2025 *Activity Report*

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

IN PARTNERSHIP WITH: **CNRS, Université Côte d'Azur**

Team

COATI

Combinatorics, Optimization and Algorithms for Telecommunications

In collaboration with Laboratoire informatique, signaux systèmes de Sophia Antipolis (I3S)

Team COATI

Creation of the Team: 2025 January 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

A1.2.1. – Dynamic reconfiguration

A1.2.3. – Routing

A1.2.9. – Social Networks

A1.3.4. – Peer to peer

A1.3.5. – Cloud

A1.3.6. – Fog, Edge

A1.6. – Green Computing

A3.5.1. – Analysis of large graphs

A7.1. – Algorithms

A7.1.1. – Distributed algorithms

A7.1.3. – Graph algorithms

A8.1. – Discrete mathematics, combinatorics

A8.2. – Optimization

A8.2.1. – Operations research

A8.7. – Graph theory

A8.8. – Network science

A9.7. – AI algorithmics

A9.9. – Distributed AI, Multi-agent

Other research topics and application domains

B1.2.3. – Computational neurosciences

B6.3.3. – Network Management

B6.3.4. – Social Networks

B7.2. – Smart travel

B9.5.1. – Computer science

Contents

1 Team members, visitors, external collaborators

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2 Overall objectives

COATI is a joint project-team gathering researchers from Inria, CNRS and Université Côte d'Azur. Its objectives are to conduct fundamental research in discrete mathematics, graph and digraph theory, algorithms design and operations research, and to use these knowledge and tools for addressing specific network optimization problems. Significant advances are made for instance on graph coloring problems, graph decomposition methods, combinatorial games on graphs, on the design and engineering of algorithms, etc. Furthermore, COATI addresses practical problems issued from telecommunication networks using tools from discrete mathematics and operations research in collaboration with industrial partners such as Orange labs, Nokia bell labs, Ciena, etc. We are particularly interested in optimization problems raised by the emergence of the new technologies of software defined networks (SDN) and network functions virtualization (NFV), and more specifically the placement and reconfiguration of lightpaths, network slices, service function chains, etc. We also consider the optimization of different kinds of wireless networks, including the design of reliable microwave backhaul networks, the deployment and management of fleets of drones to collect data from (mobile) sensors, and the optimization of the capacity of low power long range (LoRAWAN) networks.

During the last years, we have started to investigate how tools from artificial intelligence (AI), and in particular machine learning based methods, can help solving networks optimization problems, and how tools from (structural, metric) graph theory can help improving AI tools. More precisely, we have started to investigate the use of AI tools for networking problems, for instance for the reconfiguration of network slices in software defined networks or for the scheduling of machine learning tasks in heterogeneous clusters (Section 8.4). Furthermore, we have started to investigate the theory of deep learning, in particular by providing a rigorous understanding of some aspects of compression of artificial neural networks (Section 8.3). We have also started to investigate federated learning, for instance the privacy concern when implementing the learning algorithms in a network (Section 8.3.2).

COATI also collaborates with teams in other domains (transport, biology, resource allocation, social sciences, etc.) to share its expertise for the resolution of various problems, as well as for identifying new optimization problems. Over the years, it has initiated fruitful collaborations in the fields of transport networks with SME Instant-System and Benomad (ANR Multimod 2018-2023) and with Amadeus, structural biology with project-team ABS, neurosciences with project-team CRONOS (see e.g., [43]), and social sciences with SME MillionRoads and researchers from GREDEG and SKEMA.

The research done in COATI will result in the production of software components (proof of concepts) and to contributions to large open-source software such as Sagemath and packages of the Julia programming language eco-system. Finally, members of COATI are strongly involved in scientific mediation and actively contribute to the development of Terra Numerica.

COATI has now reached the 12 years time limit for a project-team and a proposal for a new project-team (with the same name) has been positively evaluated in July 2025. The official launch of this new project-team is pending decision.

3 Research program

Founded in 2013, COATI's goals are to conduct fundamental research in discrete mathematics, graph theory, digraph theory, algorithms and operations research, and to use these tools to study specific network optimization problems. Note that we are mainly interested in telecommunication networks. However, our expertise can be applied to solve many other problems in various fields (transport, biology, resource allocation, social sciences, etc.) and we collaborate with teams from these other fields. COATI also contributes to the development of software components to validate proposed algorithms and promote their dissemination.

The research program of COATI is therefore structured as follows.

- We conduct fundamental research in graph and digraph theory (Section 8.1). Our goal is to better understand the structure of (di)graphs and which particular (sub)structures make an optimization problem on (di)graphs difficult. We are particularly interested in digraphs which are less studied than (undirected) graphs, although most optimization problems are naturally modeled using digraphs. This is certainly due to the fact that several problems that can be solved in polynomial time on graphs are hard to solve on digraphs.

- We use this knowledge to design algorithms on (di)graphs (exact, sub-exponential, parameterized, approximation, heuristic) in order to solve various optimization problems (Section 8.2). We also study games on graphs as an algorithmic counterpart to some (di)graph theory studies, in order to gain more insight into problems and (di)graph properties. One of the challenges we face in designing algorithms is the increasing size of practical instances. Therefore, we need to find new ways of approaching problems using reduction and decomposition methods, characterizing polynomial instances (which are sometimes the practical ones), and designing algorithms with acceptable practical performance, independent of the worst-case time complexity, by exploiting some properties of the instances.

- Recently, we have begun to investigate how tools from graph theory and algorithms can help improve methods from machine learning (Section 8.3). For example, we have studied the problem of sparsifying neural networks and proved the strong lottery ticket hypothesis for convolutional neural networks. We have demonstrated the privacy vulnerability in federated graph learning and investigated methods to mitigate these risks through perturbation of the graph dataset.

- We study specific network optimization problems (Section 8.4) at both design and management levels such as energy efficiency in networks, routing reconfiguration of optical and software defined networks (SDN), placement and migration of virtual function chains (NFV), the deployment and management of fleets of drones to collect data from (mobile) sensors, the design of reliable wireless networks, the evolution of the routing in case of any type of topological modifications (maintenance operations, failures, capacity variations, ...), survivability to single and multiple failures, ... These specific problems often come from questions of our industrial partners (CIENA, Orange labs, Nokia). We first contribute to the modeling of these problems; then we either use existing tools or develop new tools in operations research and (di)graph theory to solve them.

- We tackle problems in machine learning, multi-agent systems and computational neuroscience. In machine learning, the work involves exploring the sparsification of artificial neural networks. In computational neuroscience, the research aims to develop algorithmic and mathematical tools to understand the organization of the central nervous system, addressing issues such as network alignment for brain atlases, modeling fMRI data, and interpreting brain activity. Our research on multi-agent systems is centered on computational dynamics, investigating distributed probabilistic algorithms for global coordination tasks. Significant contributions include rigorous analyses of consensus problems, along with applying theoretical insights to biological systems to understand collective animal behaviors.

- We also study optimization problems in other application areas such as structural biology, transport networks, economics, sociology, etc. For example, in the field of computational neuroscience, we have collaborated with the Inria project team CRONOS (Computational modeling of brain dynamical networks) from Sophia Antipolis. In the area of intelligent transport systems, we collaborate with the SMEs BeNomad and Instant-System on routing problems in multimodal transport systems. We also collaborate with GREDEG (Research Centre in Economics, Law and Management) and the SKEMA Business School to analyze the impact of competitive funding on the development of scientific networks. We have also investigated existing and new integrated assessment models for predicting the effect of policies on the sustainable development goals by the United Nations.

  On the one hand, these collaborations benefit the concerned domains from the dissemination of our tools. On the other hand, they give rise to new problems of interest to our community, helping us to improve our knowledge and to test our algorithms on specific instances.

The research done in COATI results in the production of prototype software and in the contribution to large open source software such as Sagemath and popular packages of the Julia programming language eco-system (Section 7.1).

Finally, besides our research activity, we are deeply involved in the dissemination of science towards a general audience and contribute actively to Terra Numerica (Section 11.3).

4 Application domains

COATI is mostly interested in telecommunications networks but also in the network structures appearing in social, molecular, and transportation networks.

4.1 Telecommunication networks

We focus on the design and management of heterogeneous physical and logical networks. The project has kept working on the design of backbone networks (optical networks, radio networks, IP networks). However, the fields of Software Defined Networks and Network Function Virtualization are growing in importance in our studies. In all these networks, we study routing algorithms and the evolution of the routing in case of any kind of topological modifications (maintenance operations, failures, capacity variations, etc.).

4.2 Other Domains

Our combinatorial tools may be well applied to solve many other problems in various areas (transport, biology, resource allocation, chemistry, smart-grids, speleology, etc.) and we collaborate with experts of some of these domains.

For instance, we collaborate with project-team ABS (Algorithms Biology Structure) from Sophia Antipolis on problems from Structural Biology and with project-team CRONOS on problems arising in computational neurosciences. Last, we collaborate with GREDEG (Groupe de Recherche en Droit, Economie et Gestion, Université Côte d'Azur) and the SKEMA business school on the analysis of the impact of competitive funding on the evolution of scientific collaboration networks.

5 Social and environmental responsibility

5.1 Footprint of research activities

Several COATI members are heavily involved in the sustainable development commission in the I3S laboratory. A citizens convention on the laboratory's climate has been set up with 17 members chosen by lot. The aim was to consider transition scenarios and actions to reduce the laboratory's carbon footprint by 30% to 50% (the more the better) by 2030. The proposals related to missions, daily transports, and laboratory life were put to a vote and some decisions have been taken. Reflecting on these actions within the laboratory enables a broader personal reflection on how to implement reduction actions in everyday life. A global reflection on the research thematics and how researchers are evaluated will be carried out.

Furthermore, COATI supports the "extended stay" initiatives of international events organized in France. The goal is to encourage attendees of an event to combine their participation to an event with a research visit in a laboratory in France (reachable by train from the conference location). We are currently registered for this initiative with IWOCA 2026.

6 Highlights of the year

6.1 Books

- Publication of the French translation [84] of the reference book in graph theory: J.A. Bondy and U.S.R. Murty: "Graph Theory," Springer, 2008. This translation has been written by Frédéric Havet. The electronic version is freely available in HAL
- Publication of the book "Teoria dos Jogos Combinatórios em Grafos" in Portuguese [63]

6.2 Awards

- Jamil Abou Ltaif, PhD student of COATI, is the recipient of the Impact award 2025 of the starthese competition organized by PUI Med'Innov

- Frédéric Giroire : Chair 3IA since Oct 2025
- Lucas Picasarri-Arrieta, former PhD student of COATI, is the recipient of an accessit to the PhD prize Graphes “Charles Delorme” 2025
- The “Naughty NOTer” team, composed ofAndré Nusser together with Mikkel Abrahamsen *(University of Copenhagen, Denmark)*, Florestan Brunck *(University of Copenhagen, Denmark)*, Jacobus Conradi *(University of Bonn, Germany)* and Benedikt Kolbe *(University of Bonn, Germany)*, won the Seventh Computational Geometry Challenge (CG:SHOP 2025). The task in this challenge was to find non-obtuse triangulations for given planar regions, respecting a given set of constraints consisting of extra vertices and edges that must be part of the triangulation. The goal was to minimize the number of introduced Steiner points. The approach of the team was to maintain a constrained Delaunay triangulation, for which they repeatedly remove, relocate, or add Steiner points. They used local search to choose the action that improves the triangulation the most, until the resulting triangulation is non-obtuse. See [44] for more details on the algorithms and implementation.

6.3 Focus

- Christelle Caillouet has been highlighted by CNRS Informatics (Section 2) for the year dedicated to Optimization. See the article.

7 Latest software developments, platforms, open data

7.1 Latest software developments

7.1.1 SageMath

Name: SageMath

Keywords: Combinatorics, Graph algorithmics, Number theory, Cryptography, Algebra

Scientific Description: SageMath is a free open-source mathematics software system. It builds on top of many existing open-source packages: NumPy, SciPy, matplotlib, Sympy, Maxima, GAP, FLINT, R and many more. Access their combined power through a common, Python-based language or directly via interfaces or wrappers.

Functional Description: SageMath is a free mathematics software system written in Python, combining a large number of mathematical libraries under a common interface.

INRIA teams contribute in different ways to the software collection. COATI adds new graph algorithms along with their documentations and contributes the improvement and maintenance of the graph module and its underlying data structures. CANARI contributes through libraries such as ARB and PARI/GP, and directly through SageMath code for algebras and ring and field extensions.

Release Contributions: See `http://www.sagemath.org/changelogs/`

News of the Year: We have pursued the maintenance of the graph module (fix bug, improve behavior, improve the performances of many methods). We have also added new methods such as faster algorithms for the k-shortest simple paths and cycles, the computation of components avoiding sets of vertices, etc.

URL: `http://www.sagemath.org/`

Contact: David Coudert

Participants: David Coudert, an anonymous participant

8 New results

8.1 Graph and digraph theory

COATI works on many topics in graph theory, ranging from structural results to algorithmic applications (see next Subsection 8.2). We study various substructure or partition problems in graphs or directed graphs (a.k.a. digraphs). For each of them, we aim at giving sufficient conditions that guarantee its existence and at determining the complexity of finding it. In particular, we aim to identify the similarities and differences between graphs and digraphs, both from structural and algorithmic perspectives. To this end, we investigate more or less systematically how some results on graphs, which can be reformulated as results on symmetric digraphs, can be generalized to digraphs.

Graph and digraph theory is a well-developed domain in the world. We are collaborating with many teams including almost all French groups in graph theory.

8.1.1 Structural graph and digraph theory

Participants: Julien Bensmail, Frédéric Havet, Nicolas Nisse, Clément Rambaud.

One of our goals is to establish structural results on graphs and digraphs that can be used to design efficient algorithms. In particular, we are looking for substructures with certain properties or ways to represent or approximate efficiently graphs and digraphs.

On the k-clique graph and the k-clique operator Given a graph G, a clique is a maximal complete subgraph of G and a biclique is a maximal induced complete bipartite subgraph of G. The intersection graphs of cliques and bicliques, denoted by $K(G)$ and $KB(G)$ respectively, have been studied largely in the last years. Several articles have been made from a structural point of view, about characterizations, recognition problem, the behavior of their respective iterated operator, etc. In [82], we generalize the clique and biclique graphs as k-clique graphs, that is, the intersection graphs of the family of all maximal induced complete k-partite subgraphs of G. We consider first $k = 3$, i.e., triclique graphs, $KT(G)$, and we then generalize our results to $k > 3$, k-clique graphs, $KC(G)$. In particular, we study the connectivity relation between G and $KT(G)$, its generalization to $KC(G)$, and we propose several structural results. We then investigate its characterization and recognition problem. Next, we consider the iterated k-clique operators KT and KC, giving sufficient conditions for a graph to be convergent or divergent under these operators. Finally, we compare all known results so far between clique, biclique and k-clique graphs, and we propose some general conjectures on the subject.

This work has been done in collaboration with Leandro Montero *(LS2N and IMT Atlantique, Nantes, France)*.

Weak coloring numbers of minor-closed graph classes In [56], we study the growth rate of weak coloring numbers of graphs excluding a fixed graph as a minor. Van den Heuvel et al. (European J. of Combinatorics, 2017) showed that for a fixed graph X, the maximum r-th weak coloring number of X-minor-free graphs is polynomial in r. We determine this polynomial up to a factor of $O(r \log r)$. Moreover, we tie the exponent of the polynomial to a structural property of X, namely, 2-treedepth. As a result, for a fixed graph X and an X-minor-free graph G, we show that $\mathrm{wcol}_r(G) = O(r^{\mathrm{td}(X)-1}\log r)$, which improves on the bound $\mathrm{wcol}_r(G) = O(r^{g(\mathrm{td}(X))})$ given by Dujmović et al. (SODA, 2024), where g is an exponential function. In the case of planar graphs of bounded treewidth, we show that the maximum r-th weak coloring number is in $O(r^2\log r)$, which is best possible.

This work has been done in collaboration with Jędrzej Hodor *(Jagiellonian University, Krakow, Poland)*, Xuan Hoang *(LISN, Université Paris-Saclay, France)* and Piotr Micek *(Jagiellonian University, Krakow, Poland)*.

The χ-Binding Function of d-Directional Segment Graphs Given a positive integer d, the class d-DIR is defined as all those intersection graphs formed from a finite collection of line segments in $\mathbb{R}^2$ having at most d slopes. Since each slope induces an interval graph, it easily follows for every G in d-DIR with clique number at most ω that the chromatic number $\chi(G)$ of G is at most $d\omega$. In [38], we show for every even value of ω how to construct a graph in d-DIR that meets this bound exactly. This partially confirms a conjecture of Bhattacharya, Dvořák and Noorizadeh [90]. Furthermore, we show that the χ-binding function of d-DIR is $\omega \mapsto d\omega$ for ω even and $\omega \mapsto d(\omega - 1) + 1$ for ω odd. This extends an earlier result by Kostochka and Nešetřil [98], which treated the special case $d = 2$.

This work has been done in collaboration with Lech Duraj *(Jagiellonian University, Krakow, Poland)*, Ross Kang *(University of Amsterdam, Netherlands)*, Xuan Hoang La *(Jagiellonian University, Krakow, Poland)*, Jonathan Narboni *(Jagiellonian University, Krakow, Poland)*, Filip Pokrývka *(Université Masaryk, Brno, Czech Republic)* and Amadeus Reinald *(LIRMM, Montpellier, France)*.

