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Activity Report 2016

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

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

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1. Members

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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 WDM, wireless (radio), satellite, overlay, 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, transportation networks and economics.

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, 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. More precisely, we plan to 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.

4. Application Domains

4.1. Telecommunication Networks

COATI is mostly interested in telecommunications networks. Within this domain, we consider applications that follow the needs and interests of our industrial partners, in particular Orange Labs or Nokia Bell-Labs, but also SME like 3-Roam.

We focus on the design and management of heterogeneous 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.).

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 have recently started a collaboration in Structural Biology with EPI ABS (Algorithms Biology Structure) from Sophia Antipolis (described in Section 7.2). Furthermore, we are working on robot moving problems coming from Artificial Intelligence/Robotic in collaboration with Japan Advanced Institute of Science and Technology. In the area of transportation networks, we have started a collaboration with Amadeus on complex trip planning, and a collaboration with SME Instant-System on dynamic car-pooling combined with multi-modal transportation systems. Last, we have started a collaboration with GREDEG (Groupe de Recherche en Droit, Economie et Gestion, Univ. Nice Sophia Antipolis) on the analysis and the modeling of systemic risks in networks of financial institutions.

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).

Fatima Zahra Moataz, former PhD student of COATI, is the recipient of an accessit to the PhD prize Graphes “Charles Delorme” 2016 for her PhD thesis entitled “Towards Efficient and Fault-Tolerant Optical Networks: Complexity and Algorithms”.

6. New Software and Platforms

6.1. BigGraphs

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.

- Participants: Luc Hogie, Nicolas Chleq, David Coudert, Michel Syska.
- Partner: This project is a joint work of the three EPI COATI, DIANA and SCALE and is supported by an ADT grant.
- Contact: Luc Hogie
- URL : http://www.i3s.unice.fr/~hogie/biggrph/

ADDITIONAL SOFTWARES

The following software are useful tools that bring basic services to the platform (they are not dedicated to BIGGRPH). Participants : Luc Hogie, Nicolas Chleq

- JAC-A-BOO is a framework aiming at facilitating the deployment and the bootstrapping of distributed Java applications over Share-Nothing Clusters (SNCs). The primary motivation for developing JAC-A-BOO is to have an efficient and comprehensive deployment infrastructure for the BIGGRPH distributed graph library. http://www.i3s.unice.fr/~hogie/jacaboo
- LDJO (Live Distributed Java Objects) is a framework for the development and the deployment of Java distributed data structures. Alongside with data aspect of distributed data structures, LDJO comes with mechanisms for processing them in a distributed/parallel way. In particular it provides implementations of Map/Reduce and Bulk Synchronous Parallel (BSP). http://www.i3s.unice.fr/~hogie/ldjo
- OCTOJUS provides an object-oriented RPC (Remote Procedure Call) implementation in Java. At a higher abstraction level, OCTOJUS provides a framework for the development of systolic algorithms, a batch scheduler, as well as an implementation of Map/Reduce. The latter is used in the BIGGRPH graph computing platform. http://www.i3s.unice.fr/~hogie/octojus

6.2. GRPH

The high performance graph library for Java
FUNCTIONAL DESCRIPTION

GRPH is an open-source Java library for the manipulation of graphs. Its main design objectives are to make it simple to use and extend, 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 solvers, a framework for distributed computing, etc.

GRPH achieves great efficiency through the use of multiple code optimization techniques such as multi-core parallelism, caching, performant data structures and use of primitive objects, interface to CPLEX linear solver, exploitation of low-level processor caches, on-the-fly compilation of specific C/C++ code, etc.

Unlike other graph libraries which impose the user to first decide if he wants to deal with directed, undirected, hyper (or not) graph, the model offered by GRPH is unified in a very general class that supports mixed graphs made of undirected and directed simple or hyper edges.

We have identified more than 600 users of GRPH since 2013. Inside Inria we collaborate with the AOSTE EPI, for example we recently added a new algorithm (proposed by N. Cohen / LRI) for iterating over the cycles of a given graph in the TimeSquare tool. We also have integrated the discrete-events simulation engine of DRMSIM and some dynamic models (evolution of the connectivity with the mobility of nodes) to GRPH. GRPH includes bridges to other graph libraries such as JUNG, JGraphT, CORESE (a software developed by the WIMMICS team Inria-I3S), LAD (C. Solnon, LIRIS), Nauty (B. D. McKay) or Sagemath. L. Viennot has proposed an implementation of the 4-sweep diameter algorithm designed at LIAFA .

- Participants: Luc Hogie, Nathann Cohen, David Coudert and Michel Syska.
- Contact: Luc Hogie
- URL: http://www.i3s.unice.fr/~hogie/grph/

6.3. Sagemath

SageMath
SageMath is a free open-source mathematics software system, initially created by William Stein (Professor of mathematics at Washington University), and now maintained by a large community of contributors. 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.
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: Jean-Claude Bermond, Christelle Caillouet, David Coudert, Frédéric Giroire, Nicolas Huin, 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.

We mainly focus on three topics: firstly Fixed wireless Backhaul Networks, with the objective of achieving a high reliability of the network. Secondly, Software-Defined networks, in which 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. Finally, the third topic investigated is Energy Efficiency within Backbone networks and for content distribution. We focus on Redudancy Elimination, and we use SDN as a tool to turn-off the links in real networks. We validated our algorithms on a real SDN platform [1].

7.1.1. Fault tolerance

7.1.1.1. Survivability in networks with groups of correlated failures

The notion of Shared Risk Link Groups (SRLG) captures survivability issues when a set of links of a network may fail simultaneously. The theory of survivable network design relies on basic combinatorial objects that are rather easy to compute in the classical graph models: shortest paths, minimum cuts, or pairs of disjoint paths. In the SRLG context, the optimization criterion for these objects is no longer the number of edges they use, but the number of SRLGs involved. Unfortunately, computing these combinatorial objects is NP-hard and hard to approximate with this objective in general. Nevertheless some objects can be computed in polynomial time when the SRLGs satisfy certain structural properties of locality which correspond to practical ones, namely the star property (all links affected by a given SRLG are incident to a unique node) and the span 1 property (the links affected by a given SRLG form a connected component of the network). The star property is defined in a multi-colored model where a link can be affected by several SRLGs while the span property is defined only in a mono-colored model where a link can be affected by at most one SRLG. We have extended in [23] these notions to characterize new cases in which these optimization problems can be solved in polynomial time. We have also investigated the computational impact of the transformation from the multi-colored model to the mono-colored one. Reported experimental results validate the proposed algorithms and principles.

7.1.1.2. Reliability of fixed wireless backaul 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. In [48], we provide 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 each leaf in the tree requires a valid routing for the network. Any such tree provides an upper and lower bound 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. We perform a computational study demonstrating that the proposed methods can calculate reliability of large backhaul networks, and can optimize topology for modest size networks.

7.1.1.3. Fault tolerance of Linear Access Network

In [52], 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, we analyze the probability for a user to experience a disconnection longer than a threshold t_*, leading to a disruption of all on-going communications between the vehicle and the infrastructure network. We provide an approximation formula to estimate this probability for large networks. We then carry out a sensitivity analysis and supply a guide for operators when choosing the parameters of the networks. We focus on two scenarios: an intercity bus and an intercity train. Last, we show that such systems are viable, as they attain a very low probability of long disconnections with a very low maintenance cost.

[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.

7.1.2. Routing in 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.

7.1.2.1. MINNIE: an SDN World with Few Compressed Forwarding Rules

While SDN brings flexibility in 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. In [34], [54], we investigate 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 entry 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 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 ASICs. Hence, both simulations and experimental results suggest that MINNIE can be safely deployed in real networks, providing compression ratios between 70% and 99%.

