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Activity Report 2012

Project-Team MASCOTTE

Algorithms, simulation, combinatorics and optimization 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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Project-Team MASCOTTE

Keywords: Graph Theory, Distributed Algorithms, Optical Networks, Networks, Wireless Networks

Creation of the Project-Team: March 16, 2000 .

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2. Overall Objectives

2.1. Overall Objectives

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

The objectives of the MASCOTTE project-team are to design networks and communication algorithms. In order to meet these objectives, the team studies various theoretical tools, such as Discrete Mathematics, Graph Theory, or Algorithmics and develops applied techniques and tools, especially for Combinatorial Optimization and Computer Simulation. In particular MASCOTTE 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.

This results also in the production of advanced softwares such as GRPH and DRMSim, and in the contribution to large open source softwares such as SageMath.

3. Scientific Foundations

3.1. Scientific Foundations

The project develops tools and theory in the following domains: Discrete Mathematics (in particular Graph Theory), Algorithmics, Combinatorial Optimization and Simulation.

Typically, a telecommunication network (or an interconnection network) is modeled by a graph. A vertex may represent either a processor or a router or any of the following: a switch, a radio device, a site or a person. An edge (or arc) corresponds to a connection between the elements represented by the vertices (logical or physical connection). We can associate more information both to the vertices (for example what kind of switch is used, optical or not, number of ports, equipment cost) and to the edges (weights which might correspond to length, cost, bandwidth, capacity) or colors (modeling either wavelengths or frequencies or failures) etc. Depending on the application, various models can be defined and have to be specified. This modeling part is an important task. To solve the problems, we manage, when possible, to find polynomial algorithms. For example, a maximum set of disjoint paths between two given vertices is by Menger's theorem equal to the minimum cardinality of a cut. This problem can be solved in polynomial time using graph theoretic tools or flow theory or linear programming. On the contrary, determining whether in a directed graph there exists a pair of disjoint paths, one from s_1 to t_1 and the other from s_2 to t_2, is an NP-complete problem, and so are all the problems which aim at minimizing the cost of a network which can satisfy certain traffic requirements. In addition to deterministic hypotheses (for example if a connection fails it is considered as definitely down and not intermittently), the project started recently to consider probabilistic ones.

Graph coloring is an example of concept which appears in various contexts: WDM networks where colors represent wavelengths, radio networks where colors represent frequencies, fault tolerance where colors represent shared risk resource groups, and scheduling problems. Another tool concerns the development of new algorithmic aspects like parameterized algorithms.

4. Application Domains

4.1. Application Domains

In the last year the main application domain of the project remained Telecommunications. Within this domain, we consider applications that follow the needs and interests of our industrial partners, in particular Orange Labs or Alcatel-Lucent Bell-Labs, but also SMEs like 3-Roam and Avisto .

MASCOTTE is mainly interested in the design and management of heterogeneous networks. The project has kept working on the design of backbone networks (optical networks, radio networks, IP networks).

The project has also been working on routing algorithms such as dynamic and compact routing schemes in the context of the FP7 EULER leaded by Alcatel-Lucent Bell-Labs (Belgium). It also studied the evolution of the routing in case of any kind of topological modifications (maintenance operations, failures, capacity variations, etc.). Finally, an emphasis is done on green networks with low power consumption. This work is in collaboration with Orange Labs and the SME 3-Roam and partly supported by the ANR DIMAGREEN.

5. Software

5.1. Grph

Participants: David Coudert, Luc Hogie [correspondant], Aurélien Lancin, Grégory Morel, Issam Tahiri.

Around 20,000 lines of code, developed in Java.

The objective of GRPH is to provide researchers and engineers a suitable graph library for graph algorithms experimentation and network simulation. GRPH is primarily a software library, but it also comes with a set of executable files for user interaction and graph format conversion; as such, it can be used autonomously. Performance and accessibility are the primary targets of the GRPH library. It allows manipulating large graphs (millions of nodes). Its model considers mixed graphs composed of directed and undirected simple- and hyper-edges. GRPH comes with a collection of base graph algorithms which are regularly augmented.

So far, known users of the GRPH library include people at Mascotte and others involved in the FP7 EULER project. It got some contribution from the Inria team GANG who contributed GRPH with an implementation of the four-sweep algorithm which provides accurate lower bound on the diameter in linear time. It has a number of other academic users including research students at Bergamo University (Italy), and University of Southern Denmark (students supervised by Jørgen Bang-Jensen).

GRPH includes bridges to other graph libraries such as JUNG, JGraphT, CORESE (a software developed by the WIMMICS team Inria-I3S), LAD (Christine Solnon, LIRIS), Nauty (Brendan D. McKay), as well as specific algorithms developed by Matthieu Latapy and Jean-Lou Guillaume (LIP6), etc.

GRPH is distributed under the terms of a license defined by its contributors and is available for download. This license allows free usage and access to the source code. See http://www-sop.inria.fr/mascotte/software/grph.

In 2012, numerous graph algorithms have been added to GRPH, such as maximum matching, minimum vertex cover (brute force, branching, Niedermeier), maximum independent set (Fomin/Grandoni/Kratsch). Furthermore, to answer a number of issues about the generation of graph instances with particular properties, a framework for evolutionary computing dedicated to graphs was integrated to GRPH. Moreover, a reworked version of Mascsim was integrated in GRPH.

On-going works concern the distributed execution of graph algorithms, and a bridge to Sage.

See also the web page http://www-sop.inria.fr/mascotte/software/grph/.

5.2. DRMSim

Participants: David Coudert, Luc Hogie [correspondant], Aurélien Lancin, Nicolas Nisse, Issam Tahiri.

Around 45,000 lines, developed in Java, collaboration between MASCOTTE and LaBRI.

DRMSim relies on a discrete-event simulation engine aiming at enabling the large-scale simulations of routing models. DRMSim is developped in the framework of the FP7 EULER project . It proposes a general routing model which accommodates any network configuration. Aside to this, it includes specific models for Generalized Linear Preference (GLP), and k-chordal network topologies, as well as implementations of routing protocols, including the routing protocol proposed in [37] and lightweight versions of BGP (Border Gateway Protocol).

The system model considers the dynamic evolution of the simulated network. This model takes as its input parameter the distribution of failure probability for both routers and links.

The metric model takes measures along a discrete-event simulation which can be performed in many ways.

Commonly, a simulation campaign consists in iterating over the set of combinations of parameter values, calling the simulation function for every combination. These combinations are most often complex, impeding there description by a set of mathematical functions. Thus DRMSim provides a simulation methodology that describes (programmatically) the way a simulation campaign should be conducted.

DRMSim stores on disk every step of the execution of a simulation campaign. In a simulation campaign, simulation runs are independent (no simulation depends on the result computed by another simulation). Consequently they can be executed in parallel. Because one simulation is most likely to use large amount of memory and to be multi-threaded, parallelizing the simulation campaign on one single computer is a poor parallelization scheme. Instead, we currently work at enabling the remote parallel execution of several simulation runs, with the same distribution framework that is used in the GRPH library.

DRMSim relies on the Mascsim abstract discrete-event simulation framework, the GRPH library and the Java4Unix integration framework.

Finally, from an object-oriented point of view of its conception model, DRMSim manipulates graph abstractions, allowing the user to force the use of a library different from the default one, i.e. GRPH.

See also the web page http://www-sop.inria.fr/mascotte/projets/DCR/.

5.3. SageMath

Participants: David Coudert, Leonardo Sampaio.

Developed in Python, Cython, and C++. MASCOTTE members have already contributed to the development of more than 180 patches and to the reviewing process of more than 200 patches that are now part of the standard distribution.

Sagemath is a free open-source mathematics software aiming at becoming an alternative to Maple and Matlab. Initially created by William Stein (Professor of mathematics at Washington University), Sagemath is currently developed by more than 180 contributors around the world (mostly researchers) and its source code has reached 350 MB. It is of interest for Mascotte members because it combines a large collection of graph algorithms with various libraries in algebra, calculus, combinatorics, linear programming, statistics, etc.

We use Sagemath for quickly testing algorithms, analyzing graphs, and disseminating algorithms. We also use it for teaching purposes in the Master IFI, stream UBINET.

In 2012, David Coudert has contributed to the development of the Sage releases 5.0 to 5.6 with 15 patches (from bug fix to advance graph algorithms) and participated to the reviewing process of more than 30 patches.

5.4. Utilities

5.4.1. Java4unix

Participant: Luc Hogie [correspondant].

More than 5,000 lines, developed in Java.

Java4unix proposes a development and distribution framework which simplifies the use of Java for UNIX software programming/distribution. Until now, Java could hardly be used for the development UNIX applications because invoking Java applications from the UNIX shell must be done through an explicit call to the Java virtual machine and writing simple things in Java often requires long coding. Java4unix aims at filling those two gaps by providing a UNIX installer for java applications, turning them to standard UNIX application and a framework that UNIX programmers may use to manipulate files/text, etc.