8.1.2 Partitioning, colouring and labelling graphs and digraphs

Participants: Julien Bensmail, Frédéric Havet, Nicolas Nisse, Lucas Picasarri-Arrieta, Clément Rambaud.

Directed colouring A *directed colouring* or *dicolouring* of a digraph is a colouring such that every colour class induces an acyclic digraph. The *dichromatic number* of a digraph D, denoted $\overrightarrow{\chi}(D)$, is the minimum number of colours needed to partition D into acyclic induced subdigraphs. This is a natural generalization of (unidirected) graph colouring. Indeed, if G is an undirected graph, and D is the symmetric digraph obtained from G by replacing each edge with the pair of oppositely directed arcs joining the same pair of vertices, then $\chi(G) = \overrightarrow{\chi}(D)$, where $\chi(G)$ denotes the chromatic number of G, that is the minimum k such that there exists a proper k-colouring of G. One of the important research directions of our team involves trying to generalize results from graph coloring to dicoloring.

Brooks' Theorem is a fundamental result on graph colouring, stating that the chromatic number of a graph G is almost always upper bounded by its maximal degree $\Delta(G)$. Lovász showed that such a colouring may then be computed in linear time when it exists. Many analogues are known for variants of (di)graph colouring, notably for list-colouring and partitions into subgraphs with prescribed degeneracy. One of the most general results of this kind is due to Borodin, Kostochka, and Toft, when asking for classes of colours to satisfy "variable degeneracy" constraints. An extension of this result to digraphs has recently been proposed by Bang-Jensen, Schweser, and Stiebitz, by considering colourings as partitions into "variable weakly degenerate" subdigraphs. Unlike earlier variants, there exists no linear-time algorithm to produce colourings for these generalizations. In [41], we introduce the notion of (variable) bidegeneracy for digraphs, capturing multiple (di)graph degeneracy variants. We define the corresponding concept of F-dicolouring, where $F = (f_1, \dots, f_s)$ is a vector of functions, and an F-dicolouring requires vertices coloured i to induce a "strictly-f_i-bidegenerate" subdigraph. We prove an analogue of Brooks' theorem for F-dicolouring, generalizing the result of Bang-Jensen et al., and earlier analogues in turn. Our new approach provides a linear-time algorithm that, given a digraph D, either produces an F-dicolouring of D, or correctly certifies that none exist. This yields the first linear-time algorithms to compute (di)colourings corresponding to the aforementioned generalizations of Brooks' theorem. In turn, it gives an unified framework to compute such colourings for various intermediate generalizations of Brooks' theorem such as list-(di)colouring and partitioning into (variable) degenerate sub(di)graphs.

Reed in 1998 conjectured the following strengthening of Brooks Theorem : $\chi(G) \leq \lceil(\Delta(G)+1+\omega(G))/2\rceil$ for every graph G. As a partial result, he proved the existence of $\varepsilon > 0$ for which every graph G satisfies $\chi(G) \leq \lceil(1-\varepsilon)(\Delta(G)+1) + \varepsilon\omega(G)\rceil$. In [58], we propose an analogue conjecture for digraphs. Given a digraph D, we let $\overleftrightarrow{\omega}(D)$ denote the size of the largest biclique (a set of vertices inducing a complete digraph) of D and $\tilde{\Delta}(D) = \max_{v \in V(D)} \sqrt{d^+(v) \cdot d^-(v)}$. We conjecture that every digraph D satisfies $\overrightarrow{\chi}(D) \leq \lceil(\tilde{\Delta}(D) + 1 + \overleftrightarrow{\omega}(D))/2\rceil$, which if true implies Reed's conjecture. As a partial result, we prove the existence of $\varepsilon > 0$ for which every digraph D satisfies $\overrightarrow{\chi}(D) \leq \lceil(1-\varepsilon)(\tilde{\Delta}(D)+1) + \varepsilon\overleftrightarrow{\omega}(D)\rceil$. This implies both Reed's result and an independent result of Harutyunyan and Mohar for oriented graphs. To obtain this upper bound on $\overrightarrow{\chi}$, we prove that every digraph D with $\overleftrightarrow{\omega}(D) > \frac{2}{3}(\Delta_{\max}(D)+1)$, where

$\Delta_{\max}(D) = \max_{v \in V(D)} \max(d^+(v), d^-(v))$, admits an acyclic set of vertices intersecting each biclique of D, which generalizes a result of King.

In [34], we give both lower and upper bounds on the dichromatic number of super-orientations of chordal graphs. In general, the dichromatic number of such digraphs is bounded above by the clique number of the underlying graph (because chordal graphs are perfect). However, this bound can be improved when we restrict the symmetric part of such a digraph. Let $D = (V, A)$ be a super-orientation of a chordal graph G. Let $B(D)$ be the undirected graph with vertex set V in which uv is an edge if and only if both uv and vu belongs to A. An easy greedy procedure shows $\vec{\chi}(D) \leq \lceil (\omega(G) + \Delta(B(D)))/2 \rceil$. In [34], we show that this bound is the best possible by constructing, for every fixed k, ℓ with $k \geq \ell + 1$, a super-orientation $D_{k,\ell}$ of a chordal graph $G_{k,\ell}$ such that $\omega(G_{k,\ell}) = k$, $\Delta(B(D_{k,\ell})) = \ell$ and $\vec{\chi}(D_{k,\ell}) = \lceil (k+\ell)/2 \rceil$. When $\Delta(B(D)) = 0$ (*i.e.* D is an orientation of G), we give another construction showing that this is tight even for orientations of interval graphs. Next, we show that $\vec{\chi}(D) \leq \frac{1}{2}\omega(G) + O(\sqrt{d \cdot \omega(G)})$ with d the maximum average degree of $B(D)$. Finally, we show that if $B(D)$ contains no cycle of order 4, C_4, as a subgraph, then $\vec{\chi}(D) \leq \lceil (\omega(G) + 3)/2 \rceil$. We justify that this is almost best possible by constructing, for every fixed k, a super-orientation D_k of a chordal graph G_k with clique number k such that $B(D_k)$ is a disjoint union of paths and $\vec{\chi}(D_k) = \lfloor (k+3)/2 \rfloor$.We also exhibit a family of orientations of cographs for which the dichromatic number is equal to the clique number of the underlying graph.

The acyclic number $\vec{\alpha}(D)$ is the maximum order of an acyclic induced subdigraph. In [21], we study $\vec{a}(n)$ and $\vec{t}(n)$ which are the minimum of $\vec{\alpha}(D)$ and the maximum of $\vec{\chi}(D)$, respectively, over all oriented triangle-free graphs of order n. For every $\epsilon > 0$ and n large enough, we show that $(1/\sqrt{2} - \epsilon)\sqrt{n \log n} \leq \vec{a}(n) \leq \frac{107}{8}\sqrt{n} \log n$ and $\frac{8}{107}\sqrt{n}/\log n \leq \vec{t}(n) \leq (\sqrt{2} + \epsilon)\sqrt{n/\log n}$. We also construct an oriented triangle-free graph on 25 vertices with dichromatic number 3, and show that every oriented triangle-free graph of order at most 17 has dichromatic number at most 2.

This work has been done in collaboration with Pierre Aboulker *(ENS, Paris, France)*, Stéphane Bessy *(LIRMM, Université de Montpellier, France)*, Daniel Gonçalves *(LIRMM, Montpellier, France)*, Ken-Ichi Kawarabayashi *(National Institute of Informatics and University of Tokyo, Japan)*, François Pirot *(LISN, Université Paris-Saclay, Fance)*, Amadeus Reinald *(LIRMM, Montpellier, France)*, and Juliette Schabanel *(LaBRI, Université de Bordeaux, France)*.

Semi-proper orientations of dense graphs An *orientation* D of a graph G is a digraph obtained from G by replacing each edge by exactly one of the two possible arcs with the same ends. An orientation D of a graph G is a k*-orientation* if the in-degree of each vertex in D is at most k. An orientation D of G is *proper* if any two adjacent vertices have different in-degrees in D. The *proper orientation number* of a graph G, denoted by $\vec{\chi}(G)$, is the minimum k such that G has a proper k-orientation. A *weighted orientation* of a graph G is a pair (D, w), where D is an orientation of G and w is an arc-weighting $A(D) \to \mathbb{N} \setminus \{0\}$. A *semi-proper orientation* of G is a weighted orientation (D, w) of G such that for every two adjacent vertices u and v in G, we have that $S_{(D,w)}(v) \neq S_{(D,w)}(u)$, where $S_{(D,w)}(v)$ is the sum of the weights of the arcs in (D, w) with head v. For a positive integer k, a *semi-proper* k*-orientation* (D, w) of a graph G is a semi-proper orientation of G such that $\max_{v \in V(G)} S_{(D,w)}(v) \leq k$. The *semi-proper orientation number* of a graph G, denoted by $\vec{\chi_s}(G)$, is the least k such that G has a semi-proper k-orientation. In [22], we first prove that $\vec{\chi_s}(G) \in \{\omega(G) - 1, \omega(G)\}$ for every split graph G, and that, given a split graph G, deciding whether $\vec{\chi_s}(G) = \omega(G) - 1$ is an NP-complete problem. We also show that, for every k, there exists a (chordal) graph G and a split subgraph H of G such that $\vec{\chi}(G) \leq k$ and $\vec{\chi}(H) = 2k - 2$. In the sequel, we show that, for every $n \geq p(p+1)$, $\vec{\chi_s}(P_n^p) = \lceil \frac{3}{2}p \rceil$, where P_n^p is the p^{th} power of the path on n vertices. We investigate further unit interval graphs with no big clique: we show that $\vec{\chi}(G) \leq 3$ for any unit interval graph G with $\omega(G) = 3$, and present a complete characterization of unit interval graphs with $\vec{\chi}(G) = \omega(G) = 3$. Then, we show that deciding whether $\vec{\chi_s}(G) = \omega(G) - 1$ can be solved in polynomial time in the class of cobipartite graphs. Finally, we prove that computing $\vec{\chi_s}(G)$ is fixed-parameter tractable (FPT) when parameterized by the minimum size of a vertex cover in G or by the treewidth of G. We also prove that not only computing $\vec{\chi_s}(G)$, but also $\vec{\chi}(G)$, admits a polynomial kernel when parameterized by the neighborhood diversity plus the value of the solution. These results imply kernels of size $4^{O(k^2)}$ and $O(2^k k^2)$, in chordal graphs and split graphs, respectively, for the problem of deciding whether $\vec{\chi_s}(G) \leq k$ parameterized by k. We also present exponential kernels for computing both $\vec{\chi}(G)$ and $\vec{\chi_s}(G)$ parameterized by the value of the solution when G is a cograph. On the other hand, we show that computing $\vec{\chi_s}(G)$ does not admit a polynomial kernel parameterized by the value of the solution when G is a chordal graph, unless NP$\subseteq$ coNP/poly.

This work has been done in collaboration with Júlio Araújo *(Universidade Federal do Ceará, Fortaleza, Brazil)*, Claudia Linhares Sales *(Universidade Federal do Ceará, Fortaleza, Brazil)* and Karol Suchan *(Universidad Diego Portales, Santiago, Chile)* in the context of the SticAm-Sud project GALOP and of the EA Inria CANOE.

Backbone colouring of chordal graphs A proper k-colouring of a graph $G = (V, E)$ is a function $c : V(G) \to \{1, \dots, k\}$ such that $c(u) \neq c(v)$ for every edge $uv \in E(G)$. Given a spanning subgraph H of G, a q-backbone k-colouring of (G, H) is a proper k-colouring c of G such that $|c(u) - c(v)| \geq q$ for every edge $uv \in E(H)$. The q-backbone chromatic number $\mathrm{BBC}_q(G, H)$ is the smallest k for which there exists a q-backbone k-colouring of (G, H). In their seminal paper, Broersma et al. ask whether, for any chordal graph G and any spanning forest H of G, we have that $\mathrm{BBC}_2(G, H) \leq \chi(G) + O(1)$.

In [45, 69], we first show that this is true as long as H is bipartite and G is an interval graph in which each vertex belongs to at most two maximal cliques. We then show that this does not extend to bipartite graphs as backbone by exhibiting a family of chordal graphs G with spanning bipartite subgraphs H satisfying $\mathrm{BBC}_2(G, H) \leq 5\chi(G)/3$. Then, we show that if G is chordal and H has bounded maximum average degree (in particular, if H is a forest), then $\mathrm{BBC}_2(G, H) \leq \chi(G) + O(\chi(G))$. We finally show that $\mathrm{BBC}_2(G, H) \leq \frac{3}{2}\chi(G) + O(1)$ holds whenever G is chordal and H is C_4-free.

This work has been done in collaboration with Júlio Araújo *(Universidade Federal do Ceará, Fortaleza, Brazil)* in the context of the EA Inria CANOE.

NSD Edge-Colourings with Strong Assignment Constraints In [76], we introduce and study a combination of two types of graph edge-colourings, namely strong edge-colourings (in which every two edges at distance at most 2 must be assigned distinct colours) and neighbor-sum-distinguishing edge-colourings (in which adjacent edges must be assigned distinct colours, and every two adjacent vertices must be incident to distinct sums of colours). In particular, we investigate how the smallest number of colours in such combined edge-colourings behaves. For several classes of graphs, we prove that such edge-colourings are very close from strong edge-colourings, in the sense that no additional colours are required. For others classes of graphs, we prove that introducing more colours is sometimes necessary. We conjecture that, in general, designing this new type of edge-colourings should always be possible provided we are allowed to introduce and assign a constant number of additional colours. We prove this conjecture for a few classes of graphs, including trees and graphs of bounded maximum degree.

This work has been done in collaboration with Leandro Montero *(LS2N and IMT Atlantique, Nantes, France)*.

Arbitrarily Partitionable Graphs In [24, 25], we pursue our investigations on so-called arbitrarily partitionable graphs, being those graphs, answering a practical network sharing problem, that can be partitioned into arbitrarily many connected subgraphs with arbitrary orders. In particular, we wonder about generalizations to partitioning other/more elements into connected subgraphs, namely edges and both vertices and edges, respectively. In each case, we wonder about similarities and discrepancies with the vertex-only case, leading to interesting questions and problems.

This work has been done in collaboration with Olivier Baudon *(LaBRI, Université de Bordeaux, France)* and Lyn Vayssieres *(IREM Aquitaine, Université de Bordeaux, France)*.

8.1.3 Distinguishing labelling problems and the 1-2-3 Conjecture

Participants: Julien Bensmail.

In distinguishing labelling problems, the general goal is, given a graph, to label some of its elements so that some pairs of elements can be distinguished accordingly to some parameter computed from the labelling. Note that this description involves many parameters that can be played with, such as the set of elements to be labelled, the set of labels to be assigned, the set of elements to be distinguished, and the distinguishing parameter computed from the labelling. A notable example is the so-called 1-2-3 Conjecture, which asks whether almost all graphs can have their edges labelled with 1,2,3 so that every two adjacent vertices are distinguished accordingly to their sums of incident labels.

A proof of the 1-2-3 Conjecture has been provided recently, in 2024, by Keusch [97]. Still, there are many related problems and questions of interest that are still open. We detail a few below.

- First, we have given results providing more evidence that some of the main related conjectures of the field might be true. In particular, in [75], we prove that the so-called 1-2 Conjecture (a total version of the 1-2-3 Conjecture where both vertices and edges are labelled) holds for more classes of graphs, namely graphs with low maximum degree or maximum average degree. In [71], we prove that a slight variation of the so-called Standard (2,2)-Conjecture (where edges are assigned coloured labels) holds true.
- We have also introduced new variants of the 1-2-3 Conjecture. In particular, we consider generalizations to 2-edge-coloured graphs [30], digraphs [28, 29], and temporal graphs [73]. We also introduce in [32] a variant with a different distinction condition (namely, it is required that no vertex has two neighbors with the same degree).
- Last, we have also investigated side questions related to the 1-2-3 Conjecture. In [26], motivated by practical concerns, we wonder about the impact of requiring proper labellings to assign label 1 as much as possible. This complements the investigations in [72], in which we wonder similarly about the impact of having certain edges forced to label 1. Different concerns have been considered in [31, 74, 27], in which we wonder about creating irregularity in graphs in different ways, namely through pushing vertices, deleting edges, and adding the edges of a walk, respectively. In each case, we devise interesting questions and problems to motivate further investigations.

These results have been obtained in collaboration with Olivier Baudon *(LaBRI, Université de Bordeaux, France)*, Romain Bourneuf *(LaBRI, Université de Bordeaux, France)*, Noémie Catherinot *(ENS Paris Saclay, France)*, Paul Colinot *(Université Grenoble Alpes, France)*, Thomas Filasto *(ENS Paris Saclay, France)*, Foivos Fioravantes *(Czech Technical University in Prague, Czech Republic)*, Hervé Hocquard *(LaBRI, Université de Bordeaux, France)*, Samuel Humeau *(ENS de Lyon, France)*, Clara Marcille *(LaBRI, Université de Bordeaux, France)*, Malory Marin *(UCBL, Lyon, France)*, Timothée Martinod *(LIFO, Orléans, France)*, Beatriz Martins *(ENS de Lyon, France)*, Sven Meyer *(ENS-PSL, Paris, France)*, Leandro Montero *(LS2N and IMT Atlantique, Nantes, France)*, Nacim Oijid *(Lebanese American University, Lebanon)*, Mano Orenga *(ENS de Lyon, France)*, Alexandre Talon *(Sorbonne Université, Paris, France)*, Chaoliang Tang *(Shanghai Center for Mathematical Statistics, China)* and Lyn Vayssieres *(IREM Aquitaine, Université de Bordeaux, France)*.