7.1.2.2. Energy-Aware Routing in Software-Defined Networks

In [51], we focus on using SDN for energy-aware routing (EAR). Since traffic load has a small influence on power consumption of routers, EAR allows to put unused devices into sleep mode to save energy. SDN can collect traffic matrix and then computes routing solutions satisfying QoS while being minimal in energy consumption. However, prior works on EAR have assumed that the forwarding table of OpenFlow switch can hold an infinite number of rules. In practice, this assumption does not hold since such flow tables are implemented in Ternary Content Addressable Memory (TCAM) which is expensive and power-hungry. We consider the use of wildcard rules to compress the forwarding tables. In this paper, we propose optimization methods to minimize energy consumption for a backbone network while respecting capacity constraints on links and rule space constraints on routers. In details, we present two exact formulations using Integer Linear Program (ILP) and introduce efficient heuristic algorithms. Based on simulations on realistic network topologies, we show that, using this smart rule space allocation, it is possible to save almost as much power consumption as the classical EAR approach

7.1.3. Reducing Networks' Energy Consumption

Due to the increasing impact of ICT (Information and Communication Technology) on power consumption and worldwide gas emissions, energy efficient ways to design and operate backbone networks are becoming a new concern for network operators. Recently, energy-aware routing (EAR) has gained an increasing popularity in the networking research community. The idea is that traffic demands are redirected over a subset of the network devices, allowing other devices to sleep to save energy. We studied variant of this problems.

7.1.3.1. Energy efficient Content Distribution

To optimize energy efficiency in network, operators try to switch off as many network devices as possible. Recently, there is a trend to introduce content caches as an inherent capacity of network equipment, with the objective of improving the efficiency of content distribution and reducing network congestion. In [36], we study the impact of using in-network caches and CDN cooperation on an energy-efficient routing. We formulate this problem as Energy Efficient Content Distribution. The objective is to find a feasible routing, so that the total energy consumption of the network is minimized subject to satisfying all the demands and link capacity. We exhibit the range of parameters (size of caches, popularity of content, demand intensity, etc.) for which caches are useful. Experiment results show that by placing a cache on each backbone router to store the most popular content, along with well choosing the best content provider server for each demand to a CDN, we can save a total up to 23% of power in the backbone, while 16% can be gained solely thanks to caches.

7.1.3.2. Energy-Efficient Service Function Chain Provisioning

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. This is of primary interest to implement energy efficient solutions, which imply to adapt dynamically the resource usage to the demands. In [53], [55], 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.

7.1.4. Other results

7.1.4.1. Well Balanced design for Data placement

The have considered in [17] a problem motivated by data placement, in particular data replication in distributed storage and retrieval systems. We are given a set V of v servers along with b files (data, documents). Each file is replicated on exactly k servers. A placement consists in finding a family of b subsets of V (representing the files) called blocks, each of size k. Each server has some probability to fail and we want to find a placement which minimizes the variance of the number of available files. It was conjectured that there always exists an optimal placement (with variance better than that of any other placement for any value of the probability of failure). We show that the conjecture is true, if there exists a well balanced design, that is a family of blocks, each of size k, such that each j-element subset of V , $1 \leq j \leq k$, belongs to the same or almost the same number of blocks (difference at most one). The existence of well balanced designs is a difficult problem as it contains as a subproblem the existence of Steiner systems. We completely solve the case $k = 2$ and give bounds and constructions for $k = 3$ and some values of v and b.

7.1.4.2. Study of Repair Protocols for Live Video Streaming Distributed Systems

In [33], we study distributed systems for live video streaming. These systems can be of two types: structured and un-structured. In an unstructured system, the diffusion is done opportunistically. The advantage is that it handles churn, that is the arrival and departure of users, which is very high in live streaming systems, in a smooth way. On the opposite, in a structured system, the diffusion of the video is done using explicit diffusion trees. The advantage is that the diffusion is very efficient, but the structure is broken by the churn. In this paper, we propose simple distributed repair protocols to maintain, under churn, the diffusion tree of a structured streaming system. We study these protocols using formal analysis and simulation. In particular, we provide an estimation of the system metrics, bandwidth usage, delay, or number of interruptions of the streaming. Our work shows that structured streaming systems can be efficient and resistant to churn.

7.1.4.3. Gathering in radio networks

In [16], we consider the problem of gathering information in a gateway in a radio mesh access network. Due to interferences, calls (transmissions) cannot be performed simultaneously. This leads us to define a round as a set of non-interfering calls. Following the work of Klasing, Morales and Pérennes, we model the problem as a Round Weighting Problem (RWP) in which the objective is to minimize the overall period of non-interfering calls activations (total number of rounds) providing enough capacity to satisfy the throughput demand of the nodes. We develop tools to obtain lower and upper bounds for general graphs. Then, more precise results are obtained considering a symmetric interference model based on distance of graphs, called the distance-d interference model (the particular case d = 1 corresponds to the primary node model). We apply the presented tools to get lower bounds for grids with the gateway either in the middle or in the corner. We obtain upper bounds which in most of the cases match the lower bounds, using strategies that either route the demand of a single node or route simul- taneously flow from several source nodes. Therefore, we obtain exact and constructive results for grids, in particular for the case of uniform demands answering a problem asked by Klasing, Morales and Pérennes.

7.2. Graph Algorithms

Participants: Jean-Claude Bermond, Nathann Cohen, David Coudert, Guillaume Ducoffe, Frédéric Giroire, Nicolas Nisse, Stéphane Pérennes.

COATI is also 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. In particular, we try to find the most efficient algorithms to solve the problems, sometimes focusing on specific graph classes from which the problems are polynomial-time solvable. Many results introduced here are presented in detail in the PhD thesis of Guillaume Ducoffe on *Metric properties of large graphs* https://team.inria.fr/coati/phd-defense-of-guillaume-ducoffe/.

7.2.1. Graph decompositions

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.

7.2.1.1. Width parameters of graphs

In [22], we design a Branch and Bound algorithm that computes the exact pathwidth of graphs and a corresponding path-decomposition. Our main contribution consists of several non-trivial techniques to reduce the size of the input graph (pre-processing) and to cut the exploration space during the search phase of the algorithm. We evaluate experimentally our algorithm by comparing it to existing algorithms of the literature. It appears from the simulations that our algorithm offers a significative gain with respect to previous work. In particular, it is able to compute the exact pathwidth of any graph with less than 60 nodes in a reasonable running-time (10 min.). Moreover, our algorithm also achieves good performance when used as a heuristic (i.e., when returning best result found within bounded time-limit). Our algorithm is not restricted to undirected graphs since it actually computes the vertex-separation of digraphs (which coincides with the pathwidth in case of undirected graphs).

Many tree-decomposition-like parameters are related to particular layouts (ordering) of the vertices of the input graph. In [45], we present a new set of constraints for modeling linear ordering problems on graphs using Integer Linear Programming (ILP). These constraints express the membership of a vertex to a prefix rather than the exact position of a vertex in the ordering. We use these constraints to propose new ILP formulations for well-known linear ordering optimization problems, namely the Pathwidth, Cutwidth, Bandwidth, SumCut and Optimal Linear Arrangement problems. Our formulations are not only more compact than previous proposals, but also more efficient as shown by our experimental evaluations on large benchmark instances.

7.2.1.2. Metric properties of graph decompositions

The decomposition of graphs by clique-minimal separators is a common algorithmic tool, first introduced by Tarjan. Since it allows to cut a graph into smaller pieces, it can be applied to pre-process the graphs in the computation of many optimization problems. However, the best known clique-decomposition algorithms have respective $O(nm)$-time and $O(n^{2.69})$-time complexity, that is prohibitive for large graphs. Here we prove that for every graph G, the decomposition can be computed in $O(T(G) + \min\{n^{2.3729}, \omega^2 n\})$-time with $T(G)$ and ω being respectively the time needed to compute a minimal triangulation of G and the clique-number of G. In particular, it implies that every graph can be clique-decomposed in $O(n^{2.3729})$-time. Based on prior work from Kratsch et al., in [46], we prove in addition that computing the clique-decomposition is at least as hard as triangle detection. Therefore, the existence of any $o(n^{2.3729})$-time clique-decomposition algorithm would be a significant breakthrough in the field of algorithmic. Finally, our main result implies that planar graphs, bounded-treewidth graphs and bounded-degree graphs can be clique-decomposed in linear or quasi-linear time.