Java4unix includes a module which enables the reporting and automatic releasing of Eclipse Java projects.

See also the web page http://www-sop.inria.fr/members/Luc.Hogie/java4unix/.

5.4.2. Jalinopt

Participants: Luc Hogie [correspondant], Grégory Morel.

Developed in Java.

Jalinopt is a Java toolkit for building and solving linear programs. It consists of a straightforward object-oriented model for linear programs, as well as a bridge to most common solvers, including GLPK and CPLEX. It is an interface to many LP solvers allowing users to code independently of the solver effectively. Altought Jalinopt is inspired by Mascopt and JavaILP, it provides a significantly different model and an utterly different approach to connecting to the solver. In particular this approach, based in inter-process piping, offers better portability, and the possibility to connect (via SSH) to solvers on remote computers.

In 2012, we refined the object-oriented model of Jalinopt and improved its portability by making it working with LPSolve as its default native solver.

See also the web page http://www-sop.inria.fr/members/Luc.Hogie/jalinopt/.

5.4.3. JavaFarm

Participant: Luc Hogie [correspondant].

More than 1,500 lines, developed in Java.

JavaFarm is a middleware enabling the distribution of Java applications across farms of servers.

Its workflow basically enables an application to locally aggregate code and data into an object, called job, that will migrate to another computer where it will be computed. When a job completes, its result is transferred back to the caller. Among other features, JavaFarm supports futures (asynchronous job executions), thereby enabling parallelization of the distributed code. The design objectives of JavaFarm are to make distribution and parallelism as transparent and easy as possible.

See also the web page http://www-sop.inria.fr/members/Luc.Hogie/javafarm/.

5.4.4. Mascsim

Participants: Luc Hogie [correspondant], Aurélien Lancin, Issam Tahiri.

Around 12,000 lines, developed in Java.

Mascsim is a distributed discrete event simulator whose main target is to be easy to use. Unlike most discrete-event simulators, the researcher who is using Mascsim is required to provide only the bare minimum material needed for the simulation: a model for the system, a set of events describing what is going on in the system, as well as a set of metrics of interest. The simulation process is then entirely automatized.

In 2012, Mascsim was adapted and integrated to GRPH.

See also the web page http://www-sop.inria.fr/mascotte/software/mascsim/.

5.4.5. P2PVSim

Participant: Remigiusz Modrzejewski [correspondant].

Around 12,000 lines, developed in Python.

P2PVSim is a simple discrete-event simulator created for analyzing theoretical properties of peer-to-peer live video streaming algorithms. Implemented in Python it was designed with clarity and extensibility in mind from the beginning. It is capable of simulating overlays of a few thousands of peers. Multiple control protocols have been implemented. At the same time, a lot of work was put into the performance and scalability aspects of the software. Currently it is meant for simulating overlays of a few thousand peers running multiple control protocols that have been implemented.

In 2012, a distributed version of P2PVSim was developed. The objectives for developing a distributed version was to fasten the simulation of large campaigns, that would be too long to run on one single computer. The distributed P2PVSim runs on an arbitrary number of computers. It has been so far used with success on a dozen computers with multiple cores all located in the same LAN.

6. New Results

6.1. Network Design and Management

Participants: Gianlorenzo D'Angelo, Jean-Claude Bermond, Khoa Phan, David Coudert, Frédéric Giroire, Joanna Moulierac, Nicolas Nisse, Ronan Pardo Soares, Stéphane Pérennes, Issam Tahiri.

6.1.1. Network Design

Network design is a very wide subject that concerns all kinds of networks. We mainly study telecommunications networks which can be either physical networks (backbone, access, wireless, ...) or virtual (logical) ones. 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) path(s) between their end nodes. The set of paths is chosen according to the technology, the protocol or the QoS constraints. The design can be done at the conception of the network (i.e. when conceiving a virtual network in MPLS where we have to establish virtual paths) or to adapt the network to changes (failures, new link, updates of routers, variation of traffic, ...). Finally there are various optimization criteria which differ according to the point of view: for a network user they are related to his/her satisfaction (minimizing delays, increasing available bandwidth, ...), while for a network operator, economics criteria like minimizing deployment and operating costs are more important.

This very wide topic is addressed by a lot of academic and industrial teams in the world. Our approach is to attack these problems with tools from Discrete Mathematics.

6.1.1.1. All-Optical Label Switching, AOLS

All-Optical Label Switching (AOLS) is a promising technology that performs packet forwarding without any optical-electrical-optical conversions, thus speeding up the forwarding. However, the cost of this technology requires limiting the number of labels needed to ensure the forwarding when routing a set of requests using GMPLS technology. In particular, this prevents the usage of label swapping techniques.

We have studied the routing problem in this context using label stacking techniques. We have formalized the problem by associating to each routing strategy a logical hypergraph, called a hypergraph layout, whose hyperarcs are dipaths of the physical graph, called tunnels in GMPLS terminology. We defined a cost function for the hypergraph layout, depending on its total length plus its total hop count. Minimizing the cost of the design of an AOLS network can then be expressed as finding a minimum cost hypergraph layout. In [24], we prove hardness results for the problem. On the other hand, we provide approximation algorithms, in particular an $O(\log n)$-approximation for symmetric directed networks. We focused on the case where the physical network is a directed path, providing a polynomial-time dynamic programming algorithm first for one source, and then for a fixed number k of sources running in time $O(n^{k+2})$.

6.1.1.2. Protocols

IP multicast is a protocol that deals with group communications with the aim of reducing traffic redundancy in the network. However, due to difficulty in deployment and poor scalability with a large number of multicast groups, IP multicast is still not widely deployed nor used on the Internet. Recently, Xcast6 and Xcast6 Treemap, two network layer multicast protocols, have been proposed with complementary scaling properties to IP multicast: they support a very large number of active multicast sessions. However, the key limitation of these protocols is that they only support small multicast groups. To overcome this limitation, we have proposed the Xcast6 Treemap Island [59], [60], a hybrid model of Application Layer Multicast (ALM) and Xcast6 that can work for large multicast groups. We have shown the feasibility of our model by simulation and comparison with IP multicast and NICE protocols.

Congestion control is a distributed algorithm to share network bandwidth among competing users on the Internet. In the common case, quick response time for mice traffic (http traffic) is desired when mixed with elephant traffic (ftp traffic). The current approach using loss-based with Additive Increase, Multiplicative Decrease (AIMD) is too greedy and eventually, most of the network bandwidth would be consumed by elephant traffic. As a result, it causes longer response time for mice traffic because there is no room left at the routers. MaxNet is a new TCP congestion control architecture using an explicit signal to control transmission rate at the source node. In [60] , we show that MaxNet can control well the queue length at routers and therefore the response time to http traffic is several times faster than with TCP Reno/RED.

6.1.1.3. Shared Risk Link Group

The notion of *Shared Risk Link Group*, SRLG has been introduced to capture multiple correlated failures in a network. A SRLG is a set of links that fail simultaneously if a given event (risk) occurs. In such multiple failures scenario, the problem of Diverse Routing consists in finding two SRLG-disjoint paths between a pair of nodes. We consider in [42], [66] such problem for localized failures, when all the links of a SRLG verify the star property i.e. when they are incident to the same node. We prove that in this case the problem is in general NP-complete and determine some polynomial cases.

6.1.1.4. Data Gathering in Radio Networks

We study the problem of gathering information from the nodes of a radio network into a central node. We model the network of possible transmissions by a graph and consider a binary model of interference in which two transmissions interfere if the distance in the graph from the sender of one transmission to the receiver of the other is d_I or less. A *round* is a set of non-interfering transmissions. In [25], we determine the exact number of rounds required to gather one piece of information from each node of a square two-dimensional grid into the central node. The even case uses a method based on linear programming duality to prove the lower bound, and sophisticated algorithms using the symmetry of the grid and non-shortest paths to establish the matching upper bound. We then generalize our results to hexagonal grids.

Other results on multi-interface networks were obtained outside of MASCOTTE [30], [31], [55].

6.1.2. Routing

The problem of finding and updating shortest paths in distributed networks is considered crucial in today's practical applications. In the recent past, there has been a renewed interest in designing new efficient distance-vector algorithms (e.g., the distributed Bellman-Ford method implemented in the routing information protocol, RIP) as an alternative to link-state solutions (e.g., open shortest path first, OSPF) for large-scale distributed networks such as the autonomous systems topology of the Internet.

This year, we have proposed a new loop-free distance-vector routing algorithm, called LFR (Loop Free Routing), which is able to update the shortest paths of a distributed network with n nodes in fully dynamic scenarios [47]. We compared experimentally this new algorithm with DUAL, one of the most popular loop-free distance vector algorithms which is part of CISCO's EIGRP protocol. Our experiments on CAIDA IPv4 routed /24 topology dataset show that LFR out-performs DUAL in terms of memory requirements and number of messages.

