC and Blockchain), and **scalability** (via automated management and connectivity extensions), positioning the NANCY ecosystem as a vital enabler for the European 6G roadmap.

5.4.3. Stakeholder Analysis / Target Audience

Based on the Exploitation Questionnaires, the Stakeholder Analysis below categorises the project's 28 results by their target audience. The majority of results address the Industry sector, followed by Researchers and the Public Sector.

Industry & Private Sector The largest group of NANCY results is directed towards the Industry and Private Sector, comprising **21 results** in total. Based on the functional roles within the ecosystem, the Industry & Private Sector stakeholders are classified into four distinct sub-groups.

- **Telecommunications operators and infrastructure managers** are the primary target for results **ER1**, **ER5**, **ER9**, **ER14**, and **ER23**. This group utilises these core architectural frameworks, AI-based RAN orchestration tools, and Big Data platforms to optimise network energy efficiency, manage extreme data volumes, and reduce operational costs in 5G/6G deployments.

- **Network equipment vendors and technology providers** are addressed by results **ER6**, **ER7**, **ER13**, **ER21**, and **ER27**. These stakeholders leverage simulation frameworks for QKD, AI virtualisers, and virtio-based transport layers to integrate advanced functionalities into their commercial hardware and software product lines, enhancing system integration and performance forecasting.

- **Cloud, edge, and software service providers** benefit from **ER10**, **ER16**, **ER17**, **ER24**, and **ER28**. This category focuses on the software lifecycle, utilising Central Management Domains with CI/CD pipelines, explainable AI frameworks, and drift detection models to maintain service quality, alongside a 5G marketplace for direct service exchange.

- **Cybersecurity, fintech, and vertical application developers** are targeted by **ER3**, **ER4**, **ER15**, and **ER22**. These results provide specialised, high-security assets such as post-quantum cryptography wallets, secure communication models, and smart contract creators, enabling financial and vertical industries to automate agreements and secure transactions against future threats.

Researchers & Academia (8 Results) The Research community is the second most targeted group, with **8 results** aimed at advancing scientific knowledge and providing experimental frameworks. This includes **ER8** and **ER11**, which offer AI models and anomaly detection frameworks for further academic development. The project also contributes significant experimental assets, such as **ER18**, **ER19**, **ER25**, and **ER26**. Furthermore, **ER22** targets researchers alongside the private sector to explore novel pricing policies, and **ER12** is explicitly listed with researchers as a target audience.

Public Sector & Authorities (4 Results) A specialised subset of **4 results** explicitly targets the Public Sector, focusing on security, standardisation, and public infrastructure. **ER2** is a key asset for this audience, providing post-quantum cryptography solutions for national identity and security applications. Additionally, **ER5**, **ER6**, and **ER10** address public authorities by offering frameworks for secure, energy-efficient, and sustainable network deployments, often overlapping with industrial applications to support broader societal goals.

Other / Unspecified (1 Result) One result, **ER20**, did not explicitly report a specific target audience in the questionnaire, though its commercial nature implies potential relevance to the industry sector.

5.4.4. Early Adopters and End User Engagement

The engagement with Early Adopters and End Users within the NANCY project varies significantly depending on the maturity of the result and the nature of the partner (Academic vs. Industrial). The findings indicate the following three primary categories of engagement: active industrial adoption, internal research utilisation, and ecosystem synergies.

Active industrial engagement and legacy customer validation

Several industrial partners are leveraging their existing market position to engage early adopters. **TDIS (ER2)** is actively conducting "awareness sessions" with legacy customers to prepare them for the post-quantum rationale. **Bi2S (ER16, ER24)** has initiated direct contact with industry partners, specifically telecommunications and Cloud providers, to formulate requirements and gather data. **INTRA (ER28)** leverages its status as a software company to offer its CI/CD solutions immediately as a commercial offering. **VOS (ER13)** reports that recent technical successes in running virtio-gpu on virtio-loopback will unlock "interesting new possibilities and stakeholders" and has started discussions with potential industrial partners. Expanding this commercial outreach, **8BELLS (ER22)** has identified Mobile Network Operators (MNOs) and Private Network Operators as key early adopters for its smart pricing policies, while also engaging research testbeds. Similarly, **CERTH (ER9, ER21)** targets telecommunications providers and MNOs alongside academic institutions for its AI network quality and throughput forecasting modules.

Internal research and academic utilisation

A significant portion of the results is currently being exploited internally by research organisations to fuel further scientific inquiry. **IJS (ER8)** and **UMU (ER18)** explicitly state that their early adoption strategy involves the integration of assets into the research activities of their groups. **CRAT (ER12)** notes that researchers within its university consortium are interested in using the results for publications. **UOWM (ER19)** highlights that its testbed is being utilised by consortium partners and stakeholders from European projects. Additionally, **INNO (ER5, ER6, ER10)** has explicitly identified Researchers as the primary early adopter group for its theoretical frameworks (B-RAN, QKD simulation) and semantic communication schemes.

Open source and ecosystem synergies

For infrastructural results, adoption is driven by community integration and cross-project synergies. **SSS (ER1)** targets the Open Source community, with early adoption allowed by the availability of the code in mailing lists and repositories of projects such as Linux and Kubernetes. **UBI (ER14)** identifies "Other HEU (Horizon Europe) projects" as the primary early adopters for their AI-based RAN orchestration. **TECNALIA (ER17)** also adopts this ecosystem approach, targeting "Other research projects**"** alongside telecommunications operators to facilitate the adoption of the 5G Market place.

The responses indicate a clear split between active industrial engagement, internal academic validation, and results that are currently in a developmental phase where external engagement is premature. However, certain partners reported that engagement is currently paused due to technical maturity or dependencies. Specifically, **ER3** (Blockchain wallet) cannot be released as a standalone component, resulting in "no early adopters" for the result. **ER4** (PQC solution) is awaiting full validation, meaning adopters "should not be involved in the evaluation" yet. Similarly, the Big Data Platform **ER23** is considered "too early to propose a prototype to telecom operators".

5.4.5. Exploitation Type

The project results are categorised into Commercial and Non-commercial exploitation types. This distinction highlights the project's dual strategy: driving industrial competitiveness while fostering open innovation and public utility.

Commercial results

This category encompasses **15 results** intended for direct market uptake, aiming to generate revenue through licensing, product integration, or service fees. A significant cluster of these assets targets high-security and infrastructure modelling, specifically **ER2**, **ER3**, and **ER4**, which deliver Post-Quantum Cryptography and blockchain wallet solutions, alongside **ER5** and **ER6**, which provide theoretical and simulation frameworks for B-RAN and QKD deployments. To support network intelligence and optimisation, the project offers a suite of AI-driven tools, including **ER7** for resource virtualisation, **ER10** for semantic communications, and **ER11** for explainable AI, complemented by **ER16** and **ER24**, which provide machine learning models and drift detection for dynamic edge environments. Operational efficiency and platform management are addressed by **ER13** (virtio-based transport), **ER20** (blockchain-AI integration), and **ER23** (Big Data platform), with **ER28** serving as the central management domain for DevOps and orchestration. Finally, **ER22** introduces smart pricing policies to create new commercial incentive models within the network architecture.

The intention of commercial results demonstrates NANCY's strong industrial relevance, specifically addressing critical market gaps in 5G/6G security, cost reduction, and automated network management. The exploitation strategy for these results involves direct sales, integration into the existing product portfolios of industrial partners, and the creation of value-added services for telecom operators and private sector clients. By identifying and roadmapping commercial results, the consortium ensures that NANCY's innovations can be rapidly adopted by the market to enhance competitiveness in the European telecommunications sector.