In [21], we establish general relationships between the topological properties of graphs and their metric properties. For this purpose, we upper-bound the diameter of the *minimal separators* in any graph by a function of their sizes. More precisely, we prove that, in any graph G, the diameter of any minimal separator S in G is at most $\lfloor \frac{\ell(G)}{2} \rfloor \cdot (|S| - 1)$ where $\ell(G)$ is the maximum length of an isometric cycle in G. We refine this bound in the case of graphs admitting a *distance preserving ordering* for which we prove that any minimal separator S has diameter at most $2(|S| - 1)$. Our proofs are mainly based on the property that the minimal separators in a graph G are connected in some power of G. Our result easily implies that the *treelength* $tl(G)$ of any graph G is at most $\lfloor \frac{\ell(G)}{2} \rfloor$ times its *treewidth* $tw(G)$. In addition, we prove that, for any graph G that excludes an *apex graph* H as a minor, $tw(G) \leq c_H \cdot tl(G)$ for some constant c_H only depending on H. We refine this constant when G has bounded genus. As a consequence, we obtain a very simple $O(\ell(G))$-approximation algorithm for computing the treewidth of n-node m-edge graphs that exclude an apex graph as a minor in $O(nm)$-time.

In [32], [50], we study metric properties of the bags of tree-decompositions of graphs. Roughly, the length and the breadth of a tree-decomposition are the maximum diameter and radius of its bags respectively. The treelength and the treebreadth of a graph are the minimum length and breadth of its tree-decompositions respectively. Pathlength and pathbreadth are defined similarly for path-decompositions. In this paper, we answer open questions of [Dragan and Köhler , Algorithmica 2014] and [Dragan, Köhler and Leitert, SWAT 2014] about the computational complexity of treebreadth, pathbreadth and pathlength. Namely, we prove that computing these graph invariants is NP-hard. We further investigate graphs with treebreadth one, i.e., graphs that admit a tree-decomposition where each bag has a dominating vertex. We show that it is NP-complete to decide whether a graph belongs to this class. We then prove some structural properties of such graphs which allows us to design polynomial-time algorithms to decide whether a bipartite graph, resp., a planar graph, has treebreadth one.

7.2.2. 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.

Topologies for data center networks have been proposed in the literature through various graph classes and operations. A common trait to most existing designs is that they enhance the symmetric properties of the underlying graphs. Indeed, symmetry is a desirable property for interconnection networks because it minimizes congestion problems and it allows each entity to run the same routing protocol. However, despite sharing similarities these topologies all come with their own routing protocol. Recently, generic routing schemes have been introduced which can be implemented for any interconnection networks. The performances of such universal routing schemes are intimately related to the hyperbolicity of the topology. Motivated by the good performances in practice of these new routing schemes, we propose in [19], [29] the first general study of the hyperbolicity of data center interconnection networks. Our findings are disappointingly negative: we prove that the hyperbolicity of most data center topologies scales linearly with their diameter, that it the worst-case possible for hyperbolicity. To obtain these results, we introduce original connection between hyperbolicity and the properties of the endomorphism monoid of a graph. In particular, our results extend to all vertex and edge-transitive graphs. Additional results are obtained for de Bruijn and Kautz graphs, grid-like graphs and networks from the so-called Cayley model.

In [20], we investigate more specifically on the hyperbolicity of bipartite graphs. More precisely, given a bipartite graph $B = (V_0 \cup V_1, E)$ we prove it is enough to consider any one side V_i of the bipartition of B to obtain a close approximate of its hyperbolicity $\delta(B)$ — up to an additive constant 2. We obtain from this result the sharp bounds $\delta(G) - 1 \leq \delta(L(G)) \leq \delta(G) + 1$ and $\delta(G) - 1 \leq \delta(K(G)) \leq \delta(G) + 1$ for every graph G, with $L(G)$ and $K(G)$ being respectively the line graph and the clique graph of G. Finally, promising extensions of our techniques to a broader class of intersection graphs are discussed and illustrated with the case of the biclique graph $BK(G)$, for which we prove $(\delta(G) - 3)/2 \leq \delta(BK(G)) \leq (\delta(G) + 3)/2$.

7.2.3. Combinatorial games on graphs

We study several two-player games on graphs.

7.2.3.1. Games and graph decompositions

Graph Searching is a game where a team of searchers aims at capturing a fugitive in a graph. Graph Searching games have been widely studied because they are an algorithmic interpretation of tree/path-decompositions of graphs.

In [18], we define a new variant of graph searching, where searchers have to capture an invisible fugitive with the constraint that no two searchers can occupy the same node simultaneously. This variant seems promising for designing approximation algorithms for computing the pathwidth of graphs. The main contribution in [18] is the characterization of trees where k searchers are necessary and sufficient to win. Our characterization leads to a polynomial-time algorithm to compute the minimum number of searchers needed in trees.

We also study graph searching in directed graphs. We prove that the graph processing variant is monotone which allows us to show its equivalence with a particular digraph decomposition [25].

7.2.3.2. Distributed computing

We also investigate the games described above in a distributed setting.

Consider a set of mobile robots with minimal capabilities placed over distinct nodes of a discrete anonymous ring. Asynchronously, each robot takes a snapshot of the ring, determining 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. The computation also depends on the required task. In [24], 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 minimal assumptions.

7.2.3.3. Spy games in graphs

In [28], 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 node. 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 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). First, we consider the computational complexity of the problem, showing that it is NP-hard and that it is PSPACE-hard in DAGs. Then, we establish tight tradeoffs between the number k of guards and the required distance d when G is a path or a cycle. Our main result is that there exists $\beta > 0$ such that $\Omega(n^{1+\beta})$ guards are required to win in any $n \times n$ grid.

7.2.4. 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.

7.2.4.1. Bin packing

Motivated by an assignment problem arising in MapReduce computations , we investigate a generalization of the Bin Packing problem which we call Bin Packing with Colocations Problem [41]. Given a set V of items with positive integer weights, an underlying graph G = (V, E), and an integer q, the goal is to pack the items into a minimum number of bins so that (i) the total weight of the items packed in every bin is at most q, and (ii) for each edge (i, j) ∈ E there is at least one bin containing both items i and j. We first show that when the underlying graph is unweighted (i.e., all the items have equal weights), the problem is equivalent to the q-clique problem, and when furthermore the underlying graph is a clique, optimal solutions are obtained from covering designs. We prove that the problem becomes NP-hard even for weighted paths and un-weighted trees and we propose approximation algorithms for particular families of graphs, including: a $(3+\sqrt{5})$-approximate algorithm for weighted complete graphs (improving a previous 8-approximation), a 2-approximate algorithm for weighted paths, a 5-approximate algorithm for weighted trees, and an (1+)-approximate algorithm for unweighted trees. For general weighted graphs, we propose a 3 + 2mad(G)/2-approximate algorithm, where mad(G) is the maximum average degree of G. Finally, we show how to convert any ρ-approximation algorithm for the Bin Packing (resp. the Densest q-Subgraph problem) into an approximation algorithm for the problem on weighted (resp. unweighted) general graphs.