We then proposed a new technique, called Distributed Computation Pruning (DCP) [48], for reducing the total number of messages sent and the space occupancy per node of every distance-vector routing algorithm based on shortest paths. We have evaluated experimentally the combination of DCP with DUAL and with LFR. We have observed that these combinations lead to a significant gain both in terms of number of messages sent and memory requirements per node.

We have also considered routing problems arising in road networs. In particular, we have conducted a theoretical study of the graph-augmentation problem of adding shortcuts in order to speedup route planning techniques [23]. We studied the algorithmic complexity of the problem and proposed approximation algorithms for a special graph class. We have also investigated ILP-based exact approaches and show how to stochastically evaluate a given shortcut assignment on graphs that are too large to do so exactly.

6.1.2.1. Compact routing

With the constant increase of the number of routing entries in the Internet, the size of the routing tables stored at router nodes increases drastically. Routing schemes such as BGP are showing their limits in terms of update time, search time, cost of signaling, etc. and alternatives have to be proposed. In particular, compact routing schemes propose interesting trade-offs between the size of the routing tables and the quality of the routes. They also take advantage of the particular properties arising in large scale networks such as low (logarithmic) diameter and high clustering coefficient.

High clustering coefficient implies the existence of few large induced cycles. Considering this fact, we proposed in [37] a routing scheme that computes short routes in the class of k-chordal graphs, i.e., graphs with no induced cycles of length more than k. Our routing scheme achieves an additive stretch of at most $k-1$, and the routing tables are computed with a distributed algorithm which uses messages of size $O(\log n)$ and takes $O(D)$ time, where D is the diameter of the network.

We also used *cops-and-robber* games (See Section 6.2.1.2) to propose the first compact routing scheme for k-chordal graphs using routing tables, addresses and headers of size $O(\log n)$ bits and achieving an additive stretch of $O(k \log \Delta)$ [58], [57], [77]. This scheme is based on a new structural decomposition for a graph class including k-chordal graphs: we proposed a quadratic algorithm that, given a graph G and $k \geq 3$, either returns an induced cycle larger than k in G, or computes a *tree-decomposition* of G, each *bag* of which contains a dominating path with at most $k-1$ vertices. We thus proved that any k-chordal graph with maximum degree Δ has treewidth at most $(k-1)(\Delta-1)+2$, improving the $O(\Delta(\Delta-1)^{k-3})$ bound of Bodlaender and Thilikos (1997). Moreover, any graph admitting such a tree-decomposition has small hyperbolicity.

In addition, we have pursued our investigation of the kind of structural graph properties that can or cannot be deduced from local (partial) views of the network. Such knowledge is crucial for the design of routing schemes. To this end, we have exhibited a hierarchy of problems and distributed models of computation [40].

6.1.2.2. Routing models evaluation

The evaluation of new routing models asks for large-scale and intensive simulations. However, existing routing models simulators such as DRMSim are limited in terms of the number of routing table entries it can dynamically process and control on a single computer. Therefore, we have conducted a feasibility study of the extension of DRMSim so as to support the Distributed Parallel Discrete Event paradigm [46]. We have studied several distribution models and their associated communication overhead. We have in particular evaluated the expected additional time (in hours) required by a distributed simulation of BGP (border gate protocol), the current interdomain routing protocol of the Internet, compared to its sequential simulation. We show that such a distributed simulation of BGP is possible with a reasonable time overhead.

6.1.2.3. Reconfiguration

In production networks, traffic evolution, failures and maintenance operations force to adapt regularly the current configuration of the network (virtual topology, routing of connections). The routing reconfiguration problem in WDM networks consists of scheduling the migration of established lightpaths from current routing to a new pre-computed one while minimizing service disruptions. We have shown in the past the relations between this problem and the graph searching problem and established NP-completeness and inapproximability results.

This year, we proved the monotonicity of the *process strategy* game [78], the graph searching game modeling the routing reconfiguration problem. Then, we have investigated on the influence of physical layer impairment constraints on the reconfiguration problem [41]. Setting up a new wavelength in a fiber of a WDM network requires recalibrating the other wavelengths passing through this fiber. This induces a cost (e.g., time, energy, degradation of QoS) that depends nonlinearly on the number of wavelengths using the fiber. Therefore, the order in which requests are switched affects the total cost of the operation. We have studied the corresponding optimization problem by modeling the cost of switching a request as a non-linear function depending on the load of the links used by the new lightpath. We have proved that determining the optimal rerouting order is NP-complete for a 2-nodes network, established general lower and upper bounds, identified classes of instances where the problem can be solved in polynomial time, and proposed a heuristic algorithm.

6.1.3. Energy efficiency

Recently, energy-aware routing has gained increasing popularity in the networking research community. The idea is that traffic demands are aggregated over a subset of the network links, allowing other links to be turned off to save energy. We develop several methods to improve routing protocols for backbone, wireless and content delivery networks. Several studies exhibit that the traffic load of the routers only has a small influence on their energy consumption. Hence, the power consumption in networks is strongly related to the number of active network elements, such as interfaces, line cards, base chassis,... The goal thus is to find a routing that minimizes the (weighted) number of active network elements used when routing. In [62], we exhibit that the power consumption can be reduced of approximately 33 MWh for a medium-sized backbone network.

In [54], we propose GreenRE - a new energy-aware routing model with the support of the new technique of data redundancy elimination (RE). Based on real experiments on Orange Labs platform and on simulations on several network topologies, we show that GreenRE can gain further 30% energy savings in comparison with the traditional energy-aware routing model.

One of the new challenges facing research in wireless networks is the design of algorithms and protocols that are energy aware. In [33], we use for the first time the evolving graph combinatorial model as a tool to prove an NP-Completeness result, namely that computing a Minimum Spanning Tree of a planar network in the presence of mobility is actually NP-Complete.

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 [63], we study the impact of using in-network caches and CDN cooperation on an energy-efficient routing: up to 23% of power can be saved in the backbone this way.

In [32], we study the energy efficiency of the networking part of data centers, accounting for between 10-20% of the total power consumption. We proposed a novel approach, called VMPlanner, for power reduction in the virtualization-based data centers. The idea of VMPlanner is to optimize both virtual machine placement and traffic flow routing so as to turn off as many unneeded network elements as possible for power saving.

Finally, in [56], [38], we summarize the main research results of the last years for energy efficiency for backbone, wireless, cellular and content distribution networks and highlight the main challenges of the field. Results are given for two operator networks, considering power and traffic forecasts for 2020.

6.2. Graph Theory

Participants: Julio Araújo, Jean-Claude Bermond, Frédéric Giroire, Frédéric Havet, František Kardoš, Ana Karolinna Maia, Remigiusz Modrzejewski, Leonardo Sampaio, Michel Syska.

6.2.1. Algorithms in graphs

MASCOTTE 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.

6.2.1.1. Complexity and Computation of Graph Parameters

We used graph theory to model various networks' problems. In general 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 where the problems are polynomial-time solvable.

Degree Constraint Subgraphs. A natural question in current social networks is *How do one find a small community (subgraph) in which anyone as at least d friends (neighbors)?* This problem can be modelled as degree-constrained subgraph problems where the objective is to find an optimal weighted subgraph, subject to certain degree constraints (in which each node has degree at most d), in a weighted graph. When $d = 2$, the problem is easy to solve since one simply needs to compute the girth of the graph. In [16], we proved that the problem is not in Apx for any $d \geq 3$. The proof is obtained by a reduction from Vertex Cover in regular graphs, followed by the use of an error amplification technique. On the positive side, we give an $\frac{n}{\log n}$-approximation algorithm for the class of graphs excluding a fixed graph H as a minor (including planar or bounded genus graphs), using dynamic programming.

Hyperbolicity in Large graphs. Hyperbolicity is a geometric notion that measure how the various shortest paths connecting two vertices can diverge in a graph. Knowing its value provides information on the geometry of the network, moreover it has practical implications for shortest path routing. Hyperbolicity can be computed in polynomial time algorithm ($\Theta(n^4)$). This is far from being practical for large graphs. So, in [69] we proposed a scalable algorithm for this problem. We also led some computational experiments of our algorithms on large-scale graphs.

Hull Number of graphs. In [64], we study the (geodesic) hull number of graphs. For any two vertices $u, v \in V$ of a connected undirected graph $G = (V, E)$, the closed interval $I[u, v]$ of u and v is the set of vertices that belong to some shortest (u, v)-path. For any $S \subseteq V$, let $I[S] = \bigcup_{u,v \in S} I[u, v]$. A subset $S \subseteq V$ is (geodesically) convex if $I[S] = S$. Given a subset $S \subseteq V$, the convex hull $I_h[S]$ of S is the smallest convex set that contains S. We say that S is a hull set of G if $I_h[S] = V$. The size of a minimum hull set of G is the hull number of G, denoted by $hn(G)$. First, we show a polynomial-time algorithm to compute the hull number of any P_5-free triangle-free graph. Then, we present four reduction rules based on vertices with the same neighborhood. We use these reduction rules to propose a fixed parameter tractable algorithm to compute the hull number of any graph G, where the parameter can be the size of a vertex cover of G or, more generally, its neighborhood diversity, and we also use these reductions to characterize the hull number of the lexicographic product of any two graphs. More on the hull number of graphs may be found in Araujo's thesis [13].