Non-commercial results

This category comprises **13 results** where the primary value lies in knowledge transfer, open-source contribution, standardisation, or societal benefit rather than immediate commercialisation. Central to this approach is **ER1**, the project's core architecture designed for open-source integration into Linux and Kubernetes. A significant cluster of results focuses on advancing research capabilities and network reliability, including **ER8, ER9,** and **ER21**, which provide AI modelling and forecasting tools for academic and operational use, alongside **ER12** and **ER14**, which offer anomaly detection and energy-efficient orchestration frameworks for validation. To foster decentralised ecosystem interactions, **ER15** and **ER17** deliver tools for automating SLAs and exchanging 5G resources. Furthermore, the project addresses public infrastructure needs through connectivity prototypes and testbeds, specifically **ER18**, **ER19**, **ER25**, and **ER26**, which are designed to extend coverage in underserved areas, supported by **ER27** for edge platform integration.

These results are crucial for ensuring the project's long-term sustainability and legacy beyond its commercial lifespan. By releasing foundational architectures like **KER1** as open source, the consortium ensures broad adoption and compatibility with global standards such as ETSI and O-RAN. The connectivity solutions (**ER25, ER26**) and testbeds (**ER19**) specifically address public sector challenges where commercial incentives may be low, but the social impact is high. This approach ensures that NANCY not only drives industrial competitiveness but also provides the academic and public sectors with the essential tools and experimental environments needed to advance 6G technologies.

5.4.6. Methods, Tools, and Activities

The exploitation activities of the NANCY project are executed through dedicated methodologies and tools categorised across three strategic groups, ensuring both commercial viability and sustainable research impact.

Commercialisation and market strategy

The commercial roadmap prioritises IPR protection, direct channel sales, and rigorous market analysis. For **ER2** (TDIS), commercialisation will proceed via its traditional sales channels, with industrial certification targeted for the end of 2025. The responsible partners for **ER3** (NEC) scheduled pitch meetings with NEC Corp. in Japan. Strategic planning for **ER5**, **ER6**, and **ER10** (INNO) follows a phased timeline: development (M1-M24), stakeholder identification (M24-M36), and market analysis (M36+). Similarly, **ER16** and **ER24** (BI2S) utilise defined timelines extending three years post-project for continuous development and forging partnerships (M19-M36). **ER22** (8BELLS) includes Detailed Market Analysis and IPR Protection across the M11-M36 period. Finally, **ER28** (INTRA, UBI) is supported by a detailed technical roadmap for new AI-driven features, market campaigns, and Proof of Concept (PoC) demonstrations, with plans to introduce an AI architecture for code monitoring post-project. The activities of this group intend to achieve a structured transition from project result to market-ready product.

Technical development and validation

This area concentrates on integrating and refining prototypes using advanced cloud-native and AI tools. System integration for **ER7** (I2CAT) utilised multi-agent communication, Pytorch, Docker, and Kubernetes during its M6-M24 validation. **ER12** (CRAT) development employed AI/ML, Federated Learning (FL) techniques, and specialised tools including NS-3, Mininet, and Kubernetes. The prototypes **ER25** and **ER26** (EHU) were developed up to a prototype implementation (M30-M36) and will undergo continuous refinement post-project. **ER13** (VOS) focuses on Partnerships to share development costs and maintain a flexible sales strategy. **ER17** (TECNALIA) scheduled refinement based on the UOWM's testbed result (M30-M36). This systematic approach of this group aims to secure the technical maturity and validation required for commercial deployment.

Academic, open source, and standards dissemination

Results targeted for knowledge transfer and community impact adhere to strict open-source and standardisation roadmaps. The primary strategy for **ER1** (SSS) involves publication as open source and submission for integration into the Linux kernel and Kubernetes. Open source contributions help in building the partner reputation, increase visibility and might even bring future R&D activities. **ER12** (CRAT) includes a final phase (M30-M36) for demonstration and "standardisation contributions". **ER9** and **ER21** (CERTH) involve continuous refinement of model accuracy and systematic assessment of market trends, to promote proactive interventions in Open RAN scenarios. **ER8** (IJS) and **ER18** (UMU) follow a non-commercial path of Result Refinement and Partnerships (M24-M36) to support academic research activities. **ER14** (UBITECH) and **ER15** (DRAXIS) rely heavily on "Partnerships and Collaborations" as their primary non-commercial exploitation method. The activities of this group intend to ensure the project's long-term influence on future research and 6G standardisation.

5.4.7. IPR Management

To ensure the effective exploitation and long-term commercial viability of NANCY's innovations, the consortium has implemented a comprehensive IPR strategy. This framework strategically combines patents, copyright, trade secrets, and licensing agreements to rigorously secure both the background knowledge brought into the project and the novel foreground assets generated during its lifecycle. This multi-layered approach is tailored to the specific nature of each result, categorised as follows:

Copyright (5 results)

- **ER9** and **ER21**: Both modules build upon a predictive analytics and forecasting framework developed in previous research activities, which is protected by Copyright (**Background**).

- **ER13**: While no formal IPR is currently in place, this result is expected to utilise Copyright and licensing as its primary form of protection upon future commercialisation.

- **ER17**: Explicitly reports **Foreground** protection via Copyright.

- **ER28**: The Maestro Orchestrator component is identified as **Background** IP protected under Copyright. Additionally, the CI/CD platform component utilises copyright agreements for its **Foreground** IP.

Patents (2 results)

- **ER3**: Utilises background knowledge regarding Blockchain and Self-Sovereign Identity (SSI), which is protected with a Patent (**Background**).

- **ER12**: Reports specific **Foreground** protection via a Patent.

Trade secrets (1 result)

- **ER28**: In addition to copyright, the CI/CD platform utilises trade secrets agreements to protect its **foreground** innovations.

Licenses (1 result)

- **ER7**: Utilises a Slice Manager as background IP, which is protected with a License (**Background**).

Other / Not specified (3 results)

- **ER16** and **ER24**: Report the use of **Background** IP related to "Reinforcement learning AI models and AI training framework".

- **ER17**: Reports **Background** IP regarding "Previous knowledge on Blockchain".

The consortium has identified key IPR protection mechanisms (patents, copyright, trade secrets), but a detailed IPR framework has not been finalised. This is primarily due to the current maturity of the project results, which predominantly range around TRL 5. At this point, focus is on research and prototyping, not commercialisation. Final licensing terms, royalty structures, and patents should be refined as the results mature in the post-project period.

Patent registration

In line with this strategy, the consortium has moved beyond theoretical planning to active legal protection. Several key innovations have already reached the patent registration stage, while additional high-potential results are currently undergoing the application process to ensure full legal compliance and technical exclusivity.

The following patents have been registered:

- Method of entrusting data using a secure component [https://data.epo.org/publication-server/rest/v1.2/patents/EP4554141NWA1/document.pdf]
- Method to execute a hybrid signature [https://data.epo.org/publication-server/rest/v1.2/publication-dates/2025-07-02/patents/EP4580117NWA1/document.pdf]
- Method for training a binary classifier to detect the presence of operational anomalies in a telecommunications network [https://www.uniroma1.it/en/brevetto/102024000030096]

Additionally, after investigating the project outcomes in terms of technical and legal compliance, three more patent applications were decided to be submitted and are currently under development:

- Self-healing and self-recovery mechanisms for telecommunication networks
- Explainable AI framework for telecommunication networks
- Federated learning intrusion detection system

5.4.8.Ownership

The majority of the project's results are exclusively owned by the partner responsible for their development. This clear ownership structure facilitates straightforward exploitation and licensing. However, there are some cases of non-exclusive / Shared Ownership.

Exclusive Ownership

- **19 Results** are identified as having **Exclusive Ownership**: **ER1** (SSS), **ER2** (TDIS), **ER4** (TEI), **ER5** (INNO), **ER6** (INNO), **ER7** (I2CAT), **ER8** (IJS), **ER9** (CERTH), **ER10** (INNO), **ER12** (CRAT), **ER13** (VOS), **ER14** (UBI), **ER15** (DRAXIS), **ER18** (UMU), **ER19** (UOWM), **ER20** (OTE), **ER21** (CERTH), **ER22** (8BELLS), and **ER23** (TEI).

