INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

# *Project-Team mascotte*

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

*Sophia Antipolis*

THEME 1B

Activity Report

2003

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# 1. Team

*MASCOTTE is a joint team between* INRIA *Sophia - Antipolis and the laboratory* I3S *(Informatique Signaux et Systèmes Sophia - Antipolis) which itself belongs to* CNRS *(Centre national de la recherche Scientifique) and* UNSA *(University of Nice - Sophia Antipolis).*

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**Expert Engineers**

David Sagnol [Contract OSSA, 01/01/03 - 28/02/03]

**Invited Researchers**

Ricardo Correa [ University of Fortaleza (Brazil), 20/08/03 - 20/10/03]
Aleksei Fishkin [University of Kiel (Germany), 27/09/03 - 04/10/03]
Xavier Muñoz [UPC Barcelona (Spain), 07/07/03 - 18/07/03]
Joseph Peters [Simon Fraser University (Canada), 17/10/03 - 21/11/03]
Joseph Yu [Simon Fraser University (Canada), 25/05/03 - 10/07/03]
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**Post-doctoral fellows**

Sébastien Choplin [Post-Doc CRESCCO, 01/05/03 - 31/08/03]
Balazs Kotnyek [Post-Doc ARACNE, 01/10/02 - 30/09/03]
Zvi Lotker [Post-Doc Ministry of research coordinated by INRIA, since 01/10/03]
Yann Verhoeven [Post-Doc ARACNE, since 01/03/03]

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Nelson Morales [Grant CONYCIT Chile, 1st year]

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Hervé Rivano [Boursier FRANCE TÉLÉCOM, 3rd year and afterwards ATER since 01/10/03]
Jean-Sébastien Sereni [Allocataire moniteur MENRT, 1st year]
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Marie-Emilie Voge [Allocataire BDI CNRS/RÉGION, 1st year]

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Louis Esperet [Magistère ENS LYON (1.5 months)]
Guillaume Joutel [Magistère ENS LYON (1.5 months)]
Marc Martinez de Albeniz [Pre-Doc UPC-Barcelona (6 months)]
Nelson Morales [Pre-Doc Chile (4.5 months)]
Aris Papadopoulos [Master Greece (6 months)]
Olivier De Rivoyre [Stage DEA RSD (5 months)]
Xavier Roche [Magistère ENS LYON (1.5 months)]
Marie-Emilie Voge [Stage DEA Grenoble ROCO (5 months)]

# 2. Overall Objectives

MASCOTTE is a joint team between INRIA Sophia - Antipolis and the laboratory I3S (Informatique Signaux et Systèmes Sophia - Antipolis) which itself belongs to CNRS (Centre national de la recherche Scientifique) and UNSA (University of Nice - Sophia Antipolis). Furthermore MASCOTTE is strongly associated with the center of research and development of France Télécom at Sophia - Antipolis via the CRC CORSO.

Its research fields are Simulation, Algorithmic, Discrete Mathematics and Combinatorial optimization with applications to telecommunication or transportation networks.

In particular, MASCOTTE has developed in the last four years both theoretical and applied tools for the design of heterogeneous networks of various types (like WDM, SDH, ATM, wireless, satellites, ...).

If the project aims to construct or design networks or communication algorithms it wants also to build software simulators or to implement algorithms but not to conceive protocols. The theoretical results can be applied to various situations and technologies.

# 3. Scientific Foundations

**Key words:** *Simulation*, *discrete event systems*, *road traffic simulator*, *Algorithmic*, *Discrete Mathematics*, *graph theory*, *combinatorial optimization*, *network design*, *fault tolerance*, *approximation algorithms*, *WDM or optical networks*, *ATM networks*, *wireless networks*, *frequency allocation*, *satellite constellations*, *evolving or dynamic networks*, *traffic grooming*, *virtual path layout*, *protection*, *connectivity*, *integer programming*, *SDP programming*, *network flows*, *parallel and distributed computing* .

The project uses tools and theory in the following domains: Discrete mathematics, Algorithmic, Combinatorial Optimization and Simulation. Typically, a telecommunication network (or an interconnection network) is modeled by a graph. A vertex may represent either a processor, a router, a switch or a person, and an edge (or arc) a connection between the elements represented by the vertices. We can add more information both on the vertices (for example what kind of switch is used, optical or not, number of ports, equipment cost) and on the edges (weights which might correspond to length, costs, bandwidth, capacities) or colors on paths etc. According to the application, various models can be defined and they have to be specified. This modeling part is an important task. To solve the problems, in some cases we can 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 and it can be determined 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 to construct or minimize the cost of a network which can realize certain traffic requests. On many problems, the project works with a deterministic hypothesis (for example if a connection fails it is considered as definitely and not intermittently). The project aims to construct or design networks or communication algorithms or to build software simulators or to implement algorithms but not to conceive protocols. The theoretical results can be applied to various situations and technologies.

# 4. Application Domains

For the last five years the project has chosen as main domain of application Telecommunication leaving the domain of parallel computing. The project has also applications in the domain of ”transportation”. However, note that there is some overlap between the two domains; in particular theoretical tools and also communication problems are not really different if one considers the network of a parallel machine or a telecommunication network. Inside the telecommunication domain the applications we consider are strongly dependent on the interest of the industrial partners with whom we collaborate. For example, we are working with Alcatel Space Technologies on the design of fault-tolerant on-board network satellites, and also with a different group on the optimization of the access layer and planning of satellite communication. With France Télécom (and other partners) we have worked on the design of telecommunication backbone networks (either SDH/SONET, WDM, or ATM networks) and on various fault-tolerance (protection) problems (in particular in case of link failures) or grooming (grouping) of small traffic containers into bigger ones. We have also used the PROSIT simulation framework developed in the project both for applications to a road traffic simulator (in the OSSA E.U. project) or in the ASIMUT simulation environment for satellite telecommunication in particular with the CNES.

# 5. Software

## 5.1. Advanced Software

- PROSIT[1] is a sequential and distributed application framework for discrete event simulation. PROSIT uses object oriented techniques to allow for efficient development of complex discrete event simulation packages. It has been used as the simulation engine for the European projects HIPERTRANS and OSSA, devoted to high performance simulation of road traffic. It has also been at the heart of the ASIMUT simulation environment developed by CNES (the French National Space Centre) for satellite telecommunication systems evaluation.
  Licenses of PROSIT have been sold to CNES and to Dassault Data Systems.

## 5.2. Prototype Software

- MASCOPT[2]: the main objective of the MASCOPT (Mascotte Optimization) project is to provide a set of tools for network optimization problems. Examples of problems are routing, grooming, survivability, or virtual network design. MASCOPT will help implementing a solution to such problems by providing a data model of the network and the demands, libraries to handle data and ready to use implementation of existing algorithms or linear programs (e.g integral multicommodity flow).
  MASCOPT is Open Source and intends to use the most standard technologies such as Java and XML format providing portability facilities. We finished to implement graph data structure, several basic

[1] http://www-sop.inria.fr/mascotte/prosit/
[2] http://www-sop.inria.fr/mascotte/mascopt/

algorithms working on graph and input/output classes. MASCOPT also provides some graphical tools to display graph results. We are currently writing network packages and performing experiments on WDM networks. A first application has been released which computes on-board networks with fault tolerance which is described after.

