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Project-Team Mascotte

Méthodes Algorithmiques, Simulation et Combinatoire pour l'OpTimisation des TElécommunications

Sophia Antipolis - Méditerranée

THEME COM

Activity Report

2008

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2. Overall Objectives

2.1. Introduction

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). Furthermore, MASCOTTE is strongly associated with Orange Labs (research and development of France Telecom) in Sophia Antipolis via the CRC CORSO (2003-2005) and CORSO2 (2006-2008). Its research fields are Algorithmics, Discrete Mathematics, Combinatorial Optimization and Simulation, with applications to telecommunication or transportation networks.

The objectives of the MASCOTTE project-team are to design networks or 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 year both these theoretical and applied tools for the design of various networks, such as WDM, SDH, wireless, satellites, overlay, peer-to-peer and even transportation networks (several being combined sometimes).

This results also in the production of advanced softwares such as the MASCOPT library (MASCOTTE optimization), and ambitious software projects such as the OSA computer Simulation Architecture.

2.2. Highlights of the year

Recruitments: Our last three PhD students have been recruited in 2008: O. Amini research associate at CNRS ENS, J-S. Sereni research associate at CNRS LIAFA and M-E. Voge associate professor at the University of Lille.
Organization: This year MASCOTTE has organized two big conferences: AdHocNow and JGA.
Marathon: Last, but not least, a team MASCOTTE has been ranked first association in the Marathon Nice-Cannes.

3. Scientific Foundations

3.1. Scientific Foundations

Keywords: *Algorithmics*, *Combinatorial optimization*, *Discrete mathematics*, *Graph theory*, *Simulation*.

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. According to 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 requests. In addition to deterministic hypothesis (for example if a connection fails it is considered as definitely down and not intermittently), the project started recently to consider probabilistic ones.

An example of tool which appears in various context is graph coloring: WDM networks where colors represent wavelengths, radio networks where colors represent frequencies, fault tolerance where colors represent shared resource risk groups, and scheduling problems.

Theoretical results are described after, with more emphasis on those of graph theory (Section 6.4) and algorithmic aspects (Section 6.5).

4. Application Domains

4.1. Application Domains

Keywords: *Telecommunication networks (Network design): backbone*, *overlay*, *peer-to-peer*, *wireless mesh*.

For the last year the main application domain of the project is Telecommunications. Within this domain, we consider applications that follow the needs and interests of our industrial partners, in particular ORANGE LABS or ALCATEL LUCENT, but also more recently SME's like UBISTORAGE or 3-ROAM.

MASCOTTE is mainly interested in the design of heterogeneous networks. The project has kept working on the design of backbone networks in particular optical ones (see Section 6.1), but has considerably increased his research on wireless (see Section 6.2), in particular inside the European FET project AEOLUS.

These researches are done inside the CRC CORSO 2, and the ANR (program for young researchers) OSERA on optimization and simulation of ambient networks. We have also developed two cooperations with SMEs. The first one is on data storage in peer-to-peer networks with the SME UBISTORAGE and the second is one on radio networks with the SME 3-ROAM. The proposal SPREADS (Safe P2P reliable Architecture for Data Storage) with UBISTORAGE and other partners has been funded by ANR. A joint PhD started in December 2007 funded by the province PACA and the SME 3-ROAM to work on the project WISDOM (Wireless IP Service Deployment Optimization and Monitoring).

5. Software

5.1. Prototype Software

- MASCOPT (http://www-sop.inria.fr/mascotte/mascopt/)
  Participants: Fabrice Peix, Michel Syska.

  MASCOPT is a free Java library distributed under the terms of the LGPL license which is dedicated to graph and network processing. MASCOPT includes a collection of Java interfaces and classes that implement fundamental data structures and algorithms.

  The main objective of MASCOPT (MASCOTTE Optimization) project is to ease software development in the field of network optimization. Examples of problems include routing, grooming, survivability, and virtual network design. MASCOPT helps implementing a solution to such problems by providing a data model of the network and the demands, classes to handle data and ready to use implementation of existing algorithms or linear programs (e.g. shortest paths or integral multicommodity flow). A new release of MASCOPT has been developed since 2005 in order to allow MASCOPT users to program an interface, not an implementation. Indeed, basic MASCOPT users may simply use the existing API, but more advanced users may like to use different implementations of some features. The applications already written will not be affected, they will not have to be rewritten but will have different choices of internal implementation. This may lead to better performances for specific issues.

  Along with the internship of M. Hadj Djilani [98] we have introduced an interface to the CLP/CBC solver using JNI.

  MASCOPT has intensively been used within MASCOTTE industrial cooperation programs for experimentation and validation purposes: with Alcatel Space Technologies on the design of fault-tolerant on-board network satellites, on the optimization of the access layer and planning of satellite communication and with Orange Labs on the design of telecommunication backbone networks.

  Another cooperation at INRIA Sophia Antipolis Méditerranée is the use of MASCOPT by the Aoste team.

- **OSA**: an Open Component-based Architecture for Discrete-Event Simulations. (http://osa.inria.fr/wiki/)
  Participants: Olivier Dalle, Fabrice Peix, Judicael Ribault.

  Component-based modeling has many well-known good properties. One of these properties is the ability to distribute the modeling effort amongst several experts, each having his/her own area of system expertise. Clearly, the less experts have to care about areas of expertise of others, the more efficient they are in modeling sub-systems in their own area. Furthermore, the process of studying complex systems using discrete-event computer simulations involves several areas of non-system expertise, such as discrete-event techniques or experiment planning.

  The Open Simulation Architecture (OSA) [103] is designed to enforce a strong separation of the end-user roles and therefore, ensure a successful cooperation of all the experts involved in the process of simulating complex systems.

  The OSA architecture is also intended to meet the expectations of a large part of the discrete-event simulation community: it provides an open platform intended to support researchers in a wide range of their simulation activities, and allows the reuse and sharing of system models in the simulation community by means of a flexible and generic component model (Fractal).

  OSA is Open Source (LGPL) and is available for download on the INRIA forge server http://osa.gforge.inria.fr/.

- CORRAL: a stackable versioning system based on Linux device-mapper.
  Participants: Olivier Dalle, Julian Monteiro.

  In the context of the SPREADS ANR project (Safe Peer-to-peer based REliable Architecture for Data-Storage), we implemented a prototype of flexible versioning system operating at the low block level in the Linux operating system [100]. This system uses the transparent Copy-On-Write mechanism provided by the Linux Device-Mapper layer to identify the modified blocks of a file-system partition. Operating at block level allows this system to be independent of the File System and provides a implicit unit a version management. For example, unchanged blocks between successive versions can be shared between versions, thus reducing the disk usage of new versions. Furthermore, the system allows for the simultaneous availability (read-only mount) of any version, which allows to navigate in historic “snapshots” of the partition.

6. New Results

6.1. Backbone Networks

Participants: Jean-Claude Bermond, David Coudert, Frédéric Giroire, Florian Huc, Dorian Mazauric, Joanna Mouliérac, Nicolas Nisse, Fabrice Peix, Stéphane Pérennes, Ignasi Sau-Valls.

Network design is a very wide subject which concerns all kinds of networks. For telecommunications networks it 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. For instance, optical backbones use the WDM technology to take better advantage of the capacity of the optical fibers often already installed. This is achieved through the multiplexing of several wavelength channels onto the same fiber. In that case a resource allocation is an optical channel, which consists of a path and a wavelength assigned on each link along the path, and is called a *lightpath*. If wavelength translation is performed in optical switching, then to each channel may be assigned different wavelengths on each link along the path; otherwise the wavelength continuity constraint must be satisfied on all links along the path. Of course, two lightpaths sharing a link must use different wavelengths on that link. 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 considered by a lot of academic and industrial teams in the world. Our approach is to attack these problems with tools from discrete mathematics and to consider mainly telecommunications networks. This approach is shared by other teams in Europe, most of them being part of European projects IST FET AEOLUS (where MASCOTTE is leader of sub-project *SP2 Resource management*) and COST 293 Graal (where MASCOTTE is leader of working group *WG-A broadband and optical networks*). Outside Europe, many teams have also this approach and sometimes we have direct collaborations with them: Vancouver (EA RESEAUXCOM), Montréal, Fortaleza,...

6.1.1. Traffic Grooming

In a WDM network, routing a connection request consists in assigning it a route in the physical network and a wavelength. When each request uses at most $1/C$ of the bandwidth of the wavelength, we say that the grooming factor is C. That means that on a given edge of the network we can groom at most C requests on the same wavelength. With this constraint the objective can be either to minimize the number of wavelengths (related to the transmission cost) or minimize the number of Add/Drop Multiplexers (ADM) used in the network (related to the cost of the nodes).

We have first addressed the problem of traffic grooming in WDM rings or paths with All-to-All uniform unitary traffic. The goal is to minimize the total number of ADMs required. We have shown that this problem corresponds to a partition of the edges of the complete graph into subgraphs, where each subgraph has at most C edges (where C is the grooming ratio) and where the total number of vertices has to be minimized. Using tools of graph and design theory, we optimally solved the problem for practical values and infinite congruence classes of values for a given C. We give optimal constructions on unidirectional rings when $C \geq N(N-1)/6$ and when $C = 3, 4, 5, 6, 12$, on paths when $C = 2$, give good upper bounds on bidirectional rings for $C = 2, 3$, and propose an approximate construction for all-to-all traffic on unidirectional rings [22]. We also showed how to improve lower bounds by using refined counting techniques, and how to determine the maximum number of connections which can be established in a path of size N or in a DAG. Furthermore, we have established the first in-approximability result on traffic grooming using a study of the complexity (including parametrized complexity) and (in)approximability of the smallest degree constraint subgraph problem [48], [82], [49] (see Section 6.5). We have also provided an approximation algorithm for ring and path networks with approximation factor of $O(n^{1/3} \log^2 n)$, independent of the grooming factor. Finally, we proposed an *a priori* placement of ADMs in unidirectional WDM rings allowing to satisfy any set of requests with bounded degree d (a node is source or destination of at most d requests) [95], [68].

6.1.2. Multicast Aggregation

Traditional IP Multicast has been proposed in order to manage group communications over the Internet in a bandwidth efficient manner. Although this proposition has been well studied, there are still many issues to deal with before its deployment. In [20], we propose a new algorithm, mQMA, that deals with two important problems of traditional IP multicast, i.e., multicast forwarding state scalability and multi-constrained QoS routing. The mQMA algorithm builds few trees and maintains few forwarding states for the groups thanks to the technique of multicast tree aggregation, which allows several groups to share the same delivery tree. Moreover, mQMA builds trees satisfying multiple QoS constraints. We show, through extensive simulations, that mQMA leverages the same QoS performance as Mamcra which is the main multi-constrained multicast routing algorithm. Moreover, mQMA dramatically reduces the number of trees to be maintained.

6.1.3. Shared Risk Resource Group.

This notion has been introduced to capture survivability issues when a set of resources may fail simultaneously. Applied to WDM networks, it expresses that some links and nodes may fail simultaneously. The reliability of a connection therefore depends on the number of Shared Risk Resource Groups (SRRG) through which it is routed. Consequently, this number has to be minimized. This problem has been proved NP-complete and hard to approximate in general, even when routing a single request. Some heuristics using shortest paths have already been designed, however the cost (the usual routing cost, not in term of SRRG) was not part of the objective. We have proposed a column generation formulation for the problem of minimizing a linear combination of the average number of SRRG per paths and the cost of the routing [55]. It allows to solve efficiently the problem of maximizing the reliability of a set of connection requests in MPLS/WDM mesh networks with SRRGs while keeping the cost of the routing low.

6.1.4. Reconfiguration in WDM Networks

In production networks, as the traffic evolves with time, the virtual topology may not remain optimal for the evolving traffic, leading to a degradation of network performance. However, adapting the virtual topology to the changing traffic may lead to service disruption. Furthermore, connection oriented networks, and in particular GMPLS and WDM networks, are facing an acceleration in both number and frequency of traffic variations. From a daily time period, reconfiguration of the network has now to be performed continuously.