8.1.4 Inversions in oriented graphs

Participants: Frédéric Havet, Lucas Picasarri-Arrieta, Clément Rambaud.

Problems, Proofs, and Disproofs on the Inversion Number The *inversion* of a set X of vertices in a digraph D consists in reversing the direction of all arcs of $D\langle X\rangle$. The *inversion number* of an oriented graph D, denoted by $inv(D)$, is the minimum number of inversions needed to transform D into an acyclic oriented graph. We study a number of problems involving the inversion number of oriented graphs. Firstly, in [23], we give bounds on $inv(n)$, the maximum of the inversion numbers of the oriented graphs of order n. We show $n - \sqrt{(n \log n} \le inv(n) \le n - \lceil \log(n+1) \rceil$. Secondly, we disprove a conjecture of Bang-Jensen et al. asserting that, for every pair of oriented graphs L and R, we have $inv(L \to R) = inv(L) + inv(R)$, where $L \to R$ is the oriented graph obtained from the disjoint union of L and R by adding all arcs from L to R. Finally, we investigate whether, for all pairs of positive integers k_1, k_2, there exists an integer $f(k_1, k_2)$ such that if D is an oriented graph with $inv(D) \ge f(k_1, k_2)$ then there is a partition (V_1, V_2) of $V(D)$ such that $inv(D\langle V_i\rangle) \ge k_i$ for $i = 1, 2$. We show that $f(1, k)$ exists and $f(1, k) \le k + 10$ for all positive integers k. Further, we show that $f(k_1, k_2)$ exists for all pairs of positive integers k_1, k_2 when the oriented graphs in consideration are restricted to be tournaments.

In [39], we study $\text{sinv}'_k(D)$ (resp. $\text{sinv}_k(D)$) which is (for some positive integer k) the minimum number of inversions needed to transform D into a k-arc-strong (resp. k-strong) digraph or $+\infty$ if no such transformation exists. Note that $\text{sinv}'_k(D) \leq \text{sinv}_k(D)$. We set $\text{sinv}'_k(n) = \max\{\text{sinv}'_k(D) \mid D \text{ is a } 2k\text{-edge-connected digraph of order } n\}$. We show the following results where k is a fixed integer for $(i) - (vi)$:

(i) $\frac{1}{2}\log(n-k+1) \leq \text{sinv}'_k(n) \leq \log n + 4k - 3$ for every $n \geq k$;

(ii) for any fixed positive integer t, deciding whether a given oriented graph D with $\text{sinv}'_k(D) < +\infty$ satisfies $\text{sinv}'_k(D) \leq t$ is NP-complete;

(iii) for any fixed positive integer t, deciding whether a given oriented graph D with $\text{sinv}_k(D) < +\infty$ satisfies $\text{sinv}_k(D) \leq t$ is NP-complete;

(iv) if T is a tournament of order at least $2k+1$, then $\text{sinv}_k(T) \leq 2k$, and $\text{sinv}'_k(T) \leq \frac{4}{3}k + o(k)$;

(v) $\frac{1}{2}\log(2k+1) \leq \text{sinv}'_k(T)$ for some tournament T of order $2k+1$;

(vi) if T is a tournament of order at least $19k-2$ (resp. $11k-2$), then $\text{sinv}_k(T) \leq 1$ (resp. $\text{sinv}_k(T) \leq 3$);

(vii) for every $\epsilon > 0$, there exists C such that for every positive integer k and every tournament T on at least $2k+1+\epsilon k$ vertices, we have $\text{sinv}_k(T) \leq C$.

This work has been done in collaboration with Guillaume Aubian *(IRIF, Université Paris-Cité, Paris, France)*, Julien Duron *(LIP, ENS Lyon, France)*, Florian Hörsch *(CISPA, Helmholtz Center for Information Security, Saarbrücken, Germany)*, Felix Kingelhoefer *(G-SCOP, Université Grenoble Alpes, France)* and Quentin Vermande *(STAMP)* in the context of the ANR Digraphs.

8.2 Graph algorithms

In the last years, COATI has conducted an intense research effort on the algorithmic aspects of graph theory. We are mainly interested in designing efficient algorithms for large graphs and in understanding how structural properties of networks can help for this purpose. In general, we try to find the most efficient algorithms, either exact algorithms or approximations, to solve various problems of graph theory, often with applications in telecommunication networks. We are involved in many international and national collaborations with academic and industrial partners.

We mainly focus on four topics: efficient computation of graph parameters, graph decompositions, combinatorial games in graphs, and distributed computing.

- We use graph theory to model various network problems. We study their complexity with the aim of identifying the key structural properties of graphs that make these problems hard or easy. We then search for the most efficient algorithms to solve the problems, sometimes focusing on specific graph classes from which the problems are polynomial-time solvable. Our algorithms are generally implemented (e.g., in Sagemath) and tested on real-life networks (e.g., road networks, Twitter, graph of co-publications from Scopus, etc.).

- Tree-decompositions are the corner-stone of many dynamic programming algorithms for solving graph problems. Since the complexity of such algorithms generally depends exponentially on the width (size of the bags) of the decomposition, much work has been devoted to compute tree-decompositions with small width. We propose different approaches, based on a pursuit-evasion perspective or on metric aspects of graphs, to compute optimal or approximate tree-decompositions of graphs.

- One important topic of COATI is the study of combinatorial games in graphs. For instance, we are strongly involved in the organization of GRASTA dedicated to pursuit-evasion games (and their relationships with tree-decompositions) and games in graphs (special issues [86, 93], organization of the 11^{th} edition of GRASTA in October 2023, scientific committee in 2025, etc.). We study combinatorial games for themselves by determining their complexity but also because they provide nice models for problems arising in telecommunication networks (e.g., localization games).

- Within the research area of the theory of distributed computing, COATI investigates the recent topics of computational dynamics on complex networks, namely the study of algorithmically-simple interaction rules among agents represented by nodes of a complex network. Such systems are of interest in many scientific areas, ranging from biology to sociology. We contribute to this research endeavor by focusing on the fundamental coordination problems, in which agents are required to agree on a configuration that satisfies some condition based on their initial input state.

8.2.1 Complexity of graph problems

Participants: Samuel N. Aráujo, Jean-Claude Bermond, Michel Cosnard, David Coudert, Frédéric Havet, Pedro P. Medeiros, Nicolas Nisse, André Nusser, Clément Rambaud, Caroline Silva.

k-shortest simple paths in bounded treewidth graphs The k-shortest simple paths problem asks to compute a set of top-k shortest simple paths from a source to a sink in a graph $G = (V, E)$ with $|V| = n$ vertices and $|E| = m$ edges. The most well-known algorithm for solving this problem is due to Yen (1971) with time complexity in $O(kn(m + n \log n))$ and the fastest algorithm is due to Gotthilf and Lewenstein (2009) with time complexity in $O(kn(m + n \log \log n))$. For bounded treewidth graphs, Eppstein and Kurz (2017) lowered the computational complexity to $O(kn)$ by retrieving paths from the k smallest solutions of a monadic second-order formula, and to $O(n + k \log(n))$ to retrieve the k shortest simple distances only. In [36], we provide an algorithm that answers k-shortest simple distances in $O(k + n)$ time on graphs with treewidth at most 2, and a constructive algorithm, simpler than that of Eppstein and Kurz, that solves the k-shortest simple paths problem in $O(kn)$ time on bounded treewidth graphs.

This is a joint work with Andrea d'Ascenzo *(Luiss University, Rome, Italy)*.

New lower bounds on the cutwidth of graphs Cutwidth is a parameter used in many layout problems. Determining the cutwidth of a graph is an NP-complete problem, but it is possible to design efficient branch-and-bound algorithms if good lower bounds are available for cutting branches during exploration. Knowing how to quickly evaluate good bounds in each node of the search tree is therefore crucial. In [33], we give new lower bounds based on different graph density parameters such as the minimum, the average and the maximum average degree. Our main result is a new bound using the notion of traffic grooming on a path network, which appears to be in many cases better than bounds in the literature. Furthermore, the bound based on grooming can be computed quickly, in $O(\log n)$ time, and so is of interest to design faster branch-and-bound algorithms. Through extensive experiments, we show that this bound behaves very well compared to other bounds. Furthermore, we show how to obtain even better results when combining it with heuristics for finding dense subgraphs.

On the rank and the general position number in cycle convexity Graph convexities have been widely investigated through various combinatorial parameters that capture different aspects of convexity-related structures. The cycle convexity has been introduced due to its applications in the field of Knot Theory. In the cycle convexity, the interval $I(S)$ of a subset S of vertices of a graph $G = (V, E)$ is the set of all vertices in S union the vertices with two neighbors in a same connected component of $G[S]$. The hull of S is the closure $H(S) = I^*(S)$, i.e., the set of vertices that can be obtained from S by recursively adding to S any vertex that is the neighbor of two vertices in a same connected component of S. In any graph convexity, it is classical to study the minimum size of a hull set S of G, i.e., a minimum set such that $H(S) = V$. Previous works on other convexities also study the general position number of G, i.e., the maximum size of a set S such that $v \notin I(S \setminus \{v\})$ for every $v \in S \subseteq V(G)$, and the rank of G, i.e., the maximum size of a set S such that $v \notin H(S \setminus \{v\})$ for every $v \in S \subseteq V(G)$. In [68], we first show that the general position number of G in the cycle convexity equals the maximum order of an induced forest in G. Then, we focus on the computational complexity of computing the rank of a given G in the cycle convexity. We show that it is NP-hard, even if the input graph is known to be bipartite, and W[1]-hard parameterized by the size of the solution. Then, we prove that it is polynomial-time computable in various graph classes such as forests, cycles, complete graphs, complete bipartite graphs, cographs, Cartesian grids, chordal graphs, starlike graphs, and $(q, q - 4)$-graphs.

Surprisingly, the classes of Cartesian grids and of not 2-connected chordal graphs are quite involved. We conclude by showing fixed-parameter tractable algorithms for computing the rank of a given graph when parameterized by the neighborhood diversity, by vertex cover, or by the treewidth of the input graph.

This work has been done in collaboration with Júlio Araújo *(UFC Fortaleza, Brazil)* in the context of the EA CANOE.

The General Expiration Streaming Model: Diameter, k-Center, Counting, Sampling, and Friends An important thread in the study of data-stream algorithms focuses on settings where stream items are active only for a limited time. In [78], we introduce a new expiration model, where each item arrives with its own expiration time. The special case where items expire in the order that they arrive, which we call consistent expirations, contains the classical sliding-window model of Datar, Gionis, Indyk, and Motwani [SICOMP 2002] and its timestamp-based variant of Braverman and Ostrovsky [FOCS 2007]. Our first set of results presents algorithms (in the expiration streaming model) for several fundamental problems, including approximate counting, uniform sampling, and weighted sampling by efficiently tracking active items without explicitly storing them all. Naturally, these algorithms have many immediate applications to other problems. Our second and main set of results designs algorithms (in the expiration streaming model) for the diameter and k-center problems, where items are points in a metric space. Our results significantly extend those known for the special case of sliding-window streams by Cohen-Addad, Schwiegelshohn, and Sohler [ICALP 2016], including also a strictly better approximation factor for the diameter in the important special case of high-dimensional Euclidean space. We develop new decomposition and coordination techniques along with a geometric dominance framework, to filter out redundant points based on both temporal and spatial proximity.

This work has been done in collaboration with Lotte Blank *(University of Bonn, Germany)*, Sergio Cabello *(University of Ljubljana, Slovenia)*, Mohammadtaghi Hajiaghayi *(University of Maryland, USA)*, Robert Krauthgamer *(Weizmann Institute of Science, Rehovot, Israel)*, Sepideh Mahabadi *(Microsoft Research, Redmond, USA)*, Jeff Phillips *(University of Utah, Salt Lake City, USA)* and Jonas Sauer *(University of Bonn, Germany)*.

8.2.2 Combinatorial games in graphs

Participants: Samuel N. Aráujo, Jean-Claude Bermond, Michel Cosnard, Frédéric Havet, Nicolas Nisse.

Teoria dos Jogos Combinatórios em Grafos The book [63] has been written in the context of the 35th Brazilian Mathematics Colloquium (Rio de Janeiro, July 27-August 1st, 2025). It is intended to be a textbook on Combinatorial games in graphs for a public from highschool to University. It has been done in collaboration with Nicolas Martins *(UNILAB - Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Brazil)* and Rudini Sampaio *(UFC Fortaleza, Brazil)* in the context of the EA CANOE.

The Convex Set Forming Game In 1984, Frank Harary introduced the first graph convexity game, focused on the geodesic convexity. A set $S \subseteq V$ of vertices of a graph $G = (V, E)$ is convex if every shortest path between two vertices of S is also included in S. In [35], we introduce the Convex Set Forming Game CFG: two players alternately select vertices in such a way that the set of selected vertices is always a convex set. In the normal (resp., misère) variant, the last player to be able to select a vertex wins (resp., loses). We also define a new graph invariant $\mathrm{gc}(G)$ as the largest integer k such that the first player has a strategy ensuring that, at the end of the game, at least k vertices of the graph G have been selected. We first show that the problems of deciding the outcome (does the first player win?) of the game in both variants (normal and misère), as well as the problem of deciding whether $\mathrm{gc}(G) \geq k$, are PSPACE-complete. As a by-product, we prove that the optimization variant of the classical KAYLES game is PSPACE-complete. Then, we focus on convexable graphs, i.e., n-node graphs G for which $\mathrm{gc}(G) = n$. For this purpose, we say that a set $S = \{v_1, \cdots, v_{|S|}\} \subseteq V$ in a graph G admits a Convex Elimination Ordering (CEO) if $\{v_1, \cdots, v_i\}$ is convex for every $1 \leq i \leq |S|$. We show that the class of graphs whose vertex-set admits a CEO coincides with the chordal graphs and that this class strictly contains the convexable graphs. Moreover, every graph which is Ptolemaic (distance-hereditary chordal) or unit interval is convexable. Finally, we give a polynomial-time algorithm for computing a largest set admitting a CEO in outerplanar graphs, which gives upper bounds on $\mathrm{gc}(G)$ in outerplanar graphs G.

This is a joint work with Caroline Brosse *(LIFO, Université d'Orléans, France)*, Nicolas Martins *(UNILAB - Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Brazil)* and Rudini Sampaio *(UFC Fortaleza, Brazil)* in the context of the CANOE associated team.

The Graph colouring Game in $4 \times n$-Grids The graph colouring game is a famous two-player game (re)introduced by Bodlaender in 1991. Given a graph G and $k \in \mathbb{N}$, Alice and Bob alternately (starting with Alice) colour an uncoloured vertex with some colour in $\{1, \cdots, k\}$ such that no two adjacent vertices receive a same colour. If eventually all vertices are coloured, then Alice wins and Bob wins otherwise. The game chromatic number $\chi_g(G)$ is the smallest integer k such that Alice has a winning strategy with k colours in G. It has been recently (2020) shown that, given a graph G and $k \in \mathbb{N}$, deciding whether $\chi_g(G) \leq k$ is PSPACE-complete. Surprisingly, this parameter is not well understood even in "simple" graph classes. Let P_n denote the path with $n \geq 1$ vertices. For instance, in the case of Cartesian grids, it is easy to show that $\chi_g(P_m \square P_n) \leq 5$ since $\chi_g(G) \leq \Delta + 1$ for any graph G with maximum degree Δ (here $\square$ denotes the Cartesian product of two graphs). However, the exact value is only known for small values of m, namely $\chi_g(P_1 \square P_n) = 3$, $\chi_g(P_2 \square P_n) = 4$ and $\chi_g(P_3 \square P_n) = 4$ for $n \geq 4$ [99]. In [48], we prove that, for every $n \geq 18$, $\chi_g(P_4 \square P_n) = 4$.

This is a joint work with Caroline Brosse *(LIFO, Université d'Orléans, France)*, Nicolas Martins *(UNILAB - Universidade da Integração Internacional da Lusofonia Afro-Brasileira, Brazil)* and Rudini Sampaio *(UFC Fortaleza, Brazil)* in the context of the CANOE associated team.

The Closed Hull Game and the Closed Interval Game Given a set S of vertices in a graph G, its geodesic interval is the set $I(S)$ containing S and all vertices on a shortest path between vertices of S. A set S is convex if $I(S) = S$. Moreover, the convex hull $H(S)$ of S is the smallest convex set containing S. In 1984, Harary introduced convexity games where two players, Alice and Bob, alternately select vertices of a graph $G = (V, E)$ such that, if the set of already selected vertices is S, the next player can only select a vertex in $V \setminus I(S)$ (closed interval game) or in $V \setminus H(S)$ (closed hull game). Normal and misère version of these games have been studied and we introduce in [70] the optimization variants of them. Formally, given a graph G and $k \in N$, Alice wins if the game ends after at most k vertices have been selected and Bob wins otherwise. The corresponding problem consists of determining which player has a winning strategy. In [70], we prove that the closed interval optimization game is PSPACE-complete in graphs with diameter 4 and that the closed hull optimization game is NP-hard in bipartite graphs and in split graphs. On the positive side, we prove that both games can be solved in polynomial time in trees and that the closed hull optimization game can be solved in polynomial time in cobipartite graphs. We conjecture that the closed interval optimization game is NP-hard in cobipartite graphs and that the closed hull optimization game is PSPACE-complete in general graphs.