Non-exclusive / Shared ownership Several key results involve collaborative development or dependencies on other partners' technologies, resulting in shared or non-exclusive ownership structures.

- **ER3:** Ownership is non-exclusive. While **NEC** is the primary developer, **TDIS** contributes the PQC signature capabilities via a software adaptor.
- **ER11:** Ownership is shared among the partners **MINDS**, **SID**, and **INNO**.
- **ER16** and **ER24:** Bi2S is the primary owner, but **UMU** and **IJS** (as WP Leaders) contribute data and coordination guidelines, making the ownership non-exclusive.
- **ER17:** TECNALIA reports non-exclusive ownership because the marketplace relies on the underlying Blockchain and wallet infrastructure provided by **NEC**.

- **ER25 & ER26:** EHU is the developer, but similar to the AI models, **UMU** and **IJS** contribute components and data as part of the larger NANCY architecture.

- **ER28:** Ownership is split between **INTRA**, which owns the IPR for the CI/CD pipeline, and **UBITECH**, which owns the IPR regarding the Maestro Orchestrator.

While the consortium has identified clear pathways for individual results, a formalised Joint Exploitation strategy, involving binding multi-partner commercial agreements, has not been addressed at this stage. The main challenge preventing this is the lack of technological maturity in the majority of the components currently tested in the project. With most exploitable results ranging around TRL5, defining a finalised strategy for bundled or integrated commercial offerings is considered premature. These technical maturity issues need to be addressed first to ensure that a joint exploitation plan is both viable and effective beyond the project's duration.

5.5. Horizon Results Platform

Following the recommendations from the previous review report and the suggestions, the consortium has actively utilised the **Horizon Results Platform (HRP)** to maximise the visibility and impact of the project's exploitable results. To date, 27 out of the 28 identified exploitable results have been successfully published to the platform. This extensive submission encompasses the majority of the project's KERs and OERs, ensuring that NANCY's exploitable results are accessible to a broad ecosystem of investors, policymakers, and potential industrial partners. This action is critical for supporting the long-term exploitation and market uptake of the developed solutions. The only exception is ER15, which is not currently published on the platform, because the partner determined that it is a background/backend component and does not fit the Horizon Results Platform's scope. Stakeholders can access the published profiles to explore collaboration opportunities **by searching for the GA number or project name on the Horizon Results Platform or by visiting the project's dedicated page** (Figure 13, Figure 14, and Figure 15).
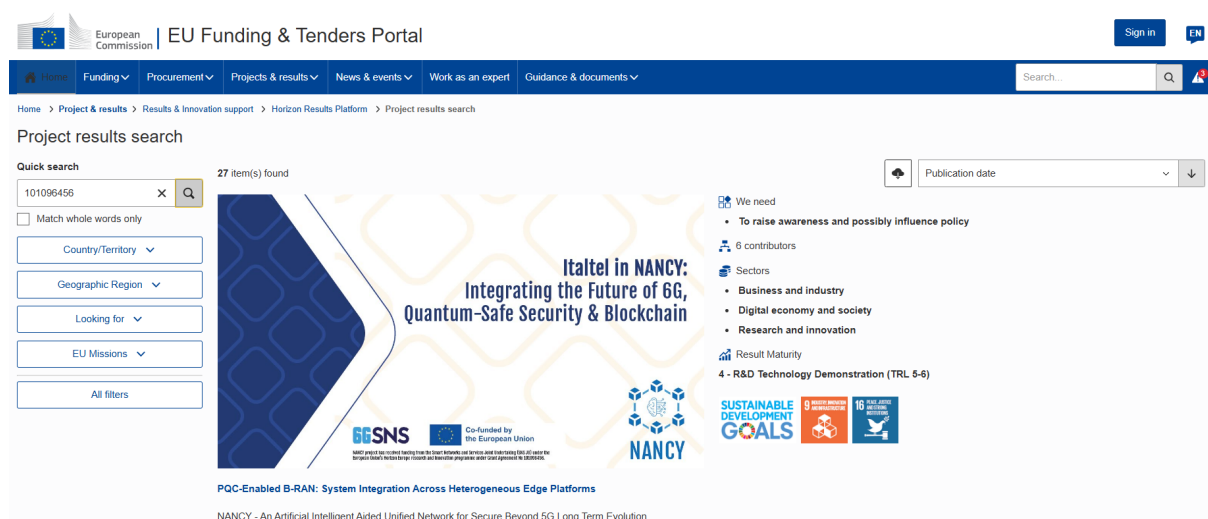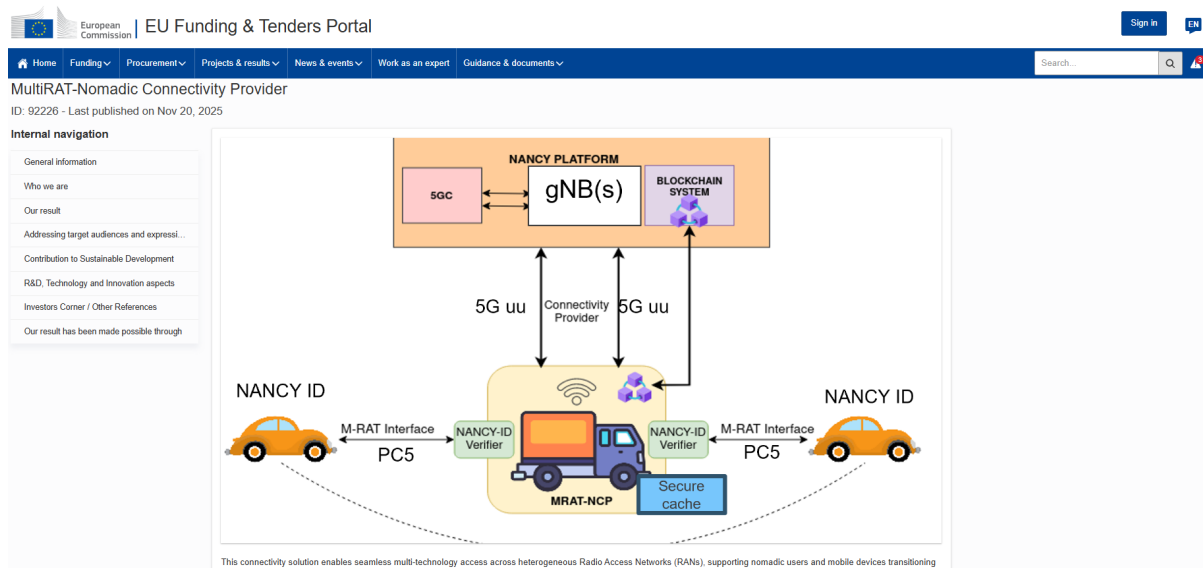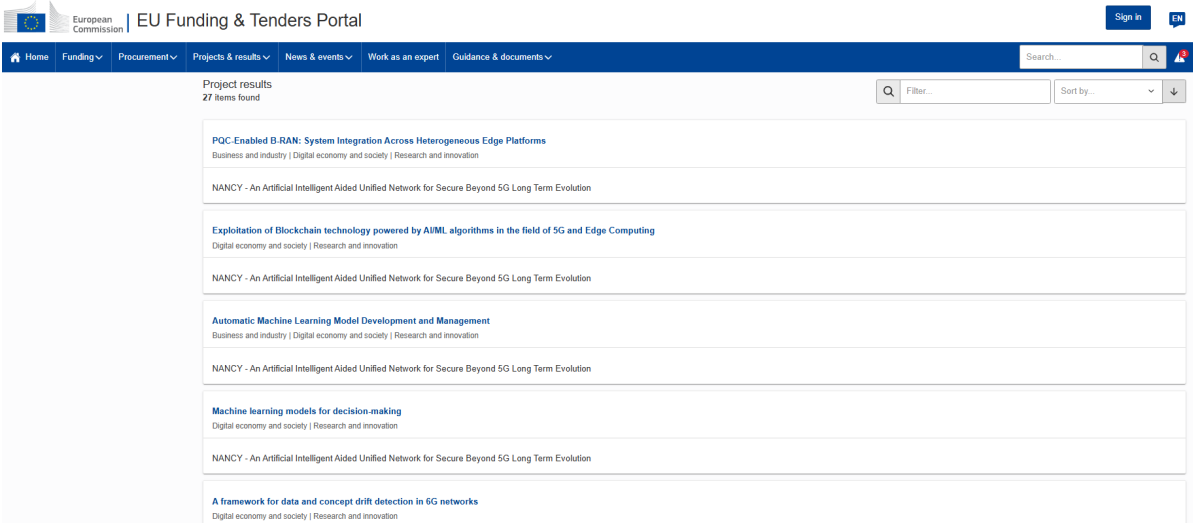