In this context, we have developed tools to switch connections from a pre-computed routing to another in a transparent way for end users, that is without service disruption. We thus concentrated on the reoptimization phase of the network, or *migration* of the routing. We have modeled this problem as a scheduling problem in a dependency digraph that may contains cycles, the *process number*, and then established some similarities and differences with two other known problems: the *pathwidth* and a particular *graph searching problem*.

Dependency cycles are broken through the use of temporary routes (called "agents" in the model) that have to be minimized. Determining the process number is in general NP-complete and difficult to approximate. In [88], we proposed a heuristic algorithms that performs better and faster than previous proposals. In [87] we have investigated the problem with the extra constraints that it might be impossible for the network operator to interrupt some connections because of the contract signed with the corresponding clients.

Related work on graph searching problem is reported in Section 6.5.

6.1.5. Permutation Routing in Hexagonal Networks.

In the permutation routing problem, each processor is the origin of at most one packet and the destination of no more than one packet. The goal is to minimize the number of time steps required to route all packets to their respective destinations, under the constraint that each link can be crossed simultaneously by no more than one packet. We study this problem in a hexagonal network, i.e. a finite subgraph of a triangular grid, which is a widely used network in practical applications.

In [44], we have presented an optimal distributed permutation routing algorithm for full-duplex hexagonal networks, using the addressing scheme described in [107]. Furthermore, we prove that this algorithm is oblivious and translation invariant.

6.1.6. Miscellaneous

Behavioral Modes in Enterprise End-Users. Traditionally, user traffic profiling is performed by analyzing traffic traces collected on behalf of the user at aggregation points located in the middle of the network. However, the modern enterprise network has a highly mobile population that frequently moves in and out of its physical perimeter. Thus an in-the-network monitor is unlikely to capture full user activity traces when users move outside the enterprise perimeter. The distinct environments, such as the cubicle and the coffee shop (among others), that users visit, may each pose different constraints and lead to varied behavioral modes. It is thus important to ask: is the profile of a user constructed in one environment representative of the same user in another environment?

In [57], we answer in the negative for the mobile population of an enterprise. Using real corporate traces collected at nearly 400 end-hosts for approximately 5 weeks, we study how end-host usage differs across three environments: inside the enterprise, outside the enterprise but using a VPN, and entirely outside the enterprise network. Within these environments, we examine three types of features: (i) environment lifetimes, (ii) relative usage statistics of network services, and (iii) outlier detection thresholds as used for anomaly detection. We find significant diversity in end-host behavior across environments for many features, thus indicating that profiles computed for a user in one environment yield inaccurate representations of the same user in a different environment.

Cardinality Estimation Algorithms. In [30], a new class of algorithms to estimate the cardinality of very large multisets using constant memory and doing only one pass on the data is introduced. It is based on order statistics rather than on bit patterns in binary representations of numbers. Three families of estimators are analyzed. They attain a standard error of using M units of storage, which places them in the same class as the best known algorithms so far. The algorithms have a very simple internal loop, which gives them an advantage in terms of processing speed. For instance, a memory of only 12 kB and only few seconds are sufficient to process a multiset with several million elements and to build an estimate with accuracy of order 2 percent. The algorithms are validated both by mathematical analysis and by experimentation on real Internet traffic.

6.2. Wireless networks

Participants: Jean-Claude Bermond, Afonso Ferreira, Jérôme Galtier ,, Cristiana Gomes, Luc Hogie, Florian Huc, Christelle Molle, Julian Monteiro, Napoleao Nepomuceno, Fabrice Peix, Stéphane Pérennes, Patricio Reyes, Hervé Rivano.

This year, MASCOTTE has intensified its effort on mesh, *ad hoc* and sensor wireless networks within international and national collaborations with academic and industrial partners, as mentioned below.

In particular, we have studied radio networks with a focus on combinatorial optimization, graph theoretic, and algorithmic properties. The approach privileged in the team, based on the aforesaid theoretical tools, with a network design flavor, is complementary with those developed in other INRIA project-teams such as PLANETE, MAESTRO, ARES or POPS. The complementarity has been exploited through an ARC collaboration with ARES and POPS and the start of a joint PhD between MAESTRO and MASCOTTE.

At the international level, our researches are comparable and collaborative with some groups in renowned research centers such as CTI of Patras in Greece, Universities of Roma or Salerno in Italy, the Technion Institute in Israël, SFU in Vancouver, Canada, Arizona State University in USA, or the University of Sao Paulo in Brazil.

We studied a wide range of issues of wireless networks, from the design of efficient medium access techniques or energy aware protocols, to the development of theoretical tools for analyzing and evaluating dynamic networks. We are also developing a specific focus on the design of radio access networks, such as radio data gathering networks, that are recently known as *Wireless Mesh Networks*. Some graph coloring problems motivated by channel assignment in wireless networks are detailed in Section 6.4 and the optimization techniques that we have developed are also cited in Section 6.3.

6.2.1. Bandwidth and Capacity Allocation in Wireless Mesh Networks

There is an increasing interest in using Wireless Mesh Networks (WMNs) as next-generation broadband and ubiquitous access network and they will play a central role in overly computing. In comparison to cellular, wireless single-hop, or wired networks, WMNs are indeed a scalable and cost-effective solution to collect information from mobile clients and send it to the Internet over a multi-hop wireless backhaul infrastructure.

A WMN is a fixed infrastructure of wireless routers, collecting and forwarding the traffic of mesh clients. This backhaul network interacts with other networks through special routers called gateways. Providing an end-to-end throughput guarantee is extremely valuable to network operators involved in WMN design and provisioning.

The Round Weighting Problem, in the settings of Wireless Mesh Networks, consists in computing the most efficient allocation of bandwidth to connections. In classical wired networks, this is closely related to multi-commodity flow problems, which have been extensively studied in the literature.

Unfortunately, radio signals are subject to signal attenuation, and to interference constraints. This means that, in radio networks, transmissions must be performed in communication steps, such that interfering transmissions do not happen at the same time.

In [36], we model non-interfering radio transmissions as independent sets. We then relate the complexity of round weighting to the complexity of various independent set problems (e.g. maximum weight independent set, vertex coloring, fractional coloring). These equivalence are obtained by studying the dual of the Round Weighting problem. From this relation, we deduce that in general, round weighting is hard to approximate within $n^{1-\varepsilon}$ (n being the size of the radio network). We also provide polynomial (exact or approximation) algorithms in specific settings.

In [73], we give exact or almost exact bounds for the same problem in the specific case of regular grids. Under very general hypothesis on the traffic demand, we mainly prove that the throughput is determined by the bottleneck around the base station.

In [72], we address joint gateways placement, routing and scheduling problems. We focus on models computing optimal solutions for WMN design and provisioning. Throughput maximization does not model a fair bandwidth allocation. It may force some links to receive very low bandwidth or even to starve in order to reduce interferences. To cope with QoS criteria asked by the network operators, we investigate max-min throughput optimization which guarantees that each source node is allocated a lower bounded amount of bandwidth.

In [59], [58], we address the routing and call scheduling problem in which one has to find a minimum-length schedule of selected links in a TDMA (Time Division Multiple Access) based wireless network. As we deal with multi-hop networks, these selected links represent a routing solution (paths) providing enough capacity to achieve the routers requirements of bandwidth. It is the relaxation of the bandwidth allocation problem, therefore the rounds might be scheduled during non integer durations and data can be routed on multiple paths. It can be considered as an upper bound for networks with distributed links scheduling, like in IEEE 802.11. It can also be useful in a context where centralized links scheduling is possible (e.g. IEEE 802.16) that can directly take advantage of our analysis. We present an efficient cross-layer formulation of the problem that computes joint routing and scheduling. We use a branch-and-price algorithm that computes the optimal solution of the problem. A column generation algorithm is used to cope with the exponential set of rounds. The branch-and-bound algorithm provides mono-routing. We run experiments on networks from the literature, with different number of gateways. We present a *lower bound* for this problem based in the coloring problem. Our analysis points out that the "bottleneck" region analysis is enough to find the optimal solution. The bottleneck is usually the gateway considering almost uniform traffic. The integer round-up property (IRUP) seems to hold for our problem.

In [76], [66], we develop another exact linear program based on path-flow formulation and provide an efficient joint line and column generation process where both paths and rounds are generated in auxiliary programs.

In [75], a more sophisticated linear model is proposed. In graph theory, the maximum flow problem is known to be the dual of the minimum cut problem. The strong theorem of duality says that the optimal solutions of both problem are equal. Using this argument, we develop a new representation of the problem which allows us to consider the activation duration of rounds in such a way that traffic can cross the network cuts. We develop a new linear programming formulation that computes the theoretical optimum of the transport capacity of a WMN. In order to cope with large instances, we exploit sophisticated process of Operational Research based on primal/dual algorithm and combined line and column generation. An asset of this formulation is to point out a bounded region, a "bottleneck" of the network, that seems to be enough to optimize in order to get the optimal throughput of the whole network.

We have also investigated the problem of minimizing the size of routers queues while ensuring a fair bandwidth allocation. This has motivated the introduction and study of a new combinatorial problem, the proportional coloring. Given a graph G with positive weights associated to its edges, we want to find a colouring which preserves the proportion given by the weights associated to each edge. If such colouring exists, we want to find one using a minimum number of colours. We have proved that deciding if a weighted graph admits a proportional colouring is polynomial while determining its proportional chromatic index is NP-hard, provided a lower bound and an upper bound for this parameter, and identified classes of graphs for which we can exactly determine the proportional chromatic index [63].

6.2.2. Gathering in Wireless Networks

We pursued during this period our study of the problem of gathering information from the nodes of a multi-hop radio network into a predefined destination node under reachability and interference constraints. We focus on binary interference models that claims that two calls are conflicting depending on their hop distance.

The problem we consider was motivated by a question asked by FRANCE TELECOM about “how to provide Internet connection to a village” and is related to the following scenario. Suppose we are given a set of communication devices placed in houses in a village. They require access to a gateway (for instance, a satellite antenna) to send and receive data through a multi-hop wireless network.

A slight variation of this problem has received much attention in the context of sensor networks. A basic activity in a sensor network is the systematic gathering of the sensed data at a base station for further processing. An important factor to consider in data gathering applications is the *latency* of the information dissemination process. Indeed, the data collected by a node can frequently change thus making essential that they are received by the base station as soon as it is possible without being delayed by collisions.

An equivalent formulation of this problem is the so-called **s-personalized broadcast** where a single device (the gateway in the problem of FRANCE TELECOM or the base station in sensor networks) has a different piece of information to broadcast to every other device in the network. The s-personalized broadcast consists of scheduling such a constrained broadcast in minimum time (the time when the last data is arrived at destination).

In [21], we consider the case in which the network is a path and the destination node is either at one end or at the center of the path. We give algorithms and lower bounds on the minimum number of rounds for this problem. The algorithms are shown to be optimal.

In [51], [52], we deal with tree networks. Here two calls in two different branches are incompatible only if they have the same sender. Our results highlight a big difference whether buffering in the intermediate nodes is allowed [52] or not [51].

In [99], we consider the distributed version of the aforesaid call scheduling problem. Assuming random arrivals, the goal is to ensure the stability of the queueing system, bounding the average number of awaiting messages in the wireless network. We propose two distributed algorithms, valid for any binary interference model, and with constant overhead.

6.2.3. Delay Tolerant Networks

Mobile Ad hoc NETworks (MANETs) are wireless networks composed of mobile nodes able to spontaneously interconnect with other nodes in their geographical neighborhood. A consequence to node mobility is that MANETs are likely to get partitioned over time. Because of this they belong to the class of Delay Tolerant Networks (DTNs).

We addressed the problem of broadcasting across DTNs [61], maximizing the number of nodes reached, minimizing the duration of the process, and minimizing the bandwidth utilized. Herein we introduce the notion of *message urgency*. Roughly the more urgent a message is, the greater number of nodes should be reached, the faster possible; and the lesser attention should being paid on bandwidth utilization. We call this broadcast protocol the “context-aware broadcast protocol” (CABP), where the urgency of the broadcast message is viewed as a context information.