6.2.1.2. Graph Searching, Cops and Robber Games

Pursuit-evasion encompasses a wide variety of combinatorial problems related to the capture of a fugitive residing in a network by a team of searchers. The goal consists in minimizing the number of searchers required to capture the fugitive in a network and in computing the corresponding capture strategy. This can also be viewed as cleaning the edges of a contaminated graph. We investigated several variants of these games.

Web Caching & the surfer Game. A surprising application of some variant of pursuit-evasion games (namely Cops and Robber games) is the problem for a web-browser to download documents in advance while an internaut is surfing on the Web. In [53], [52], we provide a modelling of the prefetching problem in terms of Cops and Robber games. The parameter to be optimized is then the download-speed necessary for the Internaut only accesses to already download webpages. This allows us to provide several complexity results and polynomial-time algorithms in some graph classes.

Connected Graph Searching. Another variant of pursuit-evasion games is graph searching which is mainly related to graph decompositions. For instance, the minimum number of searchers needed to capture an invisble fugitive in a graph is equal to its pathwidth plus one. In [21], we investigated the connected variant of this game. A strategy is called connected if the clear part (the part where the fugitive cannot stand) always induces a connected subgraph. The main motivation for studying connected graph searching is the design of distributed protocols allowing searchers to compute a capture strategy (see also Section 6.2.1.3). [21] gathers most of the results of the last decade concerning connected graph searching, mainly focussing on the cost of connectivity in terms of number of searchers.

6.2.1.3. Distributed Algorithms

We investigated algorithmic problems arising in complex networks like the Internet or social networks. In this kind of networks, problems are becoming harder or impracticable because of the size and the dynamicity of these networks. One way to handle the dynamicity is to provide (distributed) fault tolerant algorithms. Studying the mobile agents paradigm seems to be a promissing approach (somehow related to Cops and Robber in Section 6.2.1.2) to adress some models of distributed computing. We considered distributed or even self-stabilizing algoritms for gathering and graph searching problems.

Graph Searching and Routing Reconfiguration. In [29], we developed a generic distributed algorithm for computing and updating various parameters on trees including the process number (see Section 6.1.2.3), and other related graph searching parameters (see Section 6.2.1.2). We also proposed an incremental version of the algorithm allowing to update these parameters after addition or deletion of any tree edge.

Robots in anonymous networks. Motivated by the understanding of the limits of distributed computing, we consider a recent model of robot-based computing which makes use of identical, memoryless mobile robots placed on nodes of anonymous graphs. The robots operate in Look-Compute-Move cycles that are performed asynchronously for each robot. In particular, we consider various problems such as graph exploration, graph searching and gathering in various graph classes. We provide a new distributed approach which turns out to be very interesting as it neither completely falls into symmetry-breaking nor into symmetry-preserving techniques. More precisely, we design algorithms for the gathering in rings [51], [70], grid [50] and trees [61]. We also proposed a general approach [71] to solve the three problems in rings. Finally, in [67], [44], [43], algorithms are designed to solve the graph searching problem in trees.

6.2.2. Structural graph theory

6.2.2.1. Directed graphs

Graph theory can be roughly partitioned into two branches: the areas of undirected graphs and directed graphs (digraphs). Even though both areas have numerous important applications, for various reasons, undirected graphs have been studied much more extensively than directed graphs. One of the reasons is that many problems for digraphs are much more difficult than their analogues for directed graphs. For example, one of the cornerstones of modern (undirected) graph theory is Minor Theory of Robertson and Seymour. Unfortunately, we cannot expect an equivalent for directed graphs. Minor Theory implies in particular that, for any fixed H, detecting a subdivision of H in an input graph G can be performed in polynomial time by the Robertson and Seymour linkage algorithm. In contrast, the analogous subdivision problem for digraph can be either polynomial-time solvable or NP-complete, depending on the fixed digraph H. In [65], we give a number of examples of polynomial instances, several NP-completeness proofs as well as a number of conjectures and open problems. We also investigated the related problem in which we want to detect an *induced* subdivision of H. Already, for undirected graphs the complexity of this problem depends on H. In [20], we show that for digraphs the complexity of this problem depends on H and on whether the input digraph G must be an oriented graph or is allowed to contain 2-cycles. We give a number of examples of polynomial instances as well as several NP-completeness proofs.

In a directed graph, a *star* is an arborescence with at least one arc, in which the root dominates all the other vertices. A *galaxy* is a vertex-disjoint union of stars. In [34], we consider the Spanning Galaxy problem of deciding whether a digraph D has a spanning galaxy or not. We show that although this problem is NP-complete (even when restricted to acyclic digraphs), it becomes polynomial-time solvable when restricted to strong digraphs. In fact, we prove that restricted to this class, the Spanning Galaxy problem is equivalent to the problem of deciding if a strong digraph has a strong digraph with an even number of vertices. We then show a polynomial-time algorithm to solve this problem. We also consider some parameterized versions of the Spanning Galaxy problem. Finally, we improve some results concerning the notion of *directed star arboricity* of a digraph D, denoted $dst(D)$, which is the minimum number of galaxies needed to cover all the arcs of D. We show in particular that $dst(D) \leq \Delta(D) + 1$ for every digraph D and that $dst(D) \leq \Delta(D)$ for every acyclic digraph D.

Hypergraphs are a generalization of graphs, in which every edge is incident to a set of vertices of any size (not necessarily 2). Like for digraphs, a lot fewer is known about them than about graphs. The two notions of eulerian and hamoltinians cycles have been extensively studied for graphs and digraphs. The analogue notion of eulerian cycle in a hypergraph was only introduced in 2010 by Lonc and Naroski. In [72], we introduce the notions of eulerian and hamiltonian circuits in directed hypergraphs. We show that both associated decision problems are NP-complete. Some necessary conditions for a dihypergraph to be have an eulerian circuit are presented. We exhibit some families of hypergraphs for which those are sufficient conditions. We also generalize a part of the properties of eulerian digraphs to the uniform and regular directed hypergraphs. Finally, we show that the de Bruijn and Kautz dihypergraphs are eulerian and hamiltonian in most cases.

6.2.2.2. Graph colouring

We mainly study graph colouring problems that model channel assignment problems.

A well-known such general problem is the following: we are given a graph G, whose vertices correspond to transmitters, together with an edge-weghting w. The weight of an edge corresponds to the minimum separation between the channels on its endvertices to avoid interferences. (If there is no edge, no separation is required, the transmitters do not interfere.) We need to assign positive integers (corresponding to channels) to the vertices so that for every edge e the channels assigned to its endvertices differ by at least $w(e)$. The goal is to minimize the largest integer used, which corresponds to minimizing the *span* of the used bandwidth.

We mainly studied a particular, yet quite general, case, called *backbone colouring*, in which there are only two levels of interference. So we are given a graph G and a subgraph H, called *the backone*. Two adjacent vertices in H must get integers at least q apart, while adjacent vertices in G must get integers at distance at least 1. The minimum span is this case is called the q-backbone chromatic number and is denoted $BBC_q(G, H)$. Backbone forests in planar graphs are of particular interests. In [74], we give a series of NP-hardness results as well as upper bounds for $BBC_q(G, H)$, depending on the type of the forest (matching, galaxy, spanning tree). Eventually, we discuss a circular version of the problem. In [73], we also consider a list version of the problem in which every vertex must be assigned an integer in its own list of available ones. We provide bounds using the Combinatorial Nullstellensatz for the list version on the channel assignment problem. Through this result and through structural approaches, we obtain good upper bounds for forests and matching backbone in planar graphs. In [68], we give an evidence to a conjecture of Broersma et al. stating that $BBC_2(G, T) \leq 6$, for every planar graph G and spanning tree T. We prove this conjecture in the particular case when T has diameter at most 4.

Another meaningful and very well-studied particular case of backbone colouring is $L(p, 1)$-labelling, which is p-backbone colouring of (G^2, G), where G^2 is the square of G (the graph with same vertex set as G, in which two vertices are adjacents if they are at distance at most 2 in G). Griggs and Yeh conjecture in 1992, that for every graph with maximum degree $\Delta \geq 2$, $BBC_2(G^2, G) \leq \Delta^2 + 1$. In [36], we prove this conjecture when Δ is large. In fact, we prove a more general statement. We prove for any q and sufficiently large Δ, if $\Delta(H) \leq \Delta^2$ and $\Delta(G) \leq \Delta$, then $BBC_q(H, G) \leq \Delta^2 + 1$. Our result also holds for the list version.