# 6. New Results

## 6.1. Discret event systems and simulation

### *6.1.1. Road traffic Simulator*

Several developments have been made on the road traffic simulator of the OSSA E.U. project (Open Framework for Simulation of Transport Strategies and Assessment), including a new Graphical User Interface to replace the previous one based on non-open software for which the sources where not available anymore. This new interface was completely redesigned using the Java language and the Koala Graphics library , in order to improve the porting and evolution capabilities of the simulation software. In the end, this interface is expected to provide visualizations of the simulation with a high level of details (e.g. animation of stand-alone vehicles, or 3D representations).

Eventually, in order to validate the parallel execution capabilities of the simulator architecture, a new prototype has been developed based on the C++// distributed programming library (INRIA software). This prototype fully demonstrated that the software architecture of the simulator is relevant for distributed simulations and that it significantly improves simulation times for heavily time consuming simulations.

### *6.1.2. Simulation environment for telecommunications*

In the “Constellations de Satellites” partnership contract (1999-2001), we designed a component-based architecture for simulation of hierarchical, multi-level models of telecommunication networks, the ASIMUT environment. This new approach allows the simulation of telecommunication networks that exhibit a high level of complexity. Simulators based on this architecture combine network model elements each having several levels of representation. This environment was developed by CNES Toulouse Space Agency and Dassault Data Systèmes, using the PROSIT simulation framework. Nevertheless, ASIMUT is a large software platform, that has now entered in a validation and improvement process, in which Mascotte actively participates. For instance, Mascotte members O. Dalle and P. Mussi participated in a one week beta-testing period in CNES (Toulouse), during December 2002.

Besides this still active cooperation on ASIMUT, Mascotte was also invited by CNES to contribute to the European Space Agency’s preliminary reflexion on the foundation of the New Media Support Center (NMSC), the ESTEC project for a new european resource center for system simulation [40].

### *6.1.3. Simulation of Generalized DEVS models*

Discrete Event Simulation (DEVS) is a modeling formalism that was initially proposed by Conception et Zeigler in 1988 to specify discrete event systems. This formalism allows a hierarchical modeling of systems: on one hand it allows the definition of atomic models for each system component and on the other hand, it provides a coupling formalism to associate atomic components and build higher level components that may then be used themselves as atomic components. N. Giambiasi of LSIS (Marseille) introduced a Generalization of this formalism, called G-DEVS (1999) that extends the modeling capabilities of the DEVS formalism. Mascotte initiated a cooperation with LSIS, the MOEDIG project (supported by an INRIA COLOR funding) in order to study the G-DEVS formalism benefits through an implementation in the PROSIT simulation framework[50].

## 6.2. Graphs design for telecommunication

### *6.2.1. Satellite boarded fault tolerant networks.*

Inside a telecommunication satellite, audio and video signals are routed through a switching network to amplifiers. Since it is impossible to repair a satellite, we choose to multiply the components that may be faulty, that is amplifiers and switches.

The first problem is to build a valid network which allows to route $p$ input signals, chosen among $n$, to $p$ amplifiers (outputs), arbitrarily chosen among $p+k$, and thus supporting $k$ broken amplifiers. Each switch has 4 links and the routes followed by the signals must be disjoint. Thus for economical constraints, the objective is to build valid networks having the minimum number of switches.

In [32], we studied a variation of this problem where the switches have 6 links. The minimum number of switches is determined when $k \leq 6$.

*6.2.2. Hierarchical ring networks.*

A Hierarchical ring network (HRN) is obtained from a ring network by appending at most one subsidiary ring to each node of the ring and, recursively, to each node of each subsidiary ring (each node belonging to at most 2 rings). In [17], we determined the maximum number of nodes of a HRN with fixed depth and fixed diameter, and thus answered an open problem from Aiello, Bhatt, Chung, Rosenberg et Sataraman.

## 6.3. Network design

Designing a backbone network consists in computing paths for each traffic unit and then in assigning resources along these paths. The set of paths is chosen according to the technology, the protocol or the quality of service 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 multiplexing several wavelength channels onto the same fiber. In WDM networks, the huge bandwidth available on an optical fiber is divided into multiple channels. Each channel carries bandwidth up to several gigabits per second. A minimum unit of 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 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.

In the following we stress the problems and solutions we have investigated. This includes results for the wavelength routing and coloring problem, for the traffic grooming problem and for the virtual network embedding problem (with application to ATM networks).

*6.3.1. Routing and Wavelength Assignment Problem.*

[36][37][57][12]

Motivated by the quest for efficient algorithms for the Routing and Wavelength Assignment problem (RWA), we address approximations of the fractional multicommodity flow problem which is the central part of a complex randomized rounding algorithm for the integral problem. Through the use of dynamic shortest path computations and other combinatorial approaches, we improve on the best known algorithm for approximations of the fractional multicommodity flow.

We addressed the design of multi-fiber optical networks. We show that the wavelength assignment constraints change from peer conflicts in mono-fiber networks to group conflicts in multi-fiber networks. We developed a new model for the wavelength assignment problem based on *conflict hypergraphs* which structurally capture the group conflicts. This model allows for adapting hypergraph coloring approximation algorithms to the wavelength assignment problem, and for validating them on real world networks [25][41].

*6.3.2. Traffic Grooming.*

Efficient optical routing aims to minimize the number of different wavelengths used in the network but also the number of electronic/optical conversions (hops for lightpaths). Another way for reducing the cost of the network is to group the traffic in such a way that some units of traffic may share some optical channels.

In [30][31][16][24][18] we address the problem of traffic grooming in WDM rings with *All-to-All* uniform unitary traffic. The goal is to minimize the total number of SONET add-drop multiplexers (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 solve the problem for practical values and infinite congruence classes of values for a given $C$. Among others, we give optimal constructions when $C \geq N(N-1)/6$ and results when $C = 3, 4, 5, 12$. We also show how to improve lower bounds by using refined counting techniques, and how to use efficiently an ILP program by restricting the search space.

In [43][52][33] we develop traffic grooming algorithms for WDM networks with multi-layer switches. We consider a node as an $N$-layer switch, in which a given layer $k$ is an aggregate set of elements of layer $k-1$. Typical examples of layers are wavelengths, bands and fibers. The cost of a given node depends on the number of input and output ports of each layer. Assuming this model and a traffic matrix - with unity elements in layer 0 - minimizing the cost of the network will consist in grooming traffic in such a way that as much traffic as possible will be switched in the highest possible layer (fibers in our example). When some traffic is switched along a path in the network within the same layer, we represent it as a pipe. Each pipe has an associated linear cost depending on the current layer and on the number of nodes crossed in that pipe. We present an integer linear programming formulation for this model that aims to minimize the overall cost of the network for a given input traffic matrix. We ran experiments using the CPLEX optimization package on various topologies such as actual networks like the Pan-European all optical network as well as rings and meshes of various sizes.

#### *6.3.3. Virtual Path Layout.*

Another network design issue is the *Virtual Path Layout* problem (VPL for short). VPL consists in embedding a logical topology into a physical one. Our first concern was with ATM networks but the results extend to other types of networks as well. The logical topology models the set of communication requests. For each communication request a path is associated into the physical network and we measure the quality of service as the maximum length of these paths, i.e the virtual network diameter denoted by $D$. The problem is to design a network of diameter at most $D$ with a minimum edge congestion [21]. When $D = 1$ the problem reduces to minimizing the edge congestion. When $D \geq 2$ we solved (asymptotically) the problem for the *All-to-All* communication instance over path networks . We also obtained asymptotic bounds for the cycle network (sharp bounds when $D = 2$).

