IN PARTNERSHIP WITH:
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Activity Report 2017

Project-Team COATI

Combinatorics, Optimization and Algorithms for Telecommunications

IN COLLABORATION WITH: Laboratoire informatique, signaux systèmes de Sophia Antipolis (I3S)

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Networks and Telecommunications

Table of contents

Project-Team COATI

Creation of the Team: 2013 January 01, updated into Project-Team: 2013 January 01

Keywords:

Computer Science and Digital Science:

- A1.2.1. - Dynamic reconfiguration
- A1.2.3. - Routing
- A1.2.9. - Social Networks
- 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

Other Research Topics and Application Domains:

- B1.1.1. - Structural biology
- B6.3.3. - Network Management
- B6.3.4. - Social Networks
- B7.2. - Smart travel

1. Personnel

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2. Overall Objectives

2.1. Overall Objectives

COATI is a joint team between Inria Sophia Antipolis - Méditerranée and the I3S laboratory (Informatique Signaux et Systèmes de Sophia Antipolis) which itself belongs to CNRS (Centre National de la Recherche Scientifique) and UNS (Univ. Nice Sophia Antipolis). Its research fields are Algorithmics, Discrete Mathematics, and Combinatorial Optimization, with applications mainly in telecommunication networks.

The main objectives of the COATI project-team are to design networks and communication algorithms. In order to meet these objectives, the team studies various theoretical problems in Discrete Mathematics, Graph Theory, Algorithmics, and Operations Research and develops applied techniques and tools, especially for Combinatorial Optimization and Computer Simulation. In particular, COATI used in the last years both these theoretical and applied tools for the design of various networks, such as SDN (software defined networks), WDM, wireless (radio), satellite, and peer-to-peer networks. This research has been done within various industrial and international collaborations.

COATI also investigates other application areas such as bio-informatics and transportation networks.

The research done in COATI results in the production of advanced software such as GRPH, and in the contribution to large open source software such as Sagemath.

3. Research Program

3.1. Research Program

Members of COATI have a strong expertise in the design and management of wired and wireless backbone, backhaul, broadband, software defined and complex networks. On the one hand, we cope with specific problems such as energy efficiency in backhaul and backbone networks, routing reconfiguration in connection oriented networks (MPLS, WDM), traffic aggregation in SONET networks, compact routing in large-scale networks, survivability to single and multiple failures, etc. These specific problems often come from questions of our industrial partners. On the other hand, we study fundamental problems mainly related to routing and reliability that appear in many networks (not restricted to our main fields of applications) and that have been widely studied in the past. However, previous solutions do not take into account the constraints of current networks/traffic such as their huge size and their dynamics. COATI thus puts a significant research effort in the following directions:

- **Energy efficiency and Software-Defined Networks (SDN)** at both the design and management levels. We study the deployment of energy-efficient routing algorithm within SDN. We developed new algorithms in order to take into account the new constraints of SDN equipments and we evaluate their performance by simulation and by experimentation on a fat-tree architecture.
- **Larger networks:** Another challenge one has to face is the increase in size of practical instances. It is already difficult, if not impossible, to solve practical instances optimally using existing tools. Therefore, we have to find new ways to solve problems using reduction and decomposition methods, characterization of polynomial instances (which are surprisingly often the practical ones), or algorithms with acceptable practical performances.
- **Stochastic behaviors:** Larger topologies mean frequent changes due to traffic and radio fluctuations, failures, maintenance operations, growth, routing policy changes, etc. We aim at including these stochastic behaviors in our combinatorial optimization process to handle the dynamics of the system and to obtain robust designs of networks.

The methods and tools used in our studies come from discrete mathematics and combinatorial optimization, and COATI contributes to their improvements. Also, COATI works on graph-decomposition methods and various games on graphs which are essential for a better understanding of the structural and combinatorial properties of the problems, but also for the design of efficient exact or approximate algorithms. We contribute to the modelling of optimization problems in terms of graphs, study the complexity of the problems, and then we investigate the structural properties of graphs that make these problems hard or easy. We exploit these properties in the design of algorithms in order to find the most efficient ways for solving the problems.

COATI also focuses on the theory of *directed graphs*. Indeed, graph theory can be roughly partitioned into two branches: the areas of undirected graphs and directed graphs. Even though both areas have numerous important applications, for various reasons, undirected graphs have been studied much more extensively than directed graphs. It is worth noticing that many telecommunication problems are modelled with directed graphs. Therefore, a deeper understanding of the theory of directed graphs will benefit to the resolution of telecommunication networks problems. For instance, the problem of finding disjoint paths becomes much more difficult in directed graphs and understanding the underlying structures of actual directed networks would help us to propose solutions.

4. Application Domains

4.1. Telecommunication Networks

COATI is mostly interested in telecommunications 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). We also study routing algorithms such as dynamic and compact routing schemes, as we did in the context of the FP7 EULER led by Alcatel-Lucent Bell-Labs (Belgium), and the evolution of the routing in case of any kind of topological modifications (maintenance operations, failures, capacity variations, etc.). However, the fields of Software Defined Networks and Network Function Virtualization are growing in importance in our studies.

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 intend to collaborate with experts of these other domains.

For instance, we collaborate with EP ABS (Algorithms Biology Structure) from Sophia Antipolis on problems from Structural Biology (see Section 7.2.1.5). In the area of transportation networks, we have started a collaboration with SME Instant-System on dynamic car-pooling combined with multi-modal transportation systems. This collaboration will be strengthen in the near future with the support of an ANR project (starting January 2018).

5. Highlights of the Year

5.1. Highlights of the Year

5.1.1. Awards

David Coudert and Nathann Cohen (LRI) won the Flinders Hamiltonian Cycle Problem (FHCP) Challenge 2016 (http://fhcp.edu.au/fhcpcs).

Guillaume Ducoffe, former PhD student of COATI, is the recipient of an accessit to the PhD prize Graphes “Charles Delorme” 2017 for his PhD thesis entitled “Metric properties of large graphs”.

Frédéric Giroire and Joanna Moulierac are recipients of the Wilkes Award 2017 for the paper "Energy Efficient Content Distribution" [1] (The Wilkes Award is given once a year to the authors of the best paper published in the volume of *The Computer Journal* from the previous year).

6. New Software and Platforms

6.1. BigGraphs

KEYWORDS: Graph algorithmics - Distributed computing - Java - Graph processing
FUNCTIONAL DESCRIPTION: The objective of BigGraphs is to provide a distributed platform for very large graphs processing. A typical data set for testing purpose is a sample of the Twitter graph : 240GB on disk, 398M vertices, 23G edges, average degree of 58 and max degree of 24635412.

We started the project in 2014 with the evaluation of existing middlewares (GraphX / Spark and Giraph / Hadoop). After having tested some useful algorithms (written according to the BSP model) we decided to develop our own platform.

This platform is based on the existing BIGGRPH library and we are now in the phasis where we focus on the quality and the improvement of the code. In particular we have designed strong test suites and some non trivial bugs have been fixed. We also have solved problems of scalability, in particular concerning the communication layer with billions of messages exchanged between BSP steps. We also have implemented specific data structures for BSP and support for distributed debugging. This comes along with the implementation of algorithms such as BFS or strongly connected components that are run on the NEF cluster.

In 2017 we have developed a multi-threaded shared-memory parallel version of the Bulk Synchronous Parallel framework. This new version uses advanced synchronization mechanisms and strategies to minimize the congestion of multiple threads working on the same graph. Using the NEF cluster (Inria Sophia Antipolis), this parallel version exhibits speed-ups up to 6.5 using 8 nodes (16 cores each) when computing a BFS on the 23 G edges Twitter graph sample.

- Participants: Luc Hogie, Michel Syska and Nicolas Chleq
- Partner: CNRS
- Contact: Luc Hogie

6.2. GRPH

The high performance graph library for Java
KEYWORDS: Graph - Graph algorithmics - Java
FUNCTIONAL DESCRIPTION: Grph is an open-source Java library for the manipulation of graphs. Its design objectives are to make it portable, simple to use/extend, computationally/memory efficient, and, according to its initial motivation: useful in the context of graph experimentation and network simulation. Grph also has the particularity to come with tools like an evolutionary computation engine, a bridge to linear programming solvers, a framework for distributed computing, etc.

Grph offers a very general model of graphs. Unlike other graph libraries which impose the user to first decide if he wants to deal with directed, undirected, hyper (or not) graphs, the model offered by Grph is unified in a general class that supports mixed graphs made of undirected and directed simple and hyper edges. Grph achieves great efficiency through the use of multiple code optimization techniques such as multi-core parallelism, caching, adequate data structures, use of primitive objects, exploitation of low-level processor caches, on-the-fly compilation of specific C/C++ code, etc. Grph attempts to access the Internet in order to check if a new version is available and to report who is using it (login name and hostname). This has no impact whatsoever on performance and security.

- Participants: Aurélien Lancin, David Coudert, Issam Tahiri, Luc Hogie and Nathann Cohen
- Contact: Luc Hogie
- URL: http://www.i3s.unice.fr/~hogie/grph/

6.3. Sage

SageMath
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 an open-source mathematics software initially created by William Stein (Professor of mathematics at Washington University). We contribute the addition of new graph algorithms along with their documentations and the improvement of underlying data structures.

- Contact: David Coudert
- URL: http://www.sagemath.org/

7. New Results

7.1. Network Design and Management

Participants: Christelle Caillouet, David Coudert, Frédéric Giroire, Frédéric Havet, Nicolas Huin, Joanna Moulierac, Nicolas Nisse, Stéphane Pérennes, Andrea Tomassilli.

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.

We mainly focus on four topics: Firstly, we study the new network paradigms, Software-Defined Networks (SDN) and Network Function Virtualization (NFV). On the contrary to legacy networks, in SDN, a centralized controller is in charge of the control plane and takes the routing decisions for the switches and routers based on the network conditions. This new technology brings new constraints and therefore new algorithmic problems such as the problem of limited space in the switches to store the forwarding rules. We then tackle the problem of placement of virtualized resources. We validated our algorithms on a real SDN platform [1]. Secondly, we consider different scenarios regarding wireless networks, in particular, wireless backhaul networks, linear access networks for transportation systems, and connected Unmanned Aerial Vehicules (UAVs). Third, we tackle routing in the Internet. Last, we study live streaming in distributed systems.