Figure 13: NANCY's exploitable results in HRP[4]

Figure 14: Example of a specific exploitable result's HRP page[5]

Figure 15: Project results under the NANCY Project page[6]

---

[5] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/horizon-results-platform/92226
[6] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/projects-details/43108390/101096456/HORIZON

6. Impact Assessment and KPIs

NANCY's dissemination and communication strategy was designed to maximise visibility, accelerate knowledge transfer, and engage diverse stakeholder groups across Europe. The project has successfully met, and in most cases exceeded, its Key Performance Indicators (KPIs), demonstrating strong impact in scientific dissemination, public outreach, and communication of results to both specialised and non-specialised audiences.

Table 16 and Table 17 summarise performance across all major dissemination and communication dimensions, respectively. Detailed evidence supporting each KPI is provided throughout Sections 3 and 4 of this deliverable.

Table 16: Dissemination activities and respective KPIs

Activity	Indicators	Achieved	Comments
Workshops co-located with major conferences	# of workshops organized (3+/at least one per-year) # of participants in each workshop (~50)	# of workshops: 13 # of participants: mean of 50 per workshop	Workshops covered topics across AI-native networking, authentication, edge intelligence, and quantum-resilient security. Attendance remained consistently high across all three project years, demonstrating strong community interest. Additional details appear in the section Scientific Publications and Table 4.
On-site demonstrations	10 demonstrations	9 demonstrations	The project almost met expectations with high-quality demonstrations, including multiple Proof-of-Concept deployments and testbed-driven showcases. Full overview in section Demonstrations and Testbeds
Scientific papers, targeting workshops, conferences and journals, such as EuCNC event, IEEE Global Communications Conference, IEEE International Conference on Communications, IEEE Conference on Computer Communications, IEEE Transactions on Network and Service Management, IEEE	# of workshop papers published (>2 per-year) # of workshop and conference papers published (30+) # of journal papers published (50)	# of Workshop and conference papers: 45 # of journal papers: 41 # of book chapters: 2	While the number of journal papers is slightly below the target, the combined total of 88 publications exceeds the overall scientific dissemination KPI, especially considering the maturity level of early B5G/6G topics. Details in section Workshops,

Transactions on Industrial Informatics, IEEE Communication Magazine, International Journal of Computer and Telecommunications Networking, 5G Annual Journal			Conferences, and Trade Fairs and Table 1.
Social networks posts, to take advantage of modern communication channels for wider dissemination	# of NANCY posts (≥10) # of contacts (≥100) # of likes (≥ 50 likes / share) # of comments (≥2 com. / share)	Nancy Posts: 100 # of contacts: 556 # of likes/ share: ~55 # of comments/ share: N/A	Engagement levels exceeded by far the initial expectations. High visibility was supported by SNS JU resharing and partner amplification. More information in the section Social Media Engagement
Participation in trade fairs/exhibitions showcasing project's solutions	# of trade fairs/exhibitions (≥2) # of project brochure copies delivered (≥10)	# of trade fairs/exhibitions: 7 # of project brochure copies delivered: >300	Events included EuCNC & 6G Summit, BEYOND 2025, Thessaloniki International Fair, and ETSI conferences. More information in section Workshops, Conferences, and Trade Fairs, and Table 5
Project web site, providing scientific papers, public project deliverables and software tools	Top 5 Search Engine Page Ranking (SEPR)	The project appears first in many searches such as: "Nancy project", "Nancy SNS JU", "Nancy EU", "Nancy Horizon", "Nancy B5G"	Search optimisation and monthly content updates ensured sustained visibility. More information in the section Website & Blog

Table 17: Communication activities and respective KPIs.

Activity	Indicators	Achieved	Comments
Online publishing (online magazines, newspapers, blogs)	≥ 5 publications / year ≥ 500 views	# of NANCY blog posts: 22 # of views: 814 # of posts in online magazines, newspapers etc.: 6	Actual reach is significantly higher as media outlets (e.g., Telecompaper, Casadomo, Free6GTraining) do not provide detailed analytics. More information in section Website & Blog and Table 9, and in section Media Outreach and Press Coverage

Inclusion of light content for nonspecialized audience in the project website, blog, social media, as well as publishing "lighter" versions of project newsletters, leaflets, flyers, etc.	# of non-specialized material ≥ 5	# of Newsletters: 19 # of non-specialized material (leaflet, flyer, roll-up banner, infographic): 5	Content was tailored for accessibility and plain language. More information in section Newsletters and News Alerts, Table 11, and in section Promotional Material
Participation in media (TV, newspapers, radio) events in order to communicate NANCY results of the project and explain its benefits to EU citizens, industry etc.	# of media appearances ≥ 5	# of posts in online magazines, newspapers etc.: 6	Coverage included regional newspapers (La Opinión de Murcia), telecom media (Telecompaper), and technology magazines (Casadomo). More information in the section Media Outreach and Press Coverage
NANCY news will appear in blogs and websites targeting non-specialized audience, especially the youngest one, focusing on technology news and trends.	# of reads ≥100	# of reads: probably thousands	Platforms such as Free6GTraining have substantial global readership. More information in the section Media Outreach and Press Coverage
Exhibitions/workshops with free access	# of exhibitions/ workshops ≥ 1 # of non-specialized attendees ≥ 50	# of exhibitions/ workshops: 7 # of non-specialized attendees: thousands	Includes European Researchers' Night, Science Week, Thessaloniki International Fair, BEYOND 2025, etc. More information in the section Public Engagement Activities
Online and/or F2F training sessions	# of online session(s) ≥ 1 # of non-specialized attendees ≥ 50	# of online sessions: 7 # of non-specialized attendees: thousands	Often combined with university outreach and science fairs. More information in the section Public Engagement Activities
F2F interactions with local people	# of local events ≥ 1 # of appearances in local media ≥ 3	# of local events: 7 # of appearances in local media: N/A	Despite the missing media analytics, the KPI is satisfied via event volume. See more information in the section Public Engagement Activities
Free trials for general public	# of testers ≥ 5	# of testers: dozens	Free trials were conducted during open-access science events and exhibitions, where members of the general public actively interacted with NANCY demonstrators. See more information in the section Public Engagement Activities

Marketing events, e.g., trade fairs/exhibitions	# of marketing events ≥ 1 in YR2, ≥ 2 in YR3	# of marketing events: 5	Exceeded expectations. More information in the section Marketing Events and Trade Fairs

Acknowledgement of EU Funding and SNS JU

All dissemination, communication, and exploitation materials produced under the NANCY project have consistently acknowledged the financial support received from the European Union's Horizon Europe Research and Innovation Programme and the SNS JU.