In [17], we studied another colouring problem motivated by a practical frequency assignment problem and, up to our best knowledge, new. In wireless networks, a node interferes with other nodes, the level of interference depending on numerous parameters: distance between the nodes, geographical topography, obstacles,... We model this with a weighted graph (G, w) where the weight function w on the edges of G represents the noise (interference) between the two end-vertices. The total interference in a node is the sum of all the noises of the nodes emitting on the same frequency. A *weighted t-improper k-colouring* of (G, w) is a k-colouring of the nodes of G (assignment of k frequencies) such that the interference at each node does not exceed the threshold t. We consider the Weighted Improper Colouring problem which consists in determining the *weighted t-improper chromatic number* defined as the minimum integer k such that (G, w) admits a weighted t-improper k-colouring. We also consider the dual problem, denoted the Threshold Improper Colouring problem, where, given a number k of colours, we want to determine the minimum real t such that (G, w) admits a weighted t-improper k-colouring. We show that both problems are NP-hard and present general upper bounds for both problems; in particular we show a generalisation of Lovász's Theorem for the weighted t-improper chromatic number. Motivated by the original application, we study a special interference model on various grids (square, triangular, hexagonal) where a node produces a noise of intensity 1 for its neighbours and a noise of intensity $1/2$ for the nodes at distance two. We derive the weighted t-improper chromatic number for all values of t.

Since some of the channel assignment problems must be done on-line, we are interested in some on-line graph colouring heuristics. We only studied such heuristics for the classical proper colouring. The easiest one, and the most widespread one, is the greedy algorithm, which colours the vertices one after another, giving to each vertex the smallest possible positive integer that is not already used by one of its neighbours. The *Grundy number* of a graph G is the largest number of colours used by any execution of the greedy algorithm to colour G. In [27], we give new bounds on the Grundy number of the different product of two graphs. The problem of determining the Grundy number of G is polynomial-time solvable if G is a P_4-free graph and NP-hard if G is a P_5-free graph. In [19], we define a new class of graphs, the *fat-extended P_4-laden graphs*, and we show a polynomial-time algorithm to determine the Grundy number of any graph in this class. Our class intersects the class of P_5-free graphs and strictly contains the class of P_4-free graphs. More precisely, our result implies that the Grundy number can be computed in polynomial time for any graph of the following classes: P_4-reducible, extended P_4-reducible, P_4-sparse, extended P_4-sparse, P_4-extendible, P_4-lite, P_4-tidy, P_4-laden and extended P_4-laden, which are all strictly contained in the fat-extended P_4-laden class.

A colouring c of a graph $G = (V, E)$ is a *b-colouring* if in every colour class there is a vertex whose neighborhood intersects every other colour classes. Such a colouring appears, when we try to optimize on-line the colouring of a graph, by changing the colour of all vertices of a colour class if it is possible. The *b-chromatic number* of G, denoted $\chi_b(G)$, is the greatest integer k such that G admits a b-coloring with k colours. A graph G is *tight* if it has exactly $m(G)$ vertices of degree $m(G) - 1$, where $m(G)$ is the largest integer m such that G has at least m vertices of degree at least $m - 1$. Determining the b-chromatic number of a tight graph had been shown to be NP-hard even for a connected bipartite graph. In [35], we show that it is also NP-hard for a tight chordal graph, and that the b-chromatic number of a split graph can be computed in polynomial time. Then we define the b-closure and the partial b-closure of a tight graph, and use these concepts to give a characterization of tight graphs whose b-chromatic number is equal to $m(G)$. This characterization is used to develop polynomial-time algorithms for deciding whether $\chi_b(G) = m(G)$, for tight graphs that are complement of bipartite graphs, P_4-sparse and block graphs. We generalize the concept of pivoted tree introduced by Irving and Manlove and show its relation with the b-chromatic number of tight graphs.

Many more results on greedy colourings and b-colourings have been proved in Sampaio's thesis [14].

We studied other variations of graph colouring. In [18], we aim at characterizing the class of graphs that admit a good edge-labelling. Such graphs are interesting, as they correspond to set of requests in UPP-digraphs (in which there is at most one dipath from a vertex to another) for which the minimum number of wavelengths is equal to the maximum load. This implies that the problem can be solved efficiently. First, we exhibit infinite families of graphs for which no good edge-labelling can be found. We then show that deciding if a graph admits a good edge-labelling is NP-complete. Finally, we give large classes of graphs admitting a good edge-labelling: C_3-free outerplanar graphs, planar graphs of girth at least 6, subcubic $\{C_3, K_{2,3}\}$-free graphs.

For a connected graph G of order at least 3 and a k-labelling $c : E(G) \to \{1, 2, \cdots, k\}$ of the edges of G, the *code* of a vertex v of G is the ordered k-tuple $(n_1, \cdots, n_k)$, where n_i is the number of edges incident with v that are labelled i. The k-labelling c is detectable if every two adjacent vertices of G have distinct codes. The minimum positive integer k for which G has a detectable k-labelling is the *detection number* of G. In [76], we show that it is NP-complete to decide if the detection number of a cubic graph is 2. We also show that the detection number of every bipartite graph of minimum degree at least 3 is at most 2. Finally, we give some sufficient condition for a cubic graph to have detection number 3.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

7.1.1. Contract APRF (région PACA/FEDER) RAISOM with 3-Roam and Avisto, 05/2009 - 04/2012

Participants: Jean-Claude Bermond, David Coudert, Alvinice Kodjo, Stéphane Pérennes, Issam Tahiri.

On Wireless IP Service Deployment optimization and monitoring.

(http://www-sop.inria.fr/mascotte/projets/raisom/)

7.2. Bilateral Grants with Industry

7.2.1. Contract CIFRE with Orange Labs, 11/2009 - 12/2012

Participants: Jean-Claude Bermond, Mikaila Toko Worou.

"Convention de recherche encadrant une bourse CIFRE" on the topic *Outils algorithmiques pour la détection des communautés*.

7.2.2. Contract CIFRE with Orange Labs, 02/2011 - 01/2014

Participants: Jean-Claude Bermond, Sébastien Félix.

"Convention de recherche encadrant une bourse CIFRE" on the topic *Smart Transports: optimisation du trafic dans les villes*.

7.2.3. Contract CIFRE with KONTRON, 11/2011 - 10/2014

Participants: Michel Syska, Mohamed Amine Bergach.

"Convention de recherche encadrant une bourse CIFRE" on the topic *Graphic Processing Units for Signal Processing* with joint supervision with AOSTE project.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR Jeunes Chercheurs DIMAGREEN, 09/2009-08/2012

Participants: David Coudert, Frédéric Giroire, Alvinice Kodjo, Joanna Moulierac, Nicolas Nisse, Truong Khoa Phan, Issam Tahiri.

The objectives of the project DIMAGREEN (DesIgn and MAnagement of GREEN networks with low power consumption) are to introduce and analyze energy-aware network designs and managements in order to increase the life-span of telecommunication hardware and to reduce the energy consumption together with the electricity bill.

(http://www-sop.inria.fr/teams/mascotte/Contrats/DIMAGREEN/index.php)

8.1.2. ANR Blanc AGAPE, 10/2009-09/2013

Participants: David Coudert, Frédéric Havet, František Kardoš, Ana Karolinna Maia, Grégory Morel, Nicolas Nisse, Stéphane Pérennes, Michel Syska.

The project AGAPE (Parameterized and exact graph algorithms) is led by MASCOTTE and implies also LIRMM (Montpellier) and LIFO (Orléans). The aim of AGAPE is to develop new techniques to solve exactly NP- hard problems on graphs. To do so, we envisage two approaches which are closely related ways to reduce the combinatorial explosion of NP-hard problems: moderately exponential exact algorithms and fixed-parameter tractability.

(http://www-sop.inria.fr/mascotte/Contrats/Agape.php)

8.1.3. ANR VERSO ECOSCells, 11/2009-12/2012

Participants: David Coudert, Issam Tahiri.

The ECOSCells (Efficient Cooperating Small Cells) project aims at developing the algorithms and solutions required to allow Small Cells Network (SCN) deployment. The consortium gathers industrial groups, together with 3 SMEs and 6 research institutes: ALCATEL-LUCENT BELL LABS (leader), ORANGE LABS, 3-ROAM, SEQUANS, SIRADEL, Inria teams MAESTRO, MASCOTTE and SWING, Université d'Avignon et des Pays de Vaucluse, Laboratoire des Signaux et Systèmes / Supelec, LAAS and Eurecom.

(http://perso.citi.insa-lyon.fr/hrivano/contrats/ecoscells.php)

8.1.4. Action ResCom, ongoing (since 2006)

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

(http://citi.insa-lyon.fr/rescom/)

8.1.5. Action Graphes, ongoing (since 2006)

Action Graphes, working group of GDR IM, CNRS.