7.2.4.2. distance preserving ordering

For every connected graph G, a subgraph H of G is isometric if for every two vertices $x, y \in V(H)$ there exists a shortest xy-path of G in H. A distance-preserving elimination ordering of G is a total ordering of its vertex-set $V(G)$, denoted $(v_1, v_2, \cdots, v_n)$, such that any subgraph $G - i = G \setminus \{v_1, v_2, \cdots, v_i\}$ with $1 \leq i < n$ is isometric. This kind of ordering has been introduced by Chepoi in his study on weakly modular graphs. In [47], we prove that it is NP-complete to decide whether such ordering exists for a given graph — even if it has diameter at most 2. Then, we describe a heuristic in order to compute a distance-preserving ordering when it exists one that we compare to an exact exponential algorithm and an ILP formulation for the problem. Lastly, we prove on the positive side that the problem of computing a distance-preserving ordering when it exists one is fixed-parameter-tractable in the treewidth.

7.2.4.3. cycle convexity

Many notions in graph convexity have been defined and studied for various applications, such as geode-tic convexity (generalizing the classical convexity in Euclidean space to graphs), monophonic convexity (to model spreading of rumor or disease in a network), etc. Each of the convexity notions led to the study of important graph invariants such as the hull number (minimum number of vertices whose hull set is the entire graph) or the interval number (minimum number of vertices whose interval is the whole graph). Recently, Araujo et al. introduced the notion of Cycle Convexity of graphs for its application in Knot Theory. Roughly, the tunnel number of a knot embedded in a plane is equivalent to the hull number of a corresponding planar 4-regular graph in cycle convexity. In [35], we study the interval number of a graph in cycle convexity. Precisely, given a graph G, its interval number in cycle convexity, denoted by incc(G), is the minimum cardinality of a set $S \subseteq V(G)$ such that every vertex $w \in V(G) \setminus S$ has two distinct neighbors $u, v \in S$ such that u and v lie in same connected component of $G[S]$. In this work, first we provide bounds on incc(G) and its relations to other graph convexity parameters, and explore its behavior on grids. Then, we present some hardness results by showing that deciding whether $incc(G) \leq k$ is NP-complete, even if G is a split graph or a bounded-degree planar graph, and that the problem is W[1]-hard in bipartite graphs when k is the parameter. As a consequence, we obtain that it cannot be approximated up to a constant factor in the class of split graphs (unless P = N P). On the positive side, we present polynomial-time algorithms to compute incc(G) for outerplanar graphs, cobipartite graphs and interval graphs. We also present FPT algorithms to compute it for (q, q - 4)-graphs, where q is the parameter and for bounded treewidth graphs.

7.3. Graph theory

Participants: Nathann Cohen, Guillaume Ducoffe, Frédéric Havet, William Lochet, Nicolas Nisse.

Coati also 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 digraphs

7.3.1.1. Arc-disjoint branching flows

The concept of arc-disjoint flows in networks was introduced by Bang-Jensen and Bessy [Theoret. Comput. Science 526, 2014]. This is a very general framework within which many well-known and important problems can be formulated. In particular, the existence of arc-disjoint branching flows, that is, flows which send one unit of flow from a given source s to all other vertices, generalizes the concept of arc-disjoint out-branchings (spanning out-trees) in a digraph. A pair of out-branchings $B^+_{s,1}, B^+_{s,2}$ from a root s in a digraph $D = (V, A)$ on n vertices corresponds to arc-disjoint branching flows x_1, x_2 (the arcs carrying flow in x_i are those used in $B^+_{s,i}$, $i = 1, 2$) in the network that we obtain from D by giving all arcs capacity $n - 1$. It is then a natural question to ask how much we can lower the capacities on the arcs and still have, say, two arc-disjoint branching flows from the given root s. In [15], we prove that for every fixed integer $k \geq 2$ it is

- an NP-complete problem to decide whether a network $\mathcal{N} = (V, A, u)$ where $u_{ij} = k$ for every arc ij has two arc-disjoint branching flows rooted at s.
- a polynomial problem to decide whether a network $\mathcal{N} = (V, A, u)$ on n vertices and $u_{ij} = n - k$ for every arc ij has two arc-disjoint branching flows rooted at s.

The algorithm for the later result generalizes the polynomial-time algorithm, due to Lovász, for deciding whether a given input digraph has two arc-disjoint out-branchings rooted at a given vertex. Finally we prove that under the so-called Exponential Time Hypothesis (ETH), for every $\epsilon > 0$ and for every $k(n)$ with $(\log(n))^{1+\epsilon} \leq k(n) \leq \frac{n}{2}$ (and for every large i we have $k(n) = i$ for some n) there is no polynomial algorithm for deciding whether a given digraph contains two arc-disjoint branching flows from the same root so that no arc carries flow larger than $n - k(n)$.

7.3.1.2. Subdivision of oriented cycles

An *oriented cycle* is an orientation of a undirected cycle. In [43], [27], we first show that for any oriented cycle C, there are digraphs containing no subdivision of C (as a subdigraph) and arbitrarily large chromatic number. In contrast, we show that for any cycle C with two blocks, every strongly connected digraph with sufficiently large chromatic number contains a subdivision of C. This settles a conjecture of Addario-Berry et al. [J. Combin. Theory B, 97, 2007]. More generally, we conjecture that this result holds for any oriented cycle. As a further evidence, we prove this conjecture for the antidirected cycle on four vertices (in which two vertices have out-degree 2 and two vertices have in-degree 2).

7.3.2. Colourings and partitioning (di)graphs

7.3.2.1. 2-partitions of digraphs

A *k-partition* of a (di)graph D is a partition of $V(D)$ into k disjoint sets. Let $\mathbb{P}_1, \mathbb{P}_2$ be two (di)graph properties, then a *$(\mathbb{P}_1, \mathbb{P}_2)$-partition* of a (di)graph D is a 2-partition (V_1, V_2) where V_1 induces a (di)graph with property $\mathbb{P}_1$ and V_2 a (di)graph with property $\mathbb{P}_2$. In [14], [13] and [38], [37], we give a complete characterization for the complexity of $(\mathbb{P}_1, mathbbP_2)$-partition problems when $\mathbb{P}_1, \mathbb{P}_2$ are one of the following standard properties: acyclic, complete, independent (no arcs), oriented (no directed 2-cycle), semicomplete, tournament, symmetric (if two vertices are adjacent, then they induce a directed 2-cycle), strongly connected, connected, minimum out-degree at least 1, minimum in-degree at least 1, minimum semi-degree at least 1, minimum degree at least 1, having an out-branching, having an in-branching. We also investigate the influence of strong connectivity of the input digraph on this complexity. In particular, we show that some NP-complete probems become polynomial-time solvable when restricted to strongly connected input digraphs.

7.3.2.2. χ-bounded families of oriented graphs

A famous conjecture of Gyárfás and Sumner states for any tree T and integer k, if the chromatic number of a graph is large enough, either the graph contains a clique of size k or it contains T as an induced subgraph. In [57], we discuss some results and open problems about extensions of this conjecture to oriented graphs. We conjecture that for every oriented star S and integer k, if the chromatic number of a digraph is large enough, either the digraph contains a clique of size k or it contains S as an induced subgraph. As an evidence, we prove that for any oriented star S, every oriented graph with sufficiently large chromatic number contains either a transitive tournament of order 3 or S as an induced subdigraph. We then study for which sets $\mathcal{P}$ of orientations of P_4 (the path on four vertices) similar statements hold. We establish some positive and negative results.

7.3.2.3. Locally irregular decompositions of subcubic graphs

A graph G is *locally irregular* if every two adjacent vertices of G have different degrees. A *locally irregular decomposition* of G is a partition $E_1, ..., E_k$ of $E(G)$ such that each $G[E_i]$ is locally irregular. Not all graphs admit locally irregular decompositions, but for those who are decomposable, in that sense, it was conjectured by Baudon, Bensmail, Przybylo and Wozniak that they decompose into at most 3 locally irregular graphs. Towards that conjecture, it was recently proved by Bensmail, Merker and Thomassen that every decomposable graph decomposes into at most 328 locally irregular graphs. In [39], we focus on locally irregular decompositions of subcubic graphs, which form an important family of graphs in this context, as all non-decomposable graphs are subcubic. As a main result, we prove that decomposable subcubic graphs decompose into at most 5 locally irregular graphs, and only 4 when the maximum average degree is less than 12/5. We then consider weaker decompositions, where subgraphs can also include regular connected components, and prove the relaxations of the conjecture above for subcubic graphs.