This is a joint work with Fabrício Benevides *(UFC Fortaleza, Brazil)*, Nicolas Martins *(UFC Fortaleza, Brazil)* and Rudini Sampaio *(UFC Fortaleza, Brazil)* in the context of the CANOE associated team.

Complexity of Maker-Breaker Games on Edge Sets of Graphs In [37], we initiate the study of the algorithmic complexity of Maker-Breaker games played on edge sets of graphs for general graphs. We mainly consider three of the big four such games: the connectivity game, perfect matching game, and H-game. Maker wins if she claims the edges of a spanning tree in the first, a perfect matching in the second, and a copy of a fixed graph H in the third. We prove that deciding who wins the perfect matching game and the H-game is PSPACE-complete, even for the latter in graphs of small diameter if H is a tree. Seeking to find the smallest graph H such that the H-game is PSPACE-complete, we also prove that there exists such an H of order 51 and size 57. On the positive side, we show that the connectivity game and arboricity-k game are polynomial-time solvable. We then give several positive results for the H-game, first giving a structural characterization for Breaker to win the P 4-game, which gives a linear-time algorithm for the P_4-game. We provide a structural characterization for Maker to win the $K_{1,\ell}$-game in trees, which implies a linear-time algorithm for the $K_{1,\ell}$-game in trees. Lastly, we prove that the $K_{1,\ell}$-game in any graph, and the H-game in trees are both FPT parameterized by the length of the game. We leave the complexity of the last of the big four games, the Hamiltonicity game, as an open question.

This is a joint work with Eric Duchêne *(LIRIS, Lyon)*, Valentin Gledel *(LAMA, Chambery)*, Fionn Mc Inerney *(Telefonica, Barcelona, Spain)*, Nacim Oijid *(Umea University, Sweden)*, Aline Parreau *(CNRS, LIRIS, Lyon)* and Miloš Stojaković *(University of Novi Sad, Serbia)* in the context of the ANR P-Gase.

8.2.3 Algorithm engineering

Participants: André Nusser.

Algorithm Engineering is concerned with the design, analysis, implementation, tuning, and experimental evaluation of computer programs for solving algorithmic problems. It provides methodologies and tools for developing and engineering efficient algorithmic codes and aims at integrating and reinforcing traditional theoretical approaches for the design and analysis of algorithms and data structures. This approach is particularly suited when formal analysis pessimistically suggests bounds which are unlikely to appear on inputs of practical interest.

Algorithm Engineering of SSSP with Negative Edge Weights Computing shortest paths is one of the most fundamental algorithmic graph problems. It is known since decades that this problem can be solved in near-linear time if all weights are nonnegative. A recent break-through by Aaron Bernstein et al. [89] presented a randomized near-linear time algorithm for this problem. A subsequent improvement in [92] significantly reduced the number of logarithmic factors and thereby also simplified the algorithm. It is surprising and exciting that both of these algorithms are combinatorial and do not contain any fundamental obstacles for being practical. In [50], we launch the, to the best of our knowledge, first extensive investigation towards a practical implementation of [92]. To this end, we give an accessible overview of the algorithm and discuss what adaptions are necessary to obtain a fast algorithm in practice. We manifest these adaptions in an efficient implementation. We test our implementation on a benchmark data set that is adapted to be more difficult for our implementation in order to allow for a fair comparison. As in [92] as well as in our implementation there are multiple parameters to tune, we empirically evaluate their effect and thereby determine the best choices. Our implementation is then extensively compared to one of the state-of-the-art algorithms for this problem [94]. On the hardest instance type, we are faster by up to almost two orders of magnitude.

This work has been done in collaboration with Alejandro Cassis *(MPII and Saarland University Saarbrücken, Germany)*, Andreas Karrenbauer *(MPII and Saarland University Saarbrücken, Germany)* and Paolo Luigi Rinaldi *(MPII and Saarland University Saarbrücken, Germany)*.

8.2.4 Distributed algorithms

Participants: Niccolò d'Archivio, Emanuele Natale.

Threshold-Driven Streaming Graph: Expansion and Rumor Spreading A randomized distributed algorithm called RAES was introduced in [88] to extract a bounded-degree expander from a dense n-vertex expander graph $G = (V, E)$. The algorithm relies on a simple threshold-based procedure. A key assumption in [88] is that the input graph G is static – i.e., both its vertex set V and edge set E remain unchanged throughout the process – while the analysis of RAES in dynamic models is left as a major open question. In [67], we investigate the behavior of RAES under a dynamic graph model induced by a streaming node-churn process (also known as the sliding window model), where, at each discrete round, a new node joins the graph and the oldest node departs. This process yields a bounded-degree dynamic graph $\mathcal{G} = \{G_t = (V_t, E_t) : t \in \mathbb{N}\}$ that captures essential characteristics of peer-to-peer networks – specifically, node churn and threshold on the number of connections each node can manage. We prove that every snapshot G_t in the dynamic graph sequence has good expansion properties with high probability. Furthermore, we leverage this property to establish a logarithmic upper bound on the completion time of the well-known PUSH and PULL rumor spreading protocols over the dynamic graph $\mathcal{G}$.

This work has been done in collaboration with Flora Angileri *(University of Rome Tor Vergata, Rome, Italy)*, Andrea Clementi *(University of Rome Tor Vergata, Rome, Italy)*, Michele Salvi *(University of Rome Tor Vergata, Rome, Italy)* and Isabella Ziccardi *(IRIF, Université Paris-Cité, France)*.

On the h-majority dynamics with many opinions In [51], we present the first upper bound on the convergence time to consensus of the well-known h-majority dynamics with k opinions, in the synchronous setting, for h and k that are both non-constant values. We suppose that, at the beginning of the process, there is some initial additive bias towards some plurality opinion, that is, there is an opinion that is supported by x nodes while any other opinion is supported by strictly fewer nodes. We prove that, with high probability, if the bias is $\omega(\sqrt{x})$ and the initial plurality opinion is supported by at least $x = \omega(\log n)$ nodes, then the process converges to plurality consensus in $O(\log n)$ rounds whenever $h = \omega(n \log n / x)$. A main corollary is the following: if $k = o(n/\log n)$ and the process starts from an almost-balanced configuration with an initial bias of magnitude $\omega(\sqrt{n/k})$ towards the initial plurality opinion, then any function $h = \omega(k \log n)$ suffices to guarantee convergence to consensus in $O(\log n)$ rounds, with high probability. Our upper bound shows that the lower bound of $\Omega(k/h^2)$ rounds to reach consensus given by Becchetti et al. [87] cannot be pushed further than $\widetilde{\Omega}(k/h)$. Moreover, the bias we require is asymptotically smaller than the $\Omega(\sqrt{n \log n})$ bias that guarantees plurality consensus in the 3-majority dynamics: in our case, the required bias is at most any (arbitrarily small) function in $\omega(\sqrt{x})$ for any value of $k \geq 2$.

This work has been done in collaboration with Francesco d'Amore *(Gran Sasso Science Institute, L'Aquila, Italy)* and George Giakkoupis *(WIDE, Rennes, France)*.

8.3 Machine learning theory and algorithms

Participants: Francesco Diana, Davide Ferré, Frédéric Giroire, Aakash Kumar, Emanuele Natale, André Nusser, Pierre Pereira, Aurora Rossi, Chuan Xu.

In the last years, COATI has started investigating machine-learning-based methods to enhance algorithms or solve optimization problems in networks. It also investigates how to use tools from graph theory, algorithmic and combinatorics to improve machine-learning tools. We here present our last results in this direction.

8.3.1 Centralized Machine Learning

Participants: Frederic Giroire, Aakash Kumar, Emanuele Natale, André Nusser, Pierre Pereira, Aurora Rossi.

Quantization vs Pruning: Insights from the Strong Lottery Ticket Hypothesis Quantization is an essential technique for making neural networks more efficient, yet our theoretical understanding of it remains limited. Previous works demonstrated that extremely low-precision networks, such as binary networks, can be constructed by pruning large, randomly-initialized networks, and showed that the ratio between the size of the original and the pruned networks is at most polylogarithmic. The specific pruning method they employed inspired a line of theoretical work known as the Strong Lottery Ticket Hypothesis (SLTH), which leverages insights from the Random Subset Sum Problem. However, these results primarily address the continuous setting and cannot be applied to extend SLTH results to the quantized setting. In [81], we build on foundational results by Borgs et al. [91] on the Number Partitioning Problem to derive new theoretical results for the Random Subset Sum Problem in a quantized setting. Using these results, we then extend the SLTH framework to finite-precision networks. While prior work on SLTH showed that pruning allows approximation of a certain class of neural networks, we demonstrate that, in the quantized setting, the analogous class of target discrete neural networks can be represented exactly, and we prove optimal bounds on the necessary over parameterization of the initial network as a function of the precision of the target network.

Improved Learning via k-DTW: A Novel Dissimilarity Measure for Curves In [59], we introduce k-Dynamic Time Warping (k-DTW), a novel dissimilarity measure for polygonal curves. k-DTW has stronger metric properties than Dynamic Time Warping (DTW) and is more robust to outliers than the Fréchet distance, which are the two gold standards of dissimilarity measures for polygonal curves. We show interesting properties of k-DTW and give an exact algorithm as well as a $(1+\epsilon)$-approximation algorithm for k-DTW by a parametric search for the k-th largest matched distance. We prove the first dimension-free learning bounds for curves and further learning theoretic results. k-DTW not only admits smaller sample size than DTW for the problem of learning the median of curves, where some factors depending on the curves' complexity m are replaced by k, but we also show a surprising separation on the associated Rademacher and Gaussian complexities: k-DTW admits strictly smaller bounds than DTW, by a factor $\tilde{\Omega}(\sqrt{m})$ when $k \ll m$. We complement our theoretical findings with an experimental illustration of the benefits of using k-DTW for clustering and nearest neighbor classification.

This work has been done in collaboration with Amer Krivošija *(Technische Universität Dortmund, Germany)*, Alexander Munteanu *(University of Cologne, Germany)* and Chris Schwiegelshohn *(Aarhus University, Denmark)*.

Solving the Traveling Salesman Problem with Positional Encoding In [83], we propose transformer-based neural solvers for the Euclidean Traveling Salesman Problem that rely on positional encodings rather than coordinate projections. By adapting ALiBi and RoPE, modern positional encodings originally developed for large language models, to the Euclidean setting, our Positional Encoding-based Neural Solvers (PENS) inherit useful invariances and locality biases. To address the increased density of large instances, we introduce a simple yet effective rescaling of city coordinates that further boosts performance. Trained only on TSP-100, PENS achieves state-of-the-art results for instances with up to 10 000 cities, a scale that was previously dominated by methods requiring graph sparsification. These findings demonstrate that positional encodings provide effective inductive biases for neural combinatorial optimization.

Temporal graph neural networks We have contributed to the Julia open source libraries GraphNeuralNetworks.jl and MLDatasets.jl. Our project's objective was to extend the support of temporal graph neural networks in GraphNeuralNetworks.jl by creating several layers, known as temporal graph convolutional layers. These layers were designed specifically for a type of graph called `TemporalSnapshotsGNNGraph`. Particular emphasis was placed on layers combining graph convolutions with recurrent cells, using the Flux.jl machine learning framework as a reference for implementing the latter. Some implemented layers were the `DCRNN` layer for traffic prediction, the `GConvGRU` and `GConvLSTM` layers, and the `EGCN-O` layer for tasks such as node and edge classification as well as link prediction. Additionally, we adapted all the implemented temporal layers to work seamlessly with another Julia machine learning framework, Lux.jl, ensuring compatibility across frameworks. Beyond enhancing existing tools, we expanded the range of datasets available in MLDatasets.jl, a Julia package for machine learning datasets, by contributing new datasets. We restructured the repository into a multi-repository setup, created and deployed the multi-package documentation, as detailled in [42]. The package is available on GitHub.

This work has been done in collaboraiton with Carlo Lucibello *(Bocconi University, Italy)*.

Characterizing Dynamic Functional Connectivity Subnetwork Contributions in Narrative Classification with Shapley Values Functional connectivity derived from functional Magnetic Resonance Imaging (fMRI) data has been increasingly used to study brain activity. In [43], we model brain dynamic functional connectivity during narrative tasks as a temporal brain network and employ a machine learning model to classify in a supervised setting the modality (audio, movie), the content (airport, restaurant situations) of narratives, and both combined. Leveraging Shapley values, we analyze subnetwork contributions within Yeo parcellations (7- and 17-subnetworks) to explore their involvement in narrative modality and comprehension. This work represents the first application of this approach to functional aspects of the brain, validated by existing literature, and provides novel insights at the whole-brain level. Our findings suggest that schematic representations in narratives may not depend solely on pre-existing knowledge of the top-down process to guide perception and understanding, but may also emerge from a bottom-up process driven by the temporal parietal subnetwork.

This work has been done in collaboration with Yanis Aeschlimann *(CRONOS)*, Samuel Deslauriers-Gauthier *(CRONOS)* and Peter Ford Dominey *(Inserm, Université de Bourgogne, Dijon, France)*.

8.3.2 Federated Learning

Participants: Francesco Diana, Frédéric Giroire, Emanuele Natale, André Nusser, Chuan Xu.

Supervised Classification in Federated Learning via Locality-Sensitive Filters Federated Learning (FL) can struggle with high communication costs, a problem that is only exacerbated by the fact that, in FL, it is common to have heterogeneous data distributions among parties. Recently, the study of the brain of fruit flies inspired two novel ML ideas: a Locality-Sensitive Hashing (LSH) scheme, called FlyHash, and a data structure for novelty detection, called FlyBloomFilter. A recent study combined these two tools to provide a simple and efficient method for performing FL in a single shot, which is also agnostic to the heterogeneity of the data: FlyNN. Yet, despite their empirical success, theoretical understanding of both Fly-Hash and FlyBloomFilter is still limited. In [79], we distil the ideas underlying FlyHash into a variant of SimHash, one of the most famous LSH schemes. We provide a theoretical basis for the proposed algorithm and leverage the insights obtained to connect the novelty detection structure to classical Bayesian theory, yielding improvements also for FlyBloom-Filter. Ultimately, we propose a simplification of FlyNN, for which we provide both a theoretical motivation and extensive experiments demonstrating its competitive performance.

This work has been done in collaboration with Arthur Carvalho Walraven da Cuhna *(Aarhus University, Denmark)* and Paulo Bruno Serafim *(Gran Sasso Science Institute, L'Aquila, Italy)*.

Attribute Inference Attacks for Federated Regression Tasks Federated Learning enables multiple clients, such as mobile phones and IoT devices, to collaboratively train a global machine learning model while keeping their data localized. However, recent studies have revealed that the training phase of FL is vulnerable to reconstruction attacks, such as attribute inference attacks (AIA), where adversaries exploit exchanged messages and auxiliary public information to uncover sensitive attributes of targeted clients. While these attacks have been extensively studied in the context of classification tasks, their impact on regression tasks remains largely unexplored. In [52], we address this gap by proposing novel model-based AIAs specifically designed for regression tasks in FL environments. Our approach considers scenarios where adversaries can either eavesdrop on exchanged messages or directly interfere with the training process. We benchmark our proposed attacks against state-of-the-art methods using real-world datasets. The results demonstrate a significant increase in reconstruction accuracy, particularly in heterogeneous client datasets, a common scenario in FL. The efficacy of our model-based AIAs makes them better candidates for empirically quantifying privacy leakage for federated regression tasks.

This work has been done in collaboration with Othmane Marfoq *(Meta, France)*, Giovanni Neglia *(NEO)* and Eoin Thomas *(Amadeus, France)*.

Trading-off Accuracy and Communication Cost in Federated Learning Leveraging the training-by-pruning paradigm introduced by Zhou et al. [100], Isik et al. [95] introduced a federated learning protocol that achieves a 34-fold reduction in communication cost. In [85, 62], we achieve a compression improvements of orders of magnitude over the state-of-the-art. The central idea of our framework is to encode the network weights $\overrightarrow{w}$ by a the vector of trainable parameters $\overrightarrow{p}$, such that $\overrightarrow{w} = Q \cdot \overrightarrow{p}$ where Q is a carefully-generate sparse random matrix (that remains fixed throughout training). In such framework, the previous work [100] is retrieved when Q is diagonal and $\overrightarrow{p}$ has the same dimension of $\overrightarrow{w}$. We instead show that $\overrightarrow{p}$ can effectively be chosen much smaller than $\overrightarrow{w}$, while retaining the same accuracy at the price of a decrease of the sparsity of Q. Since server and clients only need to share $\overrightarrow{p}$, such a trade-off leads to a substantial improvement in communication cost. Moreover, we provide theoretical insight into our framework and establish a novel link between training-by-sampling and random convex geometry.

This work has been done in collaboration with Frederik Mallmann-Trenn *(King's College London, United Kingdom)* and Mattia Jacopo Villani *(JP Morgan AI Research, USA)*.

Cutting Through Privacy: A Hyperplane-Based Data Reconstruction Attack in Federated Learning Federated Learning enables collaborative training of machine learning models across distributed clients without sharing raw data, ostensibly preserving data privacy. Nevertheless, recent studies have revealed critical vulnerabilities in FL, showing that a malicious central server can manipulate model updates to reconstruct clients' private training data. Existing data reconstruction attacks have important limitations: they often rely on assumptions about the clients' data distribution or their efficiency significantly degrades when batch sizes exceed just a few tens of samples. In [53], we introduce a novel data reconstruction attack that overcomes these limitations. Our method leverages a new geometric perspective on fully connected layers to craft malicious model parameters, enabling the perfect recovery of arbitrarily large data batches in classification tasks without any prior knowledge of clients' data. Through extensive experiments on both image and tabular datasets, we demonstrate that our attack outperforms existing methods and achieves perfect reconstruction of data batches two orders of magnitude larger than the state of the art.