#### *6.3.4. Other network design*

We address the problem of network design for which we present a new class of valid inequalities. These inequalities arise from the "blossom" constraints of the b-matching problem. We show that the separating problem over this class of inequalities can be solved in a polynomial time of the dimension of the space in which the problem is defined [44].

During the seventies, new needs came with the numerisation of networks. To meet these needs, the SDH technology was standardized by the UIT-T. A set of interconnected rings is a possible topology for a SDH network which provides a high protection degree. We found an heuristic method to design such a ring topology, given a set of geographical sites to be connected within the same network [58].

## 6.4. Fault tolerance

#### *6.4.1. Protection in WDM networks.*

We address here the fault tolerance problems, i.e. the network has to be able to handle the traffic when a fault of a node or a link appears. We consider that in this case the rerouting of the impacted flows has to be done from end to end.

One specific problem is the one of WDM-network protection with subnetworks, particularly loop ones [19]. The advantage is that a loop (cycle) is secured by its reverse loop. If the request graph is represented by a logical graph $I$, the general problem can be turned into finding a covering of the edges of $I$ by some sub-graphs $I_k$, such that, for each $I_k$, there exists in the physical graph $G$ a disjoint routing of the edges of $I_k$. The goal is to minimize the cost of the equipments ; this last one is a complex parameter ; in some cases it is equivalent to minimize the number of $I_k$ graphs in the covering ; in some other cases one needs to minimizing the induced load. We have completely solved this problem in the case where the graph $I$ is the complete graph (which corresponds to an all-to-all instance) and when the sub-graphs $I_k$ are loops (cycles) and the graph $G$ itself is a cycle. The optimal result uses loops of length 3 or 4. We have also solved the case where only cycles of length 4 are desired in the covering. Finally, we have recently solved the case when the physical graph $G$ is a torus.

*6.4.2. Connectivity and Reliability.*

In [42] we proved the minimum number of edges that a graph of given order and diameter must have if it is to 2-connected. We also proved a similar bound for 2-edge connected graph. This answered a conjecture from Bollobás.

In [28], we investigate the problem of finding a minimum cost $k$-connected spanning subgraph in a complete and weighted graph (also referred to as the *Survivable Network Design* problem). We prove the first explicit lower bound on the approximability of this problem. On the other hand, we design an effective approximation algorithm if the input graph satisfies the sharpened $\beta$-triangle inequality. Furthermore, we present an efficient approximation algorithm for the augmentation version of the problem in which a minimum-cost set of edges to a given graph $G$ has to be found, satisfying given edge- or vertex-connectivity requirements (also referred to as the *Network Augmentation* problem).

*6.4.3. Coalitions and Distributed Computing.*

In [15], we consider the question of the influence of a coalition of vertices, seeking to gain control in local neighborhoods in a general graph. This problem is motivated by fault tolerance and recovery applications in distributed computing, where decisions are taken after a voting process using a majority rule. Say that a vertex $v$ is *controlled* by the coalition $M$ if the majority of its neighbors are from $M$. We ask how many vertices (as a function of $|M|$) can $M$ control in this fashion. Upper and lower bounds are provided for this problem, as well as for cases where the majority is computed over larger neighborhoods (either neighborhoods of some fixed radius $r \geq 1$, or all neighborhoods of radii up to $r$). In particular, we look also at the case where the coalition must control all vertices (including or excluding its own), and derive bounds for its size.

## 6.5. Resource sharing in wireless networks

*6.5.1. Fair assignment.*

In [47], we aim at assigning bandwidth fairly to calls that have minimum bandwidth requirements. Our goal is to provide a general computational tool based on Semi-Definite Programming (SDP). The advantage of our approach is that many appealing complex objective functions related to fairness criteria are special cases of our formalism. Therefore, such optimization problems can be solved in an automatic manner provided that a SDP package is available to the network manager. In particular, our approach gives the solutions of maxmin and proportional fairness assignments, and is suitable for both ATM and Internet contexts.

In [45], we analyze an existing simulated annealing approach to solve an allocation problem in a radio DAMA (Demand Assigned Multiple Access) system. We show that the parameters are sensitive to the order in which the requests are introduced, and improve significantly the performance of the algorithm.

In [46] we introduce some fairness concepts in a radio planning algorithm. We show that the problem can be reduced to some extremely simple formulation, which is itself very tractable by using methods related to dynamic programming. It turns to give interesting figures with respect to the fairness.

*6.5.2. Energy efficiency.*

Given a set $S$ of radio stations located on a line and an integer $h$ ($1 \leq h \leq |S| - 1$), the MIN ASSIGNMENT problem is to find a range assignment of minimum power consumption provided that any pair of stations can communicate in at most $h$ hops. We presented the first polynomial time, approximation algorithm for the MIN ASSIGNMENT problem [23]. The algorithm guarantees an approximation ratio of 2 and runs in time $O(hn^3)$. We also proved that, for constant $h$ and for "well spread" instances (a broad generalization of the uniform chain case), a solution can be found in time $O(hn^3)$, whose cost is at most an $(1 + \epsilon(n))$ factor from the optimum, where $\epsilon(n) = o(1)$ and $n$ is the number of stations. This result significantly improves the existing approximability result on uniform chains.

In [39] we are dealing with the *Range assignement* problem in ad-hoc wireless networks. This problem is known to be NP-hard and approximable within a worst-case constant ratio by simply computing the Minimum

Spanning Tree of the graph underlying the wireless network. The best known theoretical upper bound on this ratio is 12. Based on the computation of a lower bound, an estimated value of the approximation ratio is experimentally measured on a large number of randomly generated instances. The results seems to indicate that the ratio of 12 is largely overestimated.

*6.5.3. Frequency assignment.*

In the channel assignment problem, the following situation occurs: we need to assign radio frequency bands to transmitters (each station gets one channel which corresponds to an integer). In order to avoid interference, if two stations are too close, then the separation of the channels assigned to them has to be at least two. Moreover, if two stations are close (but not too close), then they must receive different channels. A way to model these constraints is $L(d,1)$-labellings : an $L(d,1)$-labeling of a graph $G$ is an integer assignment $L$ to the vertex set $V(G)$ such that: $|L(u)-L(v)| \geq d$ if $d_G(u,v)=1$ and $|L(u)-L(v)| \geq 1$ if $d_G(u,v)=2$. In [49], we study $(d,1)$-total labeling of graphs which correspond to $L(d,1)$-labeling of incidence graphs.

## 6.6. Dynamic networks

*6.6.1. Evolving graphs.*

New technologies and the deployment of mobile and nomadic services naturally engender new route-discovery problems under changing conditions over dynamic networks. Unfortunately, the temporal variations in the topology of dynamic networks are hard to be effectively captured in a classical graph model. We used evolving graphs, which helps capture the dynamic characteristics of such networks, in order to show that computing different types of strongly connected components in dynamic networks is NP-Complete, and then propose an algorithm to build all rooted directed minimum spanning trees in strongly connected dynamic networks [35].

We investigated the concepts of journeys in Evolving Graphs, which captures both space and time constraints in routing problems. Journeys where formalized in [22][38] as a pair (path, schedule) describing a route to follow along with departure times. At the same time, we studied different distance measures for Evolving Graphs, such as hop count, arrival date or overall journey time, and we provided polynomial time algorithms to compute optimal journeys for each of these measures.