7.1.1. Software Defined Networks (SDN)

Software-defined Networks (SDN), in particular OpenFlow, is a new networking paradigm enabling innovation through network programmability. SDN is gaining momentum with the support of major manufacturers. Over past few years, many applications have been built using SDN such as server load balancing, virtual-machine migration, traffic engineering and access control.

7.1.1.1. Minnie: an SDN World with Few Compressed Forwarding Rules

While SDN brings flexibility to the management of flows within the data center fabric, this flexibility comes at the cost of smaller routing table capacities. Indeed, the Ternary Content-Addressable Memory (TCAM) needed by SDN devices has smaller capacities than CAMs used in legacy hardware. Also, we investigate in [37] compression techniques to maximize the utility of SDN switches forwarding tables. We validate our algorithm, called MINNIE, with intensive simulations for well-known data center topologies, to study its efficiency and compression ratio for a large number of forwarding rules. Our results indicate that MINNIE scales well, being able to deal with around a million of different flows with less than 1000 forwarding entries per SDN switch, requiring negligible computation time.

To assess the operational viability of MINNIE in real networks, we deployed a testbed able to emulate a $k = 4$ Fat-Tree data center topology. We demonstrate on the one hand, that even with a small number of clients, the limit in terms of number of rules is reached if no compression is performed, increasing the delay of new incoming flows. MINNIE, on the other hand, reduces drastically the number of rules that need to be stored, with no packet losses, nor detectable extra delays if routing lookups are done in the Application-Specific Integrated Circuits (ASICs).

Hence, both simulations and experimental results suggest that MINNIE can be safely deployed in real networks, providing compression ratios between 70% and 99%.

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[1] Testbed with SDN hardware, in particular a switch HP 5412 with 96 ports, hosted at I3S laboratory. A complete fat-tree architecture with 16 servers can be built on the testbed.

7.1.1.2. *Bringing Energy Aware Routing closer to Reality with SDN Hybrid Networks*

Energy aware routing aims at reducing the energy consumption of ISP networks. The idea is to adapt routing to the traffic load in order to turn off some hardware. However, it implies to make dynamic changes to routing configurations which is almost impossible with legacy protocols. The SDN paradigm bears the promise of allowing a dynamic optimization with its centralized controller.

In [49], [59], we propose SENAtoR, an algorithm to enable energy aware routing in a scenario of progressive migration from legacy to SDN hardware. Since in real life, turning off network equipments is a delicate task as it can lead to packet losses, SENAtoR provides also several features to safely enable energy saving services: tunneling for fast rerouting, smooth node disabling and detection of both traffic spikes and link failures.

We validate our solution by extensive simulations and by experimentation. We show that MINNIE can be progressively deployed in a network using the SDN paradigm. It allows to reduce the energy consumption of ISP networks by 5 to 35% depending on the penetration of SDN hardware, while diminishing the packet loss rate compared to legacy protocols.

7.1.1.3. *Network Function Virtualization (NFV) and Service Function Chains*

Network Function Virtualization (NFV) is a promising network architecture concept to reduce operational costs. In legacy networks, network functions, such as firewall or TCP optimization, are performed by specific hardware. In networks enabling NFV coupled with the Software Defined Network (SDN) paradigm, network functions can be implemented dynamically on generic hardware. The challenge is then to efficiently provision the service chain requests, while finding the best compromise between the bandwidth requirements, the number of locations for hosting Virtual Network Functions (VNFs), and the number of chain occurrences.

In [48], we propose two ILP (Integer Linear Programming) models for routing service chain requests, one of them with a decomposition modeling. We conduct extensive numerical experiments, and show we can solve exactly the routing of service chain requests in a few minutes for networks with up to 50 nodes, and traffic requests between all pairs of nodes. We investigate the best compromise between the bandwidth requirements and the number of VNF nodes.

In [50], we study how to use NFV coupled with SDN to improve the energy efficiency of networks. We consider a setting in which a flow has to go through a Service Function Chain, that is several network functions in a specific order. We propose a decomposition model that relies on lightpath configuration to solve the problem. We show that virtualization allows to obtain between 30% to 55% of energy savings for networks of different sizes.

7.1.2. *Wireless networks*

We study optimization problems on various kinds of wireless networks.

7.1.2.1. *Computing and maximizing the exact reliability of wireless backhaul networks*

The reliability of a fixed wireless backhaul network is the probability that the network can meet all the communication requirements considering the uncertainty (e.g., due to weather) in the maximum capacity of each link. We provide in [45] an algorithm to compute the exact reliability of a backhaul network, given a discrete probability distribution on the possible capacities available at each link. The algorithm computes a conditional probability tree, where at each leaf in the tree a valid routing for the network is evaluated. Any such tree provides bounds on the reliability, and the algorithm improves these bounds by branching in the tree. We also consider the problem of determining the topology and configuration of a backhaul network that maximizes reliability subject to a limited budget. We provide an algorithm that exploits properties of the conditional probability tree used to calculate reliability of a given network design, and we evaluate its computational efficiency.

7.1.2.2. *Analysis of the Failure Tolerance of Linear Access Networks*

In [28], we study the disconnection of a moving vehicle from a linear access network composed by cheap WiFi Access Points in the context of the telecommuting in massive transportation systems. In concrete terms, we analyze the probability for a user to experience a disconnection longer than a given time interval (t^*)

such that all on-going communications between the vehicle and the infrastructure network are disrupted. We provide an approximation formula considering two scenarios (intercity bus and train). We then carry out a sensitivity analysis and supply a guide for operators when choosing the parameters of the networks. Last, we show that such systems are viable, as they attain a very low probability of long disconnections with a very low maintenance cost.

7.1.2.3. Efficient Deployment of Connected Unmanned Aerial Vehicles for Optimal Target Coverage

Anytime and anywhere network access can be provided by Unmanned Aerial Vehicles (UAV) with air-to-ground and air-to-air communications using directional antennas for targets located on the ground. Deploying these Unmanned Aerial Vehicles to cover targets is a complex problem since each target should be covered, while minimizing (i) the deployment cost and (ii) the UAV altitudes to ensure good communication quality. We also consider connectivity between the UAVs and a base station in order to collect and send information to the targets, which is not considered in many similar studies. In [40], we provide an efficient optimal program to solve this problem and show the trade-off analysis due to conflicting objectives. We propose a fair trade-off optimal solution and also evaluate the cost of adding connectivity to the UAV deployment.

7.1.3. Routing in the Internet

7.1.3.1. Routing at Large Scale: Advances and Challenges for Complex Networks

A wide range of social, technological and communication systems can be described as complex networks. Scale-free networks are one of the well-known classes of complex networks in which nodes degree follow a power-law distribution. The design of scalable, adaptive and resilient routing schemes in such networks is very challenging. In [38], we present an overview of required routing functionality, categorize the potential design dimensions of routing protocols among existing routing schemes and analyze experimental results and analytical studies performed so far to identify the main trends/trade-offs and draw main conclusions. Besides traditional schemes such as hierarchical/shortest-path path-vector routing, the article pays attention to advances in compact routing and geometric routing since they are known to significantly improve the scalability in terms of memory space. The identified trade-offs and the outcomes of this overview enable more careful conclusions regarding the (in-)suitability of different routing schemes to large-scale complex networks and provide a guideline for future routing research. This article concludes the European Project FP7 STREP EULER (2010-2014).

7.1.3.2. Grid spanners with low forwarding index for energy efficient networks

A routing R of a connected graph G is a collection that contains simple paths connecting every ordered pair of vertices in G. The *edge-forwarding index with respect to* R (or simply the forwarding index with respect to R) $\pi(G,R)$ of G is the maximum number of paths in R passing through any edge of G. The *forwarding index* $\pi(G)$ of G is the minimum $\pi(G,R)$ over all routings R's of G. This parameter has been studied for different graph classes. Motivated by energy efficiency, we look in [30] for different numbers of edges, at the best spanning graphs of a square grid, namely those with a low forwarding index.

7.1.4. Live streaming in distributed systems

Peer to peer networks are an efficient way to carry out video live streaming as the forwarding load is distributed among peers. These systems can be of two types: unstructured and structured. In unstructured overlays, the peers obtain the video in an opportunistic way. The advantage is that such systems handle churn well. However, they are less bandwidth efficient than structured overlays, and the control overhead has a non-negligible impact on the performance. In structured overlays, the diffusion of the video is made via an explicit diffusion tree. The advantage is that the peer bandwidth can be optimally exploited. The drawback is that the departure of peers may break the diffusion tree.

In [29], we propose and analyze a simple local algorithm to balance a tree. In this distributed repair algorithm, each node carries out local operations based on its degree and on the subtree sizes of its children. In a synchronous setting, we first prove that starting from any n-node tree our process converges to a balanced binary tree in $O(n^2)$ rounds. We then describe a more restrictive model, adding a small extra information to each node, under which we adapt our algorithm to converge in $\Theta(n \log n)$ rounds.

In [58], we propose new simple distributed repair protocols for video live streaming structured systems. We show, through simulations with real traces, that structured systems can be very efficient and robust to failures, even for high churn and when peers have very heterogeneous upload bandwidth capabilities.

7.2. Graph Algorithms

Participants: Julien Bensmail, Nathann Cohen, David Coudert, Guillaume Ducoffe, Valentin Garnero, Frédéric Giroire, Frédéric Havet, Fionn Mc Inerney, Nicolas Nisse, Stéphane Pérennes, Rémi Watrigant.

COATI is interested in the algorithmic aspects of Graph Theory. In general we try to find the most efficient algorithms to solve various problems of Graph Theory and telecommunication networks. We use Graph Theory to model various network problems. We study their complexity and then we investigate the structural properties of graphs that make these problems hard or easy.

7.2.1. Complexity of graph problems

We also investigate several graph problems coming from various applications. We mainly consider their complexity in general or particular graph classes. When possible, we present polynomial-time (approximation) algorithms or Fixed Parameter Tractable algorithms.