The assessment of routing protocols for ad hoc networks is a difficult task, due to the networks’ highly dynamic behavior and the absence of benchmarks. However, in some networks referred to as *Fixed Schedule Dynamic Networks* (FSDNs), the topology dynamics at different time intervals can be predicted. This happens for example in LEO satellite constellations or in Wireless Sensor Networks, where, due to energy limitations, network nodes can be scheduled to sleep in given periods. We have exploited the *Evolving Graph* theoretical model of FSDNs in order to design and evaluate least cost routing protocols for MANETs with known connectivity patterns. These protocols are then used as benchmarks for establishing fair comparisons between the four MANET routing protocols, namely DSDV, DSR, AODV and OLSR. This is done through extensive simulations using *NS2* network simulator within different realistic scenarios [67].

Moreover, we investigate the class of distributed storage systems whose content may evolve over time [81]. Each component or node of the storage system is mobile and the set of all nodes forms a DTN. We focus on efficient ways for distributing evolving files within DTNs and for managing dynamically their content, and on dynamic files where not only the latest version is useful but also previous ones; we restrict however to files which have no use if another more recent version is available. We consider both the cases when nodes do cooperate or not. Without cooperation, only the source may transmit a copy of the latest version of a file to a node that it meets, while in the other case any node may transmit a copy of a file. We provide optimal policies which maximizes a general utility function under a constraint on the number of transmissions within a slot.

6.2.4. Energy Awareness

We also performed a scalability analysis over a novel integer programming model devoted to optimize power consumption efficiency in heterogeneous wireless sensor networks [46]. This model is based upon a schedule of sensor allocation plans in multiple time intervals subject to coverage and connectivity constraints. By turning off a specific set of redundant sensors in each time interval, it is possible to reduce the total energy consumption in the network and, at the same time, avoid partitioning the whole network by losing some strategic sensors too prematurely.

6.2.5. Medium Access Control

In the context of radio distributed networks, we present a generalized approach for the Medium Access Control (MAC) with fixed congestion window [89]. Our protocol is quite simple to analyze and can be used in a lot of different situations. We give mathematical evidence showing that our performance is tight, in the sense that no protocol with fixed congestion window can do better. We also place ourselves in the WiFi/WiMax framework, and show experimental results enlightening collision reduction of 14% to 21% compared to the best known other methods. We show channel capacity improvement, and fairness considerations.

[77] is dedicated to a specific work about the impact of the MAC layer type on the capacity of the network. Using linear programming models, we compare the capacity of a network with MAC link per link acknowledgment to the case were the acknowledgments are done by the transport layer (TCP like).

6.3. Simulation and Optimization Tools

Participants: Olivier Dalle, Mohamed Hadj Djilani, Juan-Carlos Maureira, Christelle Molle, Julian Monteiro, Napoleao Nepomuceno, Fabrice Peix, Judicael Ribault, Hervé Rivano, Michel Syska.

In order to cope with the constant evolution and ever growing complexity and size of networks, new tools and modeling techniques are regularly developed within MASCOTTE. These tools are first developed to answer the internal needs of the team, but we also pay attention to the visibility and the dissemination of these tools in the scientific community.

6.3.1. Discrete-Event Simulation

In the domain of discrete-event simulation, our development efforts on the Open Simulation Architecture (OSA) are going on [104] (See Section 5.1 and http://osa.inria.fr/wiki/.); we are still exploring the benefits of original techniques and tools, such as Aspect Oriented Programming or Architecture Description Languages. In [70], we show that the combined use of these techniques can help to build new patterns of reuse in the definition of simulation scenarios. Such patterns allow for the definition of more sophisticated scenarios while still ensuring the reuse without change of existing (and validated) simulation code. These improvements have been implemented within OSA. We also investigated the possibility of porting the concept of shared component found in the Fractal Component Model in the DEVS simulation formalism[56].

Several new projects have officially started with a strong focus on simulation tools and techniques: the INRIA ARC “Broccoli” project is a two years collaboration (with Institute TELECOM in Evry and the INRIA ADAM EPI in Lille) about very large scale deployment and instrumentation of OSA distributed simulations on Grid-computing facilities (e.g. on Grid 5000); the “SPREADS” ANR project is a three years project (with four other french teams) about evaluation and optimization of a peer-to-peer based reliable storage system for which simulations of very large peer-to-peer systems will be done using OSA.

6.3.2. Combinatorial Network Optimization

The MASCOPT [106] library has reached maturity and is intensively used inside the team for testing and evaluation of optimization programs (see Section 5.1 and http://www-sop.inria.fr/mascotte/mascopt). During the last year we have pursued its development and the following research has been validated by implementing the algorithm with MASCOPT.

In [79], a hybrid optimization framework for tackling cutting and packing problems, which is based upon a particular combination scheme between heuristic and exact methods. A metaheuristic engine works as a generator of reduced instances for the original optimization problem, which are formulated as mathematical programming models. These instances, in turn, are solved by an exact optimization technique (solver), and the performance measures accomplished by the respective models are interpreted as score (fitness) values by the metaheuristic, thus guiding its search process.

In [66], [76] we address the problem of computing the transport capacity of Wireless Mesh Networks dedicated to Internet access. Routing and transmission scheduling have a major impact on the capacity provided to the clients. A cross-layer optimization of these problems allows the routing to take into account contentions due to radio interferences. We develop exact linear programs and provide an efficient column generation process computing a relaxation of the problem. It allows to work around the combinatorics of simultaneously achievable transmissions, hence computing solutions on large networks. Our approach is validated through extensive simulations.

6.4. Graph theory

Participants: Marie Asté, Jean-Claude Bermond, Nathann Cohen, Frédéric Havet, Florian Huc, Dimitrios Michail, Stéphane Pérennes, Bruce Reed, Hervé Rivano.

MASCOTTE principally investigates applications in telecommunications via graph theory (see other objectives). However it also studies a number of theoretical problems of general interest. Our research mainly focused on two important topics: graph colouring and random graphs.

- Graph colouring is a hot topic in graph theory. It is one of the oldest problem in combinatorics (with the 4-colour problem), has a central position in discrete mathematics and a huge number of applications. Lots of new results have been obtained the last ten years with the fast development of new techniques (structural and probabilistic). In MASCOTTE we studied graph colouring problems via these new methods (probabilistic method, discharging method).
- Since the seminal paper of Erdös and Rényi, the theory of random graphs has now grown a very active field with an extensive literature. There are many beautiful results in the theory of random graphs as well as various applications in computer science, biology, ... In MASCOTTE, we study random graphs for their own sake but as well as tools to solve some graph-theoretic questions which have nothing to do with randomness.

6.4.1. Graph Colouring

We study different kind of colouring problems, improper colouring, $L(p,q)$-labelling, greedy colouring and facial colouring. The first three originated in some practical problem they model. Improper colouring and $L(p,q)$-labellings are both motivated by channel assignment and greedy by on-line algorithms. We also studied perfect graphs.

Improper colouring: A *k-improper colouring* is a mapping c from its vertex set into a set of colours such that every vertex has at most k neighbours with the same colour. A result of Lovász states that for any graph G, such a partition exists if $\geq \left\lceil \frac{\Delta(G)+1}{k+1} \right\rceil$. When $k=0$, this bound can be reduced by Brooks' Theorem, unless G is complete or an odd cycle. We study [85] the following question, which can be seen as a generalisation of the celebrated Brooks' Theorem to improper colouring: does there exist a polynomial-time algorithm that decides whether a graph G of maximum degree Δ has k-improper chromatic number at most $\lceil \frac{\Delta+1}{k+1} \rceil - 1$? We show that the answer is no, unless $= P$, when $\Delta = \ell(k+1)$, $k \geq 1$ and $\ell + \sqrt{\ell} \leq 2k+3$. We also show that, if G is planar, $k=1$ or $k=2$, $\Delta = 2k+2$, and $\ell = 2$, then the answer is still no, unless $= P$. These results answer some questions of Cowen et al. [102].

$L(p,q)$-labelling: An *$L(p,q)$-labelling of G* is an integer assignment f to the vertex set $V(G)$ such that $|f(u) - f(v)| \geq p$, if u and v are adjacent, and $|f(u) - f(v)| \geq q$, if u and v have a common neighbour. Such a concept is a modelling of a simple channel assignment, in which the separation between channels depends on the distance. More precisely, it has to be at least p if they are very close and q if they are close (but not very close). The goal is to find an $L(p,q)$-labelling f of G with minimum *span* (i.e. $\max\{f(u) - f(v), u, v \in V(G)\}$). We gave various bounds on the span on such labellings [33], [60], [93], [94]. The two main results in this area are the following: Firstly, we asymptotically settle [94] Wegner's Conjecture (1977) by showing that the span of an $L(1,1)$ labelling of a planar graph G is at most $\frac{3}{2}\Delta(G) + o(\Delta(G))$, where $\Delta(G)$ is the maximum degree of G. This proof has been generalised to $L(p,q)$-labelling for any $p \geq q$ and to graph with no $K_{3,k}$-minor. Secondly, we establishe Griggs and Yeh conjecture

by showing [60], [93] that if Δ is large enough, every graph with maximum degree at most Δ has an $L(p,1)$-labelling with span at most Δ^2+1.
We also investigate the algorithmic issue of $L(p,q)$-labellings. Finding an $L(2,1)$-labelling with minimum span of a graph is an NP-hard problem. In [91], we provide a "fast" exponential algorithm to compute such a labelling.
Greedy colouring: The *Grundy number* of a graph G, denoted by $\Gamma(G)$, is the largest k such that G has a *greedy* k-colouring, that is a colouring with k colours obtained by applying the greedy algorithm according to some ordering of the vertices of G. In [50], [83], we study the Grundy number of the lexicographic, cartesian and direct products of two graphs in terms of the Grundy numbers of these graphs. Regarding the lexicographic product, we show that $\Gamma(G)\times\Gamma(H)\leq\Gamma(G[H])\leq 2^{\Gamma(G)-1}(\Gamma(H)-1)+\Gamma(G)-1$. In addition, we show that if G is a tree or $\Gamma(G)=\Delta(G)+1$, then $\Gamma(G[H])=\Gamma(G)\times\Gamma(H)$. We then deduce that for every fixed $c\leq 1$, given a graph G, it is CoNP-Complete to decide if $\Gamma(G)\leq c\times\chi(G)$ and it is CoNP-Complete to decide if $\Gamma(G)\leq c\times\omega(G)$. Regarding the cartesian product, we show that there is no upper bound of $\Gamma(G\square H)$ as a function of $\Gamma(G)$ and $\Gamma(H)$. Nevertheless, we prove that for any fixed graph G, there is a function h_G such that, for any graph H, $\Gamma(G\square H)\leq h_G(\Gamma(H))$. Regarding the direct product, we show that $\Gamma(G\times H)\geq\Gamma(G)+\Gamma(H)-2$ and construct for any k some graph G_k such that $\Gamma(G_k)=2k+1$ and $\Gamma(G_k\times K_2)=3k+1$.
Facial Colouring: A vertex colouring of a plane graph is ℓ-facial if every two distinct vertices joined by a facial walk of length at most ℓ receive distinct colours. Motivated by the well-known Cyclic Colouring Conjecture, it has been conjectured that every plane graph has an ℓ-facial colouring with at most $3\ell+1$ colours. In [92], we improve the currently best known bound and show that every plane graph has an ℓ-facial colouring with at most $\lfloor 7\ell/2\rfloor+6$ colors. Our proof uses the standard discharging technique, however, in the reduction part we have successfully applied Hall's Theorem, which seems to be quite an innovative approach in this area. In [31], we prove that every plane graph is 3-facially 11-colourable. As a consequence, we derive that every 2-connected plane graph with maximum face-size at most 7 is cyclically 11-colourable. These two bounds are for one off from those that are proposed by the $(3\ell+1)$-Conjecture and the Cyclic Colouring Conjecture.
Perfect Graphs: A graph is *perfect* if for every subgraph the chromatic number equals its clique number. M. Chudnovsky et al. in [101] settled the Strong Perfect Graph Conjecture which asserts that a graph is perfect if and only if it Berge (i.e. has no odd hole nor odd antihole). Their proof is based on a decomposition theorem stating that a Berge graph either:

(a) is in one of five basic classes of perfect graphs (line graphs of bipartite graphs, their complements, bipartite graphs, their complements, or double split graphs), or

(b) permits one of three partitions (a proper 2-join, a homogeneous pair, or a special type of skew partition which they call balanced).

