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2025 *Activity Report*

RESEARCH CENTRE: **Inria Centre at Université Côte d'Azur**

Project-Team

DIANA

Design, Implementation and Analysis of Networking Architectures

Project-Team DIANA

Creation of the Project-Team: 2015 July 01

Each year, Inria research teams publish an Activity Report presenting their work and results over the reporting period. These reports follow a common structure, with some optional sections depending on the specific team. They typically begin by outlining the overall objectives and research programme, including the main research themes, goals, and methodological approaches. They also describe the application domains targeted by the team, highlighting the scientific or societal contexts in which their work is situated. The reports then present the highlights of the year, covering major scientific achievements, software developments, or teaching contributions. When relevant, they include sections on software, platforms, and open data, detailing the tools developed and how they are shared. A substantial part is dedicated to new results, where scientific contributions are described in detail, often with subsections specifying participants and associated keywords. Finally, the Activity Report addresses funding, contracts, partnerships, and collaborations at various levels, from industrial agreements to international cooperations. It also covers dissemination and teaching activities, such as participation in scientific events, outreach, and supervision. The document concludes with a presentation of scientific production, including major publications and those produced during the year.

Keywords

Computer sciences and digital sciences

A1.1.13. – Virtualization

A1.2.1. – Dynamic reconfiguration

A1.2.2. – Supervision

A1.2.3. – Routing

A1.2.4. – QoS, performance evaluation

A1.2.9. – Social Networks

A1.3. – Distributed Systems

A1.3.3. – Blockchain

A1.3.4. – Peer to peer

A1.3.6. – Fog, Edge

Other research topics and application domains

B6.2. – Network technologies

B6.2.1. – Wired networks

B6.2.2. – wireless networks

B6.2.3. – Satellite networks

B6.3.2. – Network protocols

B6.3.3. – Network Management

B6.3.4. – Social Networks

B8.5.2. – Crowd sourcing

B9.1.1. – E-learning, MOOC

B9.5.1. – Computer science

B9.5.6. – Data science

B9.8. – Reproducibility

B9.10. – Privacy

Contents

1 Team members, visitors, external collaborators

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2 Overall objectives

2.1 Presentation of the team

The overall objective of the DIANA project-team is to provide network architectural support for improving citizen rights in the Internet. To do so, we work to provide service transparency and user data control in the context of hundreds of billions of both wired and mobile devices. Our methodology includes advanced measurement techniques, design and implementation of architectural solutions, and their validation in adequate experimental facilities.

The high complexity of the Internet architecture, protocols and services, and the economic interests of the big stakeholders result in a lack of transparency concerning information of high interest to the connected "citizen" such as possible privacy leaks, root cause of service degradation or lock-in behavior. It is therefore important to enhance the network to provide service transparency to citizens.

On the other hand, the ossification of the Internet architecture around the IP protocol makes introduction of new functionalities in the network quite difficult. Users currently have no control on their contents and depend on big companies (e.g., Google drive, iCloud, dropbox, Microsoft OneDrive) to easily access and share data at the expense of their privacy. However, the recent development of software-defined network and network functions virtualization concepts open the perspective of faster deployment of network functionalities, as it abstracts the whole network as a single piece of software, instead of a large number of heterogeneous and dedicated devices to be configured one-by-one.

In our research, we follow an **experimental approach** in which the scientific evaluation of proposed solutions should be done in both controlled and realistic environments before deployment. In this context, reproducibility is key in designing networked systems and evaluating their performance in particular in highly variable wireless access networks.

In the DIANA project-team, we pursue three main research directions: (i) designing and deploying a measurement plane providing **network service transparency**, (ii) designing mechanisms for enhanced **programmable software networks**, and (iii) proposing tools and mechanisms for **network experimentation reproducibility**. These three points are detailed in the next section.

3 Research program

3.1 Network Service Transparency

Network Service Transparency is about providing network users and application developers with reliable information about the current or predicted quality of their communication services, and about potential leakages of personal information. Service transparency therefore means to provide information meaningful to users and application developers, in terms of high-level indicators such as quality of experience (QoE), or related to societal interests of the user as a "connected citizen" (e.g. possible violation of network neutrality, opinion manipulation, etc), rather than network-level metrics such as available bandwidth, loss rate, delay or jitter. The Internet's best-effort routing service simplicity, that comes with no guarantee in terms of quality of service (QoS), has been instrumental to its huge success, but unfortunately at the expense of a variable quality at the access. Despite considerable efforts done by operators and content providers to optimize the Internet content delivery chain, service degradation is still part of the Internet. The proliferation of wireless and mobile access technologies, and the versatile nature of Internet traffic, make end users quality of experience even harder to predict. The trend with modern apps, designed for mobile terminals, seems to exacerbate the difficulty, as they tend to focus on simpler interfaces and lesser control on the network. Interestingly, this same observation explains the existing difficulty to detect and prevent privacy leaks. We argue that the lack of transparency for diagnosing QoE and for detecting privacy leaks have the same root causes and can be solved using common primitives. For instance, in both cases, it is important to be able to link data packets to an application and to infer the behavior of the application. This is however a complex task as the traffic

might be obfuscated or encrypted. Our objectives in this research direction are to come up with tools that improve transparency, and privacy awareness. The proposed measurements techniques should adapt to the network architectural changes; deployment could be done either as an overlay, or by exploiting in-network functionalities as provided in 5G networks. The ultimate goal is to have measurements as native functionality in future network architecture.

3.2 Programmable Software Networks

The tremendous growth of demand for high-definition and personalized multimedia content places significant strain on the network's capacity, particularly for mobile networks. As a complement to network service transparency as mentioned above, network programmability allows to control traffic with a very high precision at large scale. It is important to leverage network programmability, efficient data dissemination mechanisms, and QoE modeling with the objective to better utilize network resources, and thus improve QoE. The general idea being that it is not always necessary to use the shortest, fastest, most stable paths to reach the highest quality of experience, which means that we can use detours, thus freeing direct paths for traffic requiring very high performance. It is worth noticing that carrying more traffic on a given network means having less margin in case of network faults. It is therefore important to work on fault-tolerant techniques in programmable networks. It is therefore important to work on algorithms that improve the dynamic placement, migration, and scaling up or down, of Virtual Network Functions (VNFs) in order to accommodate for resource availability and demand, heterogeneity, and mobility of users, so as to support applications with stringent demands such as e.g. ultra-high-definition video streaming. This includes fault management mechanisms, with controller-hosted algorithms that react quickly in case of link failures or network partitioning, and reprogram switches accordingly, so as to achieve maximal resilience of the data plane. It is also important to extend this thread of work to more specific areas, namely 5G Radio Access Networks, Intelligent Transport Systems (ITS) and industrial networks, that each has exhibited specific constraints, service requirement, and related challenges. This move requires to rely on Software Defined Networking (SDN) that enables a programmatic approach to networking, hence offering modularity and flexibility. The challenge with SDN is to be able to certify the behavior of the system while keeping the solution generic.

3.3 Network Experimentation Reproducibility

Network Experimentation Reproducibility is key for research activities that study networking systems in general, and wireless systems in particular, particularly when it comes to performance assessment. Ensuring scientifically sound, and thus reproducible, evaluation of such systems is time-consuming as it requires simulation, emulation and controlled experimentation tools, together with rigorous methodology. The DIANA project-team has a long tradition in this domain, building tools and methods, that in turn allow us to advocate reproducible research.