7.3.2.4. Orientation and edge-weigthing inducing colouring

An orientation of a graph G is *proper* if two adjacent vertices have different indegrees. The *proper-orientation number* of a graph G is the minimum maximum indegree of a proper orientation of G. In a previous paper, we raise the question whether the proper orientation number of a planar graph is bounded. In [12], we prove that every cactus admits a proper orientation with maximum indegree at most 7. We also prove that the bound 7 is tight by showing a cactus having no proper orientation with maximum indegree less than 7. We also prove that any planar claw-free graph has a proper orientation with maximum indegree at most 6 and that this bound can also be attained.

7.3.2.5. 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.

In [58], we study the existence of sum-distinguishing injective $|E(G)|$-edge-weightings. We conjecture that such an edge-weighting always exists (except from K_2). We prove this conjecture for some classes of graphs, such as trees and regular graphs. In addition, for some other classes of graphs, such as 2-degenerate graphs and graphs with maximum average degree at most 3, we prove that, provided we use a constant number of additional edge weights, the desired edge-weighting always exists. Our investigations are strongly related to several aspects of the well-known 1-2-3 Conjecture and the Antimagic Labelling Conjecture.

One of the variants consists in considering total-labelling rather than edge-weigthing. A *k-total-weighting* of a graph G is an application from $V(G) \cup E(G)$ into $\{1, \cdots, k\}$. An edge-weigthing is *sum-distinguishing* if for every two adajcent vertices u and v, the sum of of weights of u and the edges incident to u is distinct from the sum of weights of v and the edges incident to v. The 1-2 Conjecture raised by Przybylo, lo and Wozniak in 2010 asserts that every undirected graph admits a 2-total-weighting (both vertices and eedges receives weights) such that the sums of weights "incident" to the vertices yield a proper vertex-colouring. Following several recent works bringing related problems and notions (such as the well-known 1-2-3 Conjecture, and the notion of locally irregular decompositions) to digraphs, we introduce in [40] and study several variants of the 1-2 Conjecture for digraphs. For every such variant, we raise conjectures concerning the number of weights necessary to obtain a desired total-weighting in any digraph. We verify some of these conjectures, while we obtain close results towards the ones that are still open.

7.3.2.6. Colouring game

We wish to motivate the problem of finding decentralized lower-bounds on the complexity of computing a Nash equilibrium in graph games. While the centralized computation of an equilibrium in polynomial time is generally perceived as a positive result, this does not reflect well the reality of some applications where the game serves to implement distributed resource allocation algorithms, or to model the social choices of users with limited memory and computing power. As a case study, we investigate in [31] on the parallel complexity of a game-theoretic variation of graph colouring. These “colouring games" were shown to capture key properties of the more general welfare games and Hedonic games. On the positive side, it can be computed a Nash equilibrium in polynomial-time for any such game with a local search algorithm. However, the algorithm is time-consuming and it requires polynomial space. The latter questions the use of colouring games in the modeling of information-propagation in social networks. We prove that the problem of computing a Nash equi- librium in a given colouring game is PTIME-hard, and so, it is unlikely that one can be computed with an efficient distributed algorithm. The latter brings more insights on the complexity of these games.

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 i G. It *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.

Particular interest was dedicated to grids as many processor networks have a grid topology. There are three types of regular infinite grids in the plane, namely the hexagonal grids, the square grids and the triangular grids. In [26], [42], we study the square grid $\mathcal{S}_k)$ with infinite width and bounded height k. We prove that the minimum density of an identifying code in $\mathcal{S}_k$ is at least $\frac{7}{20} + \frac{1}{20k}$ and at most $\frac{7}{20} + \frac{3}{10k}$. We also establish that the minimum density of a code in an infinite square grid of height 3 is $\frac{7}{18}$. In [49], [30], we study the minimum density $d^*(\mathcal{T}_k)$ of the triangular grid $\mathcal{S}_k)$ with infinite width and bounded height k. We prove that $d^*(T_k) = \frac{1}{4} + \frac{1}{4k}$ for every odd k and $\frac{1}{4} + \frac{1}{4k} \leq d^*(T_k) \leq \frac{1}{4} + \frac{1}{2k}$ for every even k. We also prove $d^*(T_2) = \frac{1}{2}$ and $d^*(T_4) = d^*(T_6) = \frac{1}{3}$. All these proofs are made using the discharging method, which seems not have been very rarely used for such problems whereas it applies very well.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Grants with Industry

8.1.1. Allocation Carnot Inria / Instant System

Participants: David Coudert, Idriss Hassine.

The Instant System startup company develop a platform in the area of Intelligent transportation systems (ITS). The partnership with COATI aims at designing algorithms for itinerary planning in multimodal transportation networks. The main objective is to combine public transport system and dynamic car-pooling.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

9.1.1.1. ANR Blanc STINT, 2014-2017

Participants: Pierre Aboulker, 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 is 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 will firstly establish bounds on some classical graph parameters (e.g., clique number, stability number, chromatic number) for ψ-free graphs. Then, it will design efficient algorithms to recognize ψ-free graphs and to determine or approximate some parameters for those graphs. These studies shall result in the development of new proof techniques.

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

9.1.2. PEPS

9.1.2.1. PEPS MoMis SYSTEMIC, 2015 (extended in 2016)

Participant: Frédéric Giroire.

The SYSTEMIC project was led by COATI and involves the LAMA (Paris Est), GREDEG (Sophia Antipolis) and CREM (Rennes) laboratories.

The aim of SYSTEMIC was to bring together the expertises of researchers in economics, graph theory and financial mathematics to propose new models to evaluate the systemic risk of networks of financial institutions, and to propose new methods to mitigate the risk of contagions in such networks. The novelty of the project was in particular to consider strategies for a dynamic control of heterogeneous networks.

9.1.3. GDR Actions

9.1.3.1. Action ResCom, ongoing (since 2006)

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

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

9.1.3.2. Action Graphes, ongoing (since 2006)

Action Graphes, working group of GDR IM, CNRS.

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

9.2. European Initiatives

9.2.1. Collaborations with Major European Organizations

AOR (Vassilis Zissimopoulos) : University of Athens, Department of Informatics and Telecommunications (Greece)

Combinatorial Optimization, Games and Applications (COGA), June 2015- September 2016

Participants : Jean-Claude Bermond, David Coudert, Frédéric Giroire, Nicolas Nisse, Stéphane Pérennes

9.3. International Initiatives

9.3.1. Inria International Labs

Inria Chile

Associate Team involved in the International Lab:

9.3.1.1. ALDYNET

Title: distributed ALgorithms for DYnamic NETworks

International Partner (Institution - Laboratory - Researcher):

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

Start year: 2016

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

This associated team would be the natural continuation of the fruitful EA AlDyNet (2013-2015, 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 agglomeration. We are both interested in theoretical results concerning the feasibility of computing graph properties, and by their practical implementation (using SageMath, www.sagemath.org/) for our application and their diffusion in the scientific community. There are three main objectives:

1) Design efficient algorithms to compute important graph properties (hyperbolicity, treelength, centrality, treewidth...) in real networks. We are not only interested by the worst-case time-complexity of these algorithms but by their performance in practice.

2) Implement and document our algorithms using the open-source framework SageMath. One advantage of using SageMath is that it has interfaces with other graph libraries (igraph, Boost...) and with Linear Programming solver (GLPK, Cplex...). Moreover, the success of SageMath (which has accumulated thousands of users over the last 10 years) will participate to the diffusion of our algorithms.