This work has been done in collaboration with Giovanni Neglia *(NEO)*.

8.4 Network design and management

Participants: Jean-Claude Bermond, Christelle Caillouet, Michel Cosnard, Frédéric Giroire, Joanna Moulierac, Stéphane Pérennes.

Network design is a very wide subject which concerns all kinds of networks. In telecommunications, networks can be either physical (backbone, access, wireless, ...) or virtual (logical). The objective is to design a network able to route a (given, estimated, dynamic, ...) traffic under some constraints (e.g. capacity) and with some quality-of-service (QoS) requirements. Usually, the traffic is expressed as a family of requests with parameters attached to them. In order to satisfy these requests, we need to find one (or many) paths between their end nodes. The set of paths is chosen according to the technology, the protocol or the QoS constraints. The last years have been very lively for networks and have seen the rises of several new paradigms, like Software Defined Networks (SDN) and Network Function Virtualization (NVF), of new technologies, like 5G, Elastic Optical Networks and LoRa, and of new usages, like Internet of Things, 5G, and high quality video streaming. All these changes have brought or renewed a large number of algorithmic and optimization problems for the design and management of networks. In this context, our work has mainly focused on the study of the following types of problems:

- How to build scalable routing solutions and reconfigure them without any interruptions for SDN?
- How to integrate and use AI for designing our solutions?
- How to efficiently route and place virtual resources in networks using NFV?
- How to use efficiently wireless networks?
- How to propose energy-efficient solutions?

This very wide topic is considered by a lot of academic and industrial teams in the world. Our approach is to tackle these problems with tools from operations research and discrete mathematics (some of them developed in our team, see Section 8.1 (Graph and Digraph Theory) and Section 8.2 (Algorithms and combinatorial optimization)), as well as tools from AI (see also Section 8.3). This approach is shared by a number of other teams within Inria and worldwide, e.g. UFC and UNIFOR (Fortaleza, Brazil), Concordia Univ. (Montreal, Canada), Univ. Adolfo Ibanez (Santiago, Chile) with which we have direct collaboration.

8.4.1 Maximizing the number of requests in oriented trees with a grooming factor

Participants: Jean-Claude Bermond, Michel Cosnard.

The Maximum All Request Path Grooming (MARPG) problem consists in finding the maximum number of requests (connections) which can be established in a network, where each arc has a given capacity or bandwidth C (grooming factor). The Maximum Path Coloring problem consists for a given number of colors (wavelengths) W in finding the maximum number of requests that can be established so that two requests sharing an arc have different colors. These problems are part of the more general RWA (Routing and Wavelength Assignment) problem and have been studied for various classes of networks like paths, dipaths, undirected trees and symmetric directed trees. In [77], we consider the case where the network is an oriented tree (tree in which each edge has a unique orientation) where the two problems are equivalent. We give the value of the maximum number of requests for various families of oriented trees like Fig-Trees. To do that we revisit the problem when the network is a directed path by giving the structure of a maximum set of requests and determining bounds on the maximum load of an arc of the dipath. These bounds can be used for computing the cutwidth of a graph.

8.4.2 Data Center Scheduling With Network Tasks

Participants: Frédéric Giroire, Stéphane Pérennes.

In [40] we consider the placement of jobs inside a data center. Traditionally, this is done by a task orchestrator without taking into account network constraints. According to recent studies, network transfers may account for up to 50% of the completion time of classical jobs. Thus, network resources must be considered when placing jobs in a data center. In this paper, we propose a new scheduling framework, introducing network tasks that need to be executed on network machines alongside traditional (CPU) tasks. The model takes into account the competition between communications for the network resources, which is not considered in the formerly proposed scheduling models with communication. Network transfers inside a data center can be easily modeled in our framework. As we show, classical algorithms do not efficiently handle a limited amount of network bandwidth. We thus propose new provably efficient algorithms with the goal of minimizing the makespan in this framework. We show their efficiency and the importance of taking into consideration network capacity through extensive simulations on workflows built from Google data center traces.

This work has been done in collaboration with Nicolas Huin *(IMT Atlantique, Rennes, France)*.

8.4.3 Energy efficiency and carbon footprint

Participants: Frédéric Giroire, Joanna Moulierac.

Towards Estimating the Carbon Footprint of Video Streaming Video streaming dominates the Internet traffic. Assessing the carbon footprint of video streaming has received recently a significant attention with a number of models proposed to associate a CO_2 cost to one hour of streaming. In [61], we compare the modeling assumptions and computation methods used by five recent works to inform the debate. Indeed, initial results can be at odds, with up to one order of magnitude difference in the estimates. Our contributions are: (i) we relate the difference in the results primarily to the perimeter of the study, e.g. including production cost or not, (ii) we question some of the modeling assumptions made using a real deployment of a streaming server in a controlled environment with up to 2000 clients and (iii) we propose a technique to reconcile the models and obtain a CO2 estimate in between 60 and 140 grams when considering the average worldwide carbon intensity of electricity.

This work has been done in collaboration with Guillaume Urvoy-Keller *(I3S, Université Côte d'Azur, France)*, Marco Dinuzzi *(I3S, Université Côte d'Azur, France)* and Zhejiayu Ma *(Easybroadcast, France)*.

Enhancing Energy Efficient Task Caching and Offloading in Mobile Edge Computing Mobile Edge Computing (MEC) enables both to prolong the battery life of mobile devices and support the execution of computationally intensive applications at the edge. This can be achieved by offloading these tasks to a server deployed near the base station and/or by directly caching them. Previous works focus on only one of these two strategies or formulate optimization problems that are hard to solve and propose a suboptimal solution.

In [60] we propose a linear model for the joint task caching and offloading optimization problem. Moreover, we present two efficient heuristics which provide close-to-optimal results in terms of energy efficiency with a low execution time. We further prove that the offloading subproblem can be solved with an optimal algorithm. Finally, we demonstrate the performance and scalability of our propositions by extensive simulations on a large number of 10^5 mobile devices.

This work has been done in collaboration with Fabiano Lorusso *(I3S, Université Côte d'Azur)* and Guillaume Urvoy-Keller *(I3S, Université Côte d'Azur)*.

8.4.4 SFIxM : Flexible LoRa Modulations for Elastic Resource Allocation

Participants: Christelle Caillouet.

In [55], we presents SFIxM, a flexible evolution of the LoRa modulation scheme designed to facilitate the allocation of transmission parameters across nodes within a gateway's coverage area. SFIxM increases the number of available quasiorthogonal channels and, unlike standard LoRa, offers tunable robustness to noise and interference. Because SFIxM introduces a new requirement for time-axis alignment between transmitter and receiver, we present a practical procedure to achieve this synchronization, along with an analytical estimate of its failure probability, which we find negligible. Based on this foundation, we show that SFIxM provides traffic capacity gains of 40 to 55%, comparable to the gains obtained with receiver diversity, a well-known approach to improving coverage and range, which also turns out to combine well with SFIxM .

This work has been done in collaboration with Martin Heusse *(IMAG, Grenoble, France)* and Ghislaine Maury *(CROMA, Grenoble, France)*.

8.5 Miscellaneous

8.5.1 Approximating Klee's Measure Problem and a Lower Bound for Union Volume Estimation

Participants: André Nusser.

Union volume estimation is a classical algorithmic problem. Given a family of objects $O_1, \ldots, O_n \subset \mathbb{R}^d$, we want to approximate the volume of their union. In the special case where all objects are boxes (also called hyperrectangles) this is known as Klee's measure problem. The state-of-the-art $(1+\epsilon)$-approximation algorithm [96] for union volume estimation as well as Klee's measure problem in constant dimension d uses a total of $O(n/\epsilon^2)$ queries of three types: (i) determine the volume of O_i; (ii) sample a point uniformly at random from O_i; and (iii) ask whether a given point is contained in O_i. In [47], we first show that if an algorithm learns about the objects only through these types of queries, then $\Omega(n/\epsilon^2)$ queries are necessary. In this sense, the complexity of [96] is optimal. Our lower bound holds even if the objects are equiponderous axis-aligned polygons in $\mathbb{R}^2$, if the containment query allows arbitrary (not necessarily sampled) points, and if the algorithm can spend arbitrary time and space examining the query responses. Second, we provide a more efficient approximation algorithm for Klee's measure problem, which improves the running time from $O(n/\epsilon^2)$ to $O((n+1/\epsilon^2)\cdot\log^{O(d)}(n))$. We circumvent our lower bound by exploiting the geometry of boxes in various ways: (1) We sort the boxes into classes of similar shapes after inspecting their corner coordinates. (2) With orthogonal range searching, we show how to sample points from the union of boxes in each class, and how to merge samples from different classes. (3) We bound the amount of wasted work by arguing that most pairs of classes have a small intersection.

This work has been done in collaboration with Karl Bringmann *(MPII and Saarland University, Saarbrücken, Germany)*, Kasper Green Larsen *(Aarhus University, Denmark)*, Eva Rotenberg *(Technical University of Denmark, Lyngby, Denmark)* and Yanheng Wang *(MPII and Saarland University, Saarbrücken, Germany)*.

8.5.2 Fréchet Distance Under Transformations

Participants: André Nusser.

The Fréchet distance is a computational mainstay for comparing polygonal curves. The Fréchet distance under translation, which is a translation invariant version, considers the similarity of two curves independent of their location in space. It is defined as the minimum Fréchet distance that arises from allowing arbitrary translations of the input curves. This problem and numerous variants of the Fréchet distance under some transformations have been studied, with more work concentrating on the discrete Fréchet distance, leaving a significant gap between the discrete and continuous versions of the Fréchet distance under transformations.

In collaboration with Kevin Buchin *(Technical University of Dortmund, Germany)*, Maike Buchin *(Ruhr University Bochum, Germany)*, Zijin Huang *(The University of Sidney, Australia)* and Sampson Wong *(University of Copenhagen, Denmark)*, we study in [49] the problem of computing the Fréchet distance between two polygonal curves under transformations. First, we consider translations in the Euclidean plane. Given two curves π and σ of total complexity n and a threshold $\delta \geq 0$, we present an $\tilde{O}(n^{7+1/3})$ time algorithm to determine whether there exists a translation $t \in \mathbb{R}^2$ such that the Fréchet distance between π and $\sigma + t$ is at most δ. This improves on the previous best result, which is an $\tilde{O}(n^8)$ time algorithm. We then generalize this result to any class of rationally parameterized transformations, which includes translation, rotation, scaling, and arbitrary affine transformations. For a class $\mathcal{T}$ of rationally parametrized transformations with k degrees of freedom, we show that one can determine whether there is a transformation $\tau \in \mathcal{T}$ such that the Fréchet distance between π and $\tau(\sigma)$ is at most δ in $\tilde{O}(n^{3k+4/3})$ time.

In collaboration with Lotte Blank *(University of Bonn, Germany)*, Jacobus Conradi *(University of Bonn, Germany)*, Anne Driemel *(University of Bonn, Germany)*, Benedikt Kolbe *(University of Bonn, Germany)* and Marena Richter *(University of Bonn, Germany)*, we first present in [46] an algorithm for the Fréchet distance under translation on 1-dimensional curves of complexity n with a running time of $\tilde{O}(n^{8/3}\log^3 n)$. To achieve this, we develop a novel framework for the problem for 1-dimensional curves, which also applies to other scenarios and leads to our second contribution. We then present an algorithm with the same running time of $\tilde{O}(n^{8/3}\log^3 n)$ for the Fréchet distance under scaling for 1-dimensional curves. For both algorithms we match the running times of the discrete case and improve the previously best known bounds of $\tilde{O}(n^4)$. Our algorithms rely on technical insights but are conceptually simple, essentially reducing the continuous problem to the discrete case across different length scales.

8.5.3 How Digital Twins Can Improve the Design of Distributed Computing Frameworks

Participants: Luc Hogie.

The design of distributed systems has evolved through various strategies for representing and accessing remote components, ranging from explicit message-passing and transparent remote function invocation to stubs, web-oriented APIs, and emerging approaches driven by technological advancements. In [57], we explore the advantages and limitations of these strategies and introduces a novel approach-the Idawi Digital Twinning System (IDST)-for distributed application design. IDST leverages the concept of digital twins to enhance the development of distributed systems. The paper details how IDST capitalizes on the inherent properties of digital twins, its benefits for distributed application development, and the IDAWI framework, an opensource Java reference implementation for IDST.

9 Bilateral contracts and grants with industry

9.1 Bilateral Grants with Industry

Nokia, since 2025

Participants: Frédéric Giroire, Joanna Mouliérac.

Collaboration with Nokia and NEO in the context of Défi Inria-Nokia SmartNet. The activities includes the CIFRE PhD thesis of Adrien Sardi that started his PhD on *Modèles d'intelligence artificielle génératifs et gestion énergétique des ressources au sein des réseaux distribués 6G* on January 2025 under the co-supervision of Marie-Line Alborel *(Nokia)*, Sara Alouf *(NEO)*, Frédéric Giroire and Joanna Moulierac.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 Inria associate team not involved in an IIL or an international program

CANOE

Title: Combinatorial Algorithms for Networking prOblEms

Duration: 2023 - 2025

Coordinator: Julio Araujo (julio@mat.ufc.br)

Partners: Universidade Federal do Ceará Fortaleza (Brésil)

Inria contact: Nicolas Nisse

Summary: A graph is a mathematical structure that allows modeling networks in many contexts, from route networks, telecommunication networks, biological networks, neural networks to social networks. There are graph problems arising in each of these domains that are classified as computationally difficult, where the objective is to obtain an efficient algorithm for any graph presented as input. However, studying algorithms for a problem restricted to special graphs can shed light on the problem. This approach consists in assuming that the graph has some special structural property and exploiting this property in the algorithm. Such a structural property defines a class of graphs, for example, trees or planar graphs. The aim is to build an efficient algorithm for a class of graphs, and then explore the ideas used to solve larger and larger classes of graphs or with fewer structural constraints. While a lot of work has been dedicated to the study of structural properties of graphs, very few results are known concerning directed graphs or hypergraphs which better model real life networks. For instance, road networks are intrinsically directed and so are many social networks (e.g., Twitter), co-authorship networks correspond to hypergraphs (where each publication corresponds to an hyperedge gathering the co-authors), etc. This project aims at tackling chalenging theoretical open problems in digraphs and/or hypergraphs, with applications in road, telecommunications and social networks.

The purpose of this project is also to pursue and extend our fruitful collaboration with the ParGO team from Universidade Federal do Ceara (Fortaleza), which is one of the partner universities of LNCC (Laboratório Nacional de Computação Científica).

ELECTRON

Title: Evolutionary LEarning and Compressed TRaining Of Neural networks

Webpage: team.inria.fr/electron/

Duration: 2025 - 2027

Coordinator: Emanuele Natale

Partners: King's College London

Inria contact: Emanuele Natale

Summary: The ELECTRON team focuses on understanding the role of topology in neural networks and the principles behind their efficient design. Motivated and inspired by insights from evolutionary neuroscience, on the one hand, and by the goal of improving the efficiency of deep learning techniques, on the other, the team aims to combine theoretical insights on artificial neural network sparsification and compression. To this end, our initial focus is to (i) establish rigorous guarantees for "training-by-pruning" heuristics in the context of the Strong Lottery Ticket Hypothesis, and (ii) investigate evolutionary frameworks for network topology learning. This integrated approach seeks not only to advance the theory of sparse neural architectures but also to catalyze novel interdisciplinary collaborations between computer scientists and neuroscientists.

10.1.2 Participation in other International Programs

CAPES-Cofecub project Ma 1004/23 : Graphs, Optimization, Combinatorics and Algorithms

Participants: Thomas Dissaux, Frédéric Giroire, Frédéric Havet, Nicolas Nisse, Lucas Picasarri-Arrieta, Clément Rambaud.

Title: Graphs, Optimization, Combinatorics and Algorithms

Duration: 2023 - 2026

Coordinator: Nicolas Nisse

Partners: ParGO Research Group, Department of Mathematics, Federal University of Ceará, Fortaleza, Brazil

Summary: Complementary project of the Inria EA CANOE.

French-Indian Campus

Participants: Niccolò D'Archivio, Emanuele Natale.

Title: The Franco-Indian Campus in Life Sciences of Université Côte d'Azur

Website: life.univ-cotedazur.eu/education/franco-indian-campus

Partners: IIIT-Delhi (Indraprastha Institute of Information Technology Delhi), New Dehli, Dehli, India

Summary: The Franco-Indian Campus of Université Côte d'Azur is one of the 4 projects selected in the framework of the call for projects on the creation of a Franco-Indian campus, by the Ministry of Europe and Foreign Affairs (MEAE), the Ministry of Higher Education, Research and Innovation (MESRI), the Campus France agency and the Indian embassy in France. Emanuele Natale and Niccolò D'Archivio have been part of a delegation of the Université Côte d'Azur which visited IIIT-Delhi in November 2025 to discuss future collaborations.