3.4 Methodology

We follow an experimental approach that can be described in the following techniques:

- Measurements: the aim is to get a better view of a problem in quantifiable terms. Depending on the field of interest, this may involve large scale distributed systems crawling tools; active probing techniques to infer the status and properties of a complex and non controllable system as the Internet; or even crowdsourcing-based deployments for gathering data on real-users environments or behaviors.

- Experimental evaluation: once a new idea has been designed and implemented, it is of course very desirable to assess and quantify how effective it can be, before being able to deploy it on any realistic scale. This is why a wide range of techniques can be considered for getting early, yet as significant as possible, feedback on a given paradigm or implementation. The spectrum for such techniques span from simulations to real deployments in protected and/or controlled environments.

4 Application domains

The DIANA project-team conducts research activities to provide network architectural support for improving citizen rights in the Internet. The main application domains of the teams are:

- Network and quality of experience measurement
- Detection of private information leaks
- Industrial deterministic networks
- Data center networks
- Deployment of future open radio networks (5G and beyond)
- Realistic simulations and reproducible experiments

5 Social and environmental responsibility

5.1 Socio-economic impact of research results

Over the past decade, networks have undergone a major transformation, marked by a clear shift from specialized hardware to software-based solutions running on affordable, generic infrastructures. This evolution has extended to cellular operator networks, both at the radio access and core network levels. Mastering this approach, known as "disaggregated radio networks," is crucial for France and Europe to maintain their sovereignty in the critical domain of future networks. This trend was confirmed by the publication of a manifesto by European operators in 2021. However, significant challenges remain: how to ensure high-throughput performance for software functions, how to maintain system reliability despite the complexity of interdependencies in software stacks, how to meet real-time constraints within a virtualized wireless network ? The availability of a large-scale digital infrastructure for testing and validating solutions before deployment is of critical importance.

With respect to theses challenges, our project team has played a key role in advancing SLICES-RI, contributing significantly to the design and deployment of SophiaNode, a platform jointly managed by Inria Sophia Antipolis and Eurecom. We have also led efforts to define and implement the SLICES Post-5G Blueprint and collaborated with European and American colleagues from the O-RAN initiative. Finally, we are about to engage in the upcoming DIGITAfrica project, which aims to develop a pan-African digital research infrastructure.

5.2 Non-Pharmacological Interventions (NPIs) Evaluation Model

We are working on two projects with significant societal impacts, The first one is on the definition of Non-Pharmacological Interventions evaluation model. This initiative aims to establish a standard framework for evaluating NPIs in healthcare, enhancing research quality, result comparability, and broader adoption in healthcare systems. Supported by 36 scientific societies and 14 French health authorities, it was presented at the French Senate in 2023 and is being developed at the European level for international adoption.

5.3 Greasy

This other initiative examines the persistence of cookies, revealing that users can still be tracked despite blocking or deleting cookies. It highlights how the advertising industry uses advanced tracking techniques to circumvent browser restrictions on third-party cookies. Findings from the project were presented at PrivacyCon21, hosted by the Federal Trade Commission, and received widespread media coverage in outlets like Le Monde and Techniques de l'ingénieur.

6 Highlights of the year

6.1 Awards

During the annual PEPR Future Networks Days at Enseirb-MATMECA in Bordeaux, PhD students and postdoctoral researchers from the projects presented their research work to the community. A best poster competition was held, awarding one winner per targeted project. Our PhD student Yassir Amami, supervised by Chadi Barakat and Thierry Turletti, won the best poster award for the targeted project on Network Architecture and Infrastrucuture. See the article on the PEPR page for more information.

6.2 Worldwide Dissemination and Training on the SLICES Post-5G Blueprint

In 2025, Damien Saucez led significant outreach and training activities to promote the SLICES Post-5G blueprint, to which our project team made a major contribution. Six hands-on training sessions were delivered in Chile, Guatemala, Portugal, South Africa, and France. The blueprint was presented and demonstrated at two international conferences (USA and Italy), while its experimental paradigm and redesign of experimentation practices were discussed at three additional conferences (France, Germany—industrial panel, and Poland). A dedicated hackathon on the Post-5G blueprint was also organized in Cyprus. See section 8.3 for more details.

7 Latest software developments, platforms, open data

7.1 Latest software developments

7.1.1 SLICES Post-5G Blueprint

Name: SLICES Post-5G Blueprint

Keywords: 5G protocols, Reproducibility, Evaluation platform

Functional Description: 5G's modular architecture bridges telecom and IT, fostering innovation in Post-5G research and providing a versatile framework for experimentation. However, deploying a complete 5G setup remains complex, requiring specialized expertise and significant resources, potentially diverting researchers from their core work. The SLICES Post-5G Blueprint addresses this by offering a modular, replicable framework of software, hardware, and methodologies, enabling full or partial deployments. Researchers can deploy only the 5G core, use a simulated RAN, or integrate multiple RANs with a core. The blueprint supports reproducible research through a step-by-step workflow and includes an open-source reference implementation using tools like OpenAirInterface, MinIO, FastAPI, kubernetes, and Ansible. Integrated into SLICES-RI, this framework simplifies Post-5G experimentation while promoting collaborative reproducible research.

URL: `https://doc.slices-ri.eu/BlueprintServices/beyond5G/beyond5G.html`

Contact: Damien Saucez

7.1.2 nepi-ng

Keywords: Wireless network, Experimentation

Functional Description: Experimentation is an essential step for realistic evaluation of wireless network protocols. `nepi-ng` leverages job oriented programming model, and efficient single-thread execution of parallel programs using Python's asynchronous programming paradigm (`asyncio`) to provide an efficient and modular fine-grained synchronization mechanism for networking experiments, with a light software dependency footprint. `nepi-ng` has been designed with the ambition to address the challenges of (1) efficiency: removing all possible overhead, even when an experiment is remotely controlled over several ssh hops, (2) light software dependency footprint: keeping the overall software dependencies to a strict minimum, so that the approach can be applicable in a wide variety of contexts and testbeds, and (3) modularity: allowing pieces of code to be re-used or shared.

URL: https://nepi-ng.inria.fr

Contact: Thierry Parmentelat

7.2 New platforms

Participants: Thierry Parmentelat, Thierry Turletti, Damien Saucez, Walid Dabbous.

7.2.1 Reproducible research Lab - R2lab

The R2lab testbed has been operating 24/7 since early 2016. It has been used by more than 150 users, half of them from France and the other half from all over the world to evaluate a wide range of wireless networking scenarios in a realistic and reproducible environment (see usage statistics here). The facility remains stable with minimal disruptions.

The focus is on leveraging our investments to advance reproducible research. R2lab has been upgraded with advanced equipment, including 5G Benetel ORAN Radio Units (O-RUs), 5G mmWave LITE-ON O-RU, AW2S 5G Remote RUs (RRUs), Universal Software Radio Peripherals USRP N300 and N320 devices, all connected via high-speed fiber to the SophiaNode cluster, and offering enhanced capabilities for MIMO (Multiple Input Multiple Output) configurations.

Recent software developments have focused on supporting Docker images alongside metal-based formats for images, enabling experimenters to use off-the-shelf OAI (Open Air Interface), Open5GS and SRSran images, as well as mainstream tools for building images.