7.2.1.1. Parameterized complexity of polynomial optimization problems (FPT in P)

Parameterized complexity theory has enabled a refined classification of the difficulty of NP-hard optimization problems on graphs with respect to key structural properties, and so to a better understanding of their true difficulties. More recently, hardness results for problems in P were established under reasonable complexity theoretic assumptions such as: Strong Exponential Time Hypothesis (SETH), 3SUM and All-Pairs Shortest-Paths (APSP). According to these assumptions, many graph theoretic problems do not admit truly subquadratic algorithms, nor even truly subcubic algorithms (Williams and Williams, FOCS 2010 [82] and Abboud *et al.* SODA 2015 [70]). A central technique used to tackle the difficulty of the above mentioned problems is fixed-parameter algorithms for polynomial-time problems with *polynomial dependency* in the fixed parameter (P-FPT). This technique was rigorously formalized by Giannopoulou et al. (IPEC 2015) [75], [76]. Following that, it was continued by Abboud *et al.* (SODA 2016) [71], by Husfeldt (IPEC 2016) [78] and Fomin *et al.* (SODA 2017) [74], using the treewidth as a parameter. Applying this technique to *clique-width*, another important graph parameter, remained to be done.

In [55] we study several graph theoretic problems for which hardness results exist such as *cycle problems* (triangle detection, triangle counting, girth), *distance problems* (diameter, eccentricities, Gromov hyperbolicity, betweenness centrality) and *maximum matching*. We provide hardness results and fully polynomial FPT algorithms, using clique-width and some of its upper-bounds as parameters (split-width, modular-width and P_4-sparseness). We believe that our most important result is an $\mathcal{O}(k^4 \cdot n + m)$-time algorithm for computing a maximum matching where k is either the modular-width or the P_4-sparseness. The latter generalizes many algorithms that have been introduced so far for specific subclasses such as cographs, P_4-lite graphs, P_4-extendible graphs and P_4-tidy graphs. Our algorithms are based on preprocessing methods using modular decomposition, split decomposition and primeval decomposition. Thus they can also be generalized to some graph classes with unbounded clique-width.

7.2.1.2. Finding cut-vertices in the square roots of a graph

The square of a given graph $H = (V, E)$ is obtained from H by adding an edge between every two vertices at distance two in H. Given a graph class $\mathcal{H}$, the $\mathcal{H}$-SQUARE ROOT PROBLEM asks for the recognition of the squares of graphs in $\mathcal{H}$. In [56], [46], we answer positively to an open question of Golovach *et al.* (IWOCA'16) [77] by showing that the squares of *cactus-block graphs* can be recognized in polynomial time. Our proof is based on new relationships between the decomposition of a graph by cut-vertices and the decomposition of its square by clique cutsets. More precisely, we prove that the closed neighbourhoods of cut-vertices in H induce maximal subgraphs of $G = H^2$ with no clique-cutset. Furthermore, based on this relationship, we can compute from a given graph G the block-cut tree of a desired square root (if any). Although the latter tree is not uniquely defined, we show surprisingly that it can only differ marginally between two different roots. Our approach not only gives the first polynomial-time algorithm for the $\mathcal{H}$-SQUARE ROOT PROBLEM for several graph classes $\mathcal{H}$, but it also provides a unifying framework for the recognition of the squares of trees, block graphs and cactus graphs — among others.

7.2.1.3. *Graph hyperbolicity*

The Gromov hyperbolicity is an important parameter for analyzing complex networks which expresses how the metric structure of a network looks like a tree (the smaller gap the better). It has recently been used to provide bounds on the expected stretch of greedy-routing algorithms in Internet-like graphs, and for various applications in network security, computational biology, the analysis of graph algorithms, and the classification of complex networks.

In [44], we answer open questions of Verbeek and Suri [81] on the relationships between Gromov hyperbolicity and the optimal stretch of graph embeddings in Hyperbolic space. Then, based on the relationships between hyperbolicity and Cops and Robber games, we turn necessary conditions for a graph to be Cop-win into sufficient conditions for a graph to have a large hyperbolicity (and so, no low-stretch embedding in Hyperbolic space). In doing so we derive lower-bounds on the hyperbolicity in various graph classes – such as Cayley graphs, distance-regular graphs and generalized polygons, to name a few. It partly fills in a gap in the literature on Gromov hyperbolicity, for which few lower-bound techniques are known.

In [23] we study practical improvements for the computation of hyperbolicity in large graphs. Precisely, we investigate relations between the hyperbolicity of a graph G and the hyperbolicity of its *atoms*, that are the subgraphs output by the clique-decomposition invented by Tarjan [80] and Leimer [79]. We prove that the maximum hyperbolicity taken over the atoms is at most one unit off from the hyperbolicity of G and the bound is sharp. We also give an algorithm to slightly modify the atoms, called the "substitution method", which is at no extra cost than computing the clique-decomposition, and so that the maximum hyperbolicity taken over the resulting graphs is *exactly* the hyperbolicity of the input graph G. Experimental evaluation on collaboration networks and biological networks shows that our method provides significant computation time savings. Finally, on a more theoretical side, we deduce from our results the first *linear-time* algorithm for computing the hyperbolicity of an outerplanar graph.

7.2.1.4. *Computing metric hulls in graphs*

Convexity in graphs generalises the classical convexity in Euclidean spaces. The *hull-number* of a graph is the minimum number k such that there exists a set of k vertices whose convex hull is the graph. Computing the hull-number is NP-hard even in very restricted graph classes such as partial cubes (isometric subgraphs of hypercubes). One challenging question in this area is the status of the parameterized complexity of this problem. We further investigate the complexity of a more general problem.

In [60], we prove that, given a closure function the smallest preimage of a closed set can be calculated in polynomial time in the number of closed sets. This confirms a conjecture of Albenque and Knauer and implies that there is a polynomial time algorithm to compute the convex hull-number of a graph, when all its convex subgraphs are given as input. We then show that computing if the smallest preimage of a closed set is logarithmic in the size of the ground set is LOGSNP-complete if only the ground set is given. A special instance of this problem is computing the dimension of a poset given its linear extension graph, that was conjectured to be in P.

The intent to show that the latter problem is LOGSNP-complete leads to several interesting questions and to the definition of the isometric hull, i.e., a smallest isometric subgraph containing a given set of vertices S. While for $|S| = 2$ an isometric hull is just a shortest path, we show that computing the isometric hull of a set of vertices is NP-complete even if $|S| = 3$. Finally, we consider the problem of computing the isometric hull-number of a graph and show that computing it is Σ_2^P-complete.

7.2.1.5. *Application to bioinformatics*

For a (possibly infinite) fixed family of graphs F, we say that a graph G overlays F on a hypergraph H if $V(H)$ is equal to $V(G)$ and the subgraph of G induced by every hyperedge of H contains some member of F as a spanning subgraph. While it is easy to see that the complete graph on $|V(H)|$ overlays F on a hypergraph H whenever the problem admits a solution, the Minimum F-Overlay problem asks for such a graph with the minimum number of edges. This problem allows to generalize some natural problems which may arise in practice. For instance, if the family F contains all connected graphs, then Minimum F-Overlay corresponds to the Minimum Connectivity Inference problem (also known as Subset Interconnection Design problem) introduced for the low-resolution reconstruction of macro-molecular assembly in structural biology, a problem that has been studied jointly by COATI and ABS [72], [73], or for the design of networks. In [41], we show a strong dichotomy result regarding the polynomial vs. NP-hard status with respect to the considered family F. Roughly speaking, we show that the easy cases one can think of (e.g. when edge-less graphs of the right sizes are in F, or if F contains only cliques) are the only families giving rise to a polynomial problem: all others are NP-complete. We then investigate the parameterized complexity of the problem and give similar sufficient conditions on F that give rise to W[1]-hard, W[2]-hard or FPT problems when the parameter is the size of the solution. This yields an FPT/W[1]-hard dichotomy for a relaxed problem, where every hyperedge of H must contain some member of F as a (non necessarily spanning) subgraph.

7.2.1.6. Matchings for the recovery of disrupted airline operations

In an informal collaboration with Amadeus' members (A. Salch and V. Weber), we have studied the following problem. When an aircraft is approaching an airport, it gets a short time interval (called *slot*) that it can use to land. If the landing of the aircraft is delayed (because of bad weather, or if it arrives late, or if other aircrafts have to land first), it looses its slot and Air traffic controllers have to assign it a new slot. However, slots for landing are a scare resource of the airports and, to avoid that an aircraft waits too much time, Air traffic controllers have to regularly modify the assignment of the slots of the aircrafts. Unfortunately, for legal and economical reasons, Air traffic controllers can modify the slot-assignment only through specific kind of operations. The problem is then the following. Precisely, let $k \geq 1$ be an odd integer, a graph G and a matching M (set of pairwise disjoint edges) of G. What is the maximum size of a matching that can be obtained from M by *using* only augmenting paths of length *at most* k?

By Berge's theorem, finding a *maximum matching* in a graph relies on *the use* of *augmenting paths*. When no further constraint is added (k unbounded), Edmonds' algorithm allows to compute a maximum matching in polynomial time by sequentially augmenting such paths. In [39], we first prove that this problem can be solved in polynomial time for $k \leq 3$ in any graph and that it is *NP*-complete for any fixed $k \geq 5$ in the class of planar bipartite graphs of degree at most 3 and arbitrarily large girth. We then prove that this problem is in *P*, for any k, in several subclasses of trees such as caterpillars or trees with all vertices of degree at least 3 “far appart”. Moreover, this problem can be solved in time $O(n)$ in the class of n-node trees when k and the maximum degree are fixed parameters. Finally, we consider a more constrained problem where only paths of length *exactly* k can be augmented. We prove that this latter problem becomes *NP*-complete for any fixed $k \geq 3$ and in trees when k is part of the input.

In [51], we perform a deeper analysis of the complexity of this problem for trees. On the positive side, we first show that it can be solved in polynomial time for more classes of trees, namely bounded-degree trees (via a dynamic programming approach), caterpillars and trees where the nodes with degree at least 3 are sufficiently far apart. On the negative side, we show that, when only paths of length *exactly* k can be augmented, the problem becomes *NP*-complete already for $k = 3$, in the class of planar bipartite graphs with maximum degree 3 and arbitrary large girth. We also show that the latter problem is *NP*-complete in trees when k is part of the input.