10.2 International research visitors

10.2.1 Visits of international scientists

Other international visits to the team

- Sarah houdaigou *(National Institute of Informatics (NII), Japan)*, July 5-12, 2025.
- Frederik Mallmann-Trenn *(King's College London, UK)*, September 16-19, 2025.

- Frank Hirth *(King's College London, UK)*, September 16-19, 2025.
- Luciano Gualà *(University of Rome Tor Vergata, Italy)*, November 10-16, 2025.
- Andrea Clementi *(University of Rome Tor Vergata, Italy)*, November 10-16, 2025.
- Alma Ademovic Tahirovic *(Intelligent Systems Hub)*, June 2025 - November 2025.
- Caroline Aparecido De Paula Silva *(UNICAMP, Brasil)*, until August 2025.
- Piotr Micek *(Jagiellonian University, Kraków, Poland)*, December 1-4, 2025.
- Michał Pilipczuk *(Jagiellonian University, Kraków, Poland)*, December 1-4, 2025.
- Julio Cesar Silva Araujo *(Associated Professor at UFC Fortaleza, Brazil)*, April 27 - May 10, 2025.
- Malgorzata Sulkowska *(Assistant Professor at Univ. Wroclawski, Poland)*, February 4 - March 1, 2025. 2025.

10.2.2 Visits to international teams

Research stays abroad

- Niccolò D'Archivio: visit to the team of Dr. Frederik Mallmann Trenn *(King's College London, United Kindom)*, July 21-25 and November 17-21, 2025.
- Niccolò D'Archivio: visit IIT-Delhi under the Franco-India Health Campus Event, New Dehli, Dehli, India. October 11-16, 2025.
- Frédéric Giroire: visiting researchers in the group of Xavier Defago *(Institute of Science Tokyo, Japan)* and in the group of Tsuyoshi Murata *(Institute of Science Tokyo, Japan)*, Tokyo, Japan, June 3 - July 9, 2025.
- Emanuele Natale: visit the team of Dr. Frederik Mallmann Trenn *(King's College London, United Kindom)*, November 22-28, 2025.
- Emanuele Natale: visit the IIIT-Delhi (Indraprastha Institute of Information Technology Delhi), New Dehli, Dehli, India, October 11-16, 2025.
- Emanuele Natale: invited professor at University of Rome Tor Vergata in Andrea Clementi *(University of Rome Tor Vergata, Italy)*'s Group, Rome, Italy, March 1 - April 30, 2025.
- Emanuele Natale: visiting professor at University of Bonn in Petra Mutzel *(University of Bonn, Germany)*'s Group, Bonn, Germany, September 1-15 and 26-30, October 1-9 and 16-30, November 1-10 and 15-22 and 28-30, December 1-8 and 12-23, 2025.
- Emanuele Natale: visiting researcher at Institute of Science Tokyo in Tsuyoshi Murata *(Institute of Science Tokyo, Japan)*'s Group, Tokyo, Japan, May 8 - June 7, 2025.
- Emanuele Natale: visit to the team of Flavio Vella *(University of Trento, Italy)*, January 29-31, 2025.
- Nicolas Nisse: ParGO team, Universidade Federal do Ceára, October 19 - November 17, 2025.
- André Nusser: University of Bonn, Bonn, Germany. April 2025 – April 2026.
- Clément Rambaud: Jagiellonian University, Kraów, Poland. March 31-April 26, 2025.

10.3 European initiatives

10.3.1 Horizon Europe

HORIZON-CL4-2022-HUMAN-02-02 dAIEDGE, 2023-2026

Participants: Chuan Xu, Frédéric Giroire.

Program: HORIZON-CL4-2022-HUMAN-02-02 European Network of AI Excellence Centres: Expanding the European AI lighthouse.

Project acronym: dAIEDGE

Project title: A network of excellence for distributed, trustworthy, efficient and scalable AI at the Edge Granting Authority

Duration: September 2023 - August 2026

Coordinator: Alain Pagani *(DFKI)*

Other partners: 36 partners from 15 countries.

Summary: The dAIEDGE Network of Excellence (NoE) seeks to strengthen and support the development of a dynamic European cutting-edge AI ecosystem under the umbrella of the European Lighthouse for AI and to sustain the development of advanced AI.

dAIEDGE fosters the exchange of ideas, concepts, and trends on cutting-edge next generation AI, creating links between ecosystem actors to help both the European Commission (EC) and the European Union (EU) and the peripheral AI constituency identify strategies for future developments in Europe.

Our main objective is to advance Europe's innovation and technology base by developing a comprehensive policy and governance approach to AI in order for the EU to become a world leader in innovation in the data economy and its applications.

Web: daiedge.eu

10.4 National initiatives

DGA/Inria BioSwarm, 2013-2026

Participants: Niccolò D'Archivio, Emanuele Natale.

Program: DGA/Inria

Project acronym: BioSwarm

Project title: Bio-inspired algorithms for collective search and decision-making in drone swarms

Duration: 2023 - 2026

Coordinator: Emanuele Natale

Other partners: Inria EP CHROMA

Summary: The BioSwarm project focuses on decentralized algorithms inspired by the collective behavior of biological systems. It aims to enhance research strategies in unknown environments and improve collective decision-making through consensus among agents. The project will explore computational dynamics, particularly consensus algorithms that model decision-making processes observed in natural systems. It seeks to advance the understanding of how parameters, such as the majority threshold (k), influence the robustness and efficiency of consensus processes. Additionally, BioSwarm will investigate Lévy walks, a stochastic process relevant to collective behavior in multi-agent systems, through theoretical analyses and practical simulations.

ANR-19-CE48-0013 Digraphs, 2020-2025

Participants: Julien Bensmail, David Coudert, Frédéric Havet, Nicolas Nisse, Stéphane Pérennes.

Program: ANR

Project acronym: Digraphs

Project title: Digraphs

Duration: January 2020 - June 2025

Coordinator: Frédéric Havet

Other partners: LIRMM, Montpellier; LIP, Lyon

Summary: The objectives of the project are to make some advances on digraph theory in order to get a better understanding of important aspects of digraphs and to have more insight into the differences and the similarities between graphs and digraphs. Our methodology is two-fold. On the one hand, we will focus on the tools. Indeed we believe that many proof techniques have been too rarely used or adapted to digraphs and can be developed to obtain many more results. On the other hand, we will consider many results on graphs, find their (possibly many) formulations in terms of digraphs and see if and how they can be extended. Studying such extensions has been occasionally done, but the point here is to do it in a kind of systematic way. Moreover we shall push even further the study by considering classes of digraphs: if a result does not extend to the whole class of digraphs, for which classes does it extend? If a result extends, can we get better results for some restricted classes of digraphs?

Web: project.inria.fr/anrdigraphs/

Défi Inria-Cerema ROAD-AI, 2021-2025

Participants: Christelle Caillouet, David Coudert.

Project acronym: ROAD-AI

Project title: Routes et Ouvrages d'Art Diversiformes, Augmentés & intégrés

Duration: July 2021 - June 2025

Coordinators: Nathalie Mitton *(head, Inria, FUN)*, Christophe Biernacki *(vice-head, Inria, MODAL)*, Pierre Marchand *(CEREMA, DTEC ITM)*, André Orcési *(CEREMA, DTEC ITM)*

Inria participants: Inria project-teams ACENTAURI, COATI, FUN, MODAL, STATIFY, MODAL

Other partners: CEREMA

Summary: Integrated management of infrastructure assets is an approach which aims at reconciling long-term issues with short-term constraints and operational logic. The main objective is to enjoy more sustainable, safer and more resilient transport infrastructure through effective, efficient and responsible management. To achieve this, CEREMA and Inria are joining forces in this Inria Challenge (DEFI), whose main goals are to overcome scientific and technical barriers that lead to the asset management of tomorrow for the benefit of road operators: (i) build a "digital twin" of the road and its environment at the scale of a complete network; (ii) define "laws" of pavement behavior; (iii) instrument system-wide bridges and tunnels and use the data in real time; (iv) define methods for strategic planning of investments and maintenance.

Défi Inria Fed-Malin, 2022-2026

Participants: Francesco Diana, Frédéric Giroire, Chuan Xu.

Project acronym: Fed-Malin

Project title: Federated machine Learning over the internet

Duration: 2022 - 2026

Coordinators: Aurélien Bellet *(PREMEDICAL)*, Giovanni Neglia *(NEO)*

Inria participants: Inria project-teams ARGO, COATI, COMETE, EPIONE, MAGNET, MARACAS, NEO, SPIRALS, TRIBE, WIDE

Summary: In many use-cases of Machine Learning (ML), data is naturally decentralized: medical data is collected and stored by different hospitals, crowdsensed data is generated by personal devices, etc. Federated Learning (FL) has recently emerged as a novel paradigm where a set of entities with local datasets collaboratively train ML models while keeping their data decentralized. Fed-Malin is a research project that spans 10 Inria research teams and aims to push FL research and concrete use-cases through a multidisciplinary consortium involving expertise in ML, distributed systems, privacy and security, networks, and medicine. We propose to address a number of challenges that arise when FL is deployed over the Internet, including privacy & fairness, energy consumption, personalization, and location/time dependencies. Fed-Malin will also contribute to the development of open-source tools for FL experimentation and real-world deployments, and use them for concrete applications in medicine and crowdsensing.

Défi Inria-Hive Alvearium, 2022-2026

Participants: Frédéric Giroire, Stéphane Pérennes.

Project acronym: Alvearium

Project title: Large Scale Secure and Reliable Peer-to-Peer Cloud Storage: towards a shared sovereign cloud that respects its users' data

Duration: 2022 - 2026

Coordinator: Claudia-Lavinia Ignat

Inria participants: Inria project-teams COAST, COATI, MYRIADS, WIDE

Other partners: HIVE (www.hivenet.com)

Summary: The project aims to propose an alternative peer-to-peer cloud which provides both computing and data storage via a peer-to-peer network rather than from a centralized set of data centers. HIVE proposes to exploit the unused capacity of computers and to incentivize users to contribute their computer resources to the network in exchange for similar capacity from the network and/or monetary compensation. By exchanging similar computer resources and network capacity users can benefit from all cloud services. Peers store encrypted fragments of the data of other peers. This proposed peer-to-peer cloud solution addresses users concerns about the privacy of their data and the dependency on centralized cloud providers. In this collaboration with HIVE, we will apply our work on replication mechanisms for sharded encrypted data, data placement, Byzantine fault tolerance and security mechanisms in peer-to-peer environments.

Web: project.inria.fr/alvearium/

Défi Inria-Hive Cupseli, 2025-2029

Participants: Frédéric Giroire, Chuan Xu.

Project acronym: Cupseli

Project title: Collaborative Unified Platform for a Scalable and Efficient Learning Infrastructure

Duration: 2025 - 2029

Coordinator: Olivier Beaumont

Inria participants: Inria project-teams ARGO, MINIMOVE, COAST, MAGELLAN, STACK, WIDE, OCKHAM, COATI, NEO, TADAAM, TOPAL

Other partners: HIVE (www.hivenet.com)

Summary: hivenet offers a highly original data storage architecture in which data is stored in a distributed and secure manner on the spare storage resources of participants, based on a peer-to-peer structure. This structure ensures scalability, resilience and voluntary sharing of data between users. The aim of this new challenge (after Alvearium) between hivenet and Inria is to push the limits of distributed AI computing. Its goal is to demonstrate that even the most demanding AI and Big Data applications can run efficiently on heterogeneous, distributed, and volatile resources — while maintaining accuracy, ensuring privacy, and reducing environmental impact.

Web: project.inria.fr/cupseli/

Défi Inria-Nokia LearnNet, 2024-2027

Participants: Frédéric Giroire, Chuan Xu.

Project acronym: LearnNet

Project title: Learning Networks

Duration: 2024 - 2027

Coordinator: Jean-Marie Gorce

Inria participants: Inria project-teams COATI, EPIONE, MARACAS, NEO, PREMEDICAL, STATIFY, TOTH and TRIBE

Other partners: Nokia

Summary: The LearnNet challenge explores new avenues of research at the intersection of the fields of networks and learning with two complementary objectives: rethinking the design of network protocols to serve machine learning applications, and exploring how learning can improve network management. Thus, the LearnNet challenge studies the growing entanglement between the challenges of large-scale learning and network design.

Web: www.inria.fr/en/learnnet

Défi Inria-Nokia SmartNet, 2024-2027

Participants: Frédéric Giroire, Joanna Moulierac.

Project acronym: SmartNet

Project title: AI Methods for Smart Network Management

Duration: 2024 - 2027

Coordinator: Yassine Hadjadj-Aoul

Inria participants: Inria project-teams COATI, ERMINE, NEO, SPADES and STACK

Other partners: Nokia

Summary: The challenge is dedicated to exploring the transformative potential of AI methods in enabling smart network management. The project strategically focuses on two key areas: slice provisioning and causal analysis of network malfunctions.

Web: www.inria.fr/en/smartnet

PEPR NF (Networks of the Future 2023-2030, 65M€)

Participants: Jamil Abou Ltaif, Yanis Achaichia, Christelle Caillouet, David Coudert, Frédéric Giroire, Joanna Moulierac.

Project acronym: NF

Project title: Networks of the Future

Duration: 2023 - 2030

Coordinators: Dmitri Kténas *(CEA)*, Serge Verdeyme *(CNRS)*, Daniel Koffman *(IMT)*

Inria participants: Inria project-teams AGORA, AIO, COATI, DIANA, DYOGENE, ERMINE, FUN, MARACAS, NEO, RESIST, TRIBE

Summary of PEPR NF: 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 (ITM) 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.
Inria is involved into 8 research projects over the 10 supported by the program, with the participation of 11 project-teams of the theme "Networks and Telecommunications" and the coordination of the PC9-Founds.
COATI is involed in PC1 NF-MUST (End-to-end multi domain services management), coordinated by Djamal Zeghlache (IMT), which involves Inria project-teams COATI, DIANA and ERMINE.

PEPR Cloud, 2023-2030

Participants: Davide Ferré, Frédéric Giroire, Joanna Moulierac.

Project acronym: Cloud

Project title: Développement de technologies avancées de cloud

Duration: 2023 - 2030

Coordinators: CEA, INRIA

Inria participants: AVALON, COATI, SPIRALS

Summary: *PC CARECLoud - Understanding, improving, reducing the environmental impacts of Cloud Computing.*

Cloud computing offers users considerable computing and storage capacity. The maturity of virtualization techniques has enabled the emergence of complex virtualized infrastructures, capable of rapidly deploying and reconfiguring virtual and elastic resources, in increasingly distributed infrastructures. This transparent resource management gives users the illusion of access to flexible, unlimited and virtually immaterial resources. However, the power consumption of these clouds is very real and a cause for concern, as are their overall greenhouse gas (GHG) emissions and the consumption of critical raw materials used in their manufacture.

At a time when climate change is a growing concern, with serious consequences for people and the planet worldwide, all sectors (transport, construction, agriculture, industry, etc.) must contribute to the effort to reduce GHG emissions. Clouds, despite their ability to optimize processes in other sectors, are no exception to this observation: the increasing slope of their GHG emissions must be reversed, or their potential benefits in other sectors will be wiped out. This is why the CARECloud project aims to drastically reduce the environmental impact of cloud infrastructures.

PEPR MOBIDEC - Mob Sci-Data Factory project, 2023-2030

Participants: David Coudert.

Project acronym: MOBIDEC

Project title: Digitalisation et décarbonation des mobilités

Duration: 2023 - 2030

Coordinators: IFP Energies nouvelles (IFPEN) and Université Gustave Eiffel (UGE)

Participants Mob Sci-Data Factory: INRIA (coordinator), UGE, IFPEN, IGN, CEREMA

Inria participants: AGORA, ASCII, COATI, FUN, TRIBE

Summary: The PEPR Data Technology for Mobility in the Territories (MOBIDEC) is in line with France 2030's objective of developing sober, sovereign and resilient mobility, by placing the collection, analysis and processing of mobility data at the heart of its work. It aims to understand and anticipate the mobility behaviors of goods and people, to facilitate the interpretation and processing of data, and to offer decision-making tools to simulate the impact of public policies in advance, or to assess the relevance of a new transport offer.

COATI is involved in project "Mob Sci-Data Factory", one of the three projects composing the PEPR MOBIDEC. It shares the PEPR's primary goal of contributing to developing more sustainable mobility strategies by providing decision-making support methodology and a digital toolbox fed by appropriately selecting and processing mobility data and by a deeper understanding of the involved transport uses and behaviors in mobility. It aims at clarifying and extracting the elements determining and explaining the characteristics of mobility data, which also raise the following challenging questions: (1) What data and what are their availability, accessibility, quality, and representativeness? (2) Which methods and digital tools are necessary for processing, calibrating, understanding, and enriching data while dealing with missing data and new acquisition ? (3) What are the specifications of the decision-support platform required for standard tools and data research sharing?

Mob Sci-Data Factory will make available in a secure and privacy-compliant cloud-based infrastructure different sources of mobility data together with open-source libraries and methods designed to be unified, modular, and interoperable from conception. Mob Sci-Dat Factory outcomes will facilitate data sovereignty and open-source development interoperability across multiple scientific actors in France, while accelerating research focused on mobility by offering privacy-compliant and secure data accessibility.

BPI SIRCAPASS, 2024-2028

Participants: Christelle Caillouet, David Coudert, Emi Dreckmeyr.