A *skew partition* of a graph G is a partition of its vertex set into two nonempty sets A and B such that A induces a disconnected subgraph of G and B induces a disconnected subgraph of $\overline{G}$. A skew partition is said to be balanced if every path of G with endpoints in B and interior in A is even, and every path of $\overline{G}$ with endpoints in A and interior in B is even. [43] surveys previous results on skew partitions. It outlines the proof due to M. Chudnovsky et al. [101] which shows that balanced skew partitions cannot occur in a minimal imperfect Berge graph. The paper also presents new algorithms which test for the existence of skew partitions in the five basic classes of perfect graphs in $O(n^5)$ time.
Two nonadjacent vertices of a graph form an *even pair* if every induced path between them has an even number of edges. The notion of even pair is strongly related to perfect graphs as the Strong Perfect Graph Theorem is equivalent to the following statement: Minimal imperfect graphs are minimal even pair free. A graph is strict quasi-parity (SQP) if each of its induced subgraphs is a clique or contains an even pair. A conjecture proposed by S. Hougardy in 1991 states that every minimal non-SQP is a chordless cycle of odd length at least five, or the complement of such a cycle, or the line graph of a bipartite graph. In [37], we show that this conjecture is true for planar graphs. We also give a constructive characterization of all the planar minimal forbidden subgraphs for the class of SQP's.

The class of even-hole-free graphs is a class of graphs related to the one of perfect graphs. In [17], we show that every even-hole-free graph has a bisimplicial vertex, that is a vertex whose set of neighbours is the union of two cliques. As a direct corollary, we obtain that the chromatic number of such a graph is less than twice its clique number.

Miscellaneous: Marginally, we studied fractional colouring. Given an integer p, a graph G has an odd complete minor of order p if G contains p vertex-disjoint trees such that every two of them are joined by an edge and such that all the vertices of the trees can be two-coloured in such a way that for each edge joining two trees its end vertices have the same colour. Gerards and Seymour conjectured that if a graph has no odd complete minor of order p then it is $(p-1)$-colourable. This is a generalization of Hadwiger's conjecture, which states that every graph without a complete minor of order p is $(p-1)$-colourable. In [35], every graph G with no odd complete minor of order p has a fractional $2p$-colouring.

We also studied the complementary problem to graph colouring, i.e. partitioning into cliques. Given a graph $G=(V,E)$ and a positive integer k, the partition into cliques (PIC) decision problem consists of deciding whether there exists a partition of V into k disjoint subsets $V_1, V_2, \cdots, V_k$ such that the subgraph induced by each part V_i is a complete subgraph (clique) of G. In [24], we establish both the NP-completeness of PIC for planar cubic graphs and the Max SNP-hardness of PIC for cubic graphs. We present a deterministic polynomial time approximation algorithm for finding clique partitions in maximum degree three graphs.

Let k be a positive integer. A *k-edge-weighting* of a graph G is an assignment of an integer $w(e)$ from the set $1, 2, \cdots, k$ to each edge e of G. Each k-edge-weighting of a graph can be used to induce a vertex labelling of the graph by assigning to each vertex the sum of the weights of all of the edges of the graph with which it is incident. A k-edge-weighting of a graph is said to be vertex-coloring if its induced vertex labelling is a coloring of the graph, i.e., if adjacent vertices receive different labels. In [18] we show that every graph without components isomorphic to K_2 permits a vertex-colouring 16-edge-weighting.

In 2002, S. Khot posed the Unique Games Conjecture which generalises the PCP theorem. This conjecture would imply important inapproximability results for several combinatorial optimisation problems including some of those detailed above. Intuitively, the UGC states that, for some particular class of games, namely unique games, it is NP-hard to decide if one can find a near optimal solution or if all the solutions are far from optimal. This conjecture is now one of the most important open problem in complexity and approximability theory. In [96], we study a problem closely related to the UGC: Max-E2-Lin2. In this problem, the input is a graph G having two types of edges, one imposing the two end vertices to receive different colours and the other imposing the end vertices to have the same colour. The goal is to colour G with 2 colours so that the number of edges whose constraint is satisfied is maximum. We prove that this problem is APX-complete when restricted to bipartite graphs. Using the Theorem of Parallel Repetitions, we discuss the consequences of this result in the frame of Unique Games.

6.4.2. Random Graphs

We studied various parameters of random graphs or random planar graphs.

In [28], we present a study of the mixing time of a random walk on the largest component of a supercritical random graph, also known as the giant component. We identify local obstructions that slow down the random walk, when the average degree d is at most $O(n/d)$, proving that the mixing time in this case is $\Theta((n/d)2)$ asymptotically almost surely. As the average degree grows these become negligible and it is the diameter of the largest component that takes over, yielding mixing time $\Theta(n/d)$ asymptotically almost sure.

A *total colouring* is the assignment of a colour to each vertex and edge of a graph such that no adjacent vertices or incident edges receive the same colour and no edge receives the same colour as one of its endpoints. In [40], we study the fractional total chromatic number of $G_{n,p}$ as p varies from 0 to 1. We also present an algorithm which computes the fractional total chromatic number of a random graph in polynomial expected time.

In [39] we consider a random planar graph R_n and estimate its maximum degree. More precisely, R_n is drawn uniformly at random from the set of all simple planar graphs on n labelled vertices. We see that with high probability the maximum degree of R_n is $\Theta(\ln n)$. We consider also the maximum size of a face and the maximum increase in the number of components on deleting a vertex. These results extend to graphs embeddable on any fixed surface.

We try to make ballot theorems part of the body of results that hold for all random walks (with independent identically distributed steps), regardless of the precise distribution of their steps. We succeed in proving [19] ballot-style theorems that hold for a broad class of random walks, including all random walks that can be renormalized to converge in distribution to a normal random variable. A truly general ballot theorem, however, remains beyond our grasp.

6.4.3. Miscellaneous

Hoàng-Reed conjecture asserts that every digraph D has a collection of circuits $C_1, \cdots, C_{\delta^+}$, where δ^+ is the minimum out-degree of D, such that the circuits of have a forest-like structure. Formally, $|V(C_i) \cap (V(C_1) \cup \cdots \cup V(C_{i-1}))| \leq 1$, for all $i = 2, \cdots, \delta^+$. In [32], we verify this conjecture for the class of tournaments.

Art gallery problems are, broadly speaking, the study of the relation between the shapes of regions in the plane and the number of points needed to guard them. These problems have been extensively studied over the last decade and have found different type of applications in practical situation. Normally the number of sides of a polygon or the general shape of the polygon is used as a measure of the complexity of the problem. In [45], we present and explore another measure of complexity, namely, the number of guards required to guard the boundary, or the walls, of the gallery. We prove that if n guards are necessary to guard the walls of an art gallery, then an additional team of at most $4n - 6$ will guard the whole gallery. This result improves a previously known quadratic bound, and is a step towards a possibly optimal value of $n - 2$ additional guards. The proof is algorithmic, uses ideas from graph theory (visibility graph induced on the already placed guards), and is mainly based on the definition of a new reduction operator which recursively eliminates the simple parts of the polygon. We also use the fact that every gallery with c right-turn angles can be guarded by at most $2c - 4$ guards. This latter result is optimal.

In [34], we prove there exists a function $f(k)$ such that for every $f(k)$-connected graph G and for every edge $e \in E(G)$, there exists an induced cycle C containing e such that $G \setminus E(C)$ is k-connected. This proves a weakening of a conjecture of Lovász due to Kriesell.

In [47], we give a necessary condition for a digraph to contain a directed cycle of length 4. Contrary to the undirected case in which an obvious necessary condition is the number of edges one cannot expect such an easy condition for digraphs. Therefore we introduce the suitable parameter: the mixing property.

In [26], we consider the problem of determining constructions with an asymptotically optimal oblivious diameter in small world graphs under the Kleinberg's model. In particular, we give the first general lower bound holding for any monotone distance distribution, that is induced by a monotone generating function. Namely, we prove that the expected oblivious diameter is $\Omega(\log^2 n)$ even on a path of n nodes. We then focus on deterministic constructions and after showing that the problem of minimizing the oblivious diameter is generally intractable, we give asymptotically optimal solutions, that is with a logarithmic oblivious diameter, for paths, trees and Cartesian products of graphs, including d-dimensional grids for any fixed value of d.

In [62], we investigate the following problem: given a set of jobs and a set of people with preferences over the jobs, what is the optimal way of matching people to jobs? Here we consider the notion of popularity. A matching M is popular if there is no matching M' such that more people prefer M' to M than the other way around. If there is no popular matching, a reasonable substitute is a matching whose unpopularity is bounded. We consider two measures of unpopularity - unpopularity factor denoted by u(M) and unpopularity margin denoted by g(M). Here we show that a matching M that achieves u(M) = 2 can be computed in $O(m\sqrt{n})$ time (where m is the number of edges in G and n is the number of nodes) provided a certain graph H admits a matching that matches all people.

6.5. Algorithms

Participants: David Coudert, Jérôme Galtier, Florian Huc, Dorian Mazauric, Nicolas Nisse, Stéphane Pérennes, Bruce Reed, Ignasi Sau-Valls.

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 either with exact algorithms or approximation ones. In particular we obtained many results on graph searching, a significantly growing area. For instance, the first two editions of the "Workshop on Graph Searching, Theory and Applications" took place in Crete (2006) and Brazil (2008). Graph Searching encompasses a wide variety of combinatorial problems related to the capture of an arbitrary fast 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 minimum number of searchers is called the search number of the network. In particular, this problem has been widely studied for its close relationship with graphs decompositions. Note that this problem has also a practical impact in the area of optical network reconfiguration which is dealt with in Section 6.1.4 "Reconfiguration in WDM networks". An objective of MASCOTTE is to establish the impact (in terms of number of searchers or in number of steps of the capture strategy) of some constraints the fugitive (resp., the strategy) is subject to.

6.5.1. Graph Searching

We mainly investigate three constraints of graph searching: the visibility of the fugitive, the monotony of the strategy and the connectedness of the strategy. Roughly, if the fugitive is visible (i.e., the searchers are permanently aware of the position of the fugitive) then graph searching is equivalent to treewidth, while it is equivalent to pathwidth otherwise. A strategy is said monotone if the part where the fugitive may be (the clear part) strictly inclusion-decreases. This property is crucial because it establishes the equivalence between graph searching and graph decompositions. Finally, a strategy is said connected if the clear part always induces a connected subgraph. In particular, when the strategy has to be computed online, this property ensures safe communications between the searchers during the whole strategy.

In [71], [86], [53], [54], we developed a generic distributed algorithm for computing and updating various parameters on trees including the process number, the node search number and the edge search number. We also proposed an incremental version of the algorithm allowing to update these parameters after addition or deletion of any tree edge.

In [38], we prove that non-deterministic graph searching (the fugitive is visible a limited number of steps) introduced by Fomin et al. [27] is monotone, i.e., there always exists a monotone strategy using the smallest number of searchers. This result led to the unified view of graphs decompositions in terms of partition functions and partitioning-trees. We investigate the conditions under which a partition function admits a Fixed Parameter Tractable algorithm. More precisely, we propose a set of simple sufficient conditions on a partition function Φ, that ensures the existence of a linear-time explicit algorithm deciding if a set A has Φ-width at most k (k fixed) [84].

In [41], we investigate the cost of the connectedness of a strategy. We design an algorithm that computes a connected capture strategy using at most $O(tw(G) * k)$ times the search number of G, in any k-chordal graph G with treewidth $tw(G)$. In [29] we then prove that, when the fugitive is visible, the ratio between connected search number and the search number of an n-node graph is $\Theta(\log n)$ and that, in this setting, imposing the strategy to be monotone may increase the number of searchers.

One of the main applications of the study of connected graph searching is the design of distributed algorithms allowing a team of searchers to compute (in a distributed manner) and execute a capture strategy in any connected graph. We design such a (exponential-time) algorithm using the optimal number of searchers plus one in any a priori unknown asynchronous network [23]. Then, we propose a polynomial-time distributed algorithm for clearing any network using the optimal number of searchers assuming that the searchers have some knowledge about the network they are clearing. More precisely, we prove that the amount of information necessary to clear any n-node network in a monotone distributed way is $\Theta(n \log n)$ bits [42]. Finally, if the network is unknown a priori, we propose a polynomial-time distributed algorithm for clearing any n-node network using $O(\frac{n}{\log n})$ times the optimal number of searchers and we prove this is optimal [74].