*6.6.2. Parameterized flows.*

Given a connected undirected multi-terminal flow network with $n$ nodes, we studied the effect of variations in the edge capacities upon the all-pairs maximum flows in the network. We proposed the first solution for the case where many edge capacities can vary [34]. Our main result is then that the all-pairs maximum flows problem, for the case where $k$ edge capacities vary in the network, is polynomial whenever $k = O(\text{polylog}\ n)$, since we show that it can be solved with the computation of $2^k$ Gomory-Hu trees.

## 6.7. Combinatorial optimization

*6.7.1. Orientations and colourings of graphs.*

Orientations and colourings of graphs are related in different ways but the deepness of these relations is not well understood. One of the result relating orientations to colouring is the Gallai-Roy Theorem. It states that the chromatic number of a graph is the minimum over all its orientations of the order (number of vertices) of a longest path. In 1982, Laborde, Payan et Xuong formulated the following conjecture implying Gallai-Roy Theorem : Every oriented graph contains a stable set intersecting every longest paths. In [48], we prove this result for oriented graphs with stability at most 2.

Another way to extend Gallai-Roy Theorem is in terms of unavoidable substructures of $k$-chromatic graphs. Indeed, this theorem easily implies that every $k$-chromatic oriented graph contains a directed path of length $k$. A natural problem is : what are the oriented graphs that are contained in every $k$-chromatic oriented graphs? Since $k$-chromatic graph may have girth (length of a smallest cycle) as large as we want, such unavoidable oriented graphs must be oriented trees (orientations of trees). Since the complete graph with $k$ vertices is the easiest $k$-chromatic graph, a first step is to consider the unavoidability of oriented trees in tournaments (orientation of complete graphs). Havet and Thomassé conjectured in 2001 that every oriented tree of order $n$

with $k$ leaves is contained in every tournament of order $n + k$. In [27], we prove this conjecture for a large class of oriented trees.

In [20], we show how to use acyclic orientations to prevent deadlocks in networks.

*6.7.2. Hamiltonian Decompositions.*

In [14], we prove that the tensor product of two complete graphs can be decomposed into hamiltonian networks.

*6.7.3. Flips.*

In [26], we generalize the operation of flipping an edge in a triangulation to that of flipping several edges simultaneously. Our main result is an optimal upper bound on the number of simultaneous flips that are needed to transform a triangulation into another. Our results hold for triangulations of point sets and for polygons.

*6.7.4. Enumeration of mixed models.*

Hess and Iyer have studied the problem of enumerating all non isomorphic constrained mixed models. They use their results in a SAS macro to facilitate calculations in Burdick and Graybill's method which allow to compute confidence intervals for variance components. However, the validity domain of their macro is restricted to models with five or fewer factors. Introducing a new algorithm based upon previous work done about enumeration of posets, we manage to enumerate all non isomorphic mixed models (constrained or not) with nine or less factors, thereby extending the domain of validity of the macro to mixed models with at most nine factors ([29]).

# 7. Contracts and Grants with Industry

## 7.1. Contract Ossa

**Key words:** *Simulation*, *Road Traffic*.

**Ossa (Open Framework for Simulation of Transport Strategies and Assessment)**, 2000-2003, was a RTD Project supported by the Commission of the European Communities in the framework of the Competitive And Sustainable Growth Program. The aim of OSSA was to develop a truly open simulation framework where different simulation-related modules and systems can get/feed information from/to in real time. Partners are cities of Alicante (Spain) and Manchester (UK), universities of Namur (Belgium) and Westminster (UK), research centers KTI (Hungary), TRL (UK) and the companies Etra (Spain), PTV (Germany), BKD and WS-Atkins (UK).

## 7.2. Contract Alcatel Toulouse

**Key words:** *Access layer and planification of satellite communications*.

**Contract with Alcatel Toulouse**, 2001-2003, on optimization of access layer and planning of satellite communication, also in collaboration with the INRIA project Mistral.

## 7.3. Contract Cre France Télécom R&D

**Key words:** *Matching*, *Routing*, *Protection*, *Design of telecommunication networks*.

***Contrat de recherche externalisé (CRE) with France Télécom R&D***, 2003-2005, on matching constrains for the design of telecommunication networks. This contract covers mainly the PhD grant of S. Petat.

## 7.4. Contract Crc France Télécom R&D

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

***Contrat de recherche collaborative (CRC) with France Télécom R&D***, 2003-2005.

As mentioned earlier, we have a strong collaboration with France Télécom R&D inside the CRC CORSO. This means that some researchers of MASCOTTE on one side and engineers of France Télécom R&D on the other side work together on specified subjects approved by a ”Comité de pilotage”. Among these subjects we can cite 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.

# 8. Other Grants and Activities

## 8.1. RegionalCollaborations

### *8.1.1. Action Color MOEDIG with Lsis (Marseille)*

**Color action : “MOEDIG”**, 2003, on the development of a simulation environment for discrete generalized events models, in collaboration with the LSIS (Marseille).
(http://mascotte.unice.fr/twiki/bin/view/Welcome/MoedigProject).

## 8.2. National Coolaborations

### *8.2.1. Action Spécifique du CnrsDYNAMO*

**Action Spécifique du CNRS: “DYNAMO”**, 2003, on the modeling of dynamic networks.

### *8.2.2. ATIP jeunes Chercheurs*

***Atip jeunes chercheurs* CNRS**, August 2002 - July 2004, on frequency allocation problems in cellular networks.

### *8.2.3. Aci sécurité “Presto”*

**Aci sécurité: “PRESTO”, 2003- 2006, on survivability of communication networks, in collaboration with the ENST (Paris) and the LIMOS (Clermont-Ferrand).
(http://www-sop.inria.fr/mascotte/David.Coudert/PRESTO/)**

## 8.3. European Collaborations

### *8.3.1. European contract RTD OSSA*

**(see section 7.1)**

### *8.3.2. European project RTN Aracne*

**European project RTN: “ARACNE”, 2000-2004, on Approximation and Randomized Algorithms for Communication Networks, in collaboration with the universities of Salerno (coordinator) and Roma (Italy), Patras (Greece), Geneva (Switzerland) and Kiel (Germany). The goal of this project is to study communications problems and network designs from the algorithmic side.**

### *8.3.3. European project IST CRESCCO*

**European project Ist : “CRESCCO”, 2002-2005, on critical resource sharing for cooperation in complex systems, in collaboration with the universities of Salerno and Roma (Italy), Patras (Greece, coordinator), Geneva (Switzerland) and Kiel (Germany). Mascotte works essentially on the efficient use of bandwidth in WDM networks (Workpackage 4).
(http://www.ceid.upatras.gr/faculty/kakl/crescco).**

### *8.3.4. Proposal of a Network of Excellence, Saga*

**Proposal of a Network of Excellence: “SAGA”, 2003, on structural and algorithmic aspects of communication networks, in collaboration with 51 European research centers and 28 European companies. Unfortunately, this proposal has not been accepted; but it has strengthened the collaboration between various groups in Europe and there was a successful workshop and the proposal will be resubmitted.**

## 8.4. Actions internationales

### *8.4.1. Cooperation Inria–Brazil Regal*

**Cooperation INRIA–Brazil: "REGAL",** ***2003, on algorithmic problems for telecommunication networks, in collaboration with the Federal University of Ceara (Fortaleza, Brazil).***

### *8.4.2. Bilatéral Cooperation Cnrs–Oxford*

**Cooperation CNRS–Oxford,** ***2003-2005, on frequency allocation problems in wireless networks, in collaboration with the Mathematical Institute of Oxford University.***

***Funded by the PACA province.***

### *8.4.3. Proposal of a join team with the Network Modeling Group (sfu, Vancouver, Canada)*

***One of the main objectives of this proposal done in 2003 was to structure our collaboration with SFU, since members of both teams have strong contacts (various visits of both side). Although the formal project has not been accepted, many reciprocal visits funded by INRIA, CNRS, ...have been performed.***

## 8.5. Visitors

- Joe Peters (Simon Fraser University, Canada), 17/10/03 - 21/11/03.
- Ricardo Correa (University of Fortaleza (Brazil), 20/08/03 - 20/10/03.
- Joseph Yu (Simon Fraser University, Canada), 25/05/03 - 10/07/03.
- Xavier Muñoz (UPC Barcelona, Spain), 07/07/03 - 18/07/03.
- Aleksei Fishkin (University of Kiel, Germany), 27/09/03 - 04/10/03.
- Hu Zhang (University of Kiel, Germany), 12/11/03 - 21/11/03.