Project acronym: SIRCAPASS

Project title: Monitoring road infrastructure using passive sensors

Duration: 2024 - 2028

Coordinator: SilMach

Inria participants: Inria project-team FUN

Other partners: SilMach, AIA Ingénierie, CEREMA, with the support of Vinci Autoroutes

Summary: This project aims to provide an operational response to the challenges associated with the preventive monitoring of bridges and the planning of their maintenance. SIRCAPASS will propose an innovation that breaks with current practices and concepts, based on the use of energy-free sensors.

10.4.1 GDR Actions

GDR RSD, ongoing (since 2006) Members of COATI are involved in the working group RESCOM (*Réseaux de communications*) of GDR RSD of CNRS (gdr-rsd.cnrs.fr/). In particular, Christelle Caillouet is in the steering committee since July 2022.

We are also involved in the working group "Energy" of GDR RSD (gdr-rsd.fr/gt-energie). In particular, Frédéric Giroire is co-chair of this working group.

GDR IFM, ongoing (since 2006) Members of COATI are involved in the working group "Graphes" (gtgraphes.labri.fr/) and Complexité et algorithmes (CoA) www.irif.fr/gt-coa/ of GDR IM, CNRS. In particular, Nicolas Nisse is member of the scientific committee of the GT Graphes and of the steering committee of the GT CoA.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: Steering Committees

- David Coudert :

  - member of the steering committee of the Symposium on Experimental Algorithms, since September 2022.

- Emanuele Natale :
  - member of the steering committee of the Symposium on Experimental Algorithms, since September 2022.
- Nicolas Nisse :
  - member of the steering committee of the Workshop on GRAph Searching, Theory and Applications (GRASTA), since 2014.

11.1.2 Scientific events: organization

Member of the organizing committees

- André Nusser
  - Workshop Massive Data Models and Computational Geometry II, University of Bonn, Bonn, Germany, September 22—26, 2025

11.1.3 Scientific events: selection

Chair of conference program committees

- Emanuele Natale :
  - UAI25: Area Chair for the 41st Conference on Uncertainty in Artificial Intelligence, Rio de Janeiro, Brazil, 21-25 July, 2025.
- Christelle Caillouet :
  - Co-Chair of International Workshop on Networked Robotics and Communication Systems IEEE NetRobiCS 2025 in conjunction with IEEE Infocom 2025, May 19, 2025, London, UK.

Member of the conference program committees

- Emanuele Natale :
  - AAAI: Program Committee member of the 39th Annual AAAI Conference on Artificial Intelligence, Philadelphia, Pennsylvania, USA, February 25 – March 4, 2025;
- Christelle Caillouet :
  - Slices-FR School, July 7-11, 2025, ENS Lyon;
  - WIMOB: 21st International Conference on Wireless and Mobile Computing, Networking and Communications, October 20-22, 2025, Marrakech Morocco;
  - ITC36: International Teletraffic Congress, June 2-5, 2025, Trondheim Norway;
  - ISCC: 30th IEEE Symposium on Computers and Communications, July 2-5, 2025, Bologna Italy;
  - ICCCN: 34th International Conference on Computer Communications and Networks, August 4-7, 2025, Tokyo Japan.
- David Coudert :
  - ACDA: SIAM Conference on Applied and Computational Discrete Algorithms, Montréal, Québec, Canada, July 30–August 1, 2025;
  - ATMOS: Symposium on Algorithmic Approaches for Transportation Modelling, Optimization, and Systems, Warsaw, Poland on September 18-19, 2025;

  - ONDM: Conference on Optical Network Design and Management, Pisa, Italy, May 6-9, 2025.

- Frédéric Havet

  - LAGOS: XIII Latin American Algorithms, Graphs, and Optimization Symposium, Buenos Aires, Argentina, 10–14 November, 2025.

- Nicolas Nisse

  - AlgoTel: 27ème Rencontre Francophone sur les Aspects Algorithmiques des Télécommunications, Saint Valery-sur-Somme (France), June 2-6, 2025;
  - LAGOS: XIII Latin American Algorithms, Graphs, and Optimization Symposium, Buenos Aires, Argentina, 10–14 November, 2025;
  - COCOON: 31st International Computing and Combinatorics Conference, Chengdu, China, August 15-17, 2025.

- Joanna Moulierac

  - AlgoTel: 27ème Rencontre Francophone sur les Aspects Algorithmiques des Télécommunications, Saint Valery-sur-Somme (France), June 2-6, 2025;

- André Nusser

  - SEA: 23rd Symposium on Experimental Algorithms, Venice, Italy, July 22–24, 2025;
  - WADS: 19th Algorithms and Data Structures Symposium, York University, Toronto, Canada, August 11–13, 2025;
  - CCCG: 37th Canadian Conference on Computational Geometry, York University, Toronto, Canada, August 11–15, 2025.

Reviewer

- Emanuele Natale :

  - ICML: Conference Reviewer for the Forty-Second International Conference on Machine Learning, Vancouver, Canada, July 13-19, 2025;
  - NeurIPS: Conference Reviewer for the Thirty-Ninth Annual Conference on Neural Information Processing Systems, San Diego, Dec 2 - 7, 2025.

11.1.4 Journal

Member of the editorial boards

- Jean-Claude Bermond :

  - Computer Science Reviews (Elsevier);
  - Discrete Applied Mathematics (Elsevier);
  - Discrete Mathematics (Elsevier);
  - Discrete Mathematics, Algorithms and Applications (World Scientific);
  - Journal of Graph Theory (Wiley);
  - Advisory board of Journal of Interconnection Networks (World Scientific);
  - Networks (Wiley);
  - Parallel Processing Letters (World Scientific);
  - the SIAM book series on Discrete Mathematics (SIAM).

- Christelle Caillouet :

  - Computer Communications.

- Alexandre Caminada :
  - IEEE Transactions on Mobile Computing (IEEE);
  - IEEE Transactions on Vehicular Technology (IEEE);
  - Journal of Traffic and Transportation Engineering (Elsevier);
  - Soft Computing (Springer).
- David Coudert :
  - Discrete Applied Mathematics (Elsevier);
  - Networks (Wiley).
- Frédéric Giroire :
  - Journal of Interconnection Networks (World Scientific).
- Frédéric Havet :
  - Discrete Mathematics and Theoretical Computer Science (DMTCS);
  - Innovations in Graph Theory.
- Emanuele Natale :
  - The WikiJournal of Science (Wikimedia Foundation).
- Nicolas Nisse :
  - Discrete Applied Mathematics (Elsevier).

11.1.5 Invited talks

- David Coudert: *How to compute the hyperbolicity of large graphs*, seminar of the OBELIX team, Vannes, France, July 10, 2025;
- Nicolas Nisse: *Tree and Path decompositions with small diameter bags in subclasses of planar graphs*, online seminar of the GT Graphes of the GDR IFM, April 17, 2025;
- Clément Rambaud: *Excluding a rectangular grid.* Oberwolfach Graph Theory Meeting, Oberwolfach, Germany, January 5-10, 2025;
- Clément Rambaud: *Excluding a rectangular grid.* Jagiellonian University TCS seminar, Kraków, Poland, April 9, 2025;
- Clément Rambaud: *Centered colorings in minor-closed graph classes.* Bertinoro Workshop on Algorithms and Graphs, Bertinoro, Italy, October 26-31, 2025;
- Clément Rambaud: *Excluding a rectangular grid.* AlGCo team seminar, Université de Montpellier, Montpellier, France, November 4, 2025.

11.1.6 Leadership within the scientific community

- Christelle Caillouet :
  - Member of the steering committee of the GDR RSD since July 2022;
  - Member of the mentorship actions committee of the GDR RSD.
- David Coudert :
  - Member of the steering committee of seminar Forum Numerica of Academy 1 RISE of UCA^JEDI since 2018.
- Frédéric Giroire :
  - Member of the steering committee of *GT Energy of the GDR RSD of CNRS*.
- Frédéric Havet :
  - Member of the Ramon Lull PhD prize committee (Spain).
- Joanna Moulierac :
  - Elected member of the "Conseil d'administration" of SPECIF CAMPUS (Société Professionnelle des Enseignants et Chercheurs en Informatique de France) since 2021.
- Nicolas Nisse :
  - Member of the steering committee of *GT CoA of the GDR IFM of CNRS* since 2018;
  - Member of the steering committee of *GT Graphes of the GDR IFM of CNRS* since 2025;
  - Co-president of the committee for the Ph.D. Prix "Charles Delorme" (GDR IFM, GT Graphe).

11.1.7 Scientific expertise

- Christelle Caillouet :
  - Member of the HCERES evaluation committee of the IRIT laboratory, CNRS/Université Toulouse/Toulouse INP, December 1-4, 2025.
- David Coudert :
  - Member of the HCERES evaluation committee of the LIMOS laboratory, Université Clermont Auvergne, October 13-15, 2025;
  - Member of the Inria selection committee for "Actions Exploratoires" (AEx), 2025.
- Frédéric Havet :
  - Expert for Le Fonds de la Recherche Scientifique (FNRS), Belgium.

11.1.8 Research administration

- Christelle Caillouet :
  - Elected member of Conseil de Laboratoire I3S since 2017;
  - Deputy Director of the Academy "Networks, Information, and Digital Society" funded by the Initiative of Excellence (IdEx) of Université Côte d'Azur since March 2025;
  - Member of the Comité de pilotage (CoPil) of EUR DS4H since March 2025.
- Alexandre Caminada :
  - Member of the executive board of the Sophia Interdisciplinary Institute of Artificial Intelligence started in 2019;

- Manager of the research committee for the Polytech network national academic Foundation.

- David Coudert :
  - Head of Science of the Inria Centre at Université Côte d'Azur, since September 2022;
  - Member of the "Bureau du comité des équipe-projets" of the Inria Centre at Université Côte d'Azur since 2018, head since September 2022;
  - Member of the Inria Evaluation Committee, since September 2022;
  - Member of the Inria committee for researchers promotions (CRHC, CRHC-8, DR1, DRCE, DRCE-2), 2025;
  - Member of the Inria selection committee for Senior Researchers (DR2), 2025;
  - Member of the Inria admission committee for CRCN, 2025;
  - Member of the selection committee 27 PR 27PR0957, Université de Montpellier, 2025.
- Frédéric Giroire :
  - Head of COMRED team of I3S laboratory, since April 2022;
  - In charge of the internships of stream UbiNet of Master 2 IFI, Université Côte d'Azur;
  - Chair at the 3IA Côte d'Azur Institute (3ia.univ-cotedazur.eu/) since 2025.
- Frédéric Havet :
  - Co-head of Terra Numerica.
- Joanna Moulierac:
  - Member of the I3S CO2 group since 2019 (www.i3s.unice.fr/co2/);
  - Member of the selection committee 27 MCF 25088627, Université de Nice, 2025;
  - Member of the CSPT Terra Numerica, since 2022.
- Emanuele Natale:
  - Head of the INRIA associated team ELECTRON with King's College London (team.inria.fr/electron/);
  - External member of University of Rome Tor Vergata's PhD School in Data Science (Italy);
  - Member of the Neuromod Institute of Université Côte d'Azur since 2024;
  - Chair at the 3IA Côte d'Azur Institute (3ia.univ-cotedazur.eu/) since 2024;
  - Member of the Lamarr Institute for Machine Learning and Artificial Intelligence in Bonn, Germany (lamarr-institute.org/) since October 2025.
- Nicolas Nisse :
  - Elected member for Inria at the CoSP of EUR DS4H since October 2020;
  - Nominated member for Inria at the board of doctoral school STIC, since September 2022;
  - Member of the "Comité de Suivi Doctoral" of Inria, since September 2022;
  - Member of the CSPT Terra Numerica, since 2020.
- Luc Hogie :
  - Elected member of Conseil de Laboratoire I3S.

11.2 Teaching - Supervision - Juries - Educational and pedagogical outreach

11.2.1 Teaching responsibilities

- Julien Bensmail :
  - In charge of the whole course schedules of Département QLIO of IUT Nice Côte d'Azur.
- Christelle Caillouet :
  - Member of the "Conseil de Département Informatique" of IUT Nice Côte d'Azur (since September 2022);
  - "Directrice d'études" for the 1st-year students "en alternance" of "Département Informatique" of IUT Nice Côte d'Azur (since September 2024);
  - Head of the BUT Informatique en alternance since September 2025.
- Alexandre Caminada :
  - Head of the graduate school of engineering Polytech Nice Sophia (1500 master grade students, 100 faculty members, 50 staffs);
  - Member of the executive board of the Polytech network, national network of public graduate school of engineering;
  - Member of the executive board of Université Côte d'Azur.
- Joanna Moulierac :
  - Member of the "Conseil de Département Informatique" of IUT Nice Côte d'Azur (since September 2017);
  - Co-Head of the "Département Informatique" of IUT Nice Côte d'Azur (since March 2025).
- Michel Syska :
  - Head of the MIAGE (IT methods applied to business management) Master's degree MBDS (Mobiquity, Big Data and Systems integration), of Université Côte d'Azur (since September 2022);
  - Head of the Bachelor's degree in Artificial Intelligence (Licence Sciences et Technologies parcours IA), of Université Côte d'Azur;
  - Head of "Campus des Métiers et des Qualifications - Numérique", Université Côte d'Azur, Rectorat et Région PACA. See Section 11.3.1 for more details.

11.2.2 Teaching

Members of COATI have taught for more that **750** hours (ETD) this year:

- Master and PhD: Emanuele Natale, *Elements of Computational Modeling in Julia*, 24h, Computer Science Department, University of Rome Tor Vergata, Rome, Italy.
- PeiP: Carlo Castoldi, *Informatique générale*, 12h ETD, Level L1 (prépa), CESI engineering school, Nice, France.
- PeiP: Clément Rambaud, *Environnement Informatique*, 24h ETD, Level L1 (prépa), Polytech'Nice.
- PeiP: Clément Rambaud, *Programmation impérative*, 24h ETD, Level L1 (prépa), Polytech'Nice.
- BUT: Julien Bensmail, *Bases de données*, 90h ETD, Level L2, Département QLIO of IUT Nice Côte d'Azur.
- BUT: Julien Bensmail, *Algorithmique et programmation avancées*, 64h ETD, Level L2, Département QLIO of IUT Nice Côte d'Azur.

- BUT: Julien Bensmail, *Amélioration des systèmes d'information*, 40h ETD, Level L3, Département QLIO of IUT Nice Côte d'Azur.
- BUT: Julien Bensmail, *Recherche Opérationnelle pour les systèmes de production*, 40h ETD, Level L3, Département QLIO of IUT Nice Côte d'Azur.
- BUT: Julien Bensmail, *Modélisation des systèmes d'information*, 40h ETD, Level L3, Département QLIO of IUT Nice Côte d'Azur.
- BUT: Julien Bensmail, *Fondamentaux de la Recherche Opérationnelle*, 40h ETD, Level L3, Département QLIO of IUT Nice Côte d'Azur.
- BUT: Christelle Caillouet, *Développement orienté objet*, 48h ETD, Level L1, IUT, Université Côte d'Azur.
- BUT: Christelle Caillouet, *Qualité algorithmique*, 21h ETD, Level L3, IUT, Université Côte d'Azur.
- BUT: Luc Hogie, *System programming*, 24h ETD, Level L2, IUT, Université Côte d'Azur.
- BUT: Joanna Moulierac, *Réseaux avancés*, 30h ETD, Level L2, IUT, Université Côte d'Azur.
- BUT: Joanna Moulierac, *Introduction aux Réseaux avancés*, 60h ETD, Level L1, IUT, Université Côte d'Azur.
- Licence: Michel Syska, *Algorithmics*, 33h ETD, Level L3, parcours IA Science & Technologie - Université Côte d'Azur.
- Licence: Michel Syska, *Introduction to big data*, 30h ETD, Level L3, parcours IA Science & Technologie - Université Côte d'Azur.
- Licence: Michel Syska, *Database systems*, 25h ETD, Level L3, MIAGE - Université Côte d'Azur.
- Licence: Michel Syska, *Heuristic search*, 21h ETD, Level L3, parcours IA Science & Technologie - Université Côte d'Azur.
- Licence: Pierre Pereira, *Base de l'IA*, 26h ETD, Level L3, parcours IA Science & Technologie - Université Côte d'Azur.
- Licence: Pierre Pereira, *Apprentissage*, 40h ETD, Level L3, parcours IA Science & Technologie - Université Côte d'Azur.
- Licence: Chuan Xu, *Python pour l'IA*, 30h ETD, Level L3, - Université Côte d'Azur.
- Master: Christelle Caillouet, *Introduction Algorithmic and Programming*, 60h ETD, MAM3, Polytech Nice Sophia Antipolis.
- Master: Alexandre Caminada, *Radio location systems*, 20h ETD, Master 2 (in english), Polytech Nice Sophia Antipolis.
- Master: Alexandre Caminada, *Artificial intelligence*, 40h ETD, Master 2 (in english), Polytech Nice Sophia.
- Master: Alexandre Caminada, Master grade student's internship supervision and assesment, 10h ETD, Master 2, Polytech Nice Sophia Antipolis.
- Master: Niccolò D'Archivio (course of Chuan Xu), *Distributed-memory parallel programming and its applications*, 5h ETD, M1 Computer Science - Université Côte d'Azur.
- Master: Frédéric Giroire, *Graph Algorithms*, 18h ETD, Master 2, International Track Ubinet, Université Côte d'Azur.
- Master: Frédéric Giroire, *Machine learning for networks*, 34.5 h ETD, Master 2, International Track Ubinet, Université Côte d'Azur.