In [69], [78], we investigate the so-called cops and robber games. In this setting, searchers (cops) and fugitive (robber) play turn-by-turn and have bounded speed. When cops and robber have same speed, it is a well known result that three cops are sufficient to capture a robber in any planar graph. We investigate the case when the speed of the robber is greater than the one of the cops. We prove that, in this setting, the number of cops needed to capture a robber in a grid becomes unbounded.

6.5.2. Algorithms to Find Constrained Subgraphs

An instance of the DEGREE-CONSTRAINED SUBGRAPH PROBLEM consists of an edge-weighted or vertex-weighted graph G and the objective is to find an optimal weighted subgraph, subject to certain degree constraints on the vertices of the subgraph. This class of combinatorial problems has been extensively studied due to its numerous applications in network design. If the input graph is bipartite, these problems are equivalent to classical transportation and assignment problems in operations research. We consider three natural DEGREE-CONSTRAINED SUBGRAPH PROBLEMS and study their behavior in terms of approximation algorithms. These problems take as input an undirected graph $G=(V,E)$, with $|V|=n$ and $|E|=m$. Our results, together with the definition of the three problems, are listed below. The Maximum Degree-Bounded Connected Subgraph (MDBCS$_d$) problem takes as input a weight function $\omega : E \rightarrow \mathbb{R}^+$ and an integer $d \geq 2$, and asks for a subset $E' \subseteq E$ such that the subgraph $G'=(V,E')$ is connected, has maximum degree at most d, and $\sum_e \in E' \omega(e)$ is maximized. This problem is one of the classical NP-hard problems listed by Garey and Johnson in (Computers and Intractability, W.H. Freeman, 1979), but there were no results in the literature except for $d=2$. In [48], [82], we prove that MDBCS$_d$ is not in APX for any $d \geq 2$ (this was known only for $d=2$) and we provide a $(\min m/\log n,\ nd/(2\log n))$-approximation algorithm for unweighted graphs, and a $(\min n/2,\ m/d)$-approximation algorithm for weighted graphs. We also prove that when G accepts a low-degree spanning tree, in terms of d, then MDBCS$_d$ can be approximated within a small constant factor in unweighted graphs.

The MINIMUM SUBGRAPH OF MINIMUM DEGREE $\geq$ D (MSMD D) PROBLEM consists in finding a smallest subgraph of G (in terms of number of vertices) with minimum degree at least d. In [49], we show that this problem is fixed parameter intractable for $d \geq 3$ in general graphs by showing it to be W[1]-hard by a reduction from MULTI-COLOR CLIQUE. On the algorithmic side, we show that the problem is fixed parameter tractable in graphs which excluded minors and graphs with bounded local tree-width so in particular, in planar graphs, graphs of bounded genus and graphs with bounded maximum degree. We prove [48], [82] that MSMD$_d$ is not in APX for any $d \geq 3$ and we provide an $(n/\log n)$-approximation algorithm for the classes of graphs excluding a fixed graph as a minor, using dynamic programming techniques and a known structural result on graph minors. In particular, this approximation algorithm applies to planar graphs and graphs of bounded genus.

The DUAL DEGREE-DENSE K-SUBGRAPH (DDDKS) PROBLEM consists in finding a subgraph H of G such that $|V(H)| \leq k$ and δ_H is maximized, where δ_H is the minimum degree in H. We present [48], [82] a deterministic (n^δ)-approximation algorithm in general graphs, for some universal constant $\delta < 1/3$.

We also investigate the problem of computing the STRENGTH of a graph. Our motivation came from the difficulty of scanning very large graphs like the graph of the web where we want to find efficient clustering of this graph. Other applications concern VLSI computing or graph partitioning for parallelization. We describe in [90] the first polyhedral formulation for the weighted strength in polynomial size of the problem, that is $O(mn)$, where n is the number of vertices and m the number of edges. Moreover, we describe a surprisingly simple FPTAS that gives the strength within $1+\varepsilon$ in time $O(mlog^2(n)\log{(m/n)}/\varepsilon^2)$ and space $O(m)$, outperforming by a factor of roughly $\min(n\sqrt{m}, n^{5/3})$ the best known exact algorithm of Trubin associated with the Goldberg and Rao maxflow algorithm for that problem, and of roughly sigma(G) the FPTAS of Plotkin, Shmoys, and Tardös. We also provide additional evidence of the mathematical interest of the parameter by linking it to the k-dense subgraph problem.

In [25], we study the problem of finding a large bipartite induced subgraph or equivalently a small *odd cycle vertex transversal*, that is a set of vertices whose removal leaves the graph bipartite. For each constant k, we present a linear time algorithm that, given a planar graph G, either finds a minimum odd cycle vertex transversal in G or guarantees that there is no transversal of size at most k.

In [65], we present a linear time algorithm which determines whether an input graph contains K_5 as a minor and outputs a K_5-model if the input graph contains one. If the input graph has no K_5-minor then the algorithm constructs a tree decomposition such that each node of the tree corresponds to a planar graph or a graph with eight vertices. Such a decomposition can be used to obtain algorithms to solve various optimization problems in linear time. For example, we present a linear time algorithm for finding an $O(\sqrt{n})$ separator and a linear time algorithm for solving k-realisation on graphs without a K_5-minor. Our algorithm will also be used, in a separate paper, as a key subroutine in a nearly linear time algorithm to test for the existence of an H-minor for any fixed H.

6.5.3. Disjoint Path Packing

In [64], we consider the following problem, which is called the half integral k disjoint paths packing.

> Input: A graph G, k pairs of vertices $(s_1, t_1), (s_2, t_2), \cdots, (s_k, t_k)$ in G (which are sometimes called terminals).
>
> Output: Paths $P_1, \cdots, P_k$ in G such that P_i joins s_i and t_i for $i = 1, 2, \cdots, k$ and in addition, each vertex is on at most two of these paths.

We present an $O(n \log n)$ time algorithm for this problem for fixed k. This improves a result by Kleinberg [105] who gave an $O(n^3)$ algorithm for this problem. In fact, we also have algorithms running in $O(n(1+\epsilon))$ time for any $\epsilon > 0$ for these problems, if k is up to $o((loglogn)^{2/5})$ for general graphs, up to $o((logn/(loglogn))^{1/4})$ for planar graphs, and up to $o((logn/g/(loglogn/g))^{1/4})$ for graphs on the surface with Euler genus g. Furthermore, if k is fixed, then we have linear time algorithms for the planar case and for the bounded genus case. We also obtain $O(nlogn)$ algorithms for several optimization problems related to the bounded unsplittable flow problem when the number of terminal pairs is bounded. These results can all carry over to problems involving edge capacities.

7. Contracts and Grants with Industry

7.1. Contract CRC France Telecom R&D, 2003-2008

Keywords: *Design of telecommunication networks*, *Fault Tolerance*, *Radio Networks*.

Contrat de recherche collaborative (CRC) with France Telecom R&D, 2003-2005 and 2006-2008.

As mentioned earlier, we have a strong collaboration with Orange Labs (France Télécom R&D) within the CRC CORSO for the period 2003-2005. This contract has been renewed for the period 2006-2008 under the name CORSO2. This means that some researchers of MASCOTTE on one side and engineers of Orange Labs on the other side work together on specified subjects approved by a “Comité de pilotage”. Among these subjects we can mention the design of telecommunication networks, the study of fault tolerance, and the use of radio networks for bringing Internet in places where there is no ADSL.

(http://perso.rd.francetelecom.fr/galtier/corso/)

7.2. Contract Thales Computer SA (TCT) Toulon, 2006-2008.

Accompanying contract for Ph.D. grant of Jean-Paul Perez Seva, supervised by Michel Cosnard.

8. Other Grants and Activities

8.1. National Collaborations

8.1.1. ANR Jeunes Chercheurs OSERA, 2005-2008

On optimization and simulation of ambient networks.

(http://www.inria.fr/mascotte/Contrats/ANR-JCOSERA)

8.1.2. ANR SPREADS, 2008-2010

The project SPREADS (Safe P2p-based REliable Architecture for Data Storage) is leaded the SME UBISTORAGE; other partners are the INRIA teams MASCOTTE and REGAL in Rocquencourt and Eurecom and LACL Paris XII. It concerns the evaluation and optimization of a peer-to-peer based reliable storage system for which simulations of very large peer-to-peer systems will be done using OSA. It has got the approbation and label of the "pôle de compétitivité" SCS.

(http://www.inria.fr/mascotte/Contrats/SPREADS)

8.1.3. ARC BROCCOLI, 2008-2009

ARC BROCCOLI (Building instRumenting and deplOying Component-based arChitecture fOr Large-scale applIcations) involves the INRIA teams MASCOTTE, ADAM in Lille Nord Europe and Télécom SudParis - ACMES team in Evry. The topic is the very large scale deployment and instrumentation of OSA distributed simulations on Grid-computing facilities (e.g. on Grid 5000).

(http://www.inria.fr/mascotte/Contrats/Broccoli)

8.1.4. ARC CARMA, 2007-2008

ARC CARMA (CApacité des Réseaux MAillés) involves the INRIA teams MASCOTTE (Sophia Antipolis - Méditerranée), ARES (Rhône-Alpes) and POPS (Lille Nord Europe) as well as the Drakkar team of the University of Grenoble. The goal of this ARC is to develop cross-layer approaches in order to understand and optimize the transport capacity of wireless mesh networks.

(http://www.inria.fr/mascotte/Contrats/ARCINRIACARMA/)

8.1.5. Color LARECO, 2008

With BCDS (Bandwidth Communications and Distributed Systems research group), University of Girona, Spain.

The purpose of LARECO is to study the problem of reducing the label space (i.e. overall number of labels) used for the communications in All-Optical Label Switching (AOLS) networks which is an approach to transparently route packets all-optically.

(http://www-sop.inria.fr/members/Joanna.Moulierac/LARECO/)

8.1.6. Color PAGRO, 2008.

Color PAGRO (PArtition de GRaphes Orientés) also involves LIRMM, Montpellier.

This color concerns (oriented) graph partitions under various constraints. It focuses in particular on finding orientations of graphs minimizing parameters related to these partitions.

(http://www.inria.fr/mascotte/Contrats/PAGRO)

8.1.7. Action ResCom, 2006-...

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

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

8.1.8. Action Graphes, 2006-...

Action Graphes, working group of GDR IM, CNRS.

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

8.2. European Collaborations

8.2.1. European project IST AEOLUS, Integrated Project IST-015964, 2005-2009

On Algorithmic Principles for Building Efficient Overlay Computers (AEOLUS), in collaboration with 21 European universities and coordinated by University of Patras, Greece.

The recent explosive growth of the Internet gives rise to the possibility of a global computer of grand-scale consisting of Internet-connected computing entities (possibly mobile, with varying computational capabilities, connected among them with different communication media), globally available and able to provide to its users a rich menu of high-level integrated services that make use of its aggregated computational power, storage space, and information resources. Achieving this efficiently and transparently is a major challenge that can be overcome by introducing an intermediate layer, the overlay computer.

The goal of AEOLUS is to investigate the principles and develop the algorithmic methods for building such an overlay computer that enables this efficient and transparent access to the resources of an Internet-based global computer.

MASCOTTE is the leader of Sub-Project 2 on resource management.

The work within this subproject focuses on the study of fundamental issues for accessing and managing communication resources in an overlay computer. Our research address novel and challenging algorithmic issues for efficient resource discovery and querying like construction of overlay networks, query routing and execution, and for sharing critical resources like bandwidth.

(http://aeolus.ceid.upatras.gr/)

8.2.2. European Action COST 293 Graal, 2004-2008

The main objective of this COST action is to elaborate global and solid advances in the design of communication networks by letting experts and researchers with strong mathematical background meet peers specialized in communication networks, and share their mutual experience by forming a multidisciplinary scientific co-operation community. This action has more than 25 academic and 4 industrial partners from 18 European countries. MASCOTTE works essentially on the design and efficient use of optical backbone network.