## 8.6. Stays abroad

- *J.-C. Bermond* : S.F.U. Vancouver (Canada) 11/09/03-11/10/03.
- *D. Coudert* : UPC Barcelona (Spain), 08/01/03-28/01/03.
- *F. Havet* : Mac Gill, Montreal (Canada) October.
- *R. Klasing* : RWTH Aachen, Germany 16.03.-12.04.2003 and 01.07.-31.07.2003 and 23.11.-29.11.2003 ; University of Paderborn, Germany 16.06.-27.06.2003 and King's College London, United Kingdom 28/05-29/05/03 and 25/08-29/08/2003.

# 9. Dissemination

## 9.1. Leadership within the scientific community

### *9.1.1. Participation in Committees*

- *J-C. Bermond* : member of Commission 3 du RNRT (Architectures de réseaux et systèmes de télécommunications) ; member of the Commission de Spécialistes de la 27$^{e}$ section de l'UNSA; substitute member of the Commissions de Spécialistes 27$^{e}$ section of UTC (université de Technologie de Compiègne) and Université de la Méditerranée (Aix-Marseille II) ; member of Comité des projets de l'I3S ; nominated member of the Comités RTP (réseaux thématiques) du département STIC « Réseaux » et « Mathématiques de l'Informatique ».
- *M. Cosnard* : chair of the ACI GRID ; substitute member of the Commission de Spécialistes 27$^{e}$ section of ENS Lyon ; chair of the conseil scientifique of CINES.

- *D. Coudert* : secretary for the project committee of the INRIA Sophia - Antipolis since April 2003.
- *O. Dalle* : member of the “Commission de Spécialistes 27e section” of UNSA, member of the “Commission du Développement Logiciel” de l’INRIA Sophia Antipolis, member of the “Comité Informatique” of I3S, substitute member of the “Commission des Utilisateurs des Moyens Informatiques” of INRIA Sophia Antipolis.
- *A. Ferreira* : member of the commission de suivi doctoral de l’INRIA Sophia - Antipolis, of the CNRT Télécom à Sophia - Antipolis, of the Conseil de Laboratoire de l’I3S and of Commission d’Evaluation de l’INRIA.
- *P. Mussi* : member of commission de spécialistes 27e section of l’UNSA, head of Public, industrial and international relations for Inria Sophia - Antipolis, member of Comité Technique Paritaire and Conseil Scientifique of l’INRIA and secrétaire national and trésorier local of AGOS.
- *M. Syska* : substitute member of the Conseil de Laboratoire of I3S; member of the Comité Informatique of I3S.

### 9.1.2. Editorial Boards

- *J-C. Bermond* : Combinatorics Probability and Computing, 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.
- *M. Cosnard* : Editor-in-Chief of Parallel Processing Letters. Member of the Editorial Board of Parallel Computing, of Theory of Computational Systems (TOCS) and of IEEE TPDS.
- *A. Ferreira* : *Journal of Parallel and Distributed Computing* (Academic Press), *Parallel Processing Letters* (World Scientific), *Parallel Algorithms and Applications* (Elsevier), *Journal of Interconnection Networks* (World Scientific).

### 9.1.3. Steering Committees

- *M. Cosnard* : Steering Committees: SPAA - *Symposium on Parallel Algorithms and Architectures* (2001-2004), PACT (Chair) *Parallel Computing Technologies* (2002-2005) - IFIP Working Group 10.3.
- *A. Ferreira*: Steering Committees: IEEE IPDPS (1999-2003), STACS (1997-2004), AlgoTel (2000-2006), ACM Dial M for Mobility (2000-2006).

### 9.1.4. Workshop organization

*D. Coudert, E. Deriche, A. Ferreira and H. Rivano*, organized the SAGA NoE Meeting, 13-14/02/03, Sophia - Antipolis.

### 9.1.5. Participation in program committees

- *M. Cosnard* : PACT,IPDPS, WORKSHOP ON GRID COMPUTING OF EUROPAR, VICE-CHAIRMAN OF HIPC (IEEE INTERNATIONAL HIGH PERFORMANCE COMPUTING CONFERENCE), IEEE IPDPS (2002-2006).
- *A. Ferreira*: CLADE, MWCN, PARCO, PBIT, PDCAT, RENPAR, WCSF, WEA.
- *P. Mussi* : member of program committees for ESMc2003 (The European Simulation and Modeling Conference), CSM2004 Conceptual Modeling and Simulation conference, International Conference on Parallel and Distributed Computing and Networks (PDCN 2004), Majestic’03, CNDS 2003.

## 9.2. Teaching

### 9.2.1. Theses

- The following theses have been passed in 2003:
  *H. Rivano* : « Algorithmique et télécommunications : Coloration et multiflot approchés et applications aux réseaux d'infrastructure », November 28, 2003 University of Nice-Sophia Antipolis.
  *C. Touati* : « Les principes d'équité appliqués aux réseaux de télécommunications », September 26, 2003 University of Nice-Sophia Antipolis.
- The following theses are in preparation :
  *G. Huiban* : Dimensionnement de réseaux optiques;
  *A. Jarry* : Connexité et protection dans les réseaux de télécommunications;
  *J.-F. Lalande* : Dimensionnement et optimisation dans les réseaux de télécommunications;
  *N. Morales* : Méthodes d'approximation pour les problèmes de réseaux de télécommunications avec de contraintes économiques et de traffic incertain;
  *S. Petat* : Contraintes de couplages pour la conception de réseaux de télécommunications;
  *J-S. Sereni* : Coloration par listes appliquée à l'allocation de fréquences;
  *M-E. Voge* : Protection et groupage dans les réseaux de télécommunications.

### 9.2.2. Member of Ph.D. Committees

- *M. Cosnard, J. Galtier and A. Ferreira* : were members of the Ph.D. Committee of H. Rivano (University of Nice-Sophia Antipolis).
- *M. Cosnard* : was member of the H.D.R. Committee of J. Durand-Lose (University of Nice-Sophia Antipolis) and of the Ph.D Committee of A. Denis University of Rennes).
- *A. Ferreira* was president of the Ph.D Committee of T. Garcia (University of Amiens).
- *J. Galtier* : was member of the Ph.D. Committee of C. Touati (University of Nice - Sophia Antipolis).
- *R. Klasing* : was member of the Ph.D. Committee of A. Navarra (Università di L'Aquila, Italy) (Reviewer of Thesis) and of Nicolas Lichiardopol (University of Nice-Sophia Antipolis).
- *M. Syska* : was member of the Ph.D. Committee of Nicolas Lichiardopol (University of Nice - Sophia Antipolis).