- Master: Frédéric Giroire, *ICT and Environment, Green algorithm design*, 4.5h ETD, Master 2, Université Côte d'Azur.
- Master: Rémi Godet (course of Chuan Xu), *Federated Learning*, 5h ETD, M2 IF - Université Côte d'Azur.
- Master: Nicolas Nisse, *Graphs*, 36h ETD, M1 Informatique Fondamentale, Université Côte d'Azur.
- Master: Nicolas Nisse, *Graphs*, 15h ETD, M2 Informatique Fondamentale, Université Côte d'Azur.
- Master: Nicolas Nisse, *Algorithms for Telecoms*, 15h ETD, M2 Ubinet, Université Côte d'Azur.
- Master: Clément Rambaud, *Programmation en C++*, Polytech Nice, 16h ETD, 2nd year (M1), Engineer School, Polytech Nice.
- Master: Michel Syska, *Databases for big data*, 34h ETD, M1 MIAGE - Université Côte d'Azur.
- Master: Michel Syska, *Cloud computing*, 38h ETD, M2 MIAGE MBDS - Université Côte d'Azur.
- Master: Michel Syska, *Complex problem and heuristic search*, 27h ETD, M2 MIAGE IA2 - Université Côte d'Azur.
- Master: Chuan Xu, *Distributed-memory parallel programming and its applications*, 24h ETD, M1 Computer Science - Université Côte d'Azur.
- Master: Chuan Xu, *Federated Learning*, 24h ETD, M2 IF - Université Côte d'Azur.

11.2.3 Supervision

PhD thesis

- PhD in progress: Jamil Abou Ltaif, *Energy-efficient QoE-aware Beyond 5G Future Mobile Networks*, since November 2024. Co-supervisors: Chadi Barakat *(DIANA)*, Frédéric Giroire, Joanna Moulierac and Thierry Turletti *(DIANA)*;
- PhD in progress: Yanis Achaichia, *Optimizing the orchestration of virtualized services in a multi-domain environment*, since October 2024. Co-supervisors: Christelle Caillouet, Nicolas Huin *(IMT Atlantique)*, Géraldine Texier *(IMT Atlantique)*;
- PhD in progress: Niccolò D'Archivio, *Bio-inspired algorithms for collective search and decision-making*, since April 2024. Co-supervisors: Emanuele Natale and Frédéric Giroire;
- PhD in progress: Carlo Castoldi, *Unlearning across brains and models: neuro-computational insights*, since November 2025. Supervisors: Emanuele Natale and Bianca Silva *(IPMC, Université Côte d'Azur)*;
- PhD in progress: Francesco Diana, *Privacy Attacks in Federated Learning*, since January 2024. Co-supervisors: Chuan Xu and Giovanni Neglia *(NEO)*;
- PhD in progress: Emi Dreckmeyr, *Data capture and collection by energy-free sensors and ultra-low power transmission in hostile environments*, since January 2025. Co-supervisors: Christelle Caillouet and Nathalie Mitton *(FUN)*;
- PhD in progress: Davide Ferré, *Energy efficient deployment of applications in the edge-network-cloud continuum*, since January 2024. Co-supervisors: Frédéric Giroire and Emanuele Natale;
- PhD in progress: Rémi Godet, *Privacy on-demand and Security preserving Federated Generative Networks or Models*, since April 2025. Co-supervisors: Frédéric Giroire and Chuan Xu;
- PhD in progress: Sayf Eddine Halmi, *Impact of multidisciplinarity on research productivity*, since October 2025. Co-supervisors: Frédéric Giroire and Nicolas Nisse and Michele Pezzoni *(Université Côte d'Azur, Groupe de Recherche en Droit, Economie, Gestion (GREDEG))*;

- PhD in progress: Aakash Kumar, *Phase Transitions in Artificial Neural Networks*, since September 2025. Supervisor: Emanuele Natale;
- PhD in progress: Henrique Lovisi Ennes, *Calcul quantique en topologie*, since October 2023. Co-supervisors: Clément Maria *(DATASHAPE)* and Nicolas Nisse;
- PhD in progress: Samuel Nascimento, *Convexity Games on Graphs*, PhD student in the Postgraduate Program in Computer Science at the Federal University of Ceará (UFC Fortaleza, Brazil) since March 2023, one year in France since November 2024. Supervisor : Rudini Menezes Sampaio *(UFC Fortaleza, Brazil)* and Nicolas Nisse;
- PhD in progress: Pierre Pereira, *Problem Size Generalization in Neural Combinatorial Optimization*, since October 2024. Co-supervisors: Emanuele Natale and Frédéric Giroire;
- PhD in progress: Caroline Aparecida de Paula Silva, *Universality and madericity of digraphs*, University of Campinas, Campinas, São Paulo, Brazil. From September 2024 till August 2025. Supervisor: Frédéric Havet;
- PhD in progress: Adrien Sardi, *Modèles d'intelligence artificielle génératifs et gestion énergétique des ressources au sein des réseaux distribués 6G*, since January 2025. Co-supervisors: Marie-Line Alborel *(Nokia)*, Sara Alouf *(NEO)*, Frédéric Giroire and Joanna Moulierac;
- PhD in progress: Kyrylo Tymchenko, *Enhancing Large-Scale Distributed Caching Systems with Erasure Coding: Performance, Reliability, and Design Trade-offs*, since October 2025. Co-supervisors: Sara Alouf *(NEO)* and Frédéric Giroire;
- PhD: Tiago da Silva Barros, *Optimizing Performance and Energy Consumption for Machine Learning Inference* [64], Defended: November 3 2025. Co-supervisors: Ramon Aparicio Pardo *(I3S, Université Côte d'Azur)* and Frédéric Giroire;
- PhD: Clément Rambaud, *Structures of graph classes and of their excluded minors* [65], Defended: December 3 2025. Supervisor: Frédéric Havet;
- PhD: Aurora Rossi, *Computational methods and analysis of temporal networks : applications in neurosciences* [66], Defended: September 25 2025. Supervisor: David Coudert;

Internships

- Google Summer of Code: Janmenjaya Panda, *addition of the class of matching covered graphs in Sagemath*, IIT Madras, India, from May till November 2025. Mentor: David Coudert.
- Google Summer of Code: Yuta Inoue, *implementation of faster algorithms for the enumeration of (weighted) (directed) paths and cycles in Sagemath*, University of Tokyo, Japan, from May till November 2025. Mentor: David Coudert.
- Licence 3: Pablo Bernard, *réalisation d'une application d'un jeu de labyrinthe*, Université Côte d'Azur, from June until July 2025. Supervisor: Nicolas Nisse
- Licence 3: Eloi Rathgeber Kivits, *Pushability of oriented graphs*, Université Côte d'Azur, from June until August 2025. Supervisor: Frédéric Havet
- Master 2: Sayf Eddine Halmi, *étude de la recherche multidisciplinaire entre domaines et au cours du temps*, Université Côte d'Azur, from April until August 2025. Supervisors: Frédéric Giroire and Nicolas Nisse
- Master 2: Skander Meziou, *estimation de la proximité thématique des chercheurs*, Université Côte d'Azur, from April until August 2025. Supervisors: Frédéric Giroire and Nicolas Nisse
- Master 2: Matteo Stromieri, *Mathematical Approaches to Comparative Evolutionary Neuroscience*, Université Côte d'Azur, from April until September 2025. Supervisor: Emanuele Natale

- Master 2: Davide Toniatti, *An Empirical Evaluation of Expand-and-Sparsify Classifiers*, Université Côte d'Azur, from March until August 2025. Supervisor: Emanuele Natale
- Master 2: Kyrylo Tymchenko, *Study of large distributed systems*, Université Côte d'Azur, from March until August 2025. Supervisor: Frédéric Giroire, Stéphane Pérennes, and Sara Alouf *(NEO)*.
- Relai-thèse (followed by PhD): Rémi Godet, *Privacy on-demand and Security preserving Federated Generative Networks or Models*, August 2024 till March 2025. Co-supervisors: Chuan Xu, Frédéric Giroire and Marco Lorenzi *(EPIONE)*.

Apprentices (for Terra Numerica)

- Vincent Chayé *(BUT Informatique, Université Côte d'Azur)*, since September 2023. Supervisor: Frédéric Havet.
- Hamadi Daghar *(Master 2 Informatique, Université Côte d'Azur)*, since September 2024. Supervisor: Nicolas Nisse.
- Mael Rivière *(Master 2 MIAGE, Université Côte d'Azur)*, since September 2024. Supervisor: Joanna Moulierac.

11.2.4 Juries

- Julien Bensmail:
  - Member of the PhD committee of Clara Marcille, Université de Bordeaux, June 24, 2025;
  - Member of the annual "Comité de suivi individuel" (CSI) of Abdallah Skender, Université de Bourgogne, July 2, 2025.
- Christelle Caillouet :
  - Referee and member of PhD committee of Stanislas Pedebearn, Univ. de Toulouse, March 2025;
  - Referee and member of PhD committee of Zahraa El Attar, IMT Atlantique, April 2025.
- David Coudert :
  - Member of the annual "Comité de suivi individuel" (CSI) of Berend Baas *(GRAPHDECO)*, June 20, 2025;
  - Member of the annual "Comité de suivi individuel" (CSI) of Sebastian Gallardo Diaz *(BIOVISION)*, June 24, 2025.
- Frédéric Giroire :
  - Referee and member of the PdD committee of Oualid Zari, Sorbonne Université and Eurecom, January 14, 2025;
  - External Member of the Commission de qualification pour promotion et changement d'appellation de Telecom Paris, October 13, 2025.
- Frédéric Havet :
  - President of the PdD committee of Laure Morelle, Université de Montpellier, September 23, 2025;
  - Member of the annual "Comité de suivi individuel" (CSI) of Quentin Vermande *(STAMP)*, June 18, 2025;
- Joanna Moulierac :
  - Member of PhD committee of David Baldassin, Université Côte d'Azur, December 2025;
  - Member of the annual "Comité de suivi individuel" (CSI) of Yu Li, Université Côte d'Azur, June 13, 2025;
  - Member of the annual "Comité de suivi individuel" (CSI) of Yassir Amami, Université Côte d'Azur, June 16, 2025.

11.3 Popularization

11.3.1 Specific official responsibilities in science outreach structures

- Frédéric Havet is co-head of Terra Numerica and one of the responsible of the "Comité Scientifique, Pédagogique et Technique"; Nicolas Nisse is a member of this committee; Joanna Moulierac is the referent of Terra Numerica for higher education; Luc Hogie is in charge of hardware and software development.
- Frédéric Havet is member of the editorial board of *1024, le bulletin de la SIF (Société Informatique de France*, in which he draws cartoons to illustrate some articles.
- Michel Syska is Head of "Campus des Métiers et des Qualifications (CMQ)- Numérique" (Université Côte d'Azur, Rectorat et Région PACA). The CMQ brings together educational institutions to address national and regional economic needs in partnership with local authorities and businesses. In the PACA region, several studies reveal significant tension in digital professions. To address this gap, the PACA Digital CMQ aims to: 1) Make digital training programs more attractive, 2) Support the evolution of profession by offering comprehensive training opportunities across all qualification levels.

11.3.2 Production (articles, videos, podcasts, serious games, ...)

- Press articles related to Terra Numerica can be found at terra-numerica.org/presse/. Members of COATI have contributed to several of them.
- Frédéric Giroire: Interview for the press article of Jila Varoquier *(Le Parisien)*, *Du réveil au coucher, comment les algorithmes ont pris le pouvoir sur nos journées*, Le Parisien, Mars 2, 2025.
- Frédéric Giroire, Joanna Moulierac, Tiago da Silva Barros, Ramon Aparicio Pardo *(SigNet, I3S)*: Article in the New Scientist, a popular science magazine covering all aspects of science and technology, on our new study on how to reduce AI energy consumption worldwide through model selection.
- Frédéric Havet : Interview for the press article of Elena Mas *(Var Matin & Nice Matin)*, *l'IA n'est pas magique*, Var Matin & Nice Matin, October 13, 2025.
- Frédéric Havet : Monthly radio program *Un p'tit quart d'heure de science* on Radio Verdon.

11.3.3 Education

Most of the members of COATI are involved in Terra Numerica. During the year 2025, more than 300 events held, Terra Numerica has been visited by 410 classes (about 8000 primary school/college/highschool students, for 2 hours in average). We have trained about 360 persons (including 250 teachers) and touched more than 36 000 people during events such as Fête de la science, etc.

11.3.4 Participation in Live events

Many members of COATI (Michel Cosnard, Frédéric Giroire, Frédéric Havet, Joanna Moulierac, Nicolas Nisse, Clément Rambaud, Michel Syska) participated in some general audience science fairs, such as the Fête de la Science in October 2025 (we were present on the "Village des Sciences" in Antibes-Juan-les-Pins, Valbonne, Villeneuve-Loubet, Vinon-sur Verdon). They also occasionally act as scientific facilitator at Terra Numerica.

Frédéric Havet also gave general audience conferences in several cities (Bonson, Brignoles, Draguignan, Falicon, Puget-Theniers, Rians, Vinon-sur-Verdon) as well as in for Esope 21, Science pour Tous 06, and Terra Numerica.

12 Scientific production

12.1 Major publications

[1] L. Becchetti, A. Clementi, E. Natale, F. Pasquale and L. Trevisan. 'Find Your Place: Simple Distributed Algorithms for Community Detection'. In: *SIAM Journal on Computing* 49.4 (Jan. 2020), pp. 821–864. DOI: 10.1137/19M1243026. URL: https://hal.science/hal-03025943.

[2] L. Becchetti, A. Clementi, E. Natale, F. Pasquale and L. Trevisan. 'Finding a Bounded-Degree Expander Inside a Dense One'. In: *Proceedings of the thirty-first Annual ACM-SIAM Symposium on Discrete Algorithms (SODA)*. Salt Lake City, United States, Jan. 2020. URL: https://hal.archives-ouvertes.fr/hal-02002377.

[3] J. Bensmail, V. Campos, A. K. Maia, N. Nisse and A. Silva. 'Deciding the Erdős-Pósa property in 3-connected digraphs ⋆'. In: WG 2023 - 49th International Workshop on Graph-Theoretic Concepts in Computer Science. LNCS. Fribourg (CH), Switzerland, 28th June 2023. URL: https://inria.hal.science/hal-04084227.

[4] J. Bensmail, A. Harutyunyan, T.-N. Le and S. Thomassé. 'Edge-partitioning a graph into paths: beyond the Barát-Thomassen conjecture'. In: *Combinatorica* 39.2 (Apr. 2019), pp. 239–263. DOI: 10.1007/s00493-017-3661-5. URL: https://hal.archives-ouvertes.fr/hal-01744515.

[5] J.-C. Bermond, F. Giroire and N. Nisse. 'Graphes et Télécommunications'. In: *Bibliothèque Tangente*. Hors Serie 75 La recherche opérationnelle Hors Serie 75 (2021), pp. 120–125. URL: https://hal.archives-ouvertes.fr/hal-03455881.

[6] N. Bousquet, F. Havet, N. Nisse, L. Picasarri-Arrieta and A. Reinald. 'Digraph redicolouring'. In: *European Journal of Combinatorics* 116 (Feb. 2024), p. 103876. DOI: 10.1016/j.ejc.2023.103876. URL: https://hal.science/hal-04306893.

[7] C. Caillouet, F. Giroire and T. Razafindralambo. 'Efficient Data Collection and Tracking with Flying Drones'. In: *Ad Hoc Networks*. Ad Hoc Networks 89.C (2019), pp. 35–46. DOI: 10.1016/j.adhoc.2019.01.011. URL: https://hal.inria.fr/hal-02043136.

[8] N. Cohen, F. Havet, W. Lochet and N. Nisse. 'Subdivisions of oriented cycles in digraphs with large chromatic number'. In: *Journal of Graph Theory* 89.4 (Apr. 2018), pp. 439–456. DOI: 10.1002/jgt.22360. URL: https://hal.archives-ouvertes.fr/hal-01834779.

[9] D. Coudert, G. Ducoffe and N. Nisse. 'To Approximate Treewidth, Use Treelength!' In: *SIAM Journal on Discrete Mathematics* 30.3 (2016), p. 13. DOI: 10.1137/15M1034039. URL: https://hal.inria.fr/hal-01348965.

[10] D. Coudert, G. Ducoffe and A. Popa. 'P-FPT algorithms for bounded clique-width graphs'. In: *ACM Transactions on Algorithms* 15.3 (June 2019), pp. 1–57. DOI: 10.1145/3310228. URL: https://hal.archives-ouvertes.fr/hal-02152971.

[11] A. da Cunha, E. Natale and L. Viennot. 'Proving the Strong Lottery Ticket Hypothesis for Convolutional Neural Networks'. In: ICLR 2022 - 10th International Conference on Learning Representations. Virtual, France, 25th Apr. 2022. URL: https://hal.archives-ouvertes.fr/hal-03548226.

[12] F. Dross and F. Havet. 'On the unavoidability of oriented trees'. In: *Journal of Combinatorial Theory, Series B* 151 (Nov. 2021), pp. 83–110. DOI: 10.1016/j.jctb.2021.06.003. URL: https://hal.inria.fr/hal-03269226.

[13] F. Giroire, F. Havet and J. Moulierac. 'On the Complexity of Compressing Two Dimensional Routing Tables with Order'. In: *Algorithmica* 80.1 (Jan. 2018), pp. 209–233. DOI: 10.1007/s00453-016-0243-7. URL: https://hal.inria.fr/hal-01686641.

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