(http://www.cost293.org).

8.2.3. ECO-NET with Prague and Ljubljana Universities, 2007-2008

ECO-NET project is an exchange program between MASCOTTE and Charles University (Prague, Czech Republic) and the University of Ljubljana (Slovenia). The research program focuses on colourings of planar graphs.

8.2.4. Alliance program with Royal Holloway College (London) and the London School of Economics 2007-2008

Hubert Curien program Alliance is an exchange program between MASCOTTE, LIRMM (Montpellier), Royal Holloway College (London, United Kingdom) and London School of Economics. The research program focuses on digraph partitions.

8.3. International Collaborations

8.3.1. Join team "RESEAUXCOM", 2003-2008

Joint team with the Network Modeling Group (SFU, Vancouver, Canada). One of the main objectives is to strengthen our collaboration with SFU. Many reciprocal visits have been performed.

(http://www-sop.inria.fr/mascotte/David.Coudert/EquipeAssociee/)

8.3.2. INRIA-FAPESP MOBIDYN, 2003-2008

Cooperation with the university of Sao Paolo (resp Alfredo Goldman), Brazil, join project Mobidyn INRIA-FAPESP on combinatorial models for dynamic networks.

8.4. Guests

Lenka Carr Motykova: Palacky University, Brno, Czech Republic, December 8-20, 2008 (2 weeks).

Denis Conan: INT, TELECOM & Management SudParis, September 8-12, December 3-4, 2008.

Nicole Eggemann: Brunel University, UK, January 5 - March 31, 2008 (3 months).

Luisa Gargano: Salerno Italy, July 1 - August 31 2008 (2 months).

Daniel Gonçalves: LIRMM, Montpellier, February (1 week).

Sebastien Leriche: INT, TELECOM & Management SudParis, September 8-12, Dec 2-3, 2008.

Jose Luis Marzo: University of Girona, Spain, May 27-28 2008.

Giorgos B. Mertzios: RWTH Aachen University, Aachen, Germany. October, 2008 (2 weeks).

Tobias Müller: Eindhoven University, October (1 week).

Jaroslav Opatrny: Concordia U., Montreal, Canada, October 1 - December 20, 2008 (3 months).

Joseph Peters: S.F.U. Vancouver, Canada, April 24 - May 28, 2008 (1 month)] months).

Alexandre Pinlou: LIRMM, Montpellier, February (1 week).

Nicolas Puech: ENST Paris, France, Sabbatical leave, February 1 - August 31, 2008 (7 months).

Leonardo Sampaio Rocha: Universidade Federal do Ceara, Fortaleza, Brasil, January 1 - March 31 (3 months).

Juan Jose Rue: Universitat Politecnica de Catalunya, Barcelona, Spain, June, 2008 (2 weeks).

Fernando Solano Donado: University of Girona, Spain, January 20-27 2008 and University of Warsaw, Poland, May 14-28 2008.

Alban Tiberghien: INRIA Lille Nord-Europe (EPI ADAM), December 1-5, 2008.

Ugo Vaccaro: Salerno Italy, July 1 - August 31, 2008 (2 months).

Fabrice Valois: INRIA/INSA CITI Lab, Lyon, France, March 18-19, 2008.

Jan Van Den Heuvel: London School of Economics, London, United Kingdom, December 10-18, 2008 (1 week).

Gabriel A. Wainer: March 2-8, May 30-June 22, 2008.

Joseph Yu: S.F.U Vancouver, Canada, January 20 - April 24, 2008 (3 months).

Shmuel Zaks: Technion Israel Institute, Haifa, Israël, September 26 - December 31, 2008 (3 months).

Bernard P. Zeigler: University of Arizona Tucson USA, March 3-29 2008.

8.5. Visits of Mascotte members to other research institutions

J-C. Bermond: CTI (AEOLUS project), Patras, Greece, June 11 - July 6, 2008; SFU (EA RESEAUX-COM), Vancouver, Canada, July 25-August 29 2008.

N. Cohen London School of Economics, London, United Kingdom, November 10-17 2008. Royal Holloway University of London, Egham, United Kingdom, November 17-21 2008.

D. Coudert: IRCICA, University of Lille, France, January 14-18 2008; Universidade Federal do Ceara, Fortaleza Brazil, February 22 March 1 2008; SFU (EA RESEAUXCOM), Vancouver, Canada, July 25-August 29 2008; LIAFA, University of Paris 7, October 3 2008.

O. Dalle: Visit to LIP6 (SPREADS project), Paris, February 16-19 2008; Visit to Ubiquitous Storage (SPREADS project), Amiens, July 1-4 2008; Visit to ADAM EPI (Broccoli ARC), Lille, July 8-11 2008; Visit to the Arizona State University, Phoenix, USA, December 11-17 2008; Visit to LSIS-CNRS, Marseille, France, November 7-8, 2008.

F. Giroire: Intel Research, Berkeley, USA, January 01-31 2008 (1 month).

F. Havet: LIRMM, Montpellier, France, 2 weeks, January 2008 + 1 week October 2008. Charles University, Prague, Czech Republic, one week Sept. 2008 + 3 days November 2008. University of Kosice, Slovaquia, 1 week, November 2008.

F. Huc: Brazil, Departamento de Computaçao, Laboratório de Inteligência Artificial, Universidade Federal do Ceará, Fortaleza, Brazil, January 29-March 1st (1 month).

C. Molle: CITI laboratory INRIA-INSA involved in ARC CARMA, Lyon, France, June 2008 (1 week); Department of Science and Technology ITN, Linköping University, Norrköping, Sweden, October 2008 (3 weeks).

J. Monteiro: LIP6 - REGAL team, Paris, France, Feb. 18 2008 (1 day); Ubistorage, Amiens, France, Jul. 1–4 2008 (4 days).

J. Moulierac: Alcatel-Lucent, Antwerpen, Belgium, July 13-26 2008 (2 weeks); Institute of Telecommunications, Warsaw University of Technology, Poland, November 24 - December 4 (2 weeks).

N. Nepomuceno: Federal University of Ceara, Fortaleza, Ceara, Brazil, Jul 4 - Aug 17 2008 (6 weeks).

J. Ribault: LIP6, Paris, France, Febrary 16-25 2008; LIPS6, Paris, France, April 5-24 2008; TELECOM & Management SudParis, Evry, France, May 25 June 6 2008; TELECOM & Management SudParis, Paris, France, June 19-20 2008; INRIA - ADAM Project, Lille, France, july 05-11 2008; INRIA - ADAM Project, Lille, France, October 27-31 2008; TELECOM & Management SudParis, Evry, France, November 24-28 2008.

H. Rivano: Univerity of São Paulo, Brazil, October 13 - October 26 2008 (2 weeks), CITI lab, Lyon, France, (2 weeks).

I. Sau-Valls: Departamento de Computacao of Universidade Federal do Ceara, Fortaleza, Brazil, Jan. 25 - Mar 4 2008 (6 weeks). Research Group on Graph Theory and Combinatorics of Universitat Politecnica de Catalunya, Barcelona, Spain, several visits during 2008 (around 2 months and a half overall). Research Internship of Ignasi Sau-Valls: Computer Science Department of Technion, Haifa, Israel, May 24 - Jun. 9 2008 (2 weeks and a half). Department of Mathematics of NKU, Athens, Greece, Nov. 23 - Dec. 5 2008 (2 weeks). Department of Theoretical Computer Science of IMFM, Ljubljana, Slovenia, Dec. 9 - Dec 19 (10 days).

9. Dissemination

9.1. Leadership within the scientific community

9.1.1. Participation in Committees

J-C. Bermond: Expert for RNRT, DRTT, ANR and various projects outside France (Canada,...); member of the "Commission de Spécialistes de la 27^{e} section" of UNS; responsible of *Pôle ComRed* of I3S; member of the PhD committee of Marseille.

D. Coudert: Member of the COST Action 293 Management Committee (working group learder, WG-A "broadband and optical networks"); expert for the National Sciences and Engineering Research Council of Canada (NSERC).

O. Dalle: Member of the “Commission de Spécialistes 27^{e} section” of UNS.

J. Galtier: Member of the COST Action 293, expert senior for France Telecom; elected member of the SEE - Groupe régional cote d'Azur; program committee member of NCP'07.

F. Havet: Elected member of I3S laboratory committee; member of the selection committee for a lecturer position Section 27 of University of Marseille 2,

H. Rivano: Elected member of the Comité National de la Recherche Scientifique (CoNRS); nominated member of I3S laboratory committee; member of CUMIR.

I. Sau-Valls: Member of the COST Action 293.

M. Syska: Member of the "Commission de Spécialistes 27^{e} section" of the University of Avignon; director of the Licence LP SIL degree at IUT.

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 and the SIAM book series on Discrete Mathematics.

A. Ferreira: Journal of Parallel and Distributed Computing (Academic Press), Parallel Processing Letters (World Scientific), Journal of Interconnection Networks (World Scientific), Wireless Networks (Springer);

B. Reed: Journal of Combinatorial Theory, Series B (Elsevier).

9.1.3. Steering Committees

J-C. Bermond: Member of the Advisory Committee of ISPAN'08, Sydney, Australia, May 7-9 2008.

D. Coudert: Pôle ResCom du GDR ASR du CNRS.

F. Havet: JCALM.

N. Nisse: 2nd edition of the International workshop on Mobility, Algorithms, Graph Theory In dynamic Networks (IMAGINE 2008) that was held in conjonction with ICALP 2008 - Reykjavik, Iceland - July 12th, 2008.

B. Reed: Canadian Conference on Discrete Mathematics.

9.1.4. Workshop organization

NMS'08, Workshop on Net-Centric Modeling and Simulation, co-located with SIMUTools 2008, Marseille, France, March 3-7, 2008 (15 participants).
O. Dalle co-chair.

SIMUTools'08, Marseille, France, March 3-7, 2008.
J. Moulierac Local Workshop Chair.

JCALM'08, Sophia-Antipolis, France, June 5-6 2008 (20 participants).
F. Havet organizing Chair.

AEOLUS Workshop, Sophia-Antipolis, France, September 8-10, 2008 (30 participants).
http://www-sop.inria.fr/mascotte/adhocnow/aeolus/ - D. Coudert and H. Rivano co-chair.

AdHoc-NOW'08, 7th International Conference on AD-HOC Networks & Wireless (AdHoc-NOW), Sophia-Antipolis, France, September 10-13, 2008 (70 participants).
http://www-sop.inria.fr/mascotte/adhocnow/ [80]

- D. Coudert: General Chair;
- H. Rivano: Publicity chair;
- M. Syska: Poster and demo chair;

C. Gomes, F. Huc, P. Lachaume, C. Molle, I. Sau-Valls: Members of the organizing comittee.

AdhocAmC, 1st International Workshop on Ad-hoc Ambient Computing, Sophia-Antipolis, France, September 13, 2008 (15 participants).
D. Coudert General Chair. Proceedings available on hal: http://hal.inria.fr/ADHOCAMC08.

PhD-NOW'08, Sophia-Antipolis, France, September 13, 2008 (20 participants).
D. Coudert General Chair. Proceedings available on hal: http://hal.inria.fr/PHDNOW08

JGA'08, 10emes Journées Graphes et Algorithmes, Sophia-Antipolis, France, November 6-7 2008 (70 participants).
Organizing comittee: M. Asté, N. Cohen, F. Havet, F. Huc, C. Jullien, P. Lachaume, I. Sau-Valls.

Workshop on Graph Colouring, Puyloubier, France, December 1-5 2008 (15 participants).
F. Havet organizing chair.

9.1.5. Participation in program committees

D. Coudert: TPC member of the 16th Annual European Symposium on Algorithms (ESA'08) Track B, Karlsruhe, Germany, September 15-17, 2008; TPC member of the 10èmes Rencontres Francophones sur les Aspects Algorithmiques de Télécommunications (AlgoTel'08), Saint-Malo, France, May 13-16, 2008.

O. Dalle: Program Chair of SIMUTools 2008, Program Chair of the 2008 ECMS-METH track; TPC Member of the WNS2 and ASSESS08 worksohps.