The official acknowledgement text and disclaimer have been included in every press release, presentation, public deliverable, newsletter, and online publication, in line with the EU visibility and SNS JU communication guidelines. The following statement has been systematically used:

"NANCY project has received funding from the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101096456."

In addition to the textual acknowledgement, all materials prominently feature the **EU emblem** and the **SNS JU logo** (Figure 16), ensuring full compliance with the programme's branding requirements. The acknowledgement appears in:

- All **official deliverables** (public and restricted).
- **Press releases**, newsletters, and news alerts.
- The **NANCY website**, social media channels, and YouTube videos.
- **Event presentations**, posters, roll-ups, and printed dissemination materials.
- **Scientific publications** and **conference papers**, where applicable.

Figure 16: EU emblem and the SNS JU logo

Furthermore, coordination with the **SNS JU Communication Office** ensured consistent alignment with the overall identity of the European 6G research initiative. NANCY regularly contributed content to the **SNS JU Newsflash**, **Smart Networks Portal**, and **SNS webinars**, reinforcing its visibility as part of the broader European effort to build secure, intelligent, and sustainable B5G networks.

Moreover, a disclaimer is included in the footer of every page on the NANCY website, stating that all content reflects only the author's view and that neither the European Commission nor the Agency is responsible for any use that may be made of the information provided.

"Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the SNS JU. Neither the European Union nor the granting authority can be held responsible for them."

This systematic acknowledgment practice not only fulfils contractual obligations but also underscores NANCY's active participation in the collaborative European research ecosystem fostered by the SNS JU.

7. Supporting Europe's 6G ecosystem

NANCY's stakeholder and community engagement strategy has played a central role in ensuring that the project's technologies, methodologies, and results are shared widely across Europe's 6G research ecosystem. By actively contributing to the SNS JU community, collaborating with external stakeholders, and engaging with industry, academia, public authorities, and innovation clusters, NANCY has strengthened its impact beyond traditional research dissemination. This section summarises the project's key engagement activities and their contribution to the development of secure, intelligent, and quantum-ready B5G networks.

NANCY has systematically aligned its engagement efforts with the broader SNS JU strategy, maintaining continuous interaction with the Phase 1, Phase 2, and Phase 3 project ecosystems. This collaboration has been instrumental in ensuring interoperability, knowledge exchange, and harmonisation with European research priorities.

Participation in SNS JU Communication and Outreach Activities

The project maintained a strong, recurring presence in SNS JU communication channels:

- **15 appearances in the monthly SNS JU Newsflash**, showcasing major updates, events, and results.

- **Inclusion in the Smart Networks portal** as part of the SNS Phase 1 project portfolio.

- **Participation in the SNS JU Lunchtime Webinar #2**, which introduced NANCY's objectives and results to a pan-European audience.

- **Contributions to the SNS JU Standards Tracker**, highlighting NANCY's technical input to ongoing standardisation efforts.

These activities ensured alignment with SNS JU guidelines and maximised visibility across the European 6G research community.

Joint SNS JU Webinar on Security and Trust in Multi-Domain 6G Networks

In December 2025, NANCY co-organised a major **SNS JU joint webinar** together with three sister projects, **ACROSS**, **RIGOROUS**, and **6G-PATH**.

Webinar: "Security & Trust in Multi-Domain 6G Networks"

- **Date:** 2 December 2025
- **Time:** 12:00–14:00 CET
- **Platform:** Microsoft Teams
- **Content:** Four expert project teams presented complementary work on security-by-design, orchestration, and trust mechanisms across multi-domain 6G infrastructures.

This two-hour event strengthened technical alignment among SNS JU projects addressing secure network architectures and highlighted NANCY's role.

Contribution to SNS JU White Papers

NANCY partners significantly contributed to three major SNS JU white papers, strengthening the project's role in shaping the European 6G roadmap:

- **AI/ML as a Key Enabler of 6G Networks: Methodology, Approach and AI-Mechanisms in SNS JU**
- **Sustainability in SNS JU Projects - Targets, Methodologies, Trade-offs and Implementation Considerations Towards 6G Systems**
- **Towards 6G Architecture: Key Concepts, Challenges, and Building Blocks**
- **6G for Media and Entertainment**

These papers addressed architectural principles, trust frameworks, AI-enabled network automation, and security mechanisms—topics directly aligned with NANCY's research contributions.

Presence in the 2023, 2024, and 2025 SNS JU Journals

NANCY was featured in all three editions of the annual **SNS JU Journal**:

- **2023 SNS JU Journal**
- **2024 SNS JU Journal**
- **2025 SNS JU Journal**

These publications highlighted NANCY's innovations in AI-enabled orchestration, blockchain-driven trust, multi-domain security, and quantum-safe mechanisms.

Contribution to Policy Dialogue: NANCY Policy Brief

As part of its contribution to the SNS JU policy ecosystem, NANCY prepared a dedicated **Policy Brief** titled: **"Securing Europe's 6G Sovereignty: A Policy Brief for Quantum-Resilient and AI-Transparent Networks".**

This brief—developed at the request of SNS JU—summarises key policy recommendations on:

- quantum-resilient cryptography and the urgency of PQC/QKD adoption
- self-sovereign identity frameworks for decentralised trust
- explainability and transparency in AI-based network automation
- hybrid security schemes supporting the transition to post-quantum environments
- compliance with GDPR, the AI Act, the Data Act, and the Cyber Resilience Act

The brief synthesises evidence from four NANCY security deliverables (D5.1–D5.4) and supports EU-level policymaking on next-generation networks. Publication is pending approval by the SNS JU Communication Office. The NANCY Policy Brief draft is available in ANNEX.

Cross-Project Synergies and Technical Exchange

NANCY collaborated informally with several SNS JU projects addressing complementary research areas, including network management, AI-native network automation, post-quantum security, and edge intelligence. These interactions were primarily conducted through:

- joint conference sessions and workshops at EuCNC & 6G Summit, IEEE events, and ETSI conferences;
- participation in cross-project discussions during SNS JU events;
- coordination through partners engaged in multiple European projects, research alliances, and industry groups.

This cross-pollination facilitated methodological alignment, shared understanding of key challenges, and dissemination of research insights across the wider 6G landscape.

Alignment with SNS JU Guidelines

The NANCY DCE strategy fully adhered to the **SNS JU branding and communication framework**, ensuring visibility, consistency, and synergy with the wider European 6G research ecosystem. This alignment included both **strategic coherence** and **operational compliance**:

- **Brand and visibility:** NANCY adopted the SNS JU branding, logos, and acknowledgment statements across all communication materials, websites, deliverables, and presentations, ensuring uniform recognition under the SNS initiative.
- **Contribution to the SNS JU communication ecosystem:** The project was regularly featured in the **SNS JU Newsflash**, the **SNS Standards Tracker**, and participated in **SNS-organised events and webinars**, presenting its results to a broad European audience.
- **Open access and transparency:** All scientific publications followed **open access principles**, in line with SNS JU and Horizon Europe requirements, ensuring free availability of project results for maximum societal and research impact.
- **Coordination with peer projects:** NANCY maintained an active presence in SNS Cluster activities, aligning its dissemination with **Stream A** (priorities and collaborating on joint visibility opportunities).
- **Impact-driven messaging:** Communication efforts followed the SNS JU guideline to translate technical advancements into **clear, accessible narratives** emphasising societal benefits such as enhanced trust, energy efficiency, and resilience in next-generation networks.