### 9.2.3. Internships

- J-C. Bermond et M. Syska supervised the internship of Olivier de Rivoyre (DEA RSD) and of P. Cahier (ENS Lyon)
- D. Coudert and H. Rivano supervised the internship of X. Roche (ENS Lyon).
- *D. Coudert* is supervising the internship of Marc Martinez de Albeniz (UPC Barcelona)
- O. Dalle and P. Mussi supervised the master of A. Acosta (ENST BRETAGNE).
- J. Galtier supervised the internship of G. Joutel (ENS Lyon).
- F. Havet supervised the internship of L. Esperet (ENS Lyon) and of A. Gomez (University of Bogota, Columbia).
- R. Klasing supervised the masters of N. Morales (Chile) and A. Papadopoulos (Greece).
- A. Laugier supervised jointly with M. Burlet the internship of M-E. Voge (DEA ROCO GRENOBLE).

### *9.2.4. Teaching*

The members of MASCOTTE strongly participate in a lot of teaching activities in undergraduate studies (DEUG, IUT, Licence Maîtrise, Engineering Schools like ESSI). The teaching is insured by members of the University as their teaching duties and for INRIA CNRS or PhD's as extra work. It represents more than 1000 hours per year.

For graduate studies, MASCOTTE was strongly involved in the creation of the DEA RSD (Réseaux and Systèmes Distribués) and now members of MASCOTTE teach both in the mandatory lectures and in 3 options of the DEA RSD. Members of MASCOTTE are also involved in teaching in other DEA's like the DEA MDFI of Marseille or in DESS like the DESS Telecoms or in the 3rd year of engineering schools. Altogether that represents around 200 hours per year.

The members of MASCOTTE supervise on the average around 20 internships per year at all levels (Maîtrise, Engineering School, DEA). The students come from various places in France as well as from abroad (e.g. Europe, Chile, United States, India). Some of the internship reports are listed in the bibliography under the heading miscellaneous.

## 9.3. Participation in conferences and workshops

### *9.3.1. Invited talks*

- *J-C. Bermond*: S.F.U. Vancouver, September.
- *O. Dalle*: Intl. Conference "Solutions Linux", Paris, CNIT la Défense, February.
- *A. Ferreira*: Colloquium "Optimization et Télécoms", Ecole Polytechnique, September. Seminars at LIRMM, LIFL, and LARIA, November and December.
- *F. Havet*: RAND03, Oxford, December and Bogota,Columbia.
- *R. Klasing*: Departmental Colloquium, RWTH Aachen, Germany, March; and Departmental Colloquium, University of Paderborn, Germany, June.
- *H. Rivano*: Euro/Informs 2003, Istanbul, Turkey.

### *9.3.2. Participation in scientific meetings*

- *J-C. Bermond, D. Coudert, A. Ferreira, F. Havet, A. Jarry, J-F. Lalande, S. Petat, H. Rivano, M. Syska and M-E. Voge* attended the meeting of the ACI PRESTO Sophia - Antipolis November 14th.
- *Members of Mascotte*, SAGA NoE Meeting, 13-14/02/03, Sophia - Antipolis.
- *J-C. Bermond, D. Coudert, H. Rivano* attended the Journées TAROT Paris, March.
- *J-C. Bermond, D. Coudert, S. Perennes, M. Syska*, 14/07/03, Marconi Selenia, Genova, Italy.
- *J-C. Bermond* attended the RTP meeting on networks in Saint Jean de Luz, February.
- *D. Coudert, A. Ferreira, R.Klasing and H. Rivano* attended the Journées TAROT, Lyon, October.
- *D. Coudert, M-E. Voge*, ACI-SI meeting, 11-12/12/03, Rennes.
- *O. Dalle* attended the "Journée Technologies Emergentes" meeting, Paris, March 2003.
- *O. Dalle and P. Mussi* attended the "Journée du groupe Modélisation Multiple et Simulation" meeting, Marseille, 24/01.
- *A. Ferreira* attended the meeting on "Dynamic Wireless Networks at INRIA", Porquerolles, September.
- *A. Ferreira* attended the meeting of the Steering Committee of the CNRS RTP "Réseaux", Marseille, September.
- *F. Havet* attended the Journées Graphes et Algorithmique Dijon, April.
- *P. Mussi* : Inria Industrial day, Rocquencourt 16/01, Modélisation Multiple et Simulation national group (Marseille, 24/01, St-Etienne, 21/03, Bordeaux, 17/10), Telecom World'03, Geneva 14-15/10
- *P. Mussi, D. Sagnol* participated in the OSSA final meeting, Alicante (Spain) 23-25/02.
- *S. Petat* attended the Journée d'Optimisation Polyédrale in Marseille 22/05/03.

### *9.3.3. Participation in conferences*

- *A. Acosta, P. Mussi* attended Majestic'03, Marseille, 29-31/10.
- *R. Klasing and M. Syska* attended the CRESCCO review meeting and workshop, January 30th - February 4th Paphos, Cyprus.
- *A. Ferreira and M. Syska*, CRESCCO Workshop, Santorini, Greece, June 4-6.
- *J-C. Bermond, D. Coudert, J-F. Lalande, H. Rivano and M. Syska* attended the CRESCCO meeting and workshop, December 5th - December 8th Athens, Greece.
- *A. Jarry, J-F. Lalande, A. Laugier, M. Syska*, attended ROADEF in Avignon (France), 26-28/02.
- *J-C. Bermond, J. Galtier and A. Jarry* attended WiOPT03 in Sophia - Antipolis (March).
- *S. Choplin, A. Ferreira, F. Havet, S. Petat, H. Rivano* attended ALGOTEL in Banyuls (France) in May.
- *O. Dalle, P. Mussi* attended ESA workshop, Nordvijk 20-22/02.
- *D. Coudert*, attended the 7th IFIP Working Conference on Optical Network Design & Modeling (ONDM '03) in Budapest (Hungary) in February, the IEEE International Conference on Communications (ICC '03) in Anchorage (AK, USA) in May, the 7th International Workshops on Interconnection Networks (IWIN '03) in Umea (Sweden) in June, the 10th Colloquium on Structural Information and Communication Complexity (SIROCCO 10) in Umea (Sweden) in june, and the Mountain Workshop on Algorithms (MWA) in Ordesa (Spain) in September.
- *A. Ferreira* attended ICT in Papetee, AdHoc Now in Montreal, and WiOpt in Sophia - Antipolis.
- *J. Galtier* attended FOCS, Cambridge, MA, USA.
- *F. Havet* attended the Workshop Structural and Probabilistic Approaches to Graph Coloring, Banff, September.
- *R. Klasing* attended WMAN 2003 3rd International Workshop on Wireless, Mobile and Ad Hoc Networks (April), the 7th Mountain Workshop on Algorithms (MWA'03) Pescasseroli, Italy, May and Liverpool Algorithms Day LAD'03 May.
- *A. Laugier and S. Petat* attended INOC '03 in Evry (France) in October.
- *H. Rivano* attended Euro/Informs 2003,stanbul, Turkey (July), WAOA 2003 (September) and ALGO 2003, Busapest, Hungary (September).
- *P. Mussi, D. Sagnol* attended OSSA workshop, Alicante (Spain) in February.
- *C. Touati* attended ITC-18, Berlin, Germany August-September.