R2lab has been integrated into the SLICES-RI infrastructure [5] via the SophiaNode. To ensure reproducibility of previous experiments conducted in R2lab, the existing equipment remains accessible through the R2lab workflows while also being compatible with the SLICES-RI workflow. In contrast, new equipment will be exclusively used within the SLICES-RI workflow. In other words, the evolution of R2lab is designed to be backward compatible.

7.2.2 SophiaNode: an open programmable 5G platform

The advent of 5G has blurred the lines between wireless and wired networks, cloud computing, and data management. To support Post-5G experimentation, R2lab is being expanded to incorporate programmable networking, cloud resources, and high-performance real-time processing at scale. This evolution, called the SophiaNode, is a SLICES-RI site developed in collaboration with Eurecom. The SophiaNode comprises three wireless facilities: the R2lab anechoic chamber at Inria augmented with 5G hardware, an indoor site at Eurecom, and an outdoor site on the SophiaTech campus. These facilities are interconnected via high-speed fiber links (600 Gbps as of this writing) to a data center at Inria, which hosts compute resources (1500^+ cores, 3^+ TB RAM), storage (planned 250^+ TiB), and hardware accelerators like GPUs and SmartNICs.

This year, significant efforts have established SophiaNode as a reference site for the SLICES-RI project. It is the first site to fully implement the SLICES Post-5G blueprint. Since entering its pre-operation phase on November 11th, 2024, the SophiaNode has become a cornerstone of the SLICES-RI deployment.

8 New results

8.1 Network Service Transparency

8.1.1 Leveraging Web browsing performance data for Network monitoring

Participants: Chadi Barakat.

Despite advances in network technologies, slow web browsing remains a persistent issue, and its troubleshooting continues to be challenging. Various tools attempting to actively collect web measurements through the injection of probes into the network exist, such as Ookla and M-Lab speed tests. These tools are known to be intrusive as each run of them incurs a non-negligible cost on the network. Further, no solution is able to identify the specific cause of web browsing performance degradation. Within the WEMON project we worked with Sanaa Ghandi, post-doctoral resarcher in DIANA in 2024, on a light-weight passive measurement solution that relies on web performance data readily available within the browser, such as the connect time, the response time, and the page load time, to infer network performance, detect anomalies, and troubleshoot their origins. Through controlled network experiments with manually injected anomalies, including multiple concurrent performance issues, and leveraging a dataset of more than 43K webpages and tens of thousands of network scenarios, we developed a predictive model using machine learning that is capable of estimating network performance metrics with acceptable accuracy by solely relying on users' daily web activity. Our solution can continuously monitor network performance, identify anomalies, and provide actionable insights, without overloading the network with measurement probes, thus making network troubleshooting accessible and non-intrusive for everyday users. Our solution can be used in the wild in the form of a browser plugin to monitor the network and shed light on its anomalies without actively probing it. The WEMON project was supported by the Academy of Excellence "Networks, Information, and Digital Society" of Université Côte d'Azur, and the results of this work were published in [11].

8.1.2 Decomposing Delay in 5G: An Empirical Study on Architecture and Configuration Impact

Participants: Chadi Barakat, Walid Dabbous, Mohammadbagher Tavassoli Kejani, Thierry Turletti.

5G networks have the potential for ultra-low latency communication, supporting a broad array of critical and delay-sensitive applications. However, end-to-end performance prediction in 5G scenarios is still a challenging problem, given the complexity of the system architecture and the interconnection of a multitude of interrelated parameters that contribute to delay. In this work, we report an experiment-driven investigation on the basis of an actual standalone 5G deployment to better understand how interdependent configuration parameters, such as Time Division Duplex (TDD) and scheduling request (SR) settings, contribute to round-trip time (RTT). For instance, in a 2 ms TDD periodicity configuration, RTT was reduced by 30% after aligning SR periodicity with the frame structure, highlighting the decisive impact of scheduling configuration. Through the integration of fine-grained measurement and delay component analysis, we reveal the major contributors to latency and highlight the crucial role of empirical assessment and careful parameter tuning in realizing dependable low-latency operation in 5G networks. This work, supported by the NF-NAI project of the PEPR Future Networks, was published in [16].

8.1.3 Toward Real-Time RAN Observability in Open-Source 5G Systems

Participants: Yassir Amami, Chadi Barakat, Ziyad Mabrouk, Thierry Turletti.

Diagnosing performance issues in 5G and future disaggregated networks remains challenging due to the complexity of the protocol stack and the multitude of interdependent metrics. This is especially true in experimental environments using opensource 5G software, where logs are often verbose, fragmented, and difficult to interpret. Real-time visual observability, especially at the Radio Access Network (RAN) level, is therefore essential for effective troubleshooting. However, tools like 5GC-Observer and Monarch provide only partial support, focusing mainly on the core network and lacking visibility into the RAN, where many performance bottlenecks originate. To tackle this, we present a Prometheus-compatible telemetry pipeline for the OpenAirInterface (OAI) Next-Generation Node B (gNB) that extracts RAN metrics, adjusts acquisition intervals via a custom FlexRIC model, and visualizes the data in real time with Grafana. The pipeline is also compatible with the open source SRSRAN software through a lightweight Telegraf-Prometheus integration, extending its use to multiple open-source stacks. We integrate our solution into the Monarch monitoring

architecture for cloud-native 5G, enabling end-to-end observability. An Ansible-based automation simplifies testbed setup and ensures reproducible experimentation. Validation on a realistic testbed shows real-time RAN metrics exposure with negligible overhead. This contribution, supported by the NF-NAI project of the PEPR Future Networks, was published in [10].

8.1.4 Evaluation of non-pharmacological intervention

Participants: Arnaud Legout.

Non-pharmacological interventions (NPIs) refer to health prevention and care protocols supervised by healthcare professionals, yet no precise and widely accepted definition currently exists. Unlike drugs, NPIs lack a global evaluation framework due to the heterogeneity of their content and study protocols, which limits scientific impact, hinders dissemination, and fosters mistrust among professionals and users. From 2022 to 2023, a large consensus study involving more than 1,000 stakeholders—including researchers, healthcare users, practitioners, health operators, scientific societies, and health authorities—was conducted to co-construct a shared NPI definition and an adapted evaluation framework, to which our team made substantial contributions. The resulting NPIS Model was developed through an iterative, transparent, and documented process coordinated by a multidisciplinary committee of 22 experts, including a member of our team. Our team carried out the statistical analysis of the consensus study, contributed to the development of the evaluation model, and subsequently led the rewriting of the manuscript and the management of journal submissions over the past year. This work is reported in two complementary publications: the original article currently under submission to an international journal [18], and a French summary published in the journal Santé Publique [9].

8.2 Programmable Software Networks

8.2.1 RIS-aided communication

Participants: Walid Dabbous, Manel Khelifi, Stefano Lioce, Damien Saucez.