7.2.2. Graph decompositions and graph searching

It is well known that many NP-hard problems are tractable in the class of bounded treewidth graphs. In particular, tree-decompositions of graphs are an important ingredient of dynamic programming algorithms for solving such problems. This also holds for other width-parameters of graphs. Therefore, computing these widths and associated decompositions of graphs has both a theoretical and practical interest.

7.2.2.1. Minimum size tree-decompositions

We study in [31] the problem of computing a tree-decomposition of a graph with width at most k and minimum number of bags. More precisely, we focus on the following problem: given a fixed $k \geq 1$, what is the complexity of computing a tree-decomposition of width at most k with minimum number of bags in the class of graphs with treewidth at most k? We prove that the problem is NP-complete for any fixed $k \geq 4$ and polynomial for $k \leq 2$; for $k = 3$, we show that it is polynomial in the class of trees and 2-connected outerplanar graphs.

7.2.2.2. *Exclusive Graph Searching and pathwidth.*

An algorithmic interpretation of tree/path-decomposition is the well known *graph searching* problem, where a team of searchers aims at capturing an intruder in a network, modeled as a graph. All variants of this problem assume that any node can be simultaneously occupied by several searchers. This assumption may be unrealistic, e.g., in the case of searchers modeling physical searchers, or may require each individual node to provide additional resources, e.g., in the case of searchers modeling software agents.

We thus introduce and investigate in [22] *Exclusive Graph Searching*, in which no two or more searchers can occupy the same node at the same time. As for the classical variants of graph searching, we study the minimum number of searchers required to capture the intruder. This number is called the *exclusive search number* of the considered graph. Exclusive graph searching appears to be considerably more complex than classical graph searching, for at least two reasons: (1) it does not satisfy the *monotonicity property*, and (2) it is not *closed under minor*. Moreover, we observe that the exclusive search number of a tree may differ exponentially from the values of classical search numbers (e.g., pathwidth). Nevertheless, we design a polynomial-time algorithm which, given any n-node tree T, computes the exclusive search number of T in time $O(n^3)$. Moreover, for any integer k, we provide a characterization of the trees T with exclusive search number at most k. Finally, we prove that the ratio between the exclusive search number and the pathwidth of a graph is bounded by its maximum degree.

In [32], we study the complexity of this new variant and show that there are graph classes where its complexity differs from the complexity of pathwidth. We show that the problem is NP-hard in planar graphs with maximum degree 3 and it can be solved in linear-time in the class of cographs. We also show that *monotone* Exclusive Graph Searching is NP-complete in split graphs where Pathwidth is known to be solvable in polynomial time. Moreover, we prove that monotone Exclusive Graph Searching is in P in a subclass of star-like graphs where Pathwidth is known to be NP-hard. Hence, the computational complexities of monotone Exclusive Graph Searching and Pathwidth cannot be compared. This is the first variant of Graph Searching for which such a difference is proved.

7.2.2.3. *Distributed Graph Searching.*

We then study exclusive graph searching in a distributed setting. Consider a set of mobile robots placed on distinct nodes of a discrete, anonymous, and bidirectional ring. Asynchronously, each robot takes a snapshot of the ring, determining the size of the ring and which nodes are either occupied by robots or empty. Based on the observed configuration, it decides whether to move to one of its adjacent nodes or not. In the first case, it performs the computed move, eventually. This model of computation is known as *Look-Compute-Move*. The computation depends on the required task. In [25], we solve both the well-known *Gathering* and *Exclusive Searching* tasks. In the former problem, all robots must simultaneously occupy the same node, eventually. In the latter problem, the aim is to clear all edges of the graph. An edge is cleared if it is traversed by a robot or if both its endpoints are occupied. We consider the *exclusive* searching where it must be ensured that two robots never occupy the same node. Moreover, since the robots are oblivious, the clearing is *perpetual*, i.e., the ring is cleared infinitely often.

In the literature, most contributions are restricted to a subset of initial configurations. Here, we design two different algorithms and provide a characterization of the initial configurations that permit the resolution of the problems under very weak assumptions. More precisely, we provide a full characterization (except for few pathological cases) of the initial configurations for which Gathering can be solved. The algorithm relies on the necessary assumption of the local-weak multiplicity detection. This means that during the Look phase a robot detects also whether the node it occupies is occupied by other robots, without acquiring the exact number.

For the exclusive searching, we characterize all (except for few pathological cases) aperiodic configurations from which the problem is feasible. We also provide some impossibility results for the case of periodic configurations.

7.2.3. Combinatorial games on graphs

We study several two-player games on graphs. Some of these games allow to model real-life applications. In the case of the Spy-game presented below, we propose a successful new approach by studying fractional relaxation of such games.

7.2.3.1. Localization Game on Geometric and Planar Graphs

Motivated by a localization problem in cellular networks, we introduce in [52] a model based on a pursuit graph game that resembles the famous Cops and Robbers game. It can be considered as a game theoretic variant of the *metric dimension* of a graph. Given a graph G we want to localize a walking agent by checking his distance to as few vertices as possible. We provide upper bounds on the related graph invariant $\zeta(G)$, defined as the least number of cops needed to localize the robber on a graph G, for several classes of graphs (trees, bipartite graphs, etc). Our main result is that, surprisingly, there exists planar graphs of treewidth 2 and unbounded $\zeta(G)$. On a positive side, we prove that $\zeta(G)$ is bounded by the pathwidth of G. We then show that the algorithmic problem of determining $\zeta(G)$ is NP-hard in graphs with diameter at most 2. Finally, we show that at most one cop can approximate (arbitrarily close) the location of the robber in the Euclidean plane.

7.2.3.2. Spy-Game on graphs

We define and study the following two-player game on a graph G. Let $k \in \mathbb{N}^*$. A set of k guards is occupying some vertices of G while one spy is standing at some vertex. At each turn, first the spy may move along at most s edges, where $s \in \mathbb{N}^*$ is his speed. Then, each guard may move along one edge. The spy and the guards may occupy the same vertices. The spy has to escape the surveillance of the guards, i.e., must reach a vertex at distance more than $d \in \mathbb{N}$ (a predefined distance) from every guard. Can the spy win against k guards? Similarly, what is the minimum distance d such that k guards may ensure that at least one of them remains at distance at most d from the spy? This game generalizes two well-studied games: Cops and robber games (when $s = 1$) and Eternal Dominating Set (when s is unbounded).

In [53], we consider the computational complexity of the problem, showing that it is NP-hard (for every speed s and distance d) and that some variant of it is PSPACE-hard in DAGs. Then, we establish tight tradeoffs between the number of guards, the speed s of the spy and the required distance d when G is a path or a cycle.

In order to determine the smallest number of guards necessary for this task, we analyze in [42], [43], [54] the game through a Linear Programming formulation and the *fractional strategies* it yields for the guards. We then show the equivalence of fractional and integral strategies in trees. This allows us to design a polynomial-time algorithm for computing an optimal strategy in this class of graphs. Using duality in Linear Programming, we also provide non-trivial bounds on the fractional guard-number of grids and torus. We believe that the approach using fractional relaxation and Linear Programming is promising to obtain new results in the field of combinatorial games.

7.2.3.3. Hyperopic Cops and Robbers

We introduce in [68] a new variant of the game of Cops and Robbers played on graphs, where the robber is invisible when located in the neighbor set of a cop. The hyperopic cop number is the corresponding analogue of the cop number, and we investigate bounds and other properties of this parameter. We characterize the cop-win graphs for this variant, along with graphs with the largest possible hyperopic cop number. We analyze the cases of graphs with diameter 2 or at least 3, focusing on when the hyperopic cop number is at most one greater than the cop number. We show that for planar graphs, as with the usual cop number, the hyperopic cop number is at most 3. The hyperopic cop number is considered for countable graphs, and it is shown that for connected chains of graphs, the hyperopic cop density can be any real number in $[0, 1/2]$.

7.3. Graph theory

Participants: Julien Bensmail, Guillaume Ducoffe, Frédéric Havet, William Lochet, Nicolas Nisse, Bruce Reed.

COATI studies theoretical problems in graph theory. If some of them are directly motivated by applications (see Subsection 7.3.3), others are more fundamental. In particular, we are putting an effort on understanding better directed graphs (also called *digraphs*) and partionning problems, and in particular colouring problems. We also try to better the understand the many relations between orientation and colourings. We study various substructures and partitions in (di)graphs. For each of them, we aim at giving sufficient conditions that guarantee its existence and at determining the complexity of finding it.

7.3.1. Substructures in (di)graphs

We study various conditions that ensure a (di)graph to contain certain substructures.

In [17], we study the question of finding a set of k vertex-disjoint cycles (resp. directed cycles) of distinct lengths in a given graph (resp. digraph). In the context of undirected graphs, we prove that, for every $k \geq 1$, every graph with minimum degree at least $\frac{k^2+5k-2}{2}$ has k vertex-disjoint cycles of different lengths, where the degree bound is the best possible. We also consider other cases such as when the graph is triangle-free, or the k cycles are required to have different lengths modulo some value r. In the context of directed graphs, we consider a conjecture of Lichiardopol concerning the least minimum out-degree required for a digraph to have k vertex-disjoint directed cycles of different lengths. We verify this conjecture for tournaments, and, by using the probabilistic method, for some regular digraphs and digraphs of small order.

A $(k_1 + k_2)$-*bispindle* is the union of k_1 (x, y)-dipaths and k_2 (y, x)-dipaths, all these dipaths being pairwise internally disjoint. Recently, Cohen et al. showed that for every $(1, 1)$-bispindle B, there exists an integer k such that every strongly connected digraph with chromatic number greater than k contains a subdivision of B. In [24], we investigate generalisations of this result by first showing constructions of strongly connected digraphs with large chromatic number without any $(3, 0)$-bispindle or $(2, 2)$-bispindle. Then we show that strongly connected digraphs with large chromatic number contains a $(2, 1)$-bispindle, where at least one of the (x, y)-dipaths and the (y, x)-dipath are long.

Let $\mathcal{H}$ be a family of graphs and let d be large enough. For every d-regular graph G, we study the existence of a spanning $\mathcal{H}$-free subgraph of G with large minimum degree. This problem is well understood if $\mathcal{H}$ does not contain bipartite graphs. In [35] we provide asymptotically tight results for many families of bipartite graphs such as cycles or complete bipartite graphs. To prove these results, we study a locally injective analogue of the question.