8. Long-term sustainability and continuation of dissemination and exploitation

Ensuring the long-term sustainability of the DCE activities is essential for maximising the visibility, impact, and uptake of NANCY's outcomes beyond the project end. By Month 36, NANCY had established a strong public presence, a coherent technical narrative, and a well-structured portfolio of 28 exploitable results. The continuation of these efforts relies on three complementary pillars: (i) sustained visibility through digital channels, including the successful publication of 27 results to the Horizon Results Platform (HRP). (ii) the integration of NANCY results into the broader SNS JU and European 6G ecosystem, and (iii) exploitation pathways that extend beyond research into policy, standardisation, and market-oriented environments, supported by a clear IPR strategy and plans for post-project commercial and non-commercial utilisation of all classified KERs and OERs.

Project Website and Knowledge Assets

The NANCY website has become a central repository for public deliverables, scientific achievements, demonstrators, videos, and news items. To ensure sustainability:

- The website will remain online for at least two years after project completion, in accordance with SNS JU requirements.

- All public deliverables, open-source components, newsletters, and communication materials will remain accessible for long-term reference.

- Key insights and outcomes—such as the Explainable AI Toolbox, Quantum Key Distribution demonstrator results, and Blockchain-based mechanisms—will remain available for researchers, industrial stakeholders, and policymakers.

Social Media Channels

NANCY's social media accounts (X/Twitter, LinkedIn, YouTube) have demonstrated strong growth, surpassing KPI expectations. To maintain visibility after M 36, consortium members will provide updates on relevant follow-up activities, publications, events, and adoption of NANCY technologies in other initiatives. Moreover, the final video materials and demonstrator showcases will remain publicly accessible to support knowledge transfer.

Publications and Open Access

All scientific papers remain deposited in open-access repositories. This ensures long-term academic visibility and supports continued citation and scholarly engagement. The consortium commits to:

- Publishing post-project scientific work that builds on NANCY's methodologies.

- Maintaining permanent access to datasets and technical tools where permitted by licensing and confidentiality rules.

- Leveraging NANCY's outputs as foundational references in new research initiatives.

Horizon Results Platform (HRP) Engagement

To maximise long-term visibility and potential market uptake, the consortium has leveraged the Horizon Results Platform. A total of 27 out of the 28 identified exploitable results have been successfully uploaded to the HRP, ensuring NANCY's innovations are accessible to a broad ecosystem of investors, policymakers, and industrial partners. This action is crucial for supporting the sustained exploitation and market access of the developed solutions.

IPR Strategy and Ownership Continuation

The project's IPR strategy provides the legal foundation for continued exploitation. Assets are protected using a multi-layered approach, including **patents (three registered and three under development)**, copyrights, and trade secrets. The ownership status of the majority of results remains exclusive to the contributing partner, facilitating clear pathways for individual commercialisation. Where shared ownership exists, existing consortium agreements govern future licensing and use.

Industrial and Commercial Prospects

Several technological components developed under NANCY have direct exploitation potential:

- **Quantum-Safe Cryptography and QKD mechanisms** for telecom operators and critical infrastructure providers.

- **Explainable AI Toolbox** for vendors developing trustworthy AI solutions for network management and automation.

- **Blockchain-based distributed security mechanisms** for multi-operator environments and future service marketplaces.

- **Self-healing and self-recovery network modules** for integration into 6G testbeds and vendor-provided orchestration platforms.

Research and Innovation Continuation

Several partners have already incorporated NANCY results into new Horizon Europe proposals, national research programmes, bilateral academic-industry collaborations, and open-source community contributions, signalling future uptake of project outputs. The quantitative performance of the demonstrators (e.g., QKD trials, XAI validation, anomaly detection models) provides a solid baseline for future experimental research.

Contribution to the SNS JU and European 6G Research Landscape

NANCY has actively contributed to the strategic objectives of the SNS JU throughout the project, and these interactions will continue as part of sustained dissemination and exploitation (check previous section).

These collaborative actions ensure that the project's results remain embedded in the long-term strategic development of Europe's 6G ecosystem.

Policy and Standardisation Actions

One of the most significant long-term impacts of NANCY is its contribution to policy and regulatory discussions. The **NANCY Policy Brief on Quantum Security and Explainable AI**, developed in collaboration with SNS JU, consolidates the project's insights into actionable recommendations for European policymakers. After publication, the brief will be disseminated through the SNS JU communication channels (Newsflash, newsletters, Smart Networks Portal) and will be integrated into workshops and industry events focused on 6G governance, sovereignty, and trust frameworks. Furthermore, NANCY technologies support contributions to ongoing or emerging standardisation efforts.

Transfer of Knowledge and Capacity Building

Beyond dissemination to external stakeholders, NANCY's outputs have long-lasting value for training and education:

- The XAI toolbox and code examples will continue to be used for training postgraduate students and early-career researchers.

- Demonstrator insights will inform course modules on mobile network security, quantum communications, and trustworthy AI.

- The consortium will continue delivering occasional guest lectures, webinars, and workshops referencing NANCY results.

Maintenance of Collaboration Networks

The relationships established during NANCY—across academia, industry, other SNS JU projects, and European policy forums—constitute a lasting asset. Partners plan to:

- Continue joint events and publications with SNS JU projects, and others.

- Pursue collaborative proposals in all Streams of the SNS JU.

- Expand international cooperation, particularly in quantum communications and AI governance.

These networks ensure that NANCY's outputs continue to grow in relevance and visibility.

Thanks to its strong dissemination performance, high scientific output, extensive SNS JU engagement, and long-term exploitation strategy, NANCY is well-positioned to influence the European 6G landscape long after the project ends. This DCE strategy has been deliberately designed for continuity, ensuring its innovations remain visible, relevant, and adoptable across research, industry, and policy domains well beyond M36, a commitment underscored by the systematic strategic planning for all 28 Exploitable Results, the established IPR framework, and the successful submission of 27 results to the Horizon Results Platform.

9. Conclusion

The NANCY project has successfully achieved its objectives in dissemination, communication, and exploitation, ensuring that its technological innovations, scientific contributions, and policy-relevant insights have reached diverse audiences across Europe and internationally. Through a coordinated, comprehensive, and adaptive impact creation strategy, the project has significantly advanced public understanding, scientific knowledge, and industry awareness of secure, intelligent, and quantum-ready B5G network technologies.

Across three years, the consortium delivered a strong portfolio of high-quality scientific publications, exceeding the planned targets for conference papers, journal articles, and workshop contributions. NANCY's results were disseminated at leading conferences, industry events, and technical workshops, demonstrating both academic excellence and practical relevance. The project's presence at major trade fairs and exhibitions—including Infocom World, BEYOND, and the Thessaloniki International Fair—strengthened visibility beyond the research community and enabled direct engagement with industry actors, SMEs, and public authorities.

The communication strategy ensured continuous visibility through an active online presence, including regular news, blog posts, videos, newsletters, and social media activity. Engagement metrics grew steadily, surpassing key KPIs for outreach and demonstrating strong public interest in the project's themes of security, trust, quantum resilience, and explainable AI. The project's YouTube videos, press releases, and media features played an important role in translating complex technical concepts into accessible narratives for non-specialised audiences.

Collaboration with the SNS JU has been a defining strength of NANCY's impact creation approach. The project actively contributed to SNS JU working groups, joint white papers, newsletters, and cross-project events, reinforcing its role within the European 6G research ecosystem. Contributions to the SNS Journals (2023, 2024, 2025), participation in joint webinars, and alignment with the SNS communication and branding guidelines ensured that NANCY remained strongly connected to the wider strategic objectives of the programme. The preparation of a dedicated policy brief on quantum security and explainable AI further strengthened NANCY's position as a contributor to European policy dialogues on network security and sovereignty.

Exploitation actions progressed throughout the project, successfully identifying and characterising a total of 28 exploitable results (ERs), which are evenly split between 13 Technological Solutions and 13 Models/Algorithms. This portfolio, which is categorised into 15 Commercial and 13 Non-Commercial exploitation pathways, has been mapped against four strategic pillars: Next-generation architecture, Future-proof security, Zero-touch intelligence, and connectivity Expansion. IPR management is secured via a multi-layered approach utilising patents (three registered and three currently under development) and copyrights, with the majority of assets under exclusive ownership. However, due to the TRL 5 maturity, the formalisation of a joint commercial exploitation plan is deferred to the post-project phase.