F. Giroire: Member of the Program Comittee of ACM CoNEXT 2008 Student Workshop, Madrid, Spain, December 12 2008; Member of the shadow Program Comittee of ACM CoNEXT 2008, Madrid, Spain, December 9-12 2008.

F. Havet: PC chair and organizing chair of JGA'08 (10emes Journées Graphes et Algorithmes), Sophia-Antipolis, France, November 6-7 2008.

L. Hogie: Member of the program comittee of Modelling, Computation and Optimization in Information Systems and Management Sciences (MCO'08), Metz-Luxembourg, September 8-10 2008; Member of the program comittee of the Workshop on Optimization Issues in Grid and Parallel Computing Environments, Nicosia, Cyprus, June 3-6, 2008.

H. Rivano: TPC member of AlgoTel'08, Saint Malo, France, May 13-16; TPC member of JDIR'08, Villeneuve d'Ascq, January 16-18, 2008.

M. Syska: Member of the program comittee of the Workshop on Optimization Issues in Grid and Parallel Computing Environments, Nicosia, Cyprus, June 3-6, 2008; Poster and Demo Chair of AdHoc-NOW'08, Sophia-Antipolis, France, September 10-13, 2008.

9.2. HdR, Theses, Internships

9.2.1. HdR

J. Galtier [15]: *L'adaptativité dans les télécommunications*, Habilitation à Diriger des Recherches, Université de Nice-Sophia Antipolis, February 21, 2008.

9.2.2. Theses

9.2.2.1. Theses defended in 2008

F. Huc [16]: *Conception de Réseaux Dynamiques Tolérants aux Pannes*. PhD thesis, Université de Nice Sophia Antipolis, November 14, 2008.

9.2.2.2. Theses in preparation

M. Asté: *Allocation de fréquences et colorations de graphes par contraintes*, since October 2007.

N. Cohen: *Allocation de fréquences et coloration des L-graphes*, since October 2008.

C. Gomez: *Optimisation des réseaux dynamiques de quatrième génération*, since September 2006.

J-C. Maureira: *Méthodes et outils pour la modélisation et la simulation centrées réseau à base de composants Fractal*, since February 2008.

D. Mazauric: *Conception et analyse d'algorithmes distribués d'ordonnancement dans les réseaux sans-fil*, since October 2008.

C. Molle: *Structures combinatoires et simulation des réseaux radio maillés*, since October 2006.

J. Monteiro: *Modélisation et analyse de réseaux pair-à-pair utilisés pour le stockage fiable de données*, since October 2007.

N. Nepomuceno: *Optimisation et routage dynamique dans les réseaux sans fil*, since December 2007.

J.P. Perez Seva: *Optimisation d'algorithmes de traitement de signal sur les nouvelles architectures modernes de calculateur parallèle embarqué*, since January 2006;

P. Reyes Valenzuela: *Optimisation et simulation pour l'étude des réseaux ambiants*, since January 2006.

J. Ribault: *Modélisation et simulation à événements discrets à base de composants Fractal*, since January 2008.

I. Sau-Valls: *Optimization in graphs under degree constraints. Application to telecommunication networks*, since October 2006.

9.2.3. Participation in thesis Committees

J-C. Bermond: PhD committee member of Florian's Huc PhD thesis (UNS), Sophia Antipolis, France, November 14, 2008; HdR Nicolas Ollinger (UNS), Nice, France, December 3, 2008.

D. Coudert: PhD committee member of Florian's Huc PhD thesis (UNS), Sophia Antipolis, France, November 14, 2008.

J. Galtier: PhD committee president of Abdelkrim Markabi, PhD Thesis, Sophia Antipolis, INRIA, France, april 2008; PhD committee member of Jean-Marc-Kelif, Paris, ENST, France, february 2008; PhD committee member of Mohammad Ibrahim, Sophia Antipolis, INRIA, France, nov 2008.

F. Havet External referee for the PhD thesis of L. Esperet (Univ. Bordeaux 1, May 2008) and P. Nejedly (Charles Univ., Prague, November 2008).

9.2.4. Internships

J-C. Bermond and D. Coudert: supervised with P. Nain (EPI MAESTRO) and J. Peters (SFU, Vancouver, Canada) the internship of D. Mazauric (Master 2 RSD, Polytech'Nice, France) on distributed algorithms for call scheduling in wireless networks [99], March-September 2008 (6 months).

(http://www-sop.inria.fr/members/Dorian.Mazauric/Bibliographie/mazauricEPU.pdf).

F. Havet: supervised the internship of N. Cohen (Master 2 en Statistiques, Informatique et Techniques Numériques de l'Université Lyon-1, France) on the coloration of planar graphs [97], April-September 2008 (6 months).

(http://www-sop.inria.fr/mascotte/rapports_stages/rapport.pdf)

F. Havet: supervised the internship of L. Sampaio (Maestrado 2 Universidade do Ceara of Fortaleza, Brazil) on graph b-coloration, January-March 2008 (3 months).

F. Peix and M. Syska: supervised the internship of M. Hadj Djilani (Licence Professionnelle SIL 3, UNS, France), May 19 - August 29, 2008. During his internship period, M. Hadj Djilani has implemented a JNI interface allowing the use of the solver CLP/CBC with the mascopt library. That means that linear programs implemented with mascopt have an improved level of performance quite similar to those of the Cplex standard [98].

(http://www-sop.inria.fr/mascotte/rapports_stages/2008_Mohamed_Hadj_Djilani.pdf)

9.3. Teaching

The members of MASCOTTE are heavily involved in teaching activities at various levels (Licence, IUT, Master 1 and 2, ENS program, Engineering Schools like Polytech'Nice). Some members are also involved in administrative duties related to teaching, for example, M. Syska is director of the Licence LP SIL degree at IUT. The teaching is carried out by members of the University as part of their teaching duties, and for INRIA CNRS or PhD's as extra work.

For graduate studies, MASCOTTE was strongly involved in the creation of the DEA RSD (Réseaux and Systèmes Distribués) now part of the Master STIC. Members of MASCOTTE are also involved in teaching in other Master's like the master MDFI of Marseille or in Master pro like the Master Telecoms or in the 3rd year of engineering schools.

The members of MASCOTTE also supervise several student projects and internships at all levels (Master 1 and 2, Engineering Schools).

Altogether that represents more than 1000 hours per year.

9.4. Participation in conferences and workshops

9.4.1. Invited talks

J-C. Bermond Keynote speaker for joint IST FET AEOLUS Workshop and AdHoc-NOW'08 session, Sophia Antipolis, September 2008; 11th COST 293 GRAAL meeting, Bordeaux, France, February 2008.

O. Dalle Seminar at Arizona Center for Integrative Modeling and Simulation (ACIMS), December 2008.

F. Havet: Seminar Discrete Optimisation (LIRMM), January 2008, "Methode de dechargement"; AMS Workshop on Structural Graph Theory, Baton-Rouge, USA, March 2008, "Facial colouring"; 14th SIAM Meeting on Discrete Mathematics, Burlington ,Vermont, USA, June 2008, "$L(p,q)$-labelling of graphs"; Cycles and Colourings in Graphs, High Tatras, Slovakia, September 2008, "Grundy number and products of graphs"; Seminar SIS of I3S, Sophia-Antipolis, France, October 2008, "Digraphes n-universels".

C. Molle: CITI Seminar, Lyon, June 2008; ITN Seminar, Linköping University, Norrköping, Sweden, October 2008.

J. Moulierac: Seminar of the Department of Computer Networks and Switching at the Institute of Telecommunications of the University of Warsaw, Poland, November 2008, "MPLS Label stacking on the line network".

N. Nisse: 2nd Workshop on GRAph Searching, Theory and Applications (GRASTA), Ceara, Brasil, February 2008.

9.4.2. Participation in scientific meetings

ANR SPREADS project meeting, St-Valery-Sur-Somme, France, January 23–25 2008.
Attended by O. Dalle, L. Hogie, J. Monteiro, J. Ribault.

11th COST 293 GRAAL meeting, Bordeaux, France, February 18-20, 2008.
Attended by J-C. Bermond (speaker), D. Coudert, J. Galtier.

MASCOTTE Team meeting, Le Boreon, France, March 10–11 2008.
Attended by almost all members of MASCOTTE.

Meeting at the COST office, Brussels, Belgium, March 17, 2008.
Attended by D. Coudert.

Rencontre DGA-Recherche et Innovation Scientifique, Paris, 20 March 2008.
Attended by C. Molle.

12th COST 293 GRAAL meeting (in conjunction with HotTina, GRAAL/AEOLUS School on Hot Topics in Network Algorithms), Bertinoro, Italy, May 8-9, 2008.
Attended by D. Coudert, C. Gomes (speaker).

ESA 2008 PC meeting, Karlsruhe, Germany, May 24-25, 2008.
Attended by D. Coudert.

ARC CARMA meetings, Lille, 15 January 2008 & Lyon, June 4, 2008.
Attended by D. Coudert, C. Molle, H. Rivano.

INRIA-DGA Prospective meeting, Arcueil, Paris, France, June 12, 2008.
Attended by O. Dalle.

Broccoli ARC meeting, Paris, France, June 18-20, 2008.
Attended by O. Dalle, F. Peix, J. Ribault.

Inauguration of Alcatel-Lucent / INRIA Joint lab, Paris, France, July 1-2, 2008.
Attended by D. Coudert.

IST FET AEOLUS Workshop, Sophia-Antipolis, France, September 8-10, 2008.
Attended by J-C. Bermond (speaker), D. Coudert, F. Giroire (speaker), H. Rivano (speaker), M. Syska.

CoNEXT 2008 shadow TPC, Paris, France, September 22-23, 2008.
Attended by F. Giroire.

13th and last COST 293 GRAAL workshop, organized jointly with COST 295 DYNAMO and DISC'08, Arcachon, France, September 23-26, 2008.
Attended by J-C. Bermond, D. Coudert, J. Galtier, F. Huc, C. Molle (speaker), N. Nisse (speaker), S. Pérennes.

IST FET AEOLUS meeting, Athens, Greece, September 30, October 1, 2008.
Attended by J-C. Bermond, D. Coudert.

7th Journées du Pôle ResCom du GDR ASR, Strasbourg, France, October 9-10, 2008.
Attended by D. Coudert, N. Nepomuceno (speaker).

Broccoli ARC meeting, Lille, France, October 27-28.
Attended by O. Dalle, J. Ribault.

IST FET AEOLUS Review, Barcelona, Spain, November 5-6, 2008.
Attended by J-C. Bermond (speaker).

Presentation of DGE Proposal to the board of the Pole de Competitivite SCS, Brignoles, France, November 13, 2008.
Attended by O. Dalle.

ANR Projet ALADDIN, Poitiers, France, November 20-21, 2008.
Attended by F. Giroire.

Graph Coloring Workshop, Puyloubier, France, November 24-28, 2008.
Attended by M. Asté, N. Cohen, F. Havet, F. Huc, S. Pérennes.

ANR SPREADS project meeting, LIP6, Paris, France, December 4-5 2008.
Attended by F. Giroire.

9.4.3. Participation in conferences

JDIR'08, 9th *Journées Doctorales en Informatique et Réseaux*, Villeneuve d'Ascq, January 16-18 2008.
Attended by D. Coudert, C. Gomes, C. Molle (speaker), H. Rivano.

GRASTA'08, 2nd Workshop on GRAph Searching, Theory and Applications, Praia da Redonda, Ceara, Brazil, February 25-28, 2008.
Attended by D. Coudert, F. Huc, N. Nisse (speaker), I. Sau-Valls.

AMS Workshop on Structural Graph Theory, Baton-Rouge, USA, March 2008.
Attended by F. Havet (speaker).

CFIP'08, Les Arcs, March 25-28, 2008.
Attended by C. Molle (speaker).

CO'08, International Symposium on Combinatorial Optimization, University of Warwick, Coventry, UK, March 2008.
Attended by C. Gomes (speaker).

SIMUtools'08, Marseille, France, Mar. 3–7 2008.
Attended by O. Dalle, J-C. Maureira, J. Monteiro, J. Ribault.