3) Apply our algorithms on the Santiago transportation network that have been collected by our Chilean partner during the last year of AlDyNet (2013-2015). Based on the results, propose tools for decision support in designing bus routes, timetables, etc. More precisely, we have collected information about the use of public transport (data of smart cards for automatic fare collection - BIP-, bus routes and bus schedules, etc.), urban infrastructure information, schools' addresses, and approximate locations where students live. We have started to clean and consolidate these data. We will then develop decision support tools, for example, for improving quality education accessibility.

9.3.2. Inria International Partners

9.3.2.1. Informal International Partners

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

Univ. of Southern Denmark, Prof. Jorgen Bang Jensen

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

Concordia Univ. - Montréal, Quebec, Canada, Prof. Brigitte Jaumard

9.3.3. Participation in Other International Programs

GAIATO : Graphs and Algorithms Applied to Telecommunications, International Cooperation FUNCAP/FAPs/Inria/INS2i-CNRS, no. INC-0083-00047.01.00/13, with Federal University of Ceará, Brasil, 2014-2016.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

Daniela Aguirre Guerrero

Universitat de Girona, Girona, Spain, Visiting PhD Student, from Sep 2016 until Nov 2016.

Jean Francois Baffier

Japanese-French Laboratory for Informatics UMI 3527, Japan, Visiting Scientist, June 2016.

Jorgen Bang Jensen

University of Southern Denmark, Odensee, Denmark, Visiting Scientist, from June 2016 until Jul 2016.

Augustin Chaintreau

Columbia University, New York, US, Visiting Scientist, 19-21st January 2016.

Clément Charpentier

Université Joseph Fourier, Grenoble, France, Visiting Scientist, 21-26th February 2016.

Romuald Elie

Université Paris-Est Marne-la-Vallée, Visiting Scientist, October 24-November 2, 2016.

Takako Kodate

Tokyo Woman's Christian Univ., Japan, Visiting Scientist, Apr 2016.

Christian Konrad

Reykjavik University, Iceland, Visiting Scientist, February 28th to March 3rd, 2016.

Aurélie Lagoutte

Université de Princeton, USA, 9-11th March, 2016.

Zvi Lotker

Ben Gurion University of the Negev, Israel, 22-27th February, 2016.

Ana Karolinna Maia De Oliveira

Univ. Federal do Ceara, Fortaleza, Brazil, Visiting Scientist, Oct 2016.

Colin McDiarmid

University of Oxford, UK, Visiting Scientist, September 26-30th 2016.

Ioannis Milis

Athens University of Economics and Business, Athens, Greece, Visiting Scientist, Feb 2016.

Eduardo Moreno

Univ. Adolfo Ibanez, Santiago, Chile, Visiting Scientist, Sep 2016.

Julio Cesar Silva Araujo

Univ. Federal do Ceara, Fortaleza, Brazil, Visiting Scientist, Oct 2016.

Guillem Perarnau-Llobet

University of Birmingham, UK, Visiting Scientist, May 9-13rd 2016.

Jean-Sébastien Sereni

CNRS, France, 22-25th February.

Yllka Velaj

Gran Sasso Science Institute, L'Aquila, Italia, Visiting PhD Student, from Feb 2016 until Apr 2016.

Joseph Yu

University of the Fraser Valley, Abbotsford, Canada, Visiting Scientist, Apr 2016.

Vassilis Zissimopoulos

National and Kapodistrian University of Athens, Athens, Greece, Visiting Scientist, Feb 2016.

9.4.2. Visits to International Teams

9.4.2.1. Research Stays Abroad

Julien Bensmail

LaBRI, University of Bordeaux, October 10-14, 2016;

LIF, Aix-Marseille University, October 17-19, 2016.

Jean-Claude Bermond

Department of Informatics and Telecommunications of the National and Kapodistrian University of Athens, Greece, June7-21, 2016.

David Coudert

LIP6, UPMC, Paris, October 11-13, 2016;

Univ. Adolfo Ibañez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AlDyNet, October 24-November 11, 2016.

Frédéric Giroire

Orange Labs, Chatillon, May 17-20, 2016;

Computer Science and Software Engineering department, Concordia University, Montréal, Canada, September 28-October 7, 2016.

Nicolas Huin

Concordia University, Montreal, Canada, August 22-November 22, 2016.

William Lochet

Université libre de Bruxelles, Belgique, June 20-25th, 2016.

Nicolas Nisse

Univ. Federal do Ceará, Fortaleza, Brazil, April, 2016;

LIF, Aix-Marseille University, July 18-22, 2016;

Univ. Adolfo Ibañez and Univ. Chile, Santiago, Chile, in the context of Inria associated team AlDyNet, October 24-November 11, 2016.

Bruce Reed

National Institute of Informatics Tokyo Japan, June 1-28th 2016;

Pacific Institute of Mathematical Sciences, June 28th-September 5th 2016;

National Institute of Informatics Tokyo Japan, October 1st-December 31th 2016.

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. Member of the Organizing Committees

Frédéric Havet

GCO 2016: 2nd French Brazilian Workshop on Graphs and Combinatorial Optimization, Redonda, Ceara, Brazil, May 28-April 1, 2016;

4th STINT meeting, January 25-27, Saint Bonnet de Champsaur, France;

Workshop on Shannon capacity, September 11-16, Cassis, France.

Bruce Reed

Workshop on Shannon capacity, September 11-16, Cassis, France.

10.1.2. Scientific Events Selection

10.1.2.1. Member of the Conference Program Committees

David Coudert

ONDM'16 : 20th International Conference on Optical Networking Design and Modeling, Cartagena, Spain, May 9-12, 2016;

IEEE ICC'16 : IEEE International Conference on Communications, Kuala Lumpur, Malaysia, May 23-27, 2016;

USRR'16 : 4th International Workshop on Understanding the Inter-play between Sustainability, Resilience and Robustness in networks, Halmstad, Sweden, September 15, 2016;

IEEE Globecom'16 : IEEE Global Communications Conference, Washington, DC, USA, December 4-8, 2016.

Frédéric Havet

AAIM 2016: 11th International Conference on Algorithmic Aspects in Information and Management, Bergamo, Italy, July 18-20, 2016;

JGA 2016: 18th Journées Graphes et Algorithmes, Paris, France, November 16-18, 2016.

Nicolas Nisse

AlgoTel 2016: 18es Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications, Bayonne, France, 24-27 May, 2016.

10.1.3. Journal

10.1.3.1. 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 , Discrete Mathematics, Algorithms and Applications.

David Coudert

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

Frédéric Havet

Discrete Mathematics and Theoretical Computer Science;

Nicolas Nisse

Guest editor of Special issue on Theory and Applications of Graph Searching Problems for Theoretical Computer Science (December 2016).

Bruce Reed

Journal of Graph Theory, Electronic Journal of Combinatorics;

10.1.3.2. 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.

10.1.4. Invited Talks

David Coudert

On the design of reliable wireless backhaul networks. International Conference on Ad Hoc Networks and Wireless (AdHoc-Now'16), Lille, France (July 4-5, 2016);

On the notion of hyperbolicity in graphs. Seminar of the Complex Networks team, LIP6, UPMC, Paris (October 12, 2016).

Nicolas Nisse

Spy Games. Groupe de travail de l'équipe CRO, LIF, Marseille, July 18th, 2016;

Recovery of disrupted airline operations. Seminar of LIMOS, Univ. Blaise Pascal, Clermont-Ferrand, January 28th, 2016.