The project's commitment to sustainability is reflected in the measures adopted to ensure long-term availability and visibility of results. These include the preservation of public deliverables, the maintenance of short-term online presence after project completion, and plans for further exploitation within ongoing standardisation, research, and industry initiatives. Crucially, 27 of the 28 results have been successfully published on the Horizon Results Platform (HRP), ensuring critical exposure to investors and partners and maximising the potential for long-term market uptake. The final

demonstrations and proof-of-concept activities underscore the project's readiness for further advancement in practical deployments and future R&I actions under subsequent EU programmes.

In conclusion, NANCY has not only met but, in many areas, surpassed its impact creation objectives. The project has delivered substantial scientific, technical, and societal impact, reinforcing Europe's leadership in secure and intelligent network technologies. Its outcomes will continue to support future research, standardisation efforts, and policy developments in the transition toward quantum-resistant and AI-enabled 6G systems. The successful identification and strategic planning for all 28 exploitable results, reinforced by their submission to the Horizon Results Platform, ensure a clear, actionable legacy. The strong foundation established through dissemination, communication, and exploitation activities ensures that NANCY's contributions will remain relevant and actionable well beyond the project's lifetime.

ANNEX – NANCY Policy Brief

NANCY: An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution

NANCY Consortium, November 2025

Securing Europe's 6G Sovereignty: A Policy Brief for Quantum-Resilient and AI-Transparent Networks

1. **Highlights**
   ➢ The rapid evolution of **quantum computing** technologies will introduce critical risks to Europe's security services, as the current encryption schemes will be obsolete.
   ➢ These risks necessitate the **prompt deployment** of **quantum-resistant solutions,** such as Quantum Key Distribution and Post-Quantum Cryptography.
   ➢ The use of **distributed identity management mechanisms** for network and end-user devices can enhance trust among network entities and reduce reliance on central authorities.
   ➢ The ability to provide **simple explanations** of how Artificial Intelligence systems work is critical for **fostering trust** among non-experts.

2. **Security and Privacy Challenges in Next-Generation Networks: From GDPR Compliance to Quantum Readiness**

The next-generation communication networks are expected to introduce novel and advanced capabilities to multiple application domains. To support these capabilities, large data volumes are collected, stored, and analyzed by Artificial Intelligence (AI) systems in order to support critical domains, such as manufacturing, smart cities, logistics, and healthcare. Therefore, securing infrastructure, devices, and data is essential to maintain public trust in new technologies.

The protection of sensitive data has become a policy and regulatory concern across Europe over the last years. The General Data Protection Regulation (GDPR) is the main regulation concerning data protection, alongside other directives and guidelines, such as the Artificial Intelligence Act [1], the Data Act [2], and the Cyber Resilience Act [3]. These guidelines, which focus on the security and privacy of data and devices, define the main principles for the deployment, management, and operation of next-generation networks.

Furthermore, the rapid evolution of quantum computing capabilities introduces a severe emerging cybersecurity threat. Experts believe that in roughly a decade or two, such systems could break today's encryption methods - a scenario called 'Q-Day'. This will affect critical

digital infrastructures, while "harvest now, decrypt later" cyberattacks will be made possible. In these cyberattacks, the adversaries collect and store encrypted data in order to decrypt it in the future using quantum computers. This is a critical risk that should be addressed by network operators and service providers.

Identifying quantum computing as a key emerging technology, the European Quantum Act was instantiated with the aim of establishing Europe as a global leader in quantum technologies [4]. Moreover, in view of the emerging quantum threats, the European Union has defined a roadmap to be adopted by the Member States, which defines the steps needed for migrating to Post-Quantum Cryptography (PQC) [5]. Moreover, Quantum Cryptography and Quantum Key Distribution (QKD) are recognized as key mechanisms for the Strategic Technologies for Europe Platform (STEP) [6], which aims to promote investments that boost industrial and economic growth.

3. Recommendations for Quantum Security and Explainable AI in Networks

In light of the aforementioned remarks, the following recommendations are outlined, stemming from the research and development activities of the NANCY project (Figure 1):

Mandating quantum-proof solutions: The next-generation networks should adopt standardized quantum safety mechanisms across the radio access network and core network. The key network entities should align with the cryptographic agility (crypto-agility) principles. These principles refer to the ability to quickly switch to new cryptographic algorithms in response to emerging threats. In this respect, the network entities should be able to evolve from classical security mechanisms to PQC and QKD mechanisms.
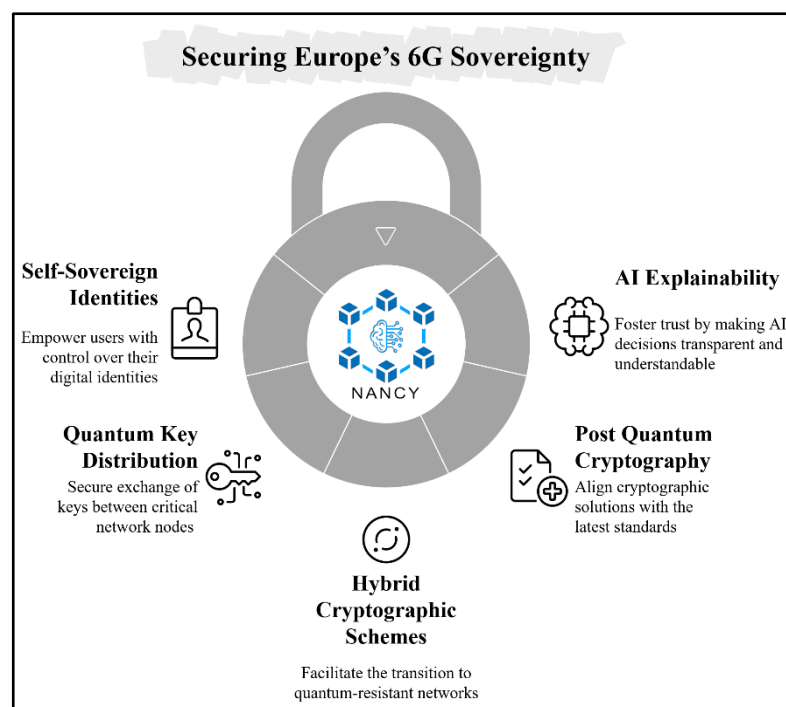

Figure 1: Recommendation Highlights

Prioritization of the adoption of PQC standards: The cryptographic solutions should be aligned with the latest NIST standards, focusing on PQC, namely FIPS 203 'Module-Lattice-Based Key-Encapsulation Mechanism Standard' [7], FIPS 204 'Module-Lattice-Based Digital Signature Standard' [8], FIPS 205 'Stateless Hash-Based Digital Signature Standard' [9].

Strategic deployment of QKD mechanisms: The relevant guidelines and recommendations should promote QKD as the preferred technology for the security of critical network entities and infrastructures. For example, this includes securing the backbone communication links, such as the connections between the core network and the base stations. The fiber optic links used for these connections can facilitate the application of such QKD mechanisms.

Promotion of Self-Sovereign Identity (SSI) frameworks: These frameworks enable users to generate digital identities without the need for formal public entities. Therefore, users have complete control over their identity lifecycle, such as identity generation and deletion, as well as management of attributes, while also employing proof-driven and decentralized management services. In this direction, Blockchain technologies can be utilized as a basis for such frameworks.