Reconfigurable Intelligent Surfaces (RIS) are emerging as a transformative technology for the evolution of 5G and beyond wireless communication networks. These surfaces are composed of tunable metasurfaces containing hundreds of controllable elements, capable of dynamically manipulating electromagnetic waves by adjusting their reflection, propagation, and reconfiguration. RIS-assisted systems facilitate signal transmission in complex environments by intelligently redirecting signals toward their destinations, mitigating blockages, and reducing interference. As a result, they enhance network coverage, improve spectrum reliability, and increase energy efficiency. Despite significant advancements in RIS-assisted systems, comprehensive studies on their integration into future networks remain limited, particularly regarding the challenges of developing robust channel models. This research has focused on modeling the behavior of RIS-assisted communication in real network scenarios. One notable contribution involves exploring the relationship between circuit parameters—critical for representing the unit cells within metasurfaces and their reconfigurability circuits—and system-level parameters, to assess the overall performance of RIS-assisted communication. A first contribution we had this year is to investigate the impact of phase quantization on communication performance. We analyzed scenarios involving both continuous and quantized phase values, examining the effects of quantization while considering the influence of circuit components in RIS unit cells. A paper detailing the findings of this research published in the LASCAS symposium 2025 [14]. We pursued our collaboration with our colleagues in Politecnico di Bari on the analysis of circuit-level non-idealities in RIS-aided wireless communications. In addition to the different phase quantization strategies, we explored the influence of the number of unit cells, and the reflection angle on the system's performance. In the specific case of RISs composed of unit cells equipped with varactor diodes to enable reconfigurability, we assessed the impact of varactor non-ideality on system performance. The results demonstrated that performance improves with increasing transmission power, increasing the number of elements, and increasing the resolution of

phase values. Conversely, performance deteriorates as the reflection angle approaches the end-fire direction. Moreover, concerning the reconfigurable unit cell based on a varactor diode, we showed that the diode non-ideality requires a subsequent surface calibration step to enhance system performance. More details can be found in our paper published in 32^{th} IEEE International Conference on Electronics Circuits and Systems, ICECS2025 [13]. We also launched a study to assess the performance gains of RIS-assisted 5G communication in indoor environments. The goal was to study if RIS can improve signal quality in the case of indoor 5G communications. To that aim, we simulate wave propagation and study the effect of the RIS on the received signal with the NVIDIA Sionna Ray Tracing (Sionna RT) library. We consider short range indoor environment (decameters) to quantify how much a RIS can improve received signal strength coverage to evaluate the signal on the entire indoor environment, not only at the expected receiver. Results show that when a RIS can help in improving the received signal, it is necessary to precisely know the location of the receiver, which is not always feasible. More details can be found in our paper published in EUSIPCO'2025 [12].

8.2.2 Vision-radio simulator

Participants: Manel Khelifi, Walid Dabbous, Damien Saucez.

Our team leads the development of the vision-radio simulator within the Converge project, which involves integrating several independent software components developed by project partners. To facilitate this integration, we have created a shared model that ensures experimental setups are specified in a rigorous and portable manner. This model is built on Pydantic to enable automatic code generation, documentation, and data validation.

Alongside this, we have implemented the Vision-Radio Simulator, using the shared model as its input/output interface. The simulator processes a 3D scene (either as a 3D mesh or points cloud) and the locations of communication and video equipment (UE, gNB, RIS). Its function is to compute the signal coverage map based on the Received Signal Strength (RSS) and the Signal to Interference plus Noise Ratio (SINR) across the entire environment using Ray-Tracing and meta-material properties. To streamline usage and integration, the simulator is encapsulated within an HTTP REST API.

8.2.3 Provable real time network updates

Participants: Damien Saucez.

Next generations of smart factories and industrial systems will rely on commodity Ethernet hardware and 5G. In this context, it is essential to provide means to guarantee that any configuration action in the network preserves network performances within known and acceptable boundaries. By means of binary decision diagrams, we are building models of incremental network updates that guarantee not only latency and bandwidth contraints but also jitter and that are immune to vulnerabilities. This ongoing work is done in collaboration with the RESIST project-team at Inria Nancy, Aalborg University, and TU Berlin. The results of this work have been published in NOMS'25 [15]. We are currently working on extending this work to support Service Function Chaining (SFC).

8.2.4 Leveraging on Bitcoin graph structure to identify illicit Bitcoin addresses.

Participants: Arnaud Legout.

In collaboration with Abdoul Nasser Hassane Amadou, Anas Motii, and Imane Fouad from UM6P, Morocco, and Konstantin Avrachenkov from Inria, we explored how to predict illicit bitcoin addresses, that

is, addresses used for illegal activity. The core idea is that illegal activities lead to specific patterns of money exchange among addresses, which can be identified through characteristic graph structures. By combining a self-supervised temporal graph neural network trained on a continuous-time dynamic transaction graph, we embed each address in a space that represents not only its local graph structure but also its temporal evolution. We then use these embeddings to train a second, supervised model based on a set of annotated addresses constructed from public datasets and addresses collected from hacker forums. The resulting model outperforms state-of-the-art approaches for predicting illicit addresses. This work is currently under submission.

8.2.5 Bitcoin Burn Addresses: Unveiling the Permanent Losses and Their Underlying Causes

Participants: Arnaud Legout.

Bitcoin burn addresses are addresses where bitcoins can be sent but never retrieved resulting in the permanent loss of those coins. Given Bitcoin's fixed supply of 21 million coins, understanding the usage and the amount of bitcoins lost in burn addresses is crucial for evaluating their economic impact. However, identifying burn addresses is challenging due to the lack of standardized format or convention. In this paper, we propose a novel methodology for the automatic detection of burn addresses using a multi-layer perceptron model trained on a manually classified dataset of 196,088 regular addresses and 2,082 burn addresses. Our model identified 7,905 true burn addresses from a pool of 1,283,997,050 addresses with only 1,767 false positive. We determined that 3,197.61 bitcoins have been permanently lost, representing only 0.016% of the total supply, yet 295 million USD on November 2024. More than 99% of the lost bitcoins are concentrated in just three addresses. This skewness highlights diverse uses of burn addresses, including token creation via proof-of-burn, storage of plain text messages, or storage of images using the OLGA Stamps protocol. This work is documented in a research report [17].

8.2.6 LISP standardization

Participants: Damien Saucez.

LISP (Locator/Identifier Separation Protocol) is an IETF-defined networking protocol that separates IP addresses into endpoint identifiers and routing locators to improve scalability, mobility, and multihoming in IP networks. In 2025, we contributed to an Internet-Draft that defines the LISP Delegated Database Tree (LISP-DDT) [30], a hierarchical, distributed control-plane database for scalable mapping between Endpoint Identifiers (EIDs) and Routing Locators (RLOCs) in the LISP architecture.

LISP-DDT relies on a static delegation of the EID namespace across control-plane entities called DDT Nodes, each authoritative for one or more EID prefixes. DDT Nodes delegate more specific prefixes to Map-Servers or child DDT Nodes, enabling efficient and scalable EID-to-RLOC resolution while preserving administrative autonomy.

The document [30] obsoletes RFC 8111 and updates RFC 9301, consolidating and refining the LISP-DDT specification as part of ongoing IETF standardization work. After several years of effort in the Internet Engineering Task Force IETF working groups on LISP standardization, three Request for Comments (RFCs) were published in 2022 : one informational track RFC on Locator/ID Separation Protocol (LISP) architecture and two standard track RFCs on LISP security protections and on inter-domain message exchanges. We are currently working on moving RFC8111 from the experimental category to the Standards Track.

8.3 Experimental Evaluation

8.3.1 SLICES-RI Post-5G Blueprint

Participants: Damien Saucez, Thierry Turletti.