An *even pair* (resp. *odd pair*) in a graph is a pair of non-adjacent vertices such that every chordless path between them has even (resp. odd) length. Even and odd pairs are important tools in the study of perfect graphs and were instrumental in the proof of the Strong Perfect Graph Theorem. We suggest that such pairs impose a lot of structure also in arbitrary, not just perfect graphs. To this end, we show in [36] that the presence of even or odd pairs in graphs imply a special structure of the stable set polytope. In fact, we give a polyhedral characterization of even and odd pairs.

7.3.2. Colourings and partitioning (di)graphs

7.3.2.1. Colouring graphs with constraints on connectivity

A graph G has maximal local edge-connectivity k if the maximum number of edge-disjoint paths between every pair of distinct vertices x and y is at most k. We prove in [11] Brooks-type theorems for k-connected graphs with maximal local edge-connectivity k, and for any graph with maximal local edge-connectivity 3. We also consider several related graph classes defined by constraints on connectivity. In particular, we show that there is a polynomial-time algorithm that, given a 3-connected graph G with maximal local connectivity 3, outputs an optimal colouring for G. On the other hand, we prove, for $k \geq 3$, that k-colourability is NP-complete when restricted to minimally k-connected graphs, and 3-colourability is NP-complete when restricted to $(k-1)$-connected graphs with maximal local connectivity k. Finally, we consider a parameterization of k-colourability based on the number of vertices of degree at least $k + 1$, and prove that, even when k is part of the input, the corresponding parameterized problem is FPT.

7.3.2.2. Sum-distinguishing edge-weightings

A *k-edge-weighting* of a graph G is an application from $E(G)$ into $\{1, \cdots, k\}$. An edge-weigthing is *sum-distinguishing* if for every two adajcent vertices u and v, the sum of weights of edges incident to u is distinct from the sum of of weights of edges incident to v. The celebrated 1-2-3-Conjecture (raised in 2004 by Karoński, Luczak and Thomason) asserts that every connected graph (except K_2, the complete graph on two vertices) admits a sum-distinguishing 3-edge-weighting. This conjecture attracted much attention and many variants are now studied. We study several of them.

Towards the 1-2-3-Conjecture, the best-known result to date is due to Kalkowski, Karoński and Pfender, who proved that it holds when relaxed to 5-edge-weightings. Their proof builds upon a weighting algorithm designed by Kalkowski for a total version (where also the vertices are weighted) of the problem. In [67], we present new mechanisms for using Kalkowski's algorithm in the context of the 1-2-3 Conjecture. As a main result we prove that every 5-regular graph admits a 4-edge-weighting that permits to distinguish its adjacent vertices via their incident sums.

In [66], we investigate the consequences on the 1-2-3 Conjecture of requiring a stronger distinction condition. Namely, we consider two adjacent vertices distinguished when their incident sums differ by at least 2. As a guiding line, we conjecture that every graph with no connected component isomorphic to K_2 admits a 5-edge-weighting permitting to distinguish the adjacent vertices in this stronger way. We verify this conjecture for several classes of graphs, including bipartite graphs and cubic graphs. We then consider algorithmic aspects, and show that it is *NP*-complete to determine the smallest k such that a given bipartite graph admits such a k-edge-weighting. In contrast, we show that the same problem can be solved in polynomial time for a given tree.

In [13], we consider the following question, which stands as a directed analogue of the 1-2-3 Conjecture: Given any digraph D with no arc $\overrightarrow{uv}$ verifying $d^+(u) = d^-(v) = 1$, is it possible to weight the arcs of D with weights among $\{1, 2, 3\}$ so that, for every arc $\overrightarrow{uv}$ of D, the sum of incident weights out-going from u is different from the sum of incident weights in-coming to v? We answer positively to this question, and investigate digraphs for which even the weights among $\{1, 2\}$ are sufficient. In relation with the so-called 1-2 Conjecture, we also consider a total version of the problem, which we prove to be false. Our investigations turn to have interesting relations with open questions related to the 1-2-3 Conjecture.

In [21], we study the following question: Is it always possible to injectively assign the weights $1, ..., |E(G)|$ to the edges of any given graph G (with no component isomorphic to K_2) so that every two adjacent vertices of G get distinguished by their sums of incident weights? One may see this question as a combination of the well-known 1-2-3 Conjecture and the Antimagic Labelling Conjecture. We exhibit evidence that this question might be true. Benefiting from the investigations on the Antimagic Labelling Conjecture, we first point out that several classes of graphs, such as regular graphs, indeed admit such assignments. We then show that trees also do, answering a recent conjecture of Arumugam, Premalatha, Bača and Semaničová-Feňovčíková. Towards a general answer to the question above, we then prove that claimed assignments can be constructed for any graph, provided we are allowed to use some number of additional edge weights. For some classes of sparse graphs, namely 2-degenerate graphs and graphs with maximum average degree 3, we show that only a small (constant) number of such additional weights suffices.

7.3.2.3. Variants of vertex- or edge-colouring

A colouring of a graph G is *properly connected* if every two vertices of G are the ends of a properly coloured path. In [57], [47], we study the *complexity* of computing the *proper connection number* (minimum number of colours in a properly connected colouring) for edge and vertex colourings, in undirected and directed graphs, respectively. First we disprove some conjectures of Magnant et al. (2016) on characterizing the strong digraphs with *proper arc connection number* at most two. Then, we prove that deciding whether a given digraph has proper arc connection number at most two is NP-complete. Furthermore, we show that there are infinitely many such digraphs with no even-length dicycle. We initiate the study of proper vertex connectivity in digraphs and we prove similar results as for the arc version. Finally, we present polynomial-time recognition algorithms for *bounded-treewidth* graphs and *bipartite* graphs with *proper edge connection number* at most two.

A graph is *locally irregular* if no two adjacent vertices have the same degree. The *irregular chromatic index* $\chi'_{\mathrm{irr}}(G)$ of a graph G is the smallest number of locally irregular subgraphs needed to edge-decompose G. Not all graphs have such a decomposition, but Baudon, Bensmail, Przybyło, and Woźniak conjectured that if G can be decomposed into locally irregular subgraphs, then $\chi'_{\mathrm{irr}}(G) \leq 3$. In support of this conjecture, Przybyło showed that $\chi'_{\mathrm{irr}}(G) \leq 3$ holds whenever G has minimum degree at least 10^{10}. In [19] we prove that every bipartite graph G which is not an odd length path satisfies $\chi'_{\mathrm{irr}}(G) \leq 10$. This is the first general constant upper bound on the irregular chromatic index of bipartite graphs. Combining this result with Przybyło's result, we show that $\chi'_{\mathrm{irr}}(G) \leq 328$ for every graph G which admits a decomposition into locally irregular subgraphs. Finally, we show that $\chi'_{\mathrm{irr}}(G) \leq 2$ for every 16-edge-connected bipartite graph G.

An (m,n)-coloured mixed graph is a mixed graph with arcs assigned one of m different colours and edges one of n different colours. A homomorphism of an (m,n)-coloured mixed graph G to an (m,n)-coloured mixed graph H is a vertex mapping such that if uv is an arc (edge) of colour c in G, then $f(u)f(v)$ is also an arc (edge) of colour c. The (m,n)-coloured mixed chromatic number, denoted $\chi_{m,n}(G)$, of an (m,n)-coloured mixed graph G is the order of a smallest homomorphic image of G. An (m,n)-clique is an (m,n)-coloured mixed graph C with $\chi_{m,n}(C) = |V(C)|$. In [16], we study the structure of (m,n)-cliques. We show that almost all (m,n)-coloured mixed graphs are (m,n)-cliques, prove bounds for the order of a largest outerplanar and planar (m,n)-clique and resolve an open question concerning the computational complexity of a decision problem related to $(0,2)$-cliques. Additionally, we explore the relationship between $\chi_{1,0}$ and $\chi_{0,2}$.

An edge colouring of a graph G is called acyclic if it is proper and every cycle contains at least three colours. We show in [33] that for every $\varepsilon > 0$, there exists a $g = g(\varepsilon)$ such that if G has maximum degree Δ and girth at least g then G admits an acyclic edge colouring with $(1+\varepsilon)\Delta + O(1)$ colours.

7.3.3. Identifying codes

Let G be a graph G. The *neighborhood* of a vertex v in G, denoted by $N(v)$, is the set of vertices adjacent to v in G. Its *closed neighborhood* is the set $N[v] = N(v) \cup \{v\}$. A set $C \subseteq V(G)$ is an *identifying code* in G if (i) for all $v \in V(G)$, $N[v] \cap C \neq \varnothing$, and (ii) for all $u, v \in V(G)$, $N[u] \cap C \neq N[v] \cap C$. The problem of finding low-density identifying codes was introduced in [Karpovsky et al., IEEE Trans. Inform. Theory 44, 1998] in relation to fault diagnosis in arrays of processors. Here the vertices of an identifying code correspond to controlling processors able to check themselves and their neighbors. Thus the identifying property guarantees location of a faulty processor from the set of “complaining” controllers. Identifying codes are also used in [Ray et al., IEEE Journal on Selected Areas in Communications 22, 2004] to model a location detection problem with sensor networks.

A particular interest was dedicated to grids as many processor networks have a grid topology. There are several types of standard regular infinite grids, in particular the hexagonal grids, the square grids, the triangular grids and the king grids. For such graphs G, the problem consists in finding the minimum density $d^*(G)$ of an identifying code of G.

In [26], we study the infinite triangular grid T_k with k rows. We show $d^*(T_1) = d^*(T_2) = 1/2$, $d^*(T_3) = d^*(T_4) = 1/3$, $d^*(T_5) = 3/10$, $d^*(T_6) = 1/3$ and $d^*(T_k) = 1/4 + 1/(4k)$ for all odd $k \geq 7$. In addition, we show that $1/4 + 1/(4k) \leq d^*(T_k) \leq 1/4 + 1/(2k)$ for all even $k \geq 8$.