Integration of explainability into all AI-based network operations: The policies should expand this principle to all aspects of network operations. To this end, Explainable AI (XAI) methods can be used to ensure that any decisions made by AI models are interpretable, understandable to humans, transparent, and auditable. In addition, the outputs of XAI methods can be analyzed by Large Language Models (LLMs) to turn them into simple explanations, thereby democratizing the interpretability to non-experts and fostering trust in AI.

Support of hybrid cryptographic schemes: The transition to PQC requires careful planning to ensure interoperability between existing systems and new quantum-resistant algorithms. To this end, hybrid schemes that combine PQC (e.g., the Crystals-Dilithium scheme) and classical encryption schemes can facilitate the transition period.

4. Evidence and analysis

The NANCY project addresses critical security and privacy challenges in current and future mobile networks by developing: a) quantum-resistant cryptographic methods to safeguard against emerging quantum computing threats, b) distributed Blockchain-based approaches to increase privacy through decentralized methods, and c) explainable AI methodologies to foster trust and transparency in the decision-making processes of AI models. The outcomes of these activities are documented in four security-focused deliverables, as also illustrated in Figure 2:
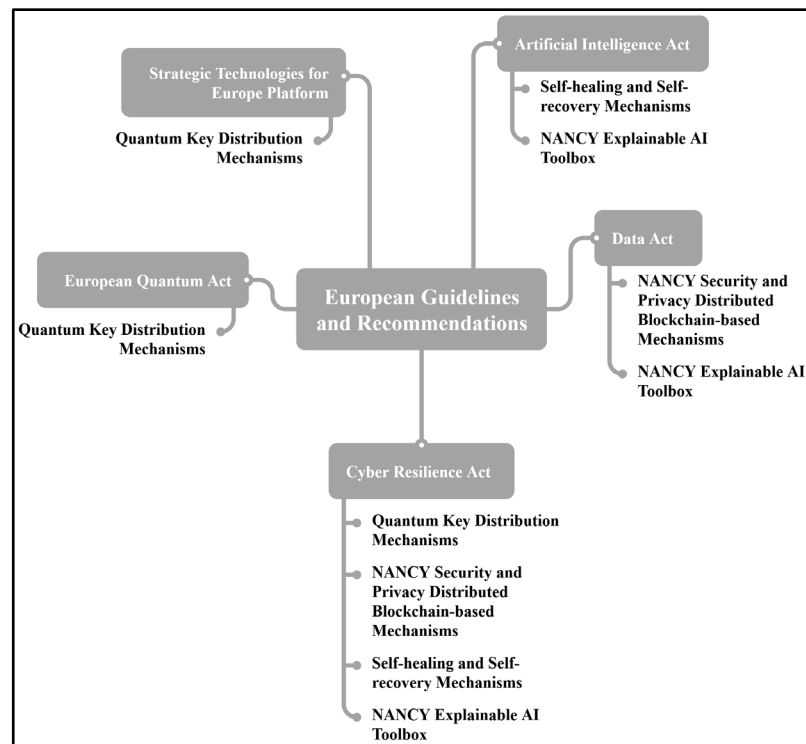

Figure *2*: Mapping of NANCY deliverables to EU guidelines and recommendations

'Quantum Key Distribution Mechanisms' [10], which documents the research and development activities of the projects focusing on QKD and PQC. Specifically, the applicability of QKD was validated in a laboratory environment, as well as through simulations. Moreover, the deliverable investigates the application of token-based PQC in resource-constrained

devices and emphasizes the use of hybrid cryptographic approaches to ensure compatibility and robustness.

'NANCY Security and Privacy Distributed Blockchain-based Mechanisms' [11], which presents a distributed Blockchain-based solution for enhancing security and privacy, as well as for verifying the exchange of services among operators. Also, the deliverable evaluates the use of smart contracts for automating security policies and enforcing access control.

'Self-healing and Self-recovery Mechanisms' [12], which documents an AI-powered solution that can detect and mitigate network anomalies caused by cyberattacks. The applicability of these mechanisms in mobile networks is evaluated and validated through realistic simulations.

'NANCY Explainable AI Toolbox' [13], which describes the architecture, functionalities, and components of the explainable AI toolbox that provides explainability into the decisions made by AI models. Furthermore, the applicability of the toolbox is evaluated in three scenarios, namely detection of cyberattacks, outage prediction, and semantic communications.

The solutions that are documented in the aforementioned deliverables have been successfully evaluated and validated in laboratory and simulated environments, demonstrating that they can improve the security, privacy, and trust of future networks.

5. Sources

[1] European Commission, "AI Act | Shaping Europe's digital future," Oct. 2025. [Online]. Available: https://digital-strategy.ec.europa.eu/en/policies/regulatory-framework-ai

[2] European Commission, "Data Act | Shaping Europe's digital future," Oct. 2023. [Online]. Available: https://digital-strategy.ec.europa.eu/en/policies/data-act

[3] European Commission, "Cyber Resilience Act | Shaping Europe's digital future," Mar. 2025. [Online]. Available: https://digital-strategy.ec.europa.eu/en/policies/cyber-resilience-act

[4] European Commission, "European Quantum Act," [Online]. Available: https://www.european-quantum-act.com/

[5] European Commission, "A Coordinated Implementation Roadmap for the Transition to Post-Quantum Cryptography," Jun. 2025. [Online]. Available: https://digital-strategy.ec.europa.eu/en/library/coordinated-implementation-roadmap-transition-post-quantum-cryptography

[6] European Union, "Communication from the Commission – Guidance Note concerning certain provisions of Regulation (EU) 2024/795 establishing the Strategic Technologies for Europe Platform (STEP), " May 2024. [Online]. Available: https://eur-lex.europa.eu/eli/C/2024/3209/oj/eng

[7] National Institute of Standards and Technology, "FIPS 203 Module-Lattice-Based Key-Encapsulation Mechanism Standard," Aug. 2024. [Online]. Available: https://doi.org/10.6028/NIST.FIPS.203

[8] National Institute of Standards and Technology, "FIPS 204 Module-Lattice-Based Digital Signature Standard," Aug. 2024. [Online]. Available: https://doi.org/10.6028/NIST.FIPS.204

[9] National Institute of Standards and Technology, "FIPS 205 Stateless Hash-Based Digital Signature Standard," Aug. 2024. [Online]. Available: https://doi.org/10.6028/NIST.FIPS.205

[10] NANCY Consortium, "D5.1 Quantum Key Distribution Mechanisms." [Online]. Available: https://nancy-project.eu/wp-content/uploads/2024/11/D5.1_Quantum_Safety_Mechanisms-v1.0.pdf

[11] NANCY Consortium, "D5.2 NANCY Security and Privacy Distributed Blockchain-based Mechanisms." [Online]. Available: https://nancy-project.eu/wp-content/uploads/2025/03/D5.2_NANCY_Security_and_Privacy_Distributed_Blockchain-based_Mechanisms_v1.0.pdf

[12] NANCY Consortium, "D5.3 Self-healing and Self-recovery Mechanisms." [Online]. Available: https://nancy-project.eu/wp-content/uploads/2025/06/NANCY_D5.3_Self-healing_and_Self-recovery_Mechanisms_v1.0.pdf

[13] NANCY Consortium, "D5.4 NANCY Explainable AI Toolbox." [Online]. Available: https://nancy-project.eu/wp-content/uploads/2025/06/NANCY_D5.4_NANCY_Explainable_AI_Toolbox_v1.0.pdf

6. Contact details

Project Title	NANCY: An Artificial Intelligent Aided Unified Network for Secure Beyond 5G Long Term Evolution
Grant Agreement ID	101096456
Project Coordinator	Prof. Panagiotis Sarigiannidis University of Western Macedonia, Greece psarigiannidis@uowm.gr
Website Link	https://nancy-project.eu/
Cordis Link	https://cordis.europa.eu/project/id/101096456

This policy brief was consolidated based on the outcomes of the research and development activities of the NANCY project.