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 COM

Activity Report

2006

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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).

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

Head of the team
Jean-Claude Bermond [Research Director (DR) CNRS]

Vice-head
Philippe Mussi [Research Associate (CR) INRIA, until 01/07/06]
David Coudert [Research Associate (CR) INRIA, since 01/07/06]

Administrative assistants
Ephie Deriche [TR INRIA (part time with the team MAESTRO)]
Patricia Lachaume [ITA CNRS (part time)]

Staff member INRIA
Michel Cosnard [Professor UNSA (temporary research position at INRIA), HdR]
Olivier Dalle [Teaching Assistant UNSA (temporary research position at INRIA)]
Luigi Liquori [Research Associate (CR) INRIA, since 01/01/06]

Staff members CNRS
Afonso Ferreira [Research Director (DR) CNRS (on leave at EEC), HdR]
Frédéric Havet [Research Associate (CR) CNRS]
Stéphane Pérennes [Research Associate (CR) CNRS]
Hervé Rivano [Research Associate (CR) CNRS]
Stéphan Thomassé [University of Lyon I, until August 2006 (délégation CNRS)]
Bruce Reed [Research Director (DR) CNRS (since 01/06/06)]

Staff members University of Nice-Sophia Antipolis
Michel Syska [Teaching Assistant UNSA]

Staff members France Telecom R&D of CRC CORSO
Jérôme Galtier [Engineer France Telecom R&D]
Alexandre Laugier [Engineer France Telecom R&D]

Expert Engineers
Cyrine Mrabet [IA INRIA since 17/10/05]
Fabrice Peix [European contract AEOLUS]

Post-doctoral fellows
Raphael Chand [Post-Doc INRIA, until 31/10/06]
Loubna Echabbi [Post-Doc CNRS, 01/10/06 - 30/11/06]
Olga Gerber [Post-Doc INRIA, since 01/12/06]
Frédéric Giroire [Post-Doc CNRS, 01/10/06 - 31/12/06]
Gurvan Huiban [co-supervision with Brazil, halftime MASCOTTE, defense 28/07/06 and ATER since 01/09/06]
Marie-Emilie Voge [BDI CNRS/Région, defense 17/11/06 and ATER since 01/09/06]

PhD Students
Omid Amini [Allocataire X since 13/10/05, 2nd year]
Cristiana Gomes [Grant Brazil, since 01/09/06, 1st year]
Florian Huc [BDI CNRS/Région, since 01/10/05, 2nd year]
Christelle Molle [Grant DGA/CNRS, since 01/10/06, 1st year]
Nelson Morales [Grant CONICYT Chile, 4st year]
Jean-Paul Perez Seva [Cifre Thales, 1st year]

Patricio Reyes Valenzuela [Grant CONICYT Chile, 2nd year]
Jean-Sébastien Sereni [Allocataire moniteur MENRT, until 30/09/06, defense 05/07/06]
Ignasi Sau Valls [BDO CNRS/Région, since 01/10/06, 1st year]

Invited Researchers

Luigi Addario-Berry [McGill University, Montreal, Canada, June 2006, 1 week]
Stéphane Bessy [Univ. of Montpellier, April 2006, 1 week]
Pierre Charbit [Univ. Of Lyon, April 2006, 1 week]
Ricardo Correa [Universidade Federal do Ceará, Brazil, April 2006, 1 month]
Fedor Fomin [Univ. Of Bergen, Norway, July 2006, 1 week]
Luisa Gargano [University of Salerno, Italy, July-August 2006, 1 month]
Frédéric Giroire [INRIA Rocquencourt, February 2006, 2 weeks]
Alfredo Goldman [Universidade of Saõ Paulo, Brazil, November 2006 (2 weeks)]
MohammadTaghi Hajiaghayi [Carnegie Mellon University, December 11-15, 2006 (1 week)]
Brigitte Jaumard [Concordia University, Montreal, Canada, June 2006, 1 week]
Ross Kang [Oxford University, United Kingdom, May 7-19 2006, 2 weeks]
Benjamin Leveque [Laboratoire Leibniz, IMAG, Grenoble, France, July 2006, 1 week]
Claudia Linhares Sales [Univ. Federal do Ceará, Fortaleza Brazil, August-December 2006, 4 months]
Frédéric Maffray [CNRS, Leibniz, Grenoble, July 2006, 1 week]
Tobias Müller [Oxford University, United Kingdom, May 12-25 2006, 2 weeks]
Nicolas Nisse [LRI, Université Paris-Sud, December 18-22 2006 (1 week)]
Cesare Pautasso [ETZ, Zurich, Switzerland, November 27-28 2006 (2 days)]
Joseph Peters [Simon Fraser University, Vancouver, Canada. June-july 2006, 1 month]
Gianluca Quercini [University of Genova, Italy, December 5-7 2006 (2 days)]
Riste Škrekovski [University of Ljubljana, Slovenia, 19 June – 05 July 2006, 2 weeks]
Arnaud Spiwack [ENS Cachan, June 2006, 1 week]
Ladislav Stacho [Simon Fraser University, Burnaby BC, Canada. June-July 2006, 3 weeks]
Ugo Vacarro [University of Salerno, Italy, July-August 2006, 1 month]
Anders Yeo [Royal Holloway College, London, UK, March 2006, 1 week]
Joseph Yu [Simon Fraser University, Vancouver, Canada, June-July 2006, 1 month]