### *9.3.4. Participation in schools*

- *J-C. Bermond* attended the School ING03 in Porquerolles in May.

# 10. Bibliography

## Major publications by the team in recent years

[1] E. ALTMAN, A. FERREIRA, J. GALTIER. *Les réseaux satellitaires de télécommunications.* Interéditions, 1999.

[2] H.-J. BÖCKENHAUER, J. HROMKOVIČ, R. KLASING, S. SEIBERT, W. UNGER. *Towards the Notion of Stability of Approximation for Hard Optimization Tasks and the Traveling Salesman Problem.* in « Theoretical Computer Science », number 1, volume 285, 2002, pages 3–24.

[3] B. BEAUQUIER, J.-C. BERMOND, L. GARGANO, P. HELL, S. PÉRENNES, U. VACCARO. *Graph problems arising from wavelength routing in all optical networks.* in « Proceedings of *WOCS'97*, Genève », 1997.

[4] B. BEAUQUIER, P. HELL, S. PÉRENNES. *Optimal wavelength-routed multicasting.* in « Discrete Applied Mathematics », volume 84, 1998, pages 15-20.

[5] M. BECKER, A.-L. BEYLOT, O. DALLE, R. DHAOU, M. MAROT, P. MUSSI, C. RIGAL, V. SUTTER. *The ASIMUT Simulation Workshop.* in « Networking and Information Systems Journal », number 2, volume 3, 2000, pages 335–348.

[6] J.-C. BERMOND, L. CHACON, D. COUDERT, F. TILLEROT. *Cycle Covering.* in « International Colloquium on Structural Information and Communication Complexity – SIROCCO », pages 21-34, June, 2001.

[7] J.-C. BERMOND, N. MARLIN, D. PELEG, S. PÉRENNES. *Directed Virtual Path layout in* ATM *networks.* in « Proc. of the 12th International Conference on Distributed Computing, Andros Greece », series Lecture Notes on Computer Science, volume 1499, Springer, pages 75-88, 1998, À paraître dans TCS en 2003.

[8] I. CARAGIANIS, A. FERREIRA, C. KAKLAMANIS, S. PÉRENNES, H. RIVANO. *Fractional path coloring on bounded degree trees* . in « Proc. of the 28th ICALP », series Lecture Notes in Computer Science, volume 2076, Springer-Verlag, F. OREJAS, P. G. SPIRAKIS, J. VAN LEEUWEN, editors, pages 732–743, Crete, Greece, July, 2001.

[9] D. COUDERT, A. FERREIRA, X. MUÑOZ. *A Multihop-Multi-OPS Optical Interconnection Network.* in « IEEE/OSA Journal of Lightwave Technology », number 12, volume 18, 2000, pages 2076–2085.

[10] F. HAVET. *Channel Assignement and Multicolouring of the Induced Subgraphs of the Triangular Lattice.* in « Discrete Mathematics », volume 233, 2001, pages 219–231.

## Books and Monographs

[11] *Cinquième Ecole d'Hiver des Télécommunications.* O. DALLE, S. FRÉNOT, M. RIVEILL, editors, INRIA - CNRS - Univ. de Nice, INRIA, Golfe Juan, France, December, 2002.

## Doctoral dissertations and "Habilitation" theses

[12] H. RIVANO. *Algorithmique et télécommunications : Coloration et multiflot approchés et applications aux réseaux d'infrastructure.* Ph. D. Thesis, Université de Nice-Sophia Antipolis, November, 2003.

[13] C. TOUATI. *Les principes d'équité appliqués aux réseaux de télécommunications.* Ph. D. Thesis, Université Nice Sophia-Antipolis, September, 2003.

## Articles in referred journals and book chapters

[14] R. BALAKHRISHNAN, J.-C. BERMOND, P. PAULRAJA, M. YU. *On Hamilton cycle decompositions of the tensor product of complete graphs.* in « Discrete Mathematics », volume 268, 2003, pages 49-58.

[15] J.-C. BERMOND, J. BOND, D. PELEG, S. PERENNES. *The power of small coalitions in graphs.* in « Discrete Applied Mathematics », volume 127, 2003, pages 399-414.

[16] J.-C. BERMOND, S. CEROI. *Minimizing SONET ADMs in unidirectional WDM rings with grooming ratio 3.* in « Networks », number 2, volume 41, 2003, pages 83-86.

[17] J.-C. BERMOND, S. CHOPLIN, S. PERENNES. *Hierarchical ring networks design.* in « Theory of Computing Systems », 2003.

[18] J.-C. BERMOND, C. COLBOURN, A. LING, M.-L. YU. *Grooming in unidirectional rings : $K_4 - e$ Designs.* in « Discrete Mathematics, Lindner's Volume », 2003.

[19] J.-C. BERMOND, D. COUDERT, M.-L. YU. *On DRC-covering of $K_n$ by Cycles.* in « Journal of Combinatorial Designs », volume 11, 2003, pages 100-112.

[20] J.-C. BERMOND, M. D. IANNI, M. FLAMMINI, S. PERENNES. *Acyclic orientations for deadlock prevention in usual networks.* in « Discrete Applied Mathematics », volume 129, 2003, pages 31-47.

[21] J.-C. BERMOND, N. MARLIN, D. PELEG, S. PÉRENNES. *Directed Virtual Path Layout in ATM networks.* in « Theoretical Computer Science », volume 291, 2003, pages 3-28.

[22] B. BUI-XUAN, A. FERREIRA, A. JARRY. *Computing shortest, fastest, and foremost journeys in dynamic networks.* in « International Journal of Foundations of Computer Science », number 2, volume 14, April, 2003, pages 267–285.

[23] A. CLEMENTI, A. FERREIRA, P. PENNA, S. PERENNES, R. SILVESTRI. *The Minimum Range Assignment Problem on Linear Radio Networks.* in « Algorithmica », number 2, volume 35, 2003, pages 95–110.

[24] D. COUDERT, X. MUÑOZ. *Recent Research Developments in Optics.* Research Signpost, to appear, chapter Graph Theory and Traffic Grooming in WDM Rings.

[25] A. FERREIRA, S. PERENNES, A. W. RICHA, H. RIVANO, N. STIER. *Models, Complexity and Algorithms for the Design of Multi-fiber WDM Networks.* in « Telecommunication Systems », number 2, volume 24, Oct, 2003, pages 123-138.

[26] J. GALTIER, F. HURTADO, M. NOY, S. PERENNES, J. HURRUTIA. *Simultaneous edge flipping in triangulations.* in « International Journal of Computational Geometry and Applications », number 2, volume 13, 2003, pages 113-133.

[27] F. HAVET. *On unavoidability of trees with $k$ leaves.* in « Graphs and Combinatorics », volume 19, 2003, pages 101-110.

## Publications in Conferences and Workshops

[28] H.-J. BÖCKENHAUER, D. BONGARTZ, J. HROMKOVIČ, R. KLASING, G. PROIETTI, S. SEIBERT, W. UNGER. *On $k$-Edge-Connectivity Problems with Sharpened Triangle Inequality (Extended Abstract).* in

« Proc. 5th Italian Conference on Algorithms and Complexity (*CIAC 2003*) », series Lecture Notes in Computer Science, Springer-Verlag, volume 2653, pages 189–200, 2003.

[29] R. BAYON, N. LYGEROS, J.-S. SERENI. *Nouveaux progrès dans lénumération des modèles mixtes.* in « Knowledge discovery and discrete mathematics : JIM'2003 », INRIA, pages 243–246, Université de Metz, France, 2003.