A significant scientific outcome of this research axis is the definition, implementation, and initial deployment of the SLICES-RI Post-5G blueprint. This blueprint fosters collaboration between engineers and non-engineers by creating a shared terminology and a consistent vision aligned with specific research objectives. It categorizes research in 5G and beyond into five distinct categories, each complementing the others.

At the top level, vertical service integration supports experimenters who use a 5G environment to transport their workloads without focusing on 5G research itself, treating 5G as a utility. The second category addresses researchers developing custom algorithms for network resource allocation, requiring access to the network control plane. Deeper layers involve researchers modifying the Medium Access Control (MAC) and physical layers, typically implemented in radio component firmware, necessitating privileged logical access to update hardware code. Another category includes researchers developing custom hardware, such as antennas or metasurfaces, which requires physical access to integrate new components into the infrastructure. Finally, the fifth category combines telecommunications and computational resources for studies such as cyber-system analysis and digital twin development to replicate real-world environments.

This clear classification of experiment categories helps identify the core requirements and building blocks necessary to support Post-5G research. Key elements include the ability to deploy custom 5G core networks and distributed Radio Access Networks, configurable and modifiable radio hardware, and unrestricted access to APIs for manipulating both control and user planes, as well as modifying codebases, firmware, and network settings. Additionally, the blueprint implementation must automatically collect experimental data and metadata, making it available to both users and the broader research community.

Based on these requirements, we have designed a fully adaptable, multi-site, multi-technology 5G environment. This environment enables researchers to select and customize specific components without needing to modify the rest of the system. A reference implementation of the blueprint has been developed and integrated into the SLICES-RI services portal. In November 2024, the Post-5G Blueprint service was deployed in a pre-operational mode within the SLICES-RI infrastructure.

This year, significant efforts have been made to advertise the SLICES Post-5G blueprint to the research community and train researchers. Two hands-on session have been provided in Chile, one in Guatemala, one in Portugal, one in South Africa, and one in France. In addition, the Post-5G blueprint has been presented and demoed in 2 conference (1 in US and the other in Italy) and the blueprint approach and how it redesigns the notion of experiments has been discussed in 3 conférences (1 in France, 1 in Germany during an industrial panel, and 1 in Poland). In addition, one hackathon was organized on this topic in Cyprus. Here is the detail of theses dissemination activities:

- Presentation and demonstration at the FABRIC Community Workshop, KNIT10, Chapel Hill, NC, March 11-12, 2025 [27].
- Demonstration at the IEEE Wireless Communications and Networking Conference (WCNC) 2025, Milan, Italy, March 24–27, 2025 [29].
- Hands-on session at the OpenRIT 6G Workshop Chile 2025, Santiago Chile, April 1-3, 2025 [19].
- Presentation at the Inaugural DIGITAfrica Workshop, Cape Town, South Africa, April 24-25, 2025 [20].
- Hackathon at the IFIP networking 2025 Conference, Limassol, Cyprus, May 26-29, 2025.
- Presentation at the European Conference on Networks and Communications (EuCNC) 2025, Poznan, Poland, June 3-6, 2025 [22].
- Hands-on session at the Converge summer school 2025, INESC Porto, Portugal, June 25-27, 2025 [24].
- Hands-on session at the SLICES-FR summer school, ENS Lyon, July 7-11, 2025 [21].
- Presentation at the Datacom Industry Association DIA 2025 gathering, Munich, September 29, 2025 [28].

- Panel participation and Hands-on session at the BridgEX LatAm Workshop, Viña del Mar, Chile, October 28, 2025 [25].
- Tutorial and Hands-on session at the IEEE Latin-American Conference on Communications (Latincom) 2025, Antigua, Guatemala, November 5–7, 2025 [26].
- Presentation at the Journées IA et Infrastructures, GDR RSD, Palaiseau, December 16-17, 2025 [23].

We have also focus our technical work on supporting data with the addition of 284 TB of user storage and integrated the SophiaNode in the SLICES Basic Infrastructure services.

8.3.2 SLICES-RI DIGITAfrica Blueprints

Participants: Damien Saucez.

A consultation with African partners has resulted in a synthesized vision of the technical services, also referred to as blueprints, that the DigitAfrica RI should provide. As a result of this consultation, two blueprints have been defined. One focuses on providing 5G/IoT connectivity to enable researchers to conduct experiments requiring such connectivity and to allow students to learn the fundamentals of networking technologies. The other aims to deliver a ready-to-use platform for running AI/ML at the edge. Based on the consultation, a tiered approach with a progressive rollout has been adopted to allow time for partners to build their competencies. The work package has emphasized that the technologies developed for SLICES-RI and GreenDigit cannot be directly applied, as the needs and technology requirements in the context of DigitAfrica are highly diverse, whereas SLICES-RI and GreenDigit relies on more standardized needs and technology.

We have defined the technical implementation of services to support the blueprints. These blueprints are modular, tiered service ecosystems designed for both local and global asynchronous management, enabling scalable, incremental deployment according to available resources. Each service is treated as a black box, starting with low-tech, low-skill solutions and progressively evolving as partners build their knowledge and competencies. The ecosystem is flexible, supporting asynchronous operations to accommodate varying local conditions and outages, while allowing both local teams to address specific needs and global teams to oversee broader management. The implementation architecture is standardized, enabling the same baseline for all blueprints, thus reducing time to production and hardware deployment. We have implemented a local and distributed authentication and identification mechanism, resistant to graph partitioning, utilizing local identity providers as aggregators.

9 Partnerships and cooperations

Participants: Chadi Barakat, Walid Dabbous, Damien Saucez, Thierry Turletti.

9.1 International research visitors

9.1.1 Visits of international scientists

Inria International Chair Professor Katia Obraczka has been awarded an Inria International Chair for the 2021-2025 period. The research program entitled: "Smart Networks: When Computational Intelligence and Networking Meet" will explore synergies between machine learning (ML) and networking domains by addressing two complementary goals: (1) Explore ML techniques as they apply to networks, their protocols, and their services towards intelligent network systems that are simple, automatically adapt to current conditions, do not require human in the loop, and deliver adequate end-to-end performance; and (2) Investigate how networking can benefit and empower ML. More specifically, as computing and storage shift to the edge of the network, this chair is interested in exploring how ML can leverage the network as

a distributed, decentralized computing resource to handle the enormous amounts of data generated at the edge by providing full decentralization without compromising accuracy and preserving end user privacy. Prof Obraczka had realized up to now two visits to Inria, one in November 2022 and one in October 2024. Since 2023, Katia has been appointed campus director of the Center for Information Technology Research in the Interest of Society (CITRIS) at UCSC reducing her availability for bilateral collaboration. Thierry Turletti is co-supervising with Katia the PhD thesis of Anuj Kaul on Decentralized Network Control and Its Applications to Autonomous Vehicles.

Other international visits to the team

Federica De Trizio

Status: visiting PhD

Institution of origin: Politechnico di Bari

Country: Italy

Dates: April 2025 - August 2025

Context of the visit: academic collaboration

Mobility program/type of mobility: research stay

Federica De Trizio visited the Diana team to consolidate her work on Digital Twins for next-generation cellular networks. In her PhD, she is interested in developing models for these networks in the form of Digital Twins that can assist in resource allocation, enabling more efficient implementation of network slicing and improved quality of service for end users.