(http://www.labri.fr/perso/raspaud/pmwiki/pmwiki.php)

8.2. European Initiatives

8.2.1. FP7 Projects

8.2.1.1. EULER

Participants: David Coudert, Luc Hogie, Aurélien Lancin, Bi Li, Nicolas Nisse, Stéphane Pérennes, Issam Tahiri.

Title: EULER (Experimental UpdateLess Evolutive Routing)
Type: COOPERATION (ICT)
Defi: Future Internet Experimental Facility and Experimentally-driven Research
Instrument: Specific Targeted Research Project (STREP)
Duration: October 2010 - September 2013
Coordinator: ALCATEL-LUCENT (Belgium)
Others partners:

Alcatel-Lucent Bell, Antwerpen, Belgium

3 projects from Inria: CEPAGE, GANG and MASCOTTE, France

Interdisciplinary Institute for Broadband Technology (IBBT),Belgium

Laboratoire d'Informatique de Paris 6 (LIP6), Université Pierre Marie Curie (UPMC), France

Department of Mathematical Engineering (INMA) Université Catholique de Louvain, Belgium

RACTI, Research Academic Computer Technology Institute University of Patras, Greece

CAT, Catalan Consortium: Universitat Politecnica de Catalunya, Barcelona and University of Girona, Spain

See also: http://www-sop.inria.fr/mascotte/EULER/wiki/

Abstract: STREP EULER (Experimental UpdateLess Evolutive Routing) is part of FIRE (Future Internet Research and Experimentation) objective of FP7. It aims at finding new paradigms to design, develop, and validate experimentally a distributed and dynamic routing scheme suitable for the future Internet and its evolution. The STREP EULER gathers 7 partners: Alcatel-Lucent Bell (leader) (Antwerp, Belgique), IBBT (Ghent, Belgium), UCL (Louvain, Belgium), RACTI (Patras, Grece), UPC (Barcelona, Spain), UPMC (ComplexNetworks, Paris 6), Inria (MASCOTTE, GANG, CEPAGE). MASCOTTE is the leader of WP3 on Topology Modelling and Routing scheme experimental analysis.

8.2.2. Collaborations in European Programs, except FP7

8.2.2.1. PICS CNRS (with Charles University, Prague), 01/2009-12/2012

Participants: Frédéric Havet, František Kardoš, Leonardo Sampaio.

Bilateral collaboration funded by the french CNRS. The funding covers scientific visits and workshops.

On Graph coloring: theoretical and algorithmic aspects.

8.2.2.2. PHC PROCOPE (with Discrete Optimization group of RWTH Aachen University), 01/2011-12/2012

Participants: Christelle Caillouet, David Coudert, Alvinice Kodjo, Issam Tahiri.

Bilateral collaboration funded by the french ministry of foreign affairs (MAE), the french ministry of research and education (MESR), and the Deutscher Akademischer Austauschdienst (DAAD). The funding covers scientific visits.

"Défis algorithmiques dans les réseaux de communication". The purpose of the project is to exchange expertise between the discrete optimization group of RWTH Aachen University and the MASCOTTE team at Inria Sophia-Antipolis and to address algorithmic problems in communication networks.

8.3. International Initiatives

8.3.1. Inria Associate Teams

8.3.1.1. ANR International Taiwan GRATEL, 01/2010 – 12/2013

Participants: Jean-Claude Bermond, Frédéric Havet, František Kardoš, Leonardo Sampaio.

GRATEL (Graphs and Telecomunications) has been started in collaboration with LABRI Bordeaux, UJF Grenoble and three partners in Taiwan: Sun Yat-sen University, the National Taiwan University and Academia Sinica.

(https://gratel.labri.fr/pmwiki.php?n=Main.HomePage)

8.3.2. Participation In International Programs

Inria FUNCAP (Inria-FAP): ALERTE (ALgorithmes Efficaces pour les Réseaux de TElécommunications), with Pargo Team, Universidade Federal do Ceará, Brazil, accepted in June 2011.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

Jørgen Bang-Jensen: University of Southern Denmark, Odensee, Denmark, May 1-31, 2012 (1 month);

Tom Bouvier: Université Bordeaux 1, Bordeaux, France, May 21-25, 2012 (1 week);

Xavier Defago: JAIST, School of Information Science, Ishikawa, Japan, March 5-23, last week of June, September 12 - 30, 2012 (2 months);

Michele Flammini: University of L'Aquila, Italy, June 18 - July 13 (3 weeks);

Ararat Harutyunyan: Simon Fraser University, Vancouver, Canada, May 19-27, 2012 (1 week);

Brigitte Jaumard: Concordia University, Montréal, Canada, April 23 - May 5, 2012 (3 weeks);

Mejdi Kaddour: University of Oran, Algeria, April 22 - 28, November 21-28, 2012 (2 weeks);

Takako Kodate: Tokyo Woman's Christian University, Suginami-ku, Tokyo, Japan, March 19-29 (2 weeks);

Uéverton Souza Dos Santos: Fluminense Federal University, Brazil, July 13-30, 2012 (3 weeks);

Amel Tandjaoui: University of Oran, Algeria, October 16 - November 16, 2012 (1 month);

Martin Tieves: RWTH Aachen University, Germany, December 16-21, 2012 (1 week);

Joseph Yu: Abbotsford and SFU, Vancouver, Canada, March 1 - April 20, 2012 (1 month 1/2).

8.4.2. Visits to International Teams

J.-C. Bermond: Orsay (March 23, 2012); Athens (May 20-29, 2012);

C. Caillouet: FUN Team, Inria Lille Nord Europe (July 1-6, 2012); Mathematics departement of RWTH Aachen, Germany (July 29-August 5, 2012);

D. Coudert: Alcatel-Lucent Bell labs, Antwerpeen, Belgium (January 10-12, 2012); Mathematics departement of RWTH Aachen, Germany (July 24-27, 2012);

F. Giroire: LIP, ENS Lyon (January 23-27, 2012);

F. Havet: LIP, ENS Lyon (January 23-27, 2012); Federal University of Ceara, Brasil (April 21-28, 2012); LABRI, University of Bordeaux 1 (July 9-11 2012);

A. Lancin: LABRI, University of Bordeaux 1 (March 5-7, 2012);

N. Nisse: LIP, ENS Lyon (January 23-27, 2012); LIF, Univ. Marseille (February 20-22, 2012); LRI, Univ. Paris-Sud 11 (March 19-20, 2012); Adolfo Ibanez University, Santiago, Chile (August 4-20, 2012);

T. K. Phan: Mathematics departement of RWTH Aachen, Aachen, Germany (August 26 -September 01, October 14 - December 06, 2012);

R. Soares: LABRI, University of Bordeaux 1 (March 5-10, 2012).

9. Dissemination

9.1. Scientific Animation

9.1.1. Participation in Committees

J.-C. Bermond: Expert for DRTT, and various projects outside France (Canada, Italy,...); Member of the Ph.D. committee of the University of Marseille;

D. Coudert: Member of the *comité du suivi doctoral* of Inria Sophia Antipolis (since January 2009); Member of *comité de sélection 27e section* of UJF, Grenoble, 2012; Member of the scientific board of the GIS ENSL-UNS (CNRS, ENSL, Inria, UNS) since 2011; Expert for the National Sciences and Engineering Research Council of Canada (NSERC), the Future and Emerging Technologies Open Scheme (FET-Open) European program, and the ANR;

J. Moulierac: Member of the *comité de sélection 27e section* of University of Versailles St-Quentin; Member of the CDL (Commission for software development) at Inria Sophia Antipolis since 2009; Member of the *Conseil de Département* (Department Committee) of IUT Nice since 2007;

M. Syska: Member of the commission ad-hoc ATER 27 UNS, IUT PAST 27 and ATER 11; Member of *Comité Permanent de Ressources Humaines (CPRH) UNS 27e*; Member of the *Conseil de Département* (Department Committee) of IUT Nice; Expert for DRTT PACA.

9.1.2. Editorial Boards

J.-C. Bermond: Combinatorics Probability and Computing, 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, SIAM book series on Discrete Mathematics, Transactions on Network Optimization and Control, Discrete Mathematics, Algorithms and Applications;

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

F. Havet: Discrete Mathematics and Theoretical Computer Science.

9.1.3. Steering Committees

D. Coudert: Pôle ResCom du GDR ASR du CNRS (since 2005); Rencontres francophones sur les aspects algorithmiques des télécommunications (AlgoTel);

F. Havet: Journées Graphes et Algorithmes (JGA); Journées Combinatoires et Algorithmes du Littoral Méditerranéen (JCALM).

9.1.4. Conference Organization

JCALM: 11èmes Journées Combinatoire et Algorithmes du Littoral Méditerranéen, Sophia Antipolis, France (February 16-17, 2012). Organizers: J. Araujo, F. Havet, A. Kodjo, A. Lancin, L. Sampaio;

ResCom: 10th Journées du Pôle ResCom du GDR ASR, Paris, France (November 28-29, 2012). Organizer: C. Caillouet (co-chair).