Bruce Reed

The Typical Structure of H-Free Graphs. Sao Paulo Advanced School on Algorithms, Combinatorics, and Optimization, Sao Paulo, Brazil, July 216;

How To Determine If A Random Graph With A Fixed Degree Sequence Has A Giant Component. Sao Paulo Advanced School on Algorithms, Combinatorics, and Optimization, Sao Paulo, Brazil. July 2016;

On The Structure Of Typical H-Free Graphs. University of Birmingham Combinatorics Seminar, Birmingham, United Kingdom, May 2016;

How To Determine If A Random Graph With A Fixed Degree Sequence Has A Giant Component. Simon Fraser University, July 2016;

40th Australian Conference on Combinatorial Mathematics and Combinatorial Computing, NewCastle Australia, December 2016;

How To Determine If A Random Graph With A Fixed Degree Sequence Has A Giant Component. 13th Workshop on Algorithms and Models for the Wb Graph, Montreal, Canada, December 2016.

10.1.5. Leadership within the Scientific Community

David Coudert

Member of the steering committee of *Pôle ResCom du GDR RSD du CNRS* (since 2005);

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

Frédéric Havet

Member of the steering committee of *GT Graphes du GDR IM du CNRS*;

Member of the steering committee of *Journées Graphes et Algorithmes (JGA)*;

Member of the steering committee of *Journée Combinatoire et Algorithmes du Littoral Méditerranéen (JCALM)*.

Bruce Reed

Member of the selection committee for the CRM-Fields-Pims Prize.

10.1.6. Scientific Expertise

Jean-Claude Bermond

Expert for DRTT-MESR (Crédit impôt recherche(CIR et agréments) and various projects outside France.

David Coudert

Expert for the Future and Emerging Technologies Open Scheme (FET-Open) European program, and the ANR.

Frédéric Giroire

Expert for ANR.

Frédéric Havet

Expert for ANR.

Michel Syska

Expert for DRTT PACA.

10.1.7. Research Administration

Jean-Claude Bermond

Responsible fo 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).

David Coudert

Scientific coordinator of the evaluation seminar of the Inria theme "Networks and Telecommunications", Rungis, France, March 22-24, 2016.

Frédéric Havet

Responsible of the ComRed Team of I3S;

Recruiting committee (comité de sélection) University of Nice 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.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence

Pierre Aboulker

Recherche opérationnelle, 74h ETD, Niveau L2, IUT de Nice Côte d'Azur, UNS.

Julien Bensmail

Système d'information et logistique, 36h ETD, niveau S3, IUT Nice Côte d'Azur, UNS.

Christelle Caillouet

Database and advanced information system, 36h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Delivery Optimization, 30h ETD, Level L3, IUT Nice Côte d'Azur, UNS;

Introduction to Programming, 60h ETD, Level L1, IUT Nice Côte d'Azur, UNS;

Guillaume Ducoffe

Introduction au Web, 28h30 ETD, Level L2, Polytech Nice Sophia, France

Programmation Orientée Objet, 39h ETD, Level L2, Polytech Nice Sophia, France

Principes des systèmes d'exploitation, 26h ETD, Level L2, IUT de Nice Côte d'Azur, UNS.

Valentin Garnero

Introduction aux systèmes informatiques, 108h, niveau S1, IUT Nice Côte d'Azur, UNS.

Luc Hogie

Programmation Répartie, 36h ETD, IUT Nice Côte d'Azur, UNS.

Nicolas Huin

Introduction aux réseaux, 21h ETD, niveau S1, IUT Nice Côte d'Azur, UNS.

William Lochet

Paradigmes et interprétation, 18h ETD, L3, Univ. Côte d'Azur

Programmation objet, 18h ETD, L3, Univ. Côte d'Azur

Compilation, 18h ETD, L3, Univ. Côte d'Azur

Projet scientifique, 30h ETD, L2, Univ. Côte d'Azur

Informatique générale, 36h ETD, L1, Univ. Côte d'Azur

Intro programmation C, 12h ETD, L1, Univ. Côte d'Azur

Joanna Moulierac

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

Nicolas Nisse

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

Steven Roumajon

Architecture des réseaux, 48h ETD, L2, IUT Nice Côte d'Azur, UNS.

Michel Syska

Operating Systems: Advanced Programming, 40h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Data Structures and Algorithms, 20h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Algorithmics, 30h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Distributed Programming, 30h ETD, Level L2, IUT Nice Côte d'Azur, UNS;

Bash Scripting, 30h ETD, Level L3, IUT Nice Côte d'Azur, UNS;

Introduction to Algorithms and Complexity, 60h ETD, Level L3, IUT Nice Côte d'Azur, UNS;

Linux System Administration, 35h 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.

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;

Frédéric Havet

Graph colouring, 4h ETD, M2 MDFI, Aix Marseille Univ., France.

Nicolas Nisse

Graph Algorithms, 18h ETD, M2 IFI, parcours UBINET, UNS, France.

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

Graph decompositions, 4h ETD, M2 MDFI, Aix Marseille Univ. , France

Stéphane Pérennes

Calcul concurrent et distribué en Java, 30h TP, Master 1 Miage. Polytec Nice.

Responsabilités pédagogiques

Julien Bensmail

Co-organizer of the « Forum sur les poursuites d'études », IUT Nice Côte d'Azur (November 10, 2016);

Representative of the QLIO department at « Salon de l'étudiant », Palais des expositions, Nice (November 26, 2016).

Christelle Caillouet

Co-Responsible of QLIO Department, until February 2016.

Joanna Moulierac

Co-Responsible of the DUT Informatique en Alternance, Computer Science Department, from January 2014 to March 2016.

10.2.2. Supervision

PhD : Guillaume Ducoffe, *Metric properties of large graphs* https://team.inria.fr/coati/phd-defense-of-guillaume-ducoffe/, Université Nice Sophia Antipolis, December 9, 2016. Supervisor : David Coudert;

PhD in progress : Nicolas Huin, *Energy efficient Software Defined Networks*, since Oct. 2014, Supervisors: Frédéric Giroire and Dino Lopez (I3S);

PhD in progress : William Lochet, *Forcing subdivisions in digraphs*, since Sept. 2015, Supervisors: Frédéric Havet and Stéphan Thomassé (ENS Lyon);

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

PhD in progress : Steven Roumajon, *Les déterminants de la compétitivité régionale : données microéconomiques et réseaux d'innovation*, since Nov. 2015, Supervisors: Patrick Musso (Gredeg) and Frédéric Giroire;

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

10.2.2.1. Internships

Rohit Agarwal

Date: from Jul 2016 until Aug 2016

Institution: Univ. Nice Sophia Antipolis (France)

Supervisor: Nicolas Nisse

Theodoros Karagkioules

Date: until March 2016

Institution: NKUA, Athens (Greece)

Supervisor: Nicolas Nisse

Raul Wayne Teixeira Lopez

Date: from Sep 2016 until Nov 2016

Institution: UFC, Fortaleza (Brazil)

Supervisor: Frédéric Havet

Ioannis Mantas

Date: from Mar 2016 until Aug 2016

Institution: Univ. Nice Sophia Antipolis (France)

Supervisor: David Coudert

Simon Nivelle

Date: from Jun 2016 until Jul 2016

Institution: ENS Cachan (France)

Supervisor: Guillaume Ducoffe et Nicolas Nisse

Stefano Ponziani

Date: from Mar 2016 until Aug 2016

Institution: Univ. Nice Sophia Antipolis (France)

Supervisor: Guillaume Ducoffe et Frédéric Giroire

Konstantinos Priftis

Date: until March 2016

Institution: Univ. of Patras (Greece)

Supervisor: David Coudert

Panagiotis Pylarinos

Date: from Nov. 2016

Institution: NKUA, Athens (Greece)

Supervisor: David Coudert

Andrea Thomassilli

Date: from Mar 2016 until Aug 2016

Institution: Univ. Nice Sophia Antipolis (France)

Supervisor: Nicolas Huin et Frédéric Giroire

Vladyslav Zaika

Date: from Mar 2016 until Aug 2016

Institution: Univ. Nice Sophia Antipolis (France)

Supervisor: Nicolas Nisse

10.2.3. Juries

David Coudert :

Member of the PhD jury of Guillaume Ducoffe, Univ. Nice Sophia Antipolis, December 9, 2016;

Referee and member of the PhD jury of Mohamad Kanj, Univ. Rennes, December 20, 2016;

Frédéric Giroire:

Member of the PhD jury of Leonardo Linguaglossa, Université Paris Diderot (Paris 7), September 9, 2016.