These models aim to help operators make appropriate decisions regarding when to accept new resource requests, how to instantiate them, and how to reallocate already admitted traffic so that quality of service is maintained while network resources are fully utilized.

Federica built upon discussions with the Diana team members to further refine her Digital Twin framework and to take operational constraints into account. Her experience in building these tools was also beneficial to the team, particularly in learning how to model network performance in order to predict performance degradations and troubleshoot their root causes.

9.2 European initiatives

9.2.1 Horizon Europe

CONVERGE

- Title: Telecommunications and Computer Vision Convergence Tools for Research Infrastructures
- Duration: 36 months, (1/2/2023, 31/1/2026)
- Coordinator: INESC TEC
- Partners: 16 members including INESC TEC (Portugal), UOulu (Finland), ALLBESMART (Portugal), Greenerwave (France), Eurecom (France).
- Inria contact: Walid Dabbous and Damien Saucez
- Website: CONVERGE
- Summary: The main objective of the CONVERGE project is the development of an innovative toolset aligned with the motto “view-to-communicate and communicate-to-view”. This toolset is a world-first and consists of vision-aided large intelligent surfaces, vision-aided fixed and mobile base stations, a vision-radio simulator and 3D environment modeler, and machine learning algorithms for multimodal data including radio signals, video streams, RF sensing, and traffic traces. This toolset

will be deployed into 7 Research Infrastructures (RIs) mostly aligned with the ESFRI SLICES-RI and improve their competitiveness. CONVERGE will also provide the scientific community with open datasets of experimental and simulated data obtained with the toolset in the RIs, meet scientific and industrial requirements by addressing relevant 6G verticals, enhance the competitiveness of the involved companies, extend the European influence to world-wide recognized RIs, enable the creation of new RIs, contribute to the development of new environment-friendly tools, and help European Union to address its societal challenges.

- DIANA project-team's role in the project: DIANA leads Task 2.4, focusing on the design and implementation of a Vision Radio Simulator, a key component of the Digital Twin for the CONVERGE experimental chamber.
- Budget allocated to the DIANA project-team: 431 k€.

SLICES - PP

- Title: Scientific Large-scale Infrastructure for Computing/Communication Experimental Studies - Preparatory Phase
- Duration: 40 months (1/9/2022 to 31/12/25)
- Coordinator: INRIA
- Partners: 25 partners with a large intersection with SLICES-SC.
- DIANA project-team contact: Damien Saucez
- Website: SLICES-PP
- Summary: The digital infrastructures research community faces challenges in designing the Next Generation Internet, a complex ecosystem integrating Internet of Things (IoT), 5/6G, and cloud-to-edge computing, alongside data management and intelligence. Addressing the need for experimental research, SLICES-RI, part of the 2021 ESFRI roadmap, aims to build a large-scale infrastructure to support experimentation in distributed computing, networking, and digital technologies. Building on SLICES-DS and SLICES-SC, the SLICES-PP project focuses on validating requirements, defining governance, legal, and financial frameworks, and finalizing the technical architecture for implementation. It seeks to secure commitments from member states and stakeholders, positioning SLICES as a key tool for advancing European research, industrial innovation, and societal impact.
- DIANA project-team's role in the project: we contribute to the definition of the long-term architecture of the SLICES-RI.
- Budget allocated to the DIANA project-team: this project budget was kept in a common pool at the national level.

DIGITAfrica

- Title: DIGITAfrica
- Duration: 36 months (1/1/2025 to 31/12/2027)
- Coordinator: Sorbonne Université (SU)
- Partners: 8 European members including SU, TUB, UTH, CNR, BSC, and 5 African members Strathmore University (Kenya), Université Cheikh Anta Diop de Dakar (Senegal), Université de la Manouba (Tunisia), Université de Ngaoundéré (Cameroon), University of Cape Town (South Africa).
- Inria contact: Damien Saucez

- Summary: The overall goal of the DIGITAfrica Coordination and Support Action is to prepare an effective and long-term pan-African Digital research infrastructure. For that purpose, the project will develop and assess a comprehensive framework to engage the research community, develop the skills, propose a first blueprint and raise awareness of the key stakeholders.

- DIANA project-team's role in the project: Expand the SLICES Blueprint to incorporate the technological considerations and needs of our African colleagues.

- Budget allocated to the DIANA project-team: 115 k€.

9.3 National initiatives

Our team is involved in three projects within the context of the acceleration PEPR on 5G and future networks.

The 5G network and the networks of the future represent a key issue for French and European industry, society and digital sovereignty. This is why the French government has decided to launch a dedicated national strategy. One of this strategy's priority ambitions is to produce significant public research efforts so the national scientific community contributes fully to making progress that clearly responds to the challenges of 5G and the networks of the future. In this context, the CNRS, the CEA and the Institut Mines-Télécom (IMT) are co-leading the 5G acceleration PEPR to support upstream research into the development of advanced technologies for 5G and the networks of the future. The DIANA project-team is involved into 3 research projects over the ten targeted supported by the program NF-MUST, NF-NAI and NF-FPNG.

9.3.1 NF-MUST

- Title: End-to-end multi domain services management architecture of the networks of the future

- Coordinator : Djamal Zeghlache (IMT)

- Inria teams participanting to the project : COATI, DIANA, ERMINE

- Summary : The 5G and 6G end-to-end Multi-Domain Services Management Architecture (NF-MUST) project aims at automating production of inter-domain (business and application level) services for 5G, 5G Beyond and 6G networks. A challenging and still unrealized evolution today compared with single domain services or pre-established static multi-domain services that are gradually emerging in 5G and Beyond. Project NF-MUST of the PEPR 5G and Future Networks, focuses mainly on transforming client requests into end-to-end service orderings and on mapping them to resources and network level services (to be) provisioned by the multiple underlying networks. There is a clear evolution of 5 and 6G networks towards the provisioning of services involving multiple players and multiple technologies. Project NF-MUST addresses the related roles and interactions between customers and multiple domains in connection to the other "PEPR 5G and Future Networks" projects, to ensure automated production and operation of multi-domain services across multiple providers. Besides ordering services, NF-MUST will drive the management of the life cycle of the infrastructures provisioned services and partake in their dynamic and automated adaptation and operation. NF-MUST operates at the business subsystem (BSS) level and at the service side of the operation subsystem (OSS) level. NF-MUST interacts directly with network services treated by project 2 of the overall program.

- Role of the DIANA team: Co-supervise a PhD thesis with COATI on "Efficient resource utilisation for service management in next generation networks", that has started in October 2024.

9.3.2 NF-NAI

- Title: Network and infrastructure architectures and network-cloud-sensing convergence

- Coordinator : Jean-Louis Rougier (IMT)

- Inria teams participanting to the project : AGORA, DIANA, RESIST, TRiBE.