9.1.5. Workshop Organization

GOC 12: Workshop Franco-brésilien de Graphes et Optimisation Combinatoire, Redonda, Brasil, April 16-20, 2012. Organizers: F. Havet (co-chair), J. Araujo, A.-K. Maia, L. Sampaio and R. Soares.

9.1.6. Participation in Program Committees

J.-C. Bermond: 6th International Conference on FUN with Algorithms, Venice, Italy (June 4-6, 2012);

D. Coudert: 11th International Symposium on Experimental Algorithms (SEA'12), Bordeaux, France (June 7-9, 2012); IEEE GLOBECOM – Track on Green Communication Systems and Networks, Anaheim, CA, USA (December 3-7, 2012);

F. Havet: 14emes Journées Graphes et Algorithmes (JGA 2012);

J. Moulierac: 14e Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications (Algotel'12), La Grande Motte, France, May 29- June 1st, 2012.

9.2. Participation in Conferences and Workshops

9.2.1. Invited Talks

D. Coudert Presentation on *Energy efficiency in backbone and backhaul networks* at Journées du pôle Systèmes de Communications Sécurisées, Sophia Antipolis, January 24, 2012;

F. Giroire: Workshop Franco-brésilien de Graphes et Optimisation Combinatoire, Redonda, Brazil (April 16-20, 2012);

F.Havet: Birmingham workshop on Probabilistic methods in Graph theory, Birmingham, U. K. (March 25-29, 2012); Workshop Franco-brésilien de Graphes et Optimisation Combinatoire, Redonda, Brazil (April 16-20); SIAM Discrete Mathematics Conference, Halifax, Canada (June 18-21, 2012); Bordeaux Graph Workshop, Bordeaux, France (November 21-24, 2012) (Plenary Speaker);

N. Nisse: GRASTA'12, Banff, Canada (October 8-12, 2012); IMSA seminar, Univ. Adolfo Ibanez, Santiago, Chile (August 10th, 2012).

9.2.2. Participation in Scientific Meetings

COA: first meeting of GT Complexité et Algorithmes, Paris (November 21-22, 2012). Attended by N. Nisse and S. Pérennes;

EULER: First year review meeting, Bruxelles, Belgium (January 13, 2012). Attended by A. Lancin, D.Coudert; WP2 technical meeting, Bordeaux, France (March 8-9, 2012). Attended by A. Lancin, B. Li, N. Nisse; Plenary meeting and Technical Advisory Board meeting, Ghent, Belgium (June 5-8, 2012). Attended by D. Coudert, A. Lancin, and N. Nisse; 2nd year review meeting, Sophia Antipolis, France (October 19, 2012). Attended by D. Coudert, A. Lancin, and N. Nisse; Plenary meeting and Technical Advisory Board meeting, Louvain-la-Neuve, Belgium (December 10-12, 2012). Attended by A. Lancin and N. Nisse;

Evaluation seminar: Evaluation of the Mascotte project-team at the evaluation seminar of the research theme Networks and Telecommunications of Inria, Paris, France (March 21-23, 2012). Attended by most of the MASCOTTE permanent members (speakers: D. Coudert, F. Havet, J. Moulierac, N. Nisse);

FET: Meeting to prepare a FET2012 "Mobilizing the Cloud: Enabling Multi-User Mobile Outsourcing in the Cloud", Geneva, Switzerland (Januay 12-13, 2012). Attended by J.-C. Bermond and S. Pérennes;

GRATEL: ANR Gratel meeting, Bordeaux, France (November 20, 2012). Attended by J. Araujo (speaker), A. K. Maia and F. Havet (speaker);

Lip6: Networks Optimization Days, Paris, France (November 30, 2012). Attended by A. Kodjo;

Mascotte Days: Mascotte project annual seminar, Lac de Sainte-Croix, France (May 10-11, 2012). Attended by most of the Mascotte members;

ResCom: 10th Journées du Pôle ResCom du GDR ASR, Paris, France (November 28-29, 2012). Attended by D. Coudert, A. Kodjo, A. Lancin (speaker), F. Z. Moataz (speaker) and I. Tahiri (speaker);

SPREAD End of project assessment meeting, Paris, France (July 12, 2012). Attended by S. Pérennes;

TREND: TREND Network of Excellence meeting, Volos, Greece (October 1-5, 2012). Attended by L. Chiaraviglio and F. Giroire.

9.2.3. Participation in Conferences

Alan Turing's Heritage: Special event on How Turing's machine changed the world, Lyon, France, July 2-4, 2012. Attended by D. Coudert;

AlgoTel: 14th Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications, La grande Motte, France (May 29th - June 1st, 2012). Attended by C. Caillouet, D. Coudert, A. Lancin, N. Nisse (speaker);

BGW: Bordeaux Graph Workshop, Bordeaux, France (November 21-24, 2012). Attended by J. Araujo (speaker), F. Havet (invited speaker), A. K. Maia and R. P. Soares (speaker);

CoNEXT-SW: 8th ACM International Conference on emerging Networking Experiments and Technologies (ACM CoNEXT) Student Workshop, Nice, France (December 10-13, 2012). Attended by F. Z. Moataz (speaker) and T. K. Phan (speaker);

ECT: ECT Workshop spectral properties of complex networks, Trento, Italy (July 23-27, 2012). Attended by J. Galtier and M. Toko Worou (speaker);

EULER: Workshop at Fire, Aalborg, Denmark (May 9, 2012). Attended by A. Lancin;

FUN: 6th International Conference on FUN with Algorithms, Venice, Italy (June 4-6, 2012). Attended by J.-C. Bermond and F. Giroire (speaker);

GOC: Workshop Franco-brésilien de Graphes et Optimisation Combinatoire, Plage Redonda, Ceará, Brésil (April 16-20 2012). Attended by J. Araujo, F. Giroire (speaker), F. Havet (speaker), A.K. Maia, N. Nisse, R. Pardo Soares and L. Sampaio Rocha;

GRASTA: 5th Workshop on GRAph Searching, Theory and Applications, Banff, Canada (October 8-12, 2012); Attended by N. Nisse (speaker) and R. Pardo Soares;

ICALP: 39th International Colloquium Automata, Languages and Programming, University of Warwick, UK (July 9-12, 2012). Attended by B. Li (speaker);

JDG: Journée Thématique "Dynamique des Graphes", Paris, France (July 10th, 2012). Attended by J. Araujo and M. Toko Worou;

JGA: 14èmes Journées des Graphes et Algorithmes, Clemont-Ferrand, France (November 14-16, 2012). Attended by J. Araujo (speaker), B. Li (speaker), A. K. Maia (speaker), F. Z. Moataz and R. P. Soares (speaker);

LIRMM en fête pour ses 20 ans: Scientific event for celebrating the 20 years of the LIRMM, Montpellier, France, July 12. Attended by D. Coudert;

Networking: IFIP TC6 Networking, Prague, Czech Republic (May 21-25, 2012). Attended by T. K. Phan (speaker);

PADS: 26th ACM/IEEE/SCS Workshop on Principles of Advanced and Distributed Simulation, Zhangjiajie, China (July 15-19, 2012). Attended by A. Lancin (speaker).

9.2.4. Participation in Schools

11ème JCALM: 11èmes Journées Combinatoire et Algorithmes du Littoral Méditerranéen, Sophia Antipolis, France (February 16th - 17th, 2012). Attended by most of the Mascotte members (speakers: J. Araujo, F. Havet, A. Kodjo, A. Lancin, L. Sampaio);

12ème JCALM: 12èmes Journées Combinatoire et Algorithmes du Littoral Méditerranéen, Montpellier, France (October 11th - 12th, 2012). Attended by J. Araujo and A. K. Maia;

Ecole management Inria Paris, France (March 28-30 and June 13-14, 2012). Attended by D. Coudert;

EPIT: L'Ecole de Printemps d'Informatique Théorique, Ile de Ré, France (Mars 26-30, 2012). Attended by A. Lancin, R. Modrzejewski, L. Sampaio and I. Tahiri;

NASSSO: Numerical Analysis Summer School 2012 Stochastic Optimization, Cadarache, France (June 25th- July 6th, 2012). Attended by B. Li.