In [27], we study the density of king grids which are strong product of two paths. We show that for every king grid G, $d^*(G) \geq 2/9$. In addition, we show this bound is attained only for king grids which are strong products of two infinite paths. Given $k \geq 3$, we denote by K_k the (infinite) king strip with k rows. We prove that $d^*(K_3) = 1/3$, $d^*(K_4) = 5/16$, $d^*(K_5) = 4/15$ and $d^*(K_6) = 5/18$. We also prove that $2/9 + 8/81k \leq d^*(K_k) \leq 2/9 + 4/9k$ for every $k \geq 7$.

7.3.4. Miscellaneous

7.3.4.1. A proof of the Barát-Thomassen conjecture

The Barát-Thomassen conjecture asserts that for every tree T on m edges, there exists a constant k_T such that every k_T-edge-connected graph with size divisible by m can be edge-decomposed into copies of T. So far this conjecture has only been verified when T is a path or when T has diameter at most 4. In [18], we prove the full statement of the conjecture.

7.3.4.2. Recursively partitionable graphs

A connected graph G is said to be *arbitrarily partitionable* (AP for short) if for every partition $(n_1, ..., n_p)$ of $|V(G)|$ there exists a partition $(V_1, ..., V_p)$ of $V(G)$ such that each V_i induces a connected subgraph of G on n_i vertices. Some stronger versions of this property were introduced, namely the ones of being *online arbitrarily partitionable* and *recursively arbitrarily partitionable* (OL-AP and R-AP for short, respectively), in which the subgraphs induced by a partition of G must not only be connected but also fulfil additional conditions. In [14], we point out some structural properties of OL-AP and R-AP graphs with connectivity 2. In particular, we show that deleting a cut pair of these graphs results in a graph with a bounded number of components, some of whom have a small number of vertices. We obtain these results by studying a simple class of 2-connected graphs called *balloons*

7.3.4.3. On oriented cliques with respect to push operation

An oriented graph is a directed graph without any directed cycle of length at most 2. An oriented clique is an oriented graph whose non-adjacent vertices are connected by a directed 2-path. To push a vertex v of a directed graph $\overrightarrow{G}$ is to change the orientations of all the arcs incident to v. A push clique is an oriented clique that remains an oriented clique even if one pushes any set of vertices of it. We show in [20] that it is NP-complete to decide if an undirected graph is the underlying graph of a push clique or not. We also prove that a planar push clique can have at most 8 vertices and provide an exhaustive list of planar push cliques.

7.3.4.4. On q-power cycles in cubic graphs

In the context of a conjecture of Erdős and Gyárfás, we consider in [15], for any $q \geq 2$, the existence of q-power cycles (*i.e.* with length a power of q) in cubic graphs. We exhibit constructions showing that, for every $q \geq 3$, there exist arbitrarily large cubic graphs with no q-power cycles. Concerning the remaining case $q = 2$ (which corresponds to the conjecture of Erdős and Gyárfás), we show that there exist arbitrarily large cubic graphs whose only 2-power cycles have length 4 only, or 8 only.

7.3.4.5. How to determine if a random graph with a fixed degree sequence has a giant component

For a fixed degree sequence $\mathcal{D} = (d_1, ..., d_n)$, let $G(\mathcal{D})$ be a uniformly chosen (simple) graph on $\{1, \cdots, n\}$ where the vertex i has degree d_i. In [34] we determine whether $G(\mathcal{D})$ has a giant component with high probability, essentially imposing no conditions on $\mathcal{D}$. We simply insist that the sum of the degrees in $\mathcal{D}$ which are not 2 is at least $\lambda(n)$ for some function λ going to infinity with n. This is a relatively minor technical condition, and when $\mathcal{D}$ does not satisfy it, both the probability that $G(\mathcal{D})$ has a giant component and the probability that $G(\mathcal{D})$ has no giant component are bounded away from 1.

7.3.4.6. A proof of the Erdős-Sands-Sauer-Woodrow conjecture

A very nice result of Barany and Lehel asserts that every finite subset X of R^d can be covered by $f(d)$ X-boxes (i.e. each box has two antipodal points in X). As shown by Gyárfás and Pálvőlgyi this result would follow from the following conjecture : If a tournament admits a partition of its arc set into k partial orders, then its domination number is bounded in terms of k. This question is in turn implied by the Erdős-Sands-Sauer-Woodrow conjecture : If the arcs of a tournament T are colored with k colors, there is a set X of at most $g(k)$ vertices such that for every vertex v of T, there is a monochromatic path from X to v. We give in [69] a short proof of this statement. We moreover show that the general Sands-Sauer-Woodrow conjecture (which as a special case implies the stable marriage theorem) is valid for directed graphs with bounded stability number. This conjecture remains however open.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

8.1.1.1. ANR Blanc STINT, 2014-2017

Participants: Julien Bensmail, Jean-Claude Bermond, David Coudert, Frédéric Havet, Luc Hogie, William Lochet, Nicolas Nisse, Stéphane Pérennes, Michel Syska.

The STINT project (*STructures INTerdites*) is led by the MC2 group (LIP, ENS-Lyon) and involves the G-SCOP laboratory (Grenoble).

The aim of STINT was to answer the following fundamental question: *given a (possibly infinite) family ψ of graphs, what properties does a ψ-free graph have?* To this end, it has firstly establish bounds on some classical graph parameters (e.g., clique number, stability number, chromatic number) for ψ-free graphs. Then, it has design efficient algorithms to recognize ψ-free graphs and to determine or approximate some parameters for those graphs. These studies have result in the development of new proof techniques.

(http://www.ens-lyon.fr/LIP/MC2/STINT/)

8.1.2. GDR Actions

8.1.2.1. Action ResCom, ongoing (since 2006)

Réseaux de communications, working group of GDR RSD, CNRS.

(http://rescom.asr.cnrs.fr/)

8.1.2.2. Action Graphes, ongoing (since 2006)

Action Graphes, working group of GDR IM, CNRS.

(http://gtgraphes.labri.fr/)

8.2. International Initiatives

8.2.1. Inria Associate Teams Not Involved in an Inria International Labs

8.2.1.1. ALDYNET

Title: distributed ALgorithms for DYnamic NETworks

International Partner (Institution - Laboratory - Researcher):

Universidad Adolfo Ibañez (Chile) - Facultad de Ingeniería y Ciencias - Karol SUCHAN

Duration: 2013-2018

See also: https://team.inria.fr/coati/projects/aldynet/

The main goal of this Associate Team is to design and implement practical algorithms for computing graph structural properties. We will then use these algorithms on a concrete case of study which concerns the transportation network of the Santiago metropolitean area. We are both interested in theoretical results concerning the feasibility of computing graph properties, and by their practical implementation (using Sagemath) for our application and their diffusion in the scientific community. See the ALDYNET project web page for more details.

8.2.2. Inria International Partners

8.2.2.1. Informal International Partners

Apart from formal collaboration COATI members maintain strong connections with the following international teams, with regular visits of both sides.

Universidade Federal do Ceará (Fortaleza, Brazil), ParGO team;

Universidade Estadual do Ceará (Fortaleza, Brazil), Prof. Leonardo Sampaio;

Univ. of Southern Denmark (Odense, Denmark), Prof. Jørgen Bang-Jensen;

RWTH Aachen Univ., Lehrstuhl II für Mathematik (Aachen, Germany), Prof. Arie M.C.A. Koster;

Concordia Univ. (Montréal, Québec, Canada), Prof. Brigitte Jaumard.

8.3. International Research Visitors

8.3.1. Visits of International Scientists

Jørgen Bang-Jensen

University of Southern Denmark, Odense, Denmark. January 2017.

Ararat Harutyunyan

Université de Toulouse III, France. February 2017.

Takako Kodate

Tokyo Woman's Christian University, Japan. From March 2017 until April 2017.

Claudia Linhares-Sales

Universidade Federal do Ceará, Fortaleza, Brazil. January 2017.

Joseph Peters

Scool of computing Science, Simon Fraser University, BC Canada. Since October 2017.

Leonardo Sampaio Rocha

Universidade Estadual do Ceará, Fortaleza, Brazil. June 2017.

Ana Shirley Ferreira Da Silva

Universidade Federal do Ceará, Fortaleza, Brazil. January 2017.

Karol Suchan

Universidad Adolfo Ibáñez, Chile. From February 2017 until March 2017.

Laurent Viennot

Inria Paris (EP Gang), France. February 2017.

Min-Li (Joseph) Yu

Univ. of the Fraser valley, Abbotsford, (BC), Canada. From March 2017 until April 2017.

8.3.2. Visits to International Teams

8.3.2.1. Research Stays Abroad

Julien Bensmail

LaBRI, Université de Bordeaux, April 24-28 and October 9-13, 2017.

Christelle Caillouet

Reunion Island University, LIM Laboratory, October 20-November 19, 2017.

David Coudert

Gran Sasso Science Institute (GSSI), L'Aquila, Italy, April 19-21, 2017;

Concordia University, Montréal, Québec, Canada, July 1-14, 2017;

Univ. Adolfo Ibáñez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AlDyNet, November 17-December 2, 2017.

Guillaume Ducoffe

Faculty of Mathematics and Informatics, University of Bucharest, January 18-August 31, 2017.

Frédéric Giroire

Department of Computer Science and Software Engineering, Condordia University, Montréal, Canada, October 11-24, 2017.

Frédéric Havet

Laboratoire ICube, Université de Strasbourg, November 8-10, 2017;

LABRI, Bordeaux, November 14-17, 2017.

William Lochet

LABRI, Université de Bordeaux, October 8-13, 2017;

LIRMM, Université de Montpellier, June 13-15, 2017.

Nicolas Nisse

LIF, Aix-Marseille Université, July 9-13, 2017;

Univ. Adolfo Ibáñez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AlDyNet, November 17-December 2, 2017.

Fionn Mc Inerney

Université de Montréal, Montréal, Canada, July 3-August 4, 2017;

Univ. Adolfo Ibáñez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AlDyNet, November 17-December 2, 2017.

Bruce Reed

IMPA, Unité CNRS Mixte, Rio de Janeiro, Brazil, January 1-March 24, 2017;

School of Computer Science, McGill University, November 1-December 31, 2017.

Andrea Tomassilli

Concordia University, Montréal, Canada, October 1-December 28, 2017.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. Member of the Organizing Committees

Whole team

Journées JCALM (May 4-5, 2017) held in Sophia-Antipolis. Topic: Designs.