- Summary: The primary challenge of the NF-NAI project lies in the efficient, secure, and cost-effective design, development, planning, and operation of networks and integrated network-cloud-sensing systems. These systems must seamlessly collaborate with diverse sectors of activity while accommodating the broad spectrum of existing applications, each with varying resource and performance demands. Furthermore, they must exhibit the flexibility and agility required to dynamically adapt to evolving future requirements. The NF-NAI project should go further than traditional objectives like throughput, execution speed, latency, or object connection density and enable the effective integration of a multitude of new technologies. This should include technologies for the physical layer (reconfigurable intelligent surfaces) , 3D transition (NTN - non-terrestrial networks), and architectural principles (like slicing and dynamic end-to-end orchestration). The project will promote the emergence of new applications and services thanks to transparency in terms of performance, robustness, and user security. The project will also put forward and implement interfaces with convergent network-cloud-sensing systems, offering a rich level of transparency to application developers, ranging from the edge to the cloud, from connected mini-objects to large data centers through multi-access edge computing (MEC).
- Role of the DIANA team: Supervise two PhDs that have started in 2024. The first one on "Monitoring plane for mobile cellular networks" and the second on "Experimental evaluation of sliced cellular networks".

9.3.3 NF-FPNG

- Title: French network of test platforms for new-generation mobile communications
- Coordinator: Raymond Knopp, Eurecom
- Inria teams participanting to the project : DIANA, MARACAS.
- Summary: The targeted NF-FPNG project is dedicated to setting up nationwide research infrastructures to test new hardware components for 5G and evaluate paradigms for the next generation of telecommunications networks. These research infrastructures will target basic technological components and also end-to-end network testing. This programme of platforms aims to work with all the important technologies in this area - from elementary electronic components to large-scale networking experiments - to provide responses to all the specific challenges defined by the Networks of the Future PEPR project. NF-FPNG's aim is firstly to structure this set of infrastructures and provide free access to existing infrastructures for the national group of PEPR researchers. Its second aim is to invest in new strategic and advanced infrastructures required to respond to the many challenges of the future.
- Role of the DIANA team: participating in the definition and deployment of the infrastructure. Our team has funding designated for acquiring necessary hardware equipment and engaging one DevOps engineer.

9.4 Regional initiatives

Arnaud Legout was awarded the Projet Bitlauder under the RISE Academy of Excellence "Networks, Information, and Digital Society" within the IdEx UCA JEDI program at Université Côte d'Azur, with funding of €60k, including €45k allocated for a server; the decision was made in February 2025.

10 Dissemination

10.1 Promoting scientific activities

10.1.1 Scientific events: organisation

General chair, scientific chair

- Damien Saucez frequently co-chairs ACM Artifacts Evaluation Committees and is part of the volunteers to assess reproducibility for the ACM. To cite only the most recent ones, he co-chaired:

  - ACM SIGCOMM'23 Artifacts Evaluation Committee
  - ACM IMC 2025 Reproducibility Track
  - ACM IMC 2026 Reproducibility Track

Member of the organizing committees

- Damien Saucez has co-organized:
  - The Hackathon on : Thought experiments, data and reproducibility for networking and FutureG research at the IFIP Networking conference. ACM SIGCOMM'23 Artifacts Evaluation Committee

10.1.2 Scientific events: selection

Member of the conference program committees

- Chadi Barakat is/was member of:
  - the Technical Program Committee for the ACM Internet Measurement Conference (IMC 2025 and 2026),
  - the Network Traffic Measurement and Analysis Conference (TMA 2025 and 2026),
  - and the International Teletraffic Congress (ITC 36) in 2025.
- Damien Saucez is/was member of:
  - the Technical Program Committee for the ACM Internet Measurement Conference (IMC 2025 and 2026).
- Thierry Turletti is/was member of:
  - the Technical Program Committee for the IEEE Conference on Communications (ICC'25),
  - the 1st International Conference on ns-3 (ICNS3'25),
  - and 21st IEEE/IFIP Network Operations and Management Symposium (NOMS'25).

10.1.3 Journal

Member of the editorial boards

- Chadi Barakat is member of:
  - the Editorial Board of the Computer Networks journal (COMNET).
- Arnaud Legout is member of:
  - the Editorial Board of the journal Proceedings on Privacy Enhancing Technologies (PoPETs).
- Thierry Turletti is member of:
  - the Editorial Board of the Wireless Networks journal published by Springer.

10.1.4 Scientific expertise

- Thierry Parmentelat is the principal Engineer in charge of the R2lab testbed.

10.1.5 Research administration

- Chadi Barakat was nominated in 2025 Director of the Academy of Excellence "Networks, Information, and Digital Society" of Université Côte d'Azur, and is serving as member of the Steering Committee of the Center of Modeling, Simulation and Interactions (MSI) of Université Côte d'Azur, the Comité de Suivi Doctoral (CSD) of Inria centre at Université Côte d'Azur, and the organizing committee for the Forum Numerica seminars of Université Côte d'Azur dedicated to sciences and their impact on society and humankind.
- Walid Dabbous served as Director of the Academy of Excellence RISE (Networks, Information and Digital Society) at Université Côte d'Azur and as a member of the Scientific Committee of the DS4H Graduate School from 2021 to April 2025. He has been a member of the Steering Committee of the Ubinet International Master's program since 2009. In 2025, he was appointed Scientific Director of IDEX Université Côte d'Azur.
- Thierry Turletti is a member of the Comité de Centre at the Inria centre at Université Côte d'Azur since 2024. He is also member of the Comité de suivi mentorat and of the Commission Locale de Formation at the Inria centre at Université Côte d'Azur since 2025.
- Arnaud Legout is local correspondent of the Inria ethical committee and member of the Université Côte d'Azur ethical committee (CER) since January 2024.

10.2 Teaching - Supervision - Juries

10.2.1 Teaching

- Master2 Ubinet: Chadi Barakat and Walid Dabbous, Evolving Internet, 21 hours.
- Master2 Ubinet: Arnaud Legout, From BitTorrent to Privacy, 15 hours.
- Master2 Estel - Electronics and Telecommunications Systems: Chadi Barakat, Voice over IP, 6 hours.
- Master1 Computer Science: Chadi Barakat, Computer Networks, 12 hours.
- Master1 Computer Science: Chadi Barakat, Advanced Computer Networks, 12 hours.
- MinesParis-PSL: Thierry Parmentelat has been heavily involved in the reformation of the Computer Science program, that he teaches to the first year students of "Cycle des ingénieurs civils" (Python, git, Web, Data Science).
- Eurecom: Arnaud Legout, AWARE (Awarness-Raising to research), last year students (equivalent to M2), 5 hours
- Eurecom: Arnaud Legout, ComEng (Communication for engineers), 1st year students (equivallent L3), 21 hours
- MOOCs: Arnaud Legout and Thierry Parmentelat are co-authors of the MOOC : "Python 3 : des fondamentaux aux concepts avancés du langage" that lasts 9 weeks on FUN, funded by Université Côte d'Azur. This MOOC has been running since 2014; it was innovative in its form at the time, since it leveraged Jupyter notebooks as a medium for complementing videos, which provides for a hands-on experience and self-correcting exercises. More than 100k persons have subscribed over time, out of which about 10k have received a success badge.
- SLICES Academy is a platform supporting the community by fostering knowledge and engagement of users of testbed facilities with future Internet technologies, including networking, cloud computing, wireless connectivity, and AI/ML. In addition to his involvement in defining the SLICES-RI post-5G blueprint, Damien Saucez delivered two online classes as part of the SLICES Academy: the "SLICES Blueprint" class teaches step by step how to deploy the Post-5G blueprint and the "Kubernetes Clusters for Operators" classes explains how to deploy a Kubernetes cluster dedicated to telecom workload.