[30] J.-C. BERMOND, D. COUDERT. *Traffic Grooming in unidirectional WDM ring networks using design theory.* in « ICC 2003, IEEE International Conference on Communications », 11-15 May, 2003.

[31] J.-C. BERMOND, D. COUDERT, X. MUNOZ. *Traffic grooming in Unidirectional WDM Ring Networks: the all-to-all unitary case.* in « ONDM 03, 7th IFIP Working Conference on Optical Network Design and Modelling », pages 1135-1153, 3-5 February, 2003.

[32] J.-C. BERMOND, O. DELMAS, F. HAVET, M. MONTASSIER, S. PERENNES. *Réseaux de télécommunications minimaux embarqués tolérants.* in « Conference ALGOTEL2003, Banyuls, May 2003 », pages 27-32, 2003.

[33] J.-C. BERMOND, O. DERIVOYRE, S. PERENNES, M. SYSKA. *Groupage par tubes.* in « Conference ALGOTEL2003, Banyuls, May 2003 », pages 169-174, 2003.

[34] P. BERTHOMÉ, M. DIALLO, A. FERREIRA. *Generalized Parametric Multi-Terminal Flows Problem.* in « Proceedings of WG'03 », series Lecture Notes in Computer Science, volume 2880, Springer Verlag, pages 71-80, June, 2003.

[35] S. BHADRA, A. FERREIRA. *Complexity of Connected Components in Evolving Graphs and the Computation of Multicast Trees in Dynamic Networks.* in « Proceedings of Adhoc-Now'03 », series Lecture Notes in Computer Science, volume 2865, Springer Verlag, S. PIERRE, M. BARBEAU, E. KRANAKIS, editors, pages 259-270, Montreal, October, 2003.

[36] M. BOUKLIT, D. COUDERT, J.-F. LALANDE, C. PAUL, H. RIVANO. *Approximate multicommodity flow for WDM networks design.* in « SIROCCO 10 », series Proceedings in Informatics, number 17, Carleton Scientific, J. SIBEYN, editor, pages 43–56, Umea, Sweden, 2003.

[37] M. BOUKLIT, D. COUDERT, J.-F. LALANDE, H. RIVANO. *Approximation combinatoire de multiflot fractionnaire : améliorations.* in « AlgoTel'03 », INRIA, Banyuls-sur-mer, France, May, 2003.

[38] B. BUI-XUAN, A. FERREIRA, A. JARRY. *Evolving graphs and least cost journeys in dynamic networks.* in « Proceedings of WiOpt'03 – Modeling and Optimization in Mobile, Ad-Hoc and Wireless Networks », INRIA Press, pages 141–150, Sophia Antipolis, March, 2003.

[39] A. E. CLEMENTI, G. HUIBAN, G. ROSSI, Y. C. VERHOEVEN. *On the Approximation Ratio of the MST-based Heuristic for the Energy-Efficient Broadcast Problem in Static Ad-Hoc Radio Networks.* in « WMAN International Parallel and Distributed Processing Symposium (IPDPS'03) WORKSHOPS », IEEE CS Press, pages 222a, 2003.

[40] O. DALLE, P. MUSSI. *Cooperative Software Development and Computational Resource Sharing.* in « NMSC System Simulation Workshop », European Space Agency, ESTEC, Noordwijk, The Netherlands, March, 2003.

[41] A. FERREIRA, S. PERENNES, A. W. RICHA, H. RIVANO, N. STIER. *On the design of multifiber WDM networks.* in « Proceedings of the 10-th International Conference on Telecommunications – ICT'2003 », volume I, IEEE, pages 12–18, Tahiti, 2003.

[42] A. JARRY, A. LAUGIER. *Graphes 2-connexes à diamètre donné.* in « ROADEF 2003 », series Proceedings in Informatics, number 5, Université d'Avignon et des Pays de Vaucluse, pages 102–104, Avignon, France, June, 2003.

[43] J.-F. LALANDE, S. PÉRENNES, M. SYSKA. *Groupage dans les réseaux dorsaux WDM.* in « ROADEF 2003 », series Proceedings in Informatics, number 5, Université d'Avignon et des Pays de Vaucluse, pages 254–255, Avignon, France, 2003.

[44] A. LAUGIER, S. PETAT. *Network Design and b-matching.* in « Proc. of International Network Optimization Conference », pages 374–379, 2003.

[45] T. TOCKER, E. ALTMAN, J. GALTIER, C. TOUATI, B. FABRE, I. BURET, C. GUIRAUD. *Slot allocation in a TDMA satellite system: simulated annealing approach.* in « Proceedings of AIAA International Communication Satellite Systems Conference and Exhibit », Yokohama, Japan, April, 2003.

[46] C. TOUATI, E. ALTMAN, J. GALTIER. *Radio Planning in Multibeam Geostationary Satellite Networks.* in « Proceedings of AIAA International Communication Satellite Systems Conference and Exhibit », Yokohama, Japan, April, 2003.

[47] C. TOUATI, E. ALTMAN, J. GALTIER. *Semi-definite programming approach for bandwidth allocation and routing in networks.* in « Proceedings of ITC 18 », pages 1091-1100, Berlin, Germany, August/September, 2003.

## Internal Reports

[48] F. HAVET. *Stable set meeting every longest path.* Technical report, 2003, http://www.inria.fr/rrrt/rr-5009.html.

[49] F. HAVET. *Upper bound for the span of (s,1)-total labelling of graphs.* Technical report, 2003, http://www.inria.fr/rrrt/rr-4816.html.

## Miscellaneous

[50] A. ACOSTA. *MOEDIG : Environnement de simulation pour modèles à évènements discrets généralisés.* Rapport de stage de Magistère en Ingénierie Electronique et Informatique (ENS Bretagne), 6 mois en 2003, encadreurs O. Dalle et P. Mussi, 2003.

[51] O. DALLE, O. FRANÇOISE. *Building High Performance Communications Through the Virtual File System API.* Solutions Linux International Conference, Paris,, February, 2003.

[52] O. DERIVOYRE. *Optimisation du groupage dans les réseaux de télécommunication.* Rapport de stage de DEA RSD, 5 mois en 2003, encadreurs J-C. Bermond et M. Syska, 2003.

[53] L. ESPERET. *Coloration* $(d, 1)$*-totale et méthode probabiliste.* Rapport de stage de Magistère d'Informatique (ENS Lyon), 5 semaines en 2003, encadreur F. Have, 2003.

[54] G. JOUTEL. *Synthèse de réseau.* Rapport de stage de Magistère d'Informatique (UFR Claude Bernard Lyon 1), 6 semaines en 2003, encadreur J. Galtier, 2003.

[55] N. MORALES. *"Robust models for simultaneous open pit and underground mines.* Rapport de stage Chilean pre-doc, 4 mois et 1/2 en 2003, encadreur R. Klasing, 2003.

[56] A. PAPADOPOULOS. *Adaptive broadcast consumption (ABC), a new heuristic and new bounds for the minimum energy broadcast routing problem.* Rapport de master, Greece, 6 mois en 2003, encadreur R. Klasing, 2003.

[57] X. ROCHE. *Approximation du multiflot fractionnaire.* 2003.

[58] M.-E. VOGE. *Conception de réseaux SDH en anneaux.* Rapport de stage de DEA ROCO (INP Grenoble), 4 mois en 2003, encadreurs M.Burlet et A.Laugier, 2003.