Internships

Foued Ben-Hfaiedh [PFE INSAT Tunis until 02/06, and Master 2 STIC “RSD”, march-june 2006, 6 months]
Ignasi Sau Valls [UPC Barcelone, until 02/06, 2 months in 2006]
Duc Phong Le [IFI Hanoi, Vietnam, march-september 2006, 7 months]
Violeta Doneva [Master 2 STIC "PMLT", UNSA, march-september 2006, 7 months]
Judicael Ribault [Master 1 STIC "Informatique", UNSA, may-july 2006, 2.5 months]
Amar Patel [Master, Sveden, september 2005-February 2006, 6 months]
Faouzi Kaabi [INSAT Tunis, until 02/06, 2 months in 2006]
Guillaume Méheut [Ecole Polytechnique, april-june 2006, 3 months]
Christelle Molle [Master 2 UPMC, Paris, april-july 2006, 4 months]
Paulo Pastorelli [Master 1, Univ. Genova, Italy, July-November 2006, 5 months]
Alex Popkin [Vanderbilt University, U.S.A., May 2006, 3 weeks]

2. Overall Objectives

2.1. 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 Telecom at Sophia-Antipolis via the CRC CORSO (the first Contrat de Recherche Collaborative INRIA with France Telecom).

Its research fields are Simulation, Algorithmics, Discrete Mathematics and Combinatorial optimization with applications to telecommunication, global computing and transportation networks.

In particular, MASCOTTE has developed in the last four years both theoretical and applied tools for the design of heterogeneous networks and networks using various technologies like wavelength division multiplexing (WDM), synchronous digital hierarchy (SDH), Asynchronous Transfer Mode (ATM), fixed, mobile or satellite wireless networks, ...

3. Scientific Foundations

3.1. Scientific Foundations

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

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 or a router or a switch or a radio device or a site or a person, and an edge (or arc) a connection between the elements represented by the vertices (logical or physical connection). 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 (modeling either wavelengths or frequencies or failures) 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 broken). The project aims at constructing or designing networks or communication algorithms or at building software simulators or at implementing algorithms but not at conceiving protocols. The theoretical results can be applied to various situations and technologies.

4. Application Domains

4.1. Application Domains

For the last four years the project has chosen Telecommunication main domain of application. We either use tools specifically devoted for the application or already developed in other fields like parallel computing. 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 Telecom (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 components of traffic into bigger ones or on radio networks. 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 with the CNES and others.

5. Software

5.1. Advanced Software

- PROSIT [1]
  Participants: Olivier Dalle, Philippe Mussi.

  PROSIT 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]
  Participants: Ricardo Correa, 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 help 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 to 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. The MASCOPT interface was defined in collaboration with Ricardo Correa (Universidade Federal do Ceará, Brazil) to make it compatible with the PAREGO library implementation to start with. The interface also enables the transparent use of different solvers when writing linear programs.

  MASCOPT was intensively 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 France Telecom on the design of telecommunication backbone networks.

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

  MASCOPT has been presented at Club InTech'Sophia.

- **OSA**[3]: an Open Component-based Architecture for Discrete-Event Simulations.
  Participants: Olivier Dalle, Cyrine Mrabet, Philippe Mussi.

  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

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

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)[62] 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/.

- **Simulator for the Overlay Network Arigatoni**
  Participants: Raphael Chand, Michel Cosnard, Luigi Liquori.

  We have implemented in C++ the Resource Discovery Algorithm and the Virtual Intermittence Protocol of the Arigatoni Overlay Network. The simulator was used to measure the load when we issued n service requests at Global Computers chosen uniformly at random. Each request contained a certain number of instances of one service, also chosen uniformly at random. Each service request was then handled by the Resource Discovery mechanism of Arigatoni networks.

6. New Results

6.1. Discrete event systems and simulation

Participants: Olivier Dalle, Judicael Ribault, Cyrine Mrabet.

Computer simulations are invaluable (and often unavoidable) for studying the dynamic behavior and performances of complex systems. In MASCOTTE, simulation techniques are used for studying large networks, such as telecommunications and (road) transport networks. This is a particularly challenging application area for computer simulations because networks usually involve a large number of entities (up to millions) each of which having a potentially complex and (time-)independent (asynchronous) behavior. Discrete-event simulation techniques are well suited for modeling the individual behavior of entities in such networks.