Frédéric Havet :

Member of the PhD jury of G. Duvillié, Université Montpellier, October 7 2016.

Nicolas Nisse :

Referee and member of the PhD jury of Valentin Garnero, Université Montpellier, July 4 2016.

Referee and member of the PhD jury of Jean-Florent Raymond, Université Montpellier, November 18 2016.

Member of the PhD jury of Guillaume Ducoffe, Univ. Nice Sophia Antipolis, December 9, 2016;

10.3. Popularization

Guillaume Ducoffe:

Fête de la Science: presented the stand "Introduction à l'algorithmique" at Valrose, Univ. Nice Sophia Antipolis, France, October 12nd, 2016.

Frédéric Havet:

Fête de la Science: co-organised the Village des Sciences at Vinon-sur-Verdon, France (November 10-14, 2016). F. Havet gave many talks and animated several stands during the whole week.

Semaine des Mathématiques : presented the stand "Les formes de largeur constantes" at Vinon sur Verdon (March 17, 2016)

Culture Science au Lycée : gave thé conference "Magie mathématique et binaire" at Lycée Caucadis Vitrolles (April 28, 2016) and the conferences "La magie du bonaire" and "La Science du Ballon de Football" at Lycée Caucadis Vitrolles (December 9, 2016).

Vendredis de la Science: conducted scientific workshops for school children (6-11 year old) on friday afternoon. Weekly in Januray-February and May-June 2016.

General audience conference : gave the conference "La Science du Ballon de Football" at Rians, Var, France (January 29, 2016).

Nicolas Nisse:

Fête de la Science: animated several stands during the Village des Sciences at Vinon-sur-Verdon, France (November 10-14, 2016).

Fête de la Science: animated several stands in Palais des Congrès de Juan-Les-Pins, October 22-23rd, 2016

Steven Roumajon:

Fête de la Science: presented the stand "Introduction à l'algorithmique" at Valrose, Univ. Nice Sophia Antipolis, France, October 12nd, 2016.

11. Bibliography

Major publications by the team in recent years

[1] D. AGARWAL, J. ARAUJO, C. CAILLOUET, F. CAZALS, D. COUDERT, S. PERENNES. *Connectivity Inference in Mass Spectrometry based Structure Determination*, in "European Symposium on Algorithms", Sophia-Antipolis, France, France, H. BODLAENDER, G. ITALIANO (editors), Lecture Notes in Computer Science - LNCS, Springer, 2013, vol. 8125, pp. 289-300 [*DOI :* 10.1007/978-3-642-40450-4_25], http://hal.inria.fr/hal-00849873

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[3] L. BLIN, J. BURMAN, N. NISSE. *Exclusive Graph Searching*, in "Algorithmica", February 2016 [*DOI :* 10.1007/S00453-016-0124-0], https://hal.archives-ouvertes.fr/hal-01266492

[4] C. CAILLOUET, S. PÉRENNES, H. RIVANO. *Framework for Optimizing the Capacity of Wireless Mesh Networks*, in "Computer Communications", 2011, vol. 34, n^o 13, pp. 1645-1659, http://hal.inria.fr/inria-00572967/en

[5] N. COHEN, D. COUDERT, A. LANCIN. *On computing the Gromov hyperbolicity*, in "ACM Journal on Experimental Algorithmics", 2015, vol. 20, n° 1, 18 p. [*DOI :* 10.1145/2780652], https://hal.inria.fr/hal-01182890

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[7] F. GIROIRE. *Order statistics and estimating cardinalities of massive data sets*, in "Discrete Applied Mathematics", 2009, vol. 157, n° 2, pp. 406-427, http://dx.doi.org/10.1016/j.dam.2008.06.020

[8] S. GUILLEMOT, F. HAVET, C. PAUL, A. PEREZ. *On the (non-)existence of polynomial kernels for P_l-free edge modification problems*, in "Algorithmica", 2013, vol. 65, n° 4, pp. 900-926, http://hal.inria.fr/hal-00821612

[9] F. HAVET, B. REED, J.-S. SERENI. *Griggs and Yeh's Conjecture and L(p,1)-labelings*, in "Siam Journal on Discrete Mathematics", February 2012, vol. 26, n° 1, pp. 145–168, http://hal.inria.fr/inria-00327909

[10] J. MOULIERAC, T. K. PHAN. *Optimizing IGP link weights for energy-efficiency in multi-period traffic matrices*, in "Computer Communications", May 2015, vol. 61, 11 p. [*DOI :* 10.1016/J.COMCOM.2015.01.004], https://hal.inria.fr/hal-01162700

Publications of the year

Doctoral Dissertations and Habilitation Theses

[11] G. DUCOFFE. *Propriés Métriques des grands graphes – Metric Properties of large graphs*, Université Côte d'Azur, 2016, http://www-sop.inria.fr/members/Guillaume.Ducoffe/these/These-Guillaume-Ducoffe.pdf

Articles in International Peer-Reviewed Journals

[12] J. ARAUJO, F. HAVET, C. LINHARES SALES, A. SILVA. *Proper orientation of cacti*, in "Journal of Theoretical Computer Science (TCS)", 2016, vol. 639, pp. 14-25 [*DOI :* 10.1016/J.TCS.2016.05.016], https://hal.inria.fr/hal-01338646

[13] J. BANG-JENSEN, N. COHEN, F. HAVET. *Finding good 2-partitions of digraphs II. Enumerable properties*, in "Journal of Theoretical Computer Science (TCS)", August 2016, vol. 640, pp. 1-19 [*DOI :* 10.1016/J.TCS.2016.05.034], https://hal.archives-ouvertes.fr/hal-01346079

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[16] J.-C. BERMOND, C. GOMES HUIBAN, P. REYES. *Round weighting problem and gathering in radio networks with symmetrical interference*, in "Discrete Mathematics, Algorithms and Applications", 2016, vol. 8, n° 2, 57 p. , 1650035 [*DOI :* 10.1142/S179383091650035X], https://hal.archives-ouvertes.fr/hal-01407591

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[20] D. COUDERT, G. DUCOFFE. *On the hyperbolicity of bipartite graphs and intersection graphs*, in "Discrete Applied Mathematics", 2016, vol. 214, pp. 187-195 [*DOI :* 10.1016/J.DAM.2016.06.017], https://hal.inria.fr/hal-01220132

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[23] D. COUDERT, S. PÉRENNES, H. RIVANO, M.-E. VOGE. *Combinatorial optimization in networks with Shared Risk Link Groups*, in "Discrete Mathematics and Theoretical Computer Science", May 2016, vol. Vol. 18, no 3, 25 p. , https://hal.inria.fr/hal-01053859

[24] G. D 'ANGELO, A. NAVARRA, N. NISSE. *A unified approach for Gathering and Exclusive Searching on rings under weak assumptions*, in "Distributed Computing", 2016, https://hal.archives-ouvertes.fr/hal-01326473

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International Conferences with Proceedings

[26] M. BOUZNIF, F. HAVET, M. PREISSMANN. *Minimum-Density Identifying Codes in Square Grids*, in "11th International Conference, AAIM 2016", Bergamo, Italy, Lecture Notes in Computer Science, Springer, July 2016, vol. 9778, pp. 77-88 [*DOI :* 10.1007/978-3-319-41168-2_7], https://hal.inria.fr/hal-01346750

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F. GRANDONI (editors), Leibniz International Proceedings in Informatics (LIPIcs), Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, 2016, vol. 49 [*DOI :* 10.4230/LIPICS.FUN.2016.10], https://hal.archives-ouvertes.fr/hal-01326446

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