10.2.2 Supervision

PhD students

- PhD in progress: Yassir Amami started his PhD on developing a monitoring plane for mobile cellular networks in October 2024. His PhD is funded by the PEPR project NF-NAI. His PhD is supervised by Chadi Barakat and Thierry Turletti.
- PhD in progress: Mohammad Bagher Tavassoli started his PhD on experimental performance evaluation of sliced cellular networks in June 2024. His PhD is funded by the PEPR project NF-NAI. His PhD is supervised by Chadi Barakat, Walid Dabbous and Thierry Turletti.
- PhD in progress: Stefano Lioce commenced his PhD on RIS-aided Communication in February 2024. His research is supported by the EU Horizon CONVERGE project and is conducted under a co-tutelle agreement with Politecnico di Bari. His PhD is supervised from the French side by Walid Dabbous and Damien Saucez and from the Italian side by Professor Gianfranco Avitabile and Dr Antonello Florio.
- PhD in progress: Jamil Abou Ltaif began his PhD on QoE-aware optimization of energy efficiency in mobile networks. His research is conducted in collaboration with researchers from the COATI project team and is supported by funding from the PEPR NF-MUST project. His PhD is supervised by Chadi Barakat and Thierry Turletti from DIANA and by Frédéric Giroire and Joanna Moulierac from COATI.

Master students

- Laila Belakhdar
  - From March until August 2025
  - Ubinet Master, Université Côte d'Azur
  - Subject: Troubleshooting video streaming problems
  - Supervisor: Chadi Barakat
- Leonardo Digirolamo
  - From March until August 2025
  - Ubinet Master, Université Côte d'Azur
  - Subject: Impact of Large Language Models on the Cognitive Process
  - Supervisor: Arnaud Legout
- Ziyad Mabrouk
  - From March until August 2025
  - Ubinet Master, Université Côte d'Azur
  - Subject: Real-Time RAN Monitoring of a Sliced 5G Network
  - Supervisor: Chadi Barakat and Thierry Turletti
- Juliette Chamard
  - from Jun 2025 until Aug 2025
  - Eurecom, first engineering year internship
  - Subject: Influence of Copilot on the Cognitive Process
  - Supervisor: Arnaud Legout
- Theodoris Donval
  - from Jun 2025 until July 2025
  - Eurecom, first engineering year internship

  - Subject: Exploration of Financial Transactions on Bitcoin
  - Supervisor: Arnaud Legout

- Sabrine Laaraj
  - from Jun 2025 until Aug 2025
  - Eurecom, first engineering year internship
  - Subject: Exploring Memory Swap Slowdown in Large Python Computations
  - Supervisor: Arnaud Legout

- Alexis Nommer
  - from Jun 2025 until Aug 2025
  - Eurecom, first engineering year internship
  - Subject: Rethinking the Statistical Evaluation of Medical Studies Using Resampling Techniques
  - Supervisor: Arnaud Legout

- Arthur Koboyoh Gnom
  - from Jun 2025 until July 2025
  - Eurecom, first engineering year internship
  - Subject: Influence of Copilot on the Cognitive Process
  - Supervisor: Arnaud Legout

- Bohdan Dyshlevyy
  - From April until June 2025
  - Intern, 2nd year IUT, Université Côte d'Azur
  - Subject: Automatic Configuration of the SLICES Research Infrastructure
  - Supervisor: Damien Saucez

- Bohdan Dyshlevyy
  - Since September 2025
  - Apprentice, 3rd year IUT, Université Côte d'Azur
  - Subject: Automatic Configuration of the SLICES Research Infrastructure
  - Supervisor: Damien Saucez

10.2.3 Juries

- Chadi Barakat served as reviewer of Johann Hugon PhD thesis "System-Constrained Feature Extraction Pipelines for Network Traffic Monitoring", defended in December 2025 at Ecole Normale Supérieure de Lyon, Lyon, France.
- Chadi Barakat served as president of Killian Castillon Du Perron PhD thesis "Accelerating Container Networking with eBPF: Performance Characterization, Evaluation, and Optimization", defended in November 2025 at Université Côte d'Azur, Sophia Antipolis, France.
- Chadi Barakat served as reviewer and president of Zahraa El Attar PhD thesis "5G Slice Monitoring using Machine Learning ", defended in April 2025 at Inria centre at Rennes University, Rennes, France.
- Walid Dabbous served as jury member of Zhiyi Zhang PhD thesis "Deployment of movable base stations in cellular networks", defended in January 2025 at INSA LYON, Lyon, France.

- Walid Dabbous served as reviewer and jury member of Theodoros Tsourdinis PhD thesis "Network reconfiguration and management in 6G telecommunication networks", defended in October 2025 at Sorbonne Université, Paris, France.
- Thierry Turletti served as reviewer of Ilhem Fajjari HDR thesis "Artificial Intelligence for Networks: Intelligent, Sustainable, and Secure Cloud-Native architectures", defended in November 18, 2025 at Paris Saclay University, France.

10.3 Popularization

10.3.1 Specific official responsibilities in science outreach structures

Participants: Damien Saucez, Arnaud Legout, Walid Dabbous.

Terra Numerica is a large-scale unifying project aimed at promoting digital science culture. It is led by CNRS, Inria and the Université Côte d'Azur and brings together a wide range of partners, including the French National Education system (notably the Regional Academic Directorate for Digital Education). Terra Numerica has developed an original, engaging and unique framework for dissemination, collaboration, and interaction among digital science stakeholders. This includes an iconic hub for promoting digital science culture, Terra Numerica@Sophia, a network of Partner Spaces throughout the Sud region, as well as outreach initiatives and online activities. The original workshops held in these spaces offer a way to engage science in a fun and enjoyable manner. DIANA members are actively involved in science popularization through Terra Numerica, frequently organizing activities for school classes visiting the center. In addition, project team members play a key role in the CHICHE program, visiting high schools to inspire and encourage students to pursue higher education in scientific fields.

10.3.2 Others science outreach relevant activities

Our project-team is actively involved in initiatives targeting both schools and the general public, with a particular focus on fostering gender diversity in scientific research:

- School Outreach through the Chiche Program: Researchers visit high schools to encourage students of all genders and backgrounds to pursue scientific studies. Arnaud Legout delivered Chiche outreach interventions at CIV: one to a 10th-grade class on March 21, 2025, and another to two 10th-grade classes on May 19, 2025.
- 9th Grade Student Visits: The team hosts 9th graders, introducing them to its research activities to spark scientific interest across a broad audience.
- Our team regularly organizes visits to the R2LAB anechoic chamber for young students, introducing them to the principles of radio wave propagation and highlighting the crucial role of reproducibility in scientific research. In December 2025, approximately 15 students attended the visit and listened to explanations about the chamber and its experiments.

11 Scientific production

11.1 Major publications

[1] O. Belmoukadam and C. Barakat. 'Unveiling the end-user viewport resolution from encrypted video traces'. In: *IEEE Transactions on Network and Service Management* 18.3 (Sept. 2021), pp. 3324–3335. DOI: 10.1109/TNSM.2021.3083070. URL: https://hal.inria.fr/hal-03230168.

[2] Y. Boussad, X. L. Chen, A. Legout, A. Chaintreau and W. Dabbous. 'Longitudinal study of exposure to radio frequencies at population scale'. In: *Environment International* 162 (24th Mar. 2022). DOI: 10.1016/j.envint.2022.107144. URL: https://inria.hal.science/hal-03618634.

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