Christelle Caillouet, David Coudert

“Journées RESCOM 2017” of GDR RSD of CNRS, Sophia Antipolis, France, January 11-13, 2017.

Frédéric Havet

6th STINT meeting, Valgaudemar, France, July 5-7, 2017;

7th STINT meeting, Sophia Antipolis, France, December 4-6, 2017.

Frédéric Havet, Bruce Reed

2nd Cassidian Workshop, Cassis, France, May 14-20, 2017.

Frédéric Giroire, Joanna Moulierac

GreenDays@Sophia 2017: 8th French workshop on Network Energy efficiency, Université Côte d’Azur, Campus SophiaTech, Sophia Antipolis, June 26-27, 2017.

Bruce Reed

Co-Organizer 2017 Barbados Graph Theory Workshop, Holetown, Barbados, March 24-31, 2017.

9.1.2. Scientific Events Selection

9.1.2.1. Chair of Conference Program Committees

David Coudert

Scientific Co-Chair of Track 7 “Cloud Computing and Data Center Management” of the 14th International Symposium on Pervasive Systems, Algorithms, and Networks (I-SPAN’17), Exeter, UK, June 21-23, 2017.

9.1.2.2. Member of the Conference Program Committees

David Coudert

AlgoTel’17: Rencontres Francophones sur les Aspects Algorithmiques de Télécommunications, Quiberon, France, May 30-June 2, 2017;

ONDM’17: International Conference on Optical Networking Design and Modeling, Budapest, Hungary, May 15-17, 2017;

IEEE ICC’17: IEEE International Conference on Communications, Paris, France, May 21-25, 2017;

IEEE Globecom’17: IEEE Global Communications Conference, Singapore, December 4-8, 2017.

Frédéric Havet

IX Latin and American Algorithms, Graphs and Optimization Symposium (LAGOS 2017), Marseille, France, September 11-15, 2017;

19th Journées Graphes et Algorithmes (JGA 2017), Bordeaux, France, November 15-17, 2017.

Nicolas Nisse

Member of the Scientific Committee of GRASTA’17, 8th workshop on GRAph Searching, Theory & Applications, Anogia, Crete, Greece, April 10–13, 2017;

FCT’17: 21st International Symposium on Fundamentals of Computation Theory, Bordeaux, France, September 11-13, 2017.

9.1.3. Journal

9.1.3.1. Member of the Editorial Boards

Jean-Claude Bermond

Computer Science Reviews, Discrete Mathematics, Discrete Applied Mathematics, Journal of Graph Theory, Journal of Interconnection Networks (Advisory Board), Mathématiques et Sciences Humaines, Networks, Parallel Processing Letters, the SIAM book series on Discrete Mathematics, Transactions on Network Optimization and Control, Algorithms and Applications.

David Coudert

Discrete Applied Mathematics (Elsevier), Networks (Wiley).

Frédéric Giroire

Journal of Interconnection Networks (World Scientific).

Frédéric Havet

Discrete Mathematics and Theoretical Computer Science.

Bruce Reed

Journal of Graph Theory, Electronic Journal of Combinatorics.

9.1.3.2. Reviewer - Reviewing Activities

Members of COATI have reviewed numerous manuscripts submitted to international journals, including: Algorithmica, Algorithms, Bulletin of the Malaysian Mathematical Sciences Society, Computer Communications, Computer Networks, Computers & Operations Research, Discrete Applied Mathematics, European Journal of Operational Research, IEEE/OSA Journal of Lightwave Technology, Networks, Photonic Network Communications, The Computer Journal, Theoretical Computer Science, IEEE/ACM Transactions on Communications, IEEE/ACM Transactions on Networking, IEEE Transactions on Network and Service Management, etc.

9.1.4. Invited Talks

Julien Bensmail

Seminar of the Graphs and Optimisation team, LaBRI, Bordeaux (April 28, 2017): “On augmenting matchings via bounded-length augmentations”.

David Coudert

Seminar of the MAORE team, LIRMM, Montpellier (January 20, 2017): “Design of reliable fixed microwave backhaul networks”;

Joint ACP and GdR RO Summer School on Constraints and Operational Research, Porquerolles, France (September 18-22, 2017): “On the Flinders Hamiltonian Cycle Problem Challenge”;

Seminario del Doctorado en Ingeniera de Sistemas Complejos, Santiago, Chile (November 23, 2017): “On the Flinders Hamiltonian Cycle Problem Challenge”.

Guillaume Ducoffe

Logic seminar, University of Bucharest, Romania (March 2, 2017): “Treewidth vs. Treelength”;

Scientific seminar, West University of Timisoara, Romania (April 26, 2017): “Revisiting Preferential Attachment with applications to Twitter”;

International Workshop on Graphs, Networks and Digital Humanities, Bucharest, Romania (October 9, 2017): “Revisiting Preferential Attachment with applications to Twitter”.

Frédéric Giroire

Entretiens Jacques Cartier, Concordia University, Montréal, Canada (October 17-18, 2017): “Towards Energy Efficient Networks with SDN and Virtualization”;

SDN Day, IRT SystemX, Palaiseau, France (November 23, 2017): “Approximation algorithms for the Placement of Ordered Service Function Chains”.

Nicolas Nisse

Seminar of the ACRO team, LIF, Marseille (July 10, 2017): “Recovery of disrupted airline operations".

Luc Hogie, Michel Syska

Action GRAMINEES (GRaph data Mining in Natural, Ecological and Environnemental Sciences), journées Science des Données MaDICS (Masses de Données, Informations et Connaissances en Sciences), Marseille, France (June 23, 2017): “Bibliothèque de fouille de graphe”.

9.1.5. Leadership within the Scientific Community

David Coudert

Member of the steering committee of *Pôle ResCom du GDR RSD du CNRS* since 2005, and co-chair since June 2017;

Member of the steering committee of *Rencontres francophones sur les aspects algorithmiques des télécommunications* (AlgoTel).

Frédéric Giroire

Member of the steering committee of *GT Energy of the GDR RSD du CNRS*.

Frédéric Havet

GT Graphes du GDR IM du CNRS;

Journées Graphes et Algorithmes (JGA);

Journées Combinatoire et Algorithmes du Littoral Méditerranéen (JCALM).

9.1.6. Scientific Expertise

Jean-Claude Bermond

Expert for DRTT-MESR (Crédit impôt recherche (CIR et agréments)).

David Coudert

Expert for the Future and Emerging Technologies Open (FET-Open) European program (RIA Cut-off September 27, 2017);

Expert for “Haut Conseil de l’évaluation de la recherche et de l’enseignement supérieur” (HCERES).

Frédéric Giroire

Expert for ANR.

Frédéric Havet

Expert for ANR and NSERC.

9.1.7. Research Administration

Jean-Claude Bermond

Responsible for the cooperation between Inria and Greece (meeting with the French Embassy in Greece, obtention of join grants and of financial support for internships via the Bodossakis Fundation).

Christelle Caillouet

Elected member of CPRH (Comité Permanent de Ressources Humaines) University of Nice Sophia Antipolis;

Elected member of I3S laboratory committee since December 2016;

Recruiting committee (comité de sélection) University of Lyon.

David Coudert :

President of “Comité de Sélection” SCIENCES / 27-PR-388, Université Nice-Sophia Antipolis, 2017;

Nominated member for Inria at the doctoral school STIC since September 2017;

Member of the “Comité de Suivi Doctoral” of Inria;

Member of the scientific council of Academy RISE (Networks, Information, Digital Society) of UCA$^{\mathrm{JEDI}}$.

Frédéric Giroire :

Elected member of I3S laboratory committee since 2012 (reelected in December 2016);

In charge of the internships of stream UbiNet of Master 2 IFI, UNS.

Frédéric Havet :

Responsible of the ComRed Team of I3S.

Joanna Moulierac

Member of a “Comité de sélection” in Marseille, France, for the 27th section;

Member of the “Conseil de Département Informatique” of IUT Nice.

Nicolas Nisse

Elected member (deputy) of the “Comité de Centre” of Inria Sophia Antipolis.

Michel Syska

Elected member of CPRH (Comité Permanent de Ressources Humaines) University of Nice-Sophia Antipolis;

Recruiting committee (comité de sélection) University of Nice-Sophia Antipolis.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Licence

Julien Bensmail

Recherche opérationnelle, 82h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Systèmes de gestion de bases de donnés, 86h ETD, Level L2, IUT Nice Côte d'Azur, UNS.

Christelle Caillouet

Object-Oriented Programming, 60h ETD, Level L1, IUT Nice Côte d'Azur, UNS.

Guillaume Ducoffe

Introduction Programmation Java, 9h ETD, Niveau L1, Polytech Nice Sophia.

Nicolas Huin

Architecture des réseaux, 21h ETD, Niveau L1, IUT de Nice Côte d'Azur, UNS;

Programmation répartie, 21h ETD, Niveau L2, IUT de Nice Côte d'Azur, UNS;

Compléments d'algorithmique, 21h ETD, Niveau L2, IUT de Nice Côte d'Azur, UNS.

Nicolas Nisse

Introduction à l'algorithmique, 24h ETD, MPSI, Lycée International Valbonne, France.

Joanna Moulierac

Networks, 100h ETD, Niveau L1, IUT Nice Côte d'Azur, UNS;

Algorithmics, 30h ETD, Niveau L1, IUT Nice Côte d'Azur, UNS;

Algorithmics, 30h ETD, Niveau L2, IUT Nice Côte d'Azur, UNS.

Andrea Tomassilli

Informatique théorique 2, 24h, Niveau L3, Polytech Nice Sophia.

Introduction to UNIX and Linux, 12h, Niveau L3, Polytech Nice Sophia.

Michel Syska

Operating Systems: Advanced Programming, 90h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Data Structures and Algorithms, 54h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Algorithmics, 51h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Distributed Programming, 51h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Introduction to Algorithms and Complexity, 30h ETD, Level L3, IUT Nice Côte d'Azur, UNS;

IT foundations, 26h ETD, Level L1, IUT Nice Côte d'Azur, UNS;

Digital culture, 10h ETD, Level L3, IUT Nice Côte d'Azur, UNS.

Master

David Coudert

Algorithms for Telecoms, 32h ETD, stream UbiNet of Master 2 IFI and Master RIF, UNS;

Hamiltonian Cycles, 4h ETD, M2 MDFI, Aix-Marseille University, France.