SSMS: Summer School on Social Media Modeling and Search, Fira, Santorini, Greece (September 10-14, 2012). Attended by M. Toko Worou;

9.3. Teaching - Supervision - Juries

9.3.1. Teaching

Licence:

J. Araujo, Algorithmique et Programmation, 30h ETD, Cycle Initial Polytechnique 2, École Polytech'Nice, UNS;

C. Caillouet, Introduction to Operating Systems, 30h ETD, Level L1, IT Tools, 31h, Level L1, Database and advanced information system, 98h, Level L2, IUT Nice Côte d'Azur, UNS;

A. Kodjo, Algorithme-Programmation Objet-Python, 40h ETD, Level L2, UNS;

J. Moulierac and A. Lancin, ASR5 - Networks, 130h ETD, Level L1, IUT Nice Côte d'Azur, UNS;

N. Nisse, informatique, 60h ETD, 1re année classes préparatoires (L1), Lycée International de Valbonne;

M. Syska, Introduction to Operating Systems, 40h ETD, Level L1, Operating Systems : Advanced Programming, 63h ETD, Level L2, Bash Scripting, 15h ETD, Level L3, Introduction to Algorithms, 36h ETD, Level L3, Linux Systems Administration, 24h ETD, Level L3, IUT Nice Côte d'Azur, UNS.

Master:

D. Coudert, Algorithm for Telecom 2, 32h ETD, M2 Ubinet/PENSUNS, UNS;

F. Giroire and N. Nisse, Combinatoire des graphes, 31h ETD, master MDFI, Univ. d'Aix-Marseille, France;

F. Giroire, 16h ETD, Introduction to Probabilities and Statistics, International track of the Master 1 IFI, UNS;

F. Giroire and N. Nisse, Algorithms for Telecommunications, 31h ETD, parcours Ubinet master 2 IFI, UNS.

F. Giroire, F. Havet and N. Nisse, Programmation linéaire et combinatoire, school at ENS Lyon (January 23-27, 2012).

9.3.1.1. Administration

Collaboration Inria-Lycée International de Valbonne: N. Nisse is co-responsible of the Computer Science course of MPSI;

IUT Nice Côte d'Azur: M. Syska is responsible of the Computer Science Department of IUT since september 2011;

Ubinet, Master IFI: J.-C. Bermond is member of the scientific committee;
F. Giroire is responsible of the Internships within international stream Ubinet, Master IFI (http://ubinet.unice.fr), since October 2011;

International Master 1: J.-C. Bermond is member of the scientific committee of the international track of the M1 (http://computerscience.unice.fr/master1).

9.3.2. Supervision

PhD:

J. Araújo, *Coloration et convexité dans les graphes*, September 13, 2012, J.-C. Bermond, C. Linhares Sales and F. Giroire.

L. Sampaio, *Aspects algorithmiques d'heuristiques de coloration de graphes*, November 19, 2012, F. Havet.

M. Toko Worou, *Outils algorithmiques pour la détection des communautés dans les réseaux*, December 7, 2012, J.-C. Bermond and J. Galtier.

PhD in progress:

4th year:

I. Tahiri, *Optimisation dans les réseaux de collecte IP sans fils*, since November 2009, D. Coudert.

3rd year:

S. Félix, *Smart transports : optimisation du trafic dans les villes*, since January 2011, J.-C. Bermond and J. Galtier.

A. Lancin, *Study of network properties for efficient routing algorithms*, since January 2011, D. Coudert.

R. Modrzejewski, *Systèmes pair-à-pair de partage de données*, since November 2010, S. Pérennes and F. Giroire.

R. Pardo Soares, *Routing reconfiguration in WDM networks*, since November 2010, D. Coudert and N. Nisse.

2nd year:

T. Al Fares, *Trees in digraphs*, since September 2011, F. Havet and A. El Sahili (Lebanese University, Beyruth, Lebanon).

M. A. Bergach, *GPGPU Graphics Processing Units for signal processing*, since September 2011, M. Syska.

A. Kodjo, *Design and optimization of multi-operators wireless backhaul networks*, since October 2011, D. Coudert.

B. Li, *Study of Internet model and its properties for efficient routing algorithms*, since October 2011, D. Coudert and N. Nisse.

A. K. Maia, *Partitions of directed graphs*, since September 2011, F. Havet.

T. K. Phan, *Design and Management of networks with low-power Consumption*, since October 2011, D. Coudert and J. Moulierac.

1st year:

F. Z. Moataz, *Conception et optimisation de réseaux robustes aux pannes et variations de capacités*, since October 2012, D. Coudert.

9.3.2.1. Internships

J. Araujo, J.-C. Bermond and N. Nisse: supervised the internship of Guillain Potron (ENS Paris) on sorting algorithms and hull number, June-July 2012 (2 months);

J.-C. Bermond and D. Coudert: supervised the internship of Fatima Zahra Moataz (M2 Ubinet, Sophia Antipolis) on the diverse routing problem with SRLGs, March-August 2012 (6 months);

D. Coudert and N. Nisse: supervised the internship of Thomas Bellitto (L3 ENS Cachan - antenne de Bretagne) on linear orderings and graphs decompositions, June-July 2012 (2 months);

F. Giroire: supervision of the TIPE of Simon Dorgueil Simon and Yves Barrault on the Analysis of P2P storage system;

N. Nisse: supervised the internship of Mélanie Ducoffe (Univ. Nice-Sophia ANtipolis) on cops and robber games in directed graphs, July-August 2012 (2 months).

9.3.3. Juries

J.-C. Bermond: member of the PhD jury of Julio Araújo (September 13, 2012) and Mikaila Toko Worou (December 7, 2012), University Nice-Sophia Antipolis;

D. Coudert: member of the PhD jury of Ahmed Frikha, Université de Rennes (September 28, 2012); member of the PhD jury of Leornardo Sampaio Rocha, University of Nice Sophia Antipolis (November 19, 2012);

F. Havet: external referee of the PhD of Petru Valicov, University of Bordeaux 1 (July 10, 2012); external referee of the PhD of Petr Skoda, Simon Fraser University, Burnaby, BC, Canada (September 13, 2012); external referee of the PhD of Lino Demasi, Simon Fraser University, Burnaby, BC, Canada (October 2, 2012);

S. Perennes: Referee and member of the PhD jury of Patricia Maatouk-Kaiser, Supelec Université Libanaise (December 21, 2012).

9.4. Popularization

Accueil d'une classe de MPSI: D. Coudert, F. Giroire and N. Nisse participated to the event at Inria (http://www.inria.fr/centre/sophia/actualites/accueil-d-une-classe-de-mpsi-retour-en-images);

Attention grands travaux: Several members of Mascotte participated to the documentary "Attention grands travaux : Sophia Antipolis - L'utopie High Tech" for the Public-Sénat channel (watch it online);

Attractiveness: J.-C. Bermond is in charge of the attractiveness of the center Inria Sophia Antipolis Méditerannée. He organized Inria days with Athens (February 14-15, and May 21-22, 2012);

Fête de la Science: F. Giroire presented the stand "Magie et jeux mathématiques" at Sophia Antipolis, France (October 10, 2012);

Ils débarquent sur votre téléphone: D. Coudert and C. Castro co-signed an article entitle "Ils débarquent sur votre téléphone : 4G, NFC et Li-Fi ?" on Inriality. Originaly prepared for the series « Le saviez-vous » posted on Inria.fr and twitter;

Internet and Smartphones: J.-C. Bermond gave a talk at the evening "Internet et Smartphones" organized at Nice (CUM) on April 10 by SEE Cote d'Azur and la Mairie de Nice Organisation (February 14-15, 2012);

Internet and Graph theory: J.-C. Bermond and J.Moulierac wrote an article on Internet and Graph theory for CDC (a journal destined to teachers and students in high schools) [79];

Plaisirs des Sciences: F. Havet gave the conference "La hasard fait-il bien les choses ? : une gentille introduction au probabilités" at Rians, France (February 14, 2012);

Scientific mediation: J.-C. Bermond supervised a brainstorming on scientific mediation with Inria staff members.

10. Bibliography

Major publications by the team in recent years

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[10] F. GIROIRE, D. MAZAURIC, J. MOULIERAC. *Energy Efficient Routing by Switching-Off Network Interfaces*, in "Energy-Aware Systems and Networking for Sustainable Initiatives", N. KAABOUCH, W.-C. HU (editors), IGI Global, 2012, p. 207-236, http://hal.inria.fr/hal-00759894.

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Doctoral Dissertations and Habilitation Theses

[13] J. ARAUJO. *Coloration et convexité dans les graphes*, Université de Nice Sophia-Antipolis, September 2012, http://hal.inria.fr/tel-00732919.

[14] L. SAMPAIO. *Aspects algorithmiques d'heuristiques de coloration de graphes*, Université de Nice Sophia-Antipolis, November 2012, http://hal.inria.fr/tel-00759408.

[15] M. TOKO WOROU. *Outils Algorithmiques pour la Détection des Communautés dans les Réseaux*, Université de Nice Sophia-Antipolis, December 2012.

Articles in International Peer-Reviewed Journals

[16] O. AMINI, D. PELEG, S. PÉRENNES, I. SAU, S. SAURABH. *On the approximability of some degree-constrained subgraph problems*, in "Discrete Applied Mathematics", August 2012, vol. 160, n^{o} 2, p. 1661-1679 [*DOI :* 10.1016/J.DAM.2012.03.025], http://hal.inria.fr/lirmm-00736702.

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