Workshop on Graph Decomposition: Theoretical, Algorithmic and Logical Aspects, CIRM, Luminy, Marseille (France), April 7-11, 2008.
Attended by M. Asté, D. Coudert, F. Havet (speaker), F. Huc, N. Nisse, I. Sau-Valls.

AlgoTel'08, 10th *rencontres francophones sur les aspects algorithmiques des télécommunications*, Saint Malo, France, May 13-16 2008.
Attended by D. Coudert, C. Molle (speaker), N. Nisse (speaker), P. Reyes (speaker), H. Rivano (speaker).

ICC'08 IEEE International Conference on Communications, Beijing, China, May 19-23, 2008.
Attended by F. Huc (speaker).

GameComp'08, Grenoble, France May 22-23 2008.
Attended by J. Galtier.

ROGICS'08, Mahdia, Tunisia, May 2008.
Attended by F. Havet (speaker).

WEA'08, 7th International Workshop on Experimental Algorithms, Provincetown, Cape Cod, USA, May 30 - June 1, 2008
Attended by J-C. Bermond.

ECMS'08, Nicosia, Cyprus, June 3-5 2008.
Attended by O. Dalle.

14th SIAM Meeting on Discrete Mathematics, Burlington ,Vermont, USA, June 2008.
Attended by F. Havet (speaker).

Usenix'08, Boston, USA, Jun. 22–27 2008.
Attended by J. Monteiro (poster).

WG'08 34th International Workshop on Graph-Theoretical Concepts in Computer Science, Durham, U.K, Jun. 30 - Jul. 2 2008.
Attended by I. Sau-Valls (speaker).

AdHoc-NOW'08, 7th International Conference on AD-HOC Networks & Wireless, Sophia-Antipolis, France, September 2008.
Attended by J-C. Bermond, D. Coudert, C. Molle, N. Nepomuceno, N. Nisse, P. Reyes, H. Rivano, I. Sau-Valls, M. Syska.

AdhocAmC'08, 1st International Workshop on Ad-hoc Ambient Computing, Sophia Antipolis, September 2008, France.
Attended by D. Coudert, H. Rivano.

CLEI'08, Santa Fe, Argentina, September 2008.
Attended by J. Monteiro (speaker).

Cycles and Colourings in Graphs, High Tatras, Slovakia, September 2008.
Attended by F. Havet (speaker).

ESA'08, 16th Annual Symposium on Algorithms, Karlsruhe, Germany, September 2008.
Attended by I. Sau-Valls (speaker).

EMSS'08, Amantea, Italy, September 2008.
Attended by J. Ribault.

MCO'08 2nd conference on Modelling, Computation and Optimization in Information Systems and Management Sciences, Metz-Luxembourg, September 2008.
Attended by L. Hogie (speaker), N. Nepomuceno (speaker).

PhD-NOW'08, Sophia Antipolis, France, September 2008.
Attended by D. Coudert, H. Rivano.

PIMRC'08, Cannes, September 2008.
Attended by C. Molle (speaker).

WAOA'08, 6th Workshop on Approximation and Online Algorithms, Karlsruhe, Germany, September 2008.
Attended by I. Sau-Valls (speaker).

JGA'08, 10th *Journées Graphes et Algorithmes*, Sophia-Antipolis, France, November 6-7, 2008.
Attended by almost all members of MASCOTTE. Speakers: J. Galtier, N. Nisse and I. Sau-Valls.

TGC'08, 4th Symposium on Trustworthy Global Computing, Barcelona, Spain, November 3-4, 2008.
Attended by H. Rivano (speaker).

BWA'08, 4th IEEE Workshop on Broadband Wireless Access, co-located with IEEE GLOBECOM, New-Orleans, US, December 2008.
Attended by C. Gomes (speaker).

OPODIS'08 12th International Conference On Principles Of DIstributed Systems, Luxor, Egypt, December 2008.
Attended by D. Mazauric (speaker).

WinterSim'08, Miami, US, December 2008.
Attended by O. Dalle.

9.4.4. Participation in schools

JCALM, 4th *Journées Combinatoire et Algorithmes du Littoral Méditerranéen*, Marseille, France, January 28 2008.
Attended by M. Asté, F. Havet, C. Molle, N. Nepomuceno, S. Pérennes, P. Reyes.

JCALM, 5th *Journées Combinatoire et Algorithmes du Littoral Méditerranéen*, Sophia-Antipolis, France, June 5-6 2008.
Attended by M. Asté, N. Cohen, D. Coudert, F. Giroire (speaker), C. Gomes, F. Havet (speaker), F. Huc (speaker), D. Mazauric, J. Monteiro, N. Nepomuceno, P. Reyes, I. Sau-Valls.

JCALM, 6th *Journées Combinatoire et Algorithmes du Littoral Méditerranéen*, Montpellier, France, October 13-14 2008.
Attended by M. Asté, N. Cohen, F. Giroire, F. Havet, D. Mazauric, N. Nisse, I. Sau-Valls.

3rd Summer School on Discrete Mathematics (project Anillo en Redes), Valparaiso, Chile, January 14-18th, 2008.
Attended by N. Nisse.

HOT-TiNA'08, GRAAL/AEOLUS School on Hot Topics in Network Algorithms, Bertinoro, Italy, May 2008.
Attended by C. Gomes, N. Nepomuceno, I. Sau-Valls.

NAPiO'08, New Algorithmic Paradigms in Optimization' in Zurich, June/July 2008.
Attended by J. Galtier.

DYNAMO'08 2nd Training School on Algorithmic Aspects of Dynamic Networks, Reykjavik - Iceland , July 4-6, 2008
Attended by N. Nisse.

ICAR'08 Summer school, Nice, France, Jul. 25–29 2008. Attended by O. Dalle, L. Hogie, J. Monteiro, J. Ribault, M. Syska.

2nd Winter School on Discrete Mathematics (project Anillo en Redes), Curacaví, Chile, August 1-3rd, 2008.
Attended by N. Nisse.

10. Bibliography

Major publications by the team in recent years

[1] L. ADDARIO-BERRY, F. HAVET, S. THOMASSÉ. *Paths with two blocks in n-chromatic digraphs*, in "Journal of Combinatorial Theory Ser. B", vol. 97, n^{o} 4, 2007, p. 620–626, http://dx.doi.org/10.1016/j.jctb.2006.10.001.

[2] O. AMINI, F. GIROIRE, F. HUC, S. PÉRENNES. *Minimal selectors and fault tolerant networks*, in "Networks", To appear, 2009, ftp://ftp-sop.inria.fr/mascotte/Publications/AG+07.pdf.

[3] J. BECKER, Z. CSIZMADIA, J. GALTIER, A. LAUGIER, J. SZABÓ, L. SZEGO. *An integer programming approach to routing in Daisy networks*, in "Networks", vol. 47, n^{o} 2, 2006, p. 116–121, ftp://ftp-sop.inria.fr/mascotte/Publications/BCG+06.pdf.

[4] J.-C. BERMOND, C. COLBOURN, D. COUDERT, G. GE, A. LING, X. MUÑOZ. *Traffic Grooming in Unidirectional WDM Rings With Grooming Ratio C=6*, in "SIAM Journal on Discrete Mathematics", vol. 19, n^{o} 2, 2005, p. 523-542, ftp://ftp-sop.inria.fr/mascotte/personnel/David.Coudert/Publication/BCC+-DM05.pdf.

[5] J.-C. BERMOND, J. GALTIER, R. KLASING, N. MORALES, S. PÉRENNES. *Hardness and approximation of Gathering in static radio networks*, in "Parallel Processing Letters", vol. 16, n^{o} 2, 2006, p. 165–183, ftp://ftp-sop.inria.fr/mascotte/personnel/Jean-Claude.Bermond/PUBLIS/BGK+06c.pdf.

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[10] F. GIROIRE. *Order statistics and estimating cardinalities of massive data sets*, in "Discrete Applied Mathematics", In Press, Corrected Proof, Available online 19 September 2008, 2008, http://dx.doi.org/10.1016/j.dam.2008.06.020.

[11] F. HAVET, J.-S. SERENI, R. SKREKOVSKI. *3-facial colouring of plane graphs*, in "SIAM Journal on Discrete Mathematics", vol. 22, n^o 1, 2008, p. 231–247, http://dx.doi.org/10.1137/060664124.

[12] J.-F. LALANDE, M. SYSKA, Y. VERHOEVEN. *Mascopt - A Network Optimization Library: Graph Manipulation*, Technical report, n^o RT-0293, INRIA Sophia Antipolis, 2004 route des lucioles - BP 93 - FR-06902 Sophia Antipolis, April 2004, http://www-sop.inria.fr/rapports/sophia/RT-0293.html.

[13] C. MOLLE, F. PEIX, H. RIVANO. *Génération de colonnes pour le routage et l'ordonnancement dans les réseaux radio maillés*, in "Colloque francophone sur l'ingénierie des protocoles (CFIP 2008)", Best student paper award, March 2008, http://cfip2008.imag.fr/wp/.

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Year Publications

Doctoral Dissertations and Habilitation Theses

[15] J. GALTIER. *L'adaptativité dans les télécommunications*, Habilitation à Diriger des Recherches, Université de Nice-Sophia Antipolis, February 2008.

[16] F. HUC. *Conception de Réseaux Dynamiques Tolérants aux Pannes*, Ph. D. Thesis, École doctorale STIC, Université de Nice-Sophia Antipolis, November 2008.

Articles in International Peer-Reviewed Journal

[17] L. ADDARIO-BERRY, M. CHUDNOVSKY, F. HAVET, B. REED, P. SEYMOUR. *Bisimplicial vertices in even-hole-free graphs*, in "Journal of Combinatorial Theory Ser. B", vol. 98, n^o 6, 2008, p. 1119–1164.

[18] L. ADDARIO-BERRY, K. DALAL, B. REED. *Degree-Constrained Subgraphs*, in "Discrete Applied Mathematics", vol. 156, 2008, p. 1168-1174.

[19] L. ADDARIO-BERRY, B. REED. *Ballot Theorems, Old and New*, in "Bolyai Society Mathematical Studies (Series 17)", 2008, p. 9-35.

[20] N. BEN ALI, B. BELGHITH, J. MOULIERAC, M. MOLNÁR. *QoS multicast aggregation under multiple additive constraints*, in "Computer Communications", vol. 31, n^o 15, September 2008, p. 3564-3578.

[21] J.-C. BERMOND, R. CORREA, M.-L. YU. *Optimal Gathering Protocols on Paths under Interference Constraints*, in "Discrete Mathematics", To appear in Discrete Mathematics. A preliminary version has been presented at CIAC06, 2008, http://dx.doi.org/10.1016/j.disc.2008.04.037.

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[29] P. FRAIGNIAUD, N. NISSE. *Monotony Properties of Connected Visible Graph Searching*, in "Information and Computation", in press, published online on oct 2, 2008., 2008, http://www.informatik.uni-trier.de/~ley/db/conf/wg/wg2006.html.

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[33] F. HAVET, M.-L. YU. *$(p, 1)$-total labelling of graphs*, in "Discrete Mathematics", vol. 308, n^o 4, February 2008, p. 496–513.

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[44] I. SAU VALLS, J. ŽEROVNIK. *An Optimal Permutation Routing Algorithm on Full-Duplex Hexagonal Networks*, in "Discrete Mathematics and Theoretical Computer Science", vol. 10, n^o 3, 2008, p. 49-62.

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[46] A. AGUIAR, P. PINHEIRO, A. COELHO, N. NEPOMUCENO, A. NETO, R. CUNHA. *Scalability Analysis of a Novel Integer Programming Model to Deal with Energy Consumption in Heterogeneous Wireless Sensor Networks*, in "Modelling, Computation and Optimization in Information Systems and Management Sciences (MCO'08)", Communications in Computer and Information Science, vol. 14, Springer, 2008, p. 11-20.

[47] O. AMINI, S. GRIFFITHS, F. HUC. *4-cycles in mixing digraphs*, in "Electronic Notes in Discrete MathematicsVolume 30, The IV Latin-American Algorithms, Graphs, and Optimization Symposium (LAGOS 07), Puerto Varas, Chile", vol. 30, February 2008, p. 63–68.

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