Frédéric Giroire

Algorithmics of Telecommunications, 18h ETD, stream UbiNet of Master 2 IFI, UNS;

Green Networks, 18h ETD, stream UbiNet of Master 2 IFI, UNS;

Introduction to probability and statistics, 15h ETD, International Master 1, UNS.

Stéphane Pérennes

Calcul concurrent et distribué en Java, 60h ETD, Level M1, Miage, Polytech Nice Sophia.

Nicolas Nisse

Graph Algorithms, 18h ETD, stream UbiNet of Master 2 IFI and Master RIF, UNS;

Resolution Methods, 15h ETD, M1 international, UNS;

Matching and Graph decompositions, 4h ETD, M2 MDFI, Aix-Marseille University.

9.2.2. Supervision

9.2.2.1. Ph.D. theses

PhD: Nicolas Huin, *Energy efficient software defined networks* https://team.inria.fr/coati/phd-defense-of-nicolas-huin/, Université Côte d'Azur, September 28, 2017. Co-supervisors: Frédéric Giroire, Dino Lopez (Signet, I3S).

PhD in progress: Fionn McInerney, *Combinatorial Games in Graphs*, since October 2016. Supervisor: Nicolas Nisse.

PhD in progress: William Lochet, *Substructures in digraphs*, since September 2015. Co-supervisors: Frédéric Havet and Stéphan Thomassé (ÉNS Lyon).

PhD in progress: Yelena Yuditsky, School of Computer Science, McGill University. Supervisor: Bruce Reed.

PhD in progress: Andrea Tomassilli, *Diffusion of information on large dynamic graphs*, since October 2016. Supervisors: Stéphane Pérennes and Frédéric Giroire.

PhD in progress: Thibaud Trolliet, *Exploring Trust on Twitter*, since October 2017. Co-supervisors: Arnaud Legout (DIANA) and Frédéric Giroire.

PhD (stopped for reorientation): Steven Roumajon, *Les déterminants de la compétitivité régionale : données microéconomiques et réseaux d'innovation*, from November 2015 until June 2017. Co-supervisors: Patrick Musso (Gredeg) and Frédéric Giroire.

9.2.2.2. Internships

Rohit Agarwal

Date: from March 2017 until August 2017

Institution: stream UbiNet of Master 2 IFI, Université Nice-Sophia Antipolis (France)

Supervisors: Frédéric Giroire

Subject: Random graph models for directed social graphs like Twitter

Eleni Batziou

Date: from November 2017 until May 2018

Institution: Master 2, National Technical University of Athens (Greece)

Supervisors: David Coudert

Subject: Enhancing urban mobility with shared on-demand services

Thibaut Blanc

Date: from May 2017 until August 2017
Institution: Licence 3, École Normale Supérieure de Rennes (France)
Co-supervisors: Julien Bensmail, Frédéric Havet
Subject: BMRN-colouring of digraphs

Samir Idwy
Date: from April 2017 until August 2017
Institution: Master 2, Institut National des Postes et Télécommunications (Morocco)
Supervisors: David Coudert
Subject: Transports collectifs personnalisés dans la ville

Lokesh Jain
Date: from June 2017 until August 2017
Institution: Master 2, Birla Institute of Technology and Science (India)
Context: Google Summer of Code (GSoC) 2017
Co-supervisors: David Coudert, Dmitrii Pasechnik (University of Oxford, UK)
Subject: Modular decomposition of graphs in Sagemath

Marko Oleksiyenko
Date: from March 2017 until August 2017
Institution: stream UbiNet of Master 2 IFI, Université Nice-Sophia Antipolis (France)
Co-supervisors: David Coudert, Nicolas Nisse
Subject: 2-mode itinerary computation

Panagiotis Pylarinos
Date: from November 2016 until May 2017
Institution: Master 2, National and Kapodistrian University of Athens (Greece)
Supervisors: David Coudert
Subject: Inclusion of dynamic ride-sharing in multimodal trip planning

Maria Spyrakou
Date: from June 2017 until August 2017
Institution: Master 2, National and Kapodistrian University of Athens (Greece)
Context: Google Summer of Code (GSoC) 2017
Co-supervisors: David Coudert, Dmitrii Pasechnik (University of Oxford, UK)
Subject: Modular decomposition of directed graphs in Sagemath

Thibaud Trolliet
Date: from February 2017 until July 2017
Institution: Master 2, École Normale Supérieure de Lyon (France)
Co-supervisors: Frédéric Giroire, Stéphane Pérennes
Subject: Modélisation du graphe des suivis de Twitter

9.2.2.3. Last-year internships

Othmane Bensouda Korachi
Date: from November 2017 until December 2017
Institution: stream UbiNet of Master 2 IFI, UNS
Co-supervisors: Christelle Caillouet, Frédéric Giroire
Subject: Maintaining wireless sensor networks using drones and wireless power transfer

Laila Daanoun

Date: from November 2017 until December 2017

Institution: stream UbiNet of Master 2 IFI, UNS

Co-supervisors: Christelle Caillouet, Frédéric Giroire

Subject: Maintaining wireless sensor networks using drones and wireless power transfer

Mohamed Janati Idrissi

Date: from November 2017 until December 2017

Institution: stream UbiNet of Master 2 IFI, UNS

Co-supervisors: Christelle Caillouet, David Coudert

Subject: Mobile target covering for efficient aerial data gathering

Nirmal Vadakke Palangatt

Date: from November 2017 until December 2017

Institution: stream UbiNet of Master 2 IFI, UNS

Co-supervisors: David Coudert, Nicolas Nisse

Subject: Routing in multimodal networks with bicycles

Mykhailo Zima

Date: from November 2017 until December 2017

Institution: stream UbiNet of Master 2 IFI, UNS

Co-supervisors: David Coudert, Nicolas Nisse

Subject: Routing in multimodal networks with bicycles

Weilin Zhou

Date: from November 2017 until December 2017

Institution: stream UbiNet of Master 2 IFI, UNS

Co-supervisors: Frédéric Giroire, Joanna Moulierac

Subject: Optimization methods for network slicing

9.2.3. Juries

Jean-Claude Bermond

President of the jury for the 2017 award "Charles Delorme" for the best PhD thesis in graph theory (http://gtgraphes.labri.fr/pmwiki/pmwiki.php/PrixTheseDelorme/);

Member of the jury Robertval (http://prixroberval.utc.fr/).

David Coudert :

Referee and member of the PhD jury of Lorenzo Severini, GSSI, L'Aquila, Italy, April 20, 2017;

President of the PhD jury of Guillaume Perez, Université Côte d'Azur, September 29, 2017;

External referee in the PhD thesis monitoring committee of M. Amine Ait-Ouahmed, Université d'Avignon et des Pays de Vaucluse, October 27, 2017;

External referee for authorizing Fen Zhou to enroll in the HDR program, Université d'Avignon et des Pays de Vaucluse, November 2017.

Frédéric Giroire

Member of the PhD jury of Radu Carpa, ÉNS Lyon and Univ. Lyon, October 26, 2017;

Member of the PhD jury of Nicolas Huin, Université Côte d'Azur, September 28, 2017.

Frédéric Havet

Referee and member of the PhD jury of Lucas Pastor, Université Grenoble Alpes, November 23, 2017.

Nicolas Nisse

Member of the PhD jury of Pedro Montealegre, Univ. Orléans, February 28, 2017;

Member of the PhD jury of Sylvain Legay, Univ. Paris Saclay, March 1, 2017;

Referee and member of the PhD jury of Noël Gillet, Université Bordeaux, March 10, 2017;

Referee and member of the PhD jury of Antoine Naudin, Aix-Marseille Université, October 25, 2017.

9.2.4. Teaching responsibilities

Joanna Moulierac

"Directrice d'études" for the 1st-year students of IUT Nice Côte d'Azur, Département Informatique (since September 2017).

9.3. Popularization

Jean-Claude Bermond

Gave a talk "50 years of passion trying to solve delectable problems about graphs and networks" on March 24 during a seminar C@fé ADSTIC organized by the ADSTIC (Doctoral Association of the SophiaTech campus).

Nathann Cohen and David Coudert

Article "le défi des 1001 graphes" [61] relating how we addressed (and won) the Flinders Hamiltonian Cycle Project Challenge. Published in Interstices on December 12, 2017.

Frédéric Havet

Co-organised the "Village des Sciences" of Vinon-sur-Verdon, France, October 9-14, 2017. Gave many talks and animated several stands during the whole week;

Animated a stand "Mathémagie" at the "Village des Sciences" of Aix-en-Provence, October 8, 2017;

Organised the "Science Tour" at Rians, January 25-28, 2017. Animated several stands during the four days;

Gave the conferences "Beauty in Mathematics", "Le métier de chercheur", "La science du ballon de football" to five classes of the International School of Manosque, France, during the "Semaine des Mathématiques", March 13-19, 2017;

Gave an interactive conference and animated stands about "Becs, pattes et plumes des oiseaux" and " Nids des oiseaux" to four classes at Rians elementary school, France, January 9 and March 23, 2017;

Gave the conference "Élégance en Mathématiques" at Valgaudemar, France, July 6, 2017;

Frédéric Havet, Joanna Moulierac

Supervised the one-week internship of two 3eme schoolboys.

Nicolas Nisse

Co-organized (with "Les petits débrouillards", see http://www.lespetitsdebrouillards.org/) series of animations for a group of schoolboys, Inria Sophia Antipolis, July 20, 2017;

Animated, during "Fête de la Science", several stands during the "Village des Sciences" at Vinon-sur-Verdon, France, October 10-13, 2017;

Animated, during "Fête de la Science", several stands in Palais des Congrès de Juan-Les-Pins, October 7-8, 2017;

Realization of series of posters for scientific popularization [62], [63], [64], [65];

Member of MASTIC (Médiation et Animation scientifiques Inria, see https://project.inria.fr/mastic/).

Frédéric Havet, Joanna Moulierac, Nicolas Nisse

Involved in the GALEJADE project supported by Fondation Blaise Pascal. The main objective of this project is to develop a series of games for initiating schoolchildren to graphs and algorithms, and to put them in a pedagogical kit and on the web.

10. Bibliography

Major publications by the team in recent years

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