In order to cope with the constant evolution and ever growing complexity and size of networks, new simulators and modeling techniques are regularly developed in MASCOTTE. However, a particular attention is paid to reuse and improve existing software and techniques from one generation to the next. Indeed, the C++ kernel framework (PROSIT) developed in the Road traffic Simulator OSSA was then reused, in cooperation with the CNES, for the simulation of satellite telecommunications (ASIMUT project); and in the latest simulator generation (OSA), the innovative design principles of ASIMUT have been preserved, but the PROSIT kernel has been replaced with a new versatile design, based on the latest advances drawn out from the Component Based Software Engineering research community (the ***ObjectWeb Consortium***'s ***Fractal*** component model). Each of these projects is further described in the following paragraphs.

6.1.1. Open Component-Based Architecture For Discrete-Event Simulation

We initiated the collaborative development of a new software platform for discrete-event simulation studies, the Open Simulation Architecture (OSA) [62], [50]. OSA is primarily intended to be a federating platform for the simulation community: it is designed to favour the integration of new or existing contributions at every level of its architecture. The platform core supports discrete-event simulation engine(s) built on top of the ***ObjectWeb Consortium***'s ***Fractal*** component model. In OSA, the systems to be simulated are modeled and instrumented using Fractal components. Fractal components offer many advanced and original features, such as multi-programming language support and the ability to share sub-components. In OSA, the event handling is mostly hidden in the controller part of the components, which noticeably alleviates the modeling process, but also eases the replacement of any part of the simulation engine. Apart from the simulation engine, OSA also aims at integrating useful tools for modeling, developing, experimenting and analyzing simulations. For this purpose it relies on the Eclipse development platform and its ability to be extended.

6.1.2. Modeling and Simulation Dictionary: English-French-Turkish

In the context of the working group Versim (GDR CNRS I3), we co-authored a French-English-Turkish dictionary on simulation [11].

6.2. Network design

Participants: Omid Amini, Jean-Claude Bermond, Michel Cosnard, David Coudert, Jérôme Galtier, Florian Huc, Gurvan Huiban, Alexandre Laugier, Fabrice Peix, Stéphane Pérennes, Ignasi Sau Valls, Jean-Sébastien Sereni.

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 MASCOTTE we have studied the wavelength routing and coloring problem, the traffic grooming problem and the virtual network embedding problem (with application to ATM networks) and other design problems for backbone telecommunication networks with SDH (Synchronous Digital Hierarchy) technology.

6.2.1. Design

6.2.1.1. An Integer Programming Approach to Routing in Daisy Networks

We are concerned in [19] with routing problems arising in special kinds of SDH networks, called daisy networks. Beside the capacity constraints, some disjoint edge-sets of the network, called arcs, are also prescribed. Our goal is to find a routing of the demands satisfying the capacities with the additional constraint that whenever a path (with value 1) enters an arc then it uses capacity 1 on all edges of that arc. We consider two types of arc-systems and give algorithms and computational results of integer programming formulations.

6.2.1.2. Generalized Nash Bargaining Solution for bandwidth allocation

For over a decade, the Nash bargaining solution (NBS) concept from cooperative game theory has been used in networks to share resources fairly. Due to its many appealing properties, it has recently been used for assigning bandwidth in a general topology network between applications that have linear utility functions. In [36], we use this concept for allocating the bandwidth between applications with general concave utilities. Our framework includes in fact several other fairness criteria, such as the max-min criteria. We study the impact of concavity on the allocation and present computational methods for obtaining fair allocations in a general topology, based on a dual Lagrangian approach and on Semi-Definite Programming.

6.2.2. RWA static and dynamic

6.2.2.1. Reconfiguration of WDM networks

In a real-time network, the traffic evolves with time. Then 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. This optimization problem hence captures the trade-off between network performance and number of reconfigurations applied to the virtual topology. The above problem is solved in [12] through a Mixed Integer Linear Programming formulation with a multivariate objective function, that captures both these parameters. However, the problem is NP-hard and such an approach is unable to solve large problem instances in a reasonable time. Thus we propose a simulated annealing based heuristic algorithm for solving problems of higher complexity. We compare the performance and the computation time of the MILP model and the heuristic algorithm considering different tests instances. Our results indicate that simulated annealing obtains results within 5% of the optimal solution, thus making it a viable approach in large scale networks.

In [12] we tried to make a concise model in relations with the number of variables and restrictions, to reduce the memory occupation during the optimization process. We also add some cuts to the model.

Then in [71] we investigate different rerouting strategies, allowing to reroute only a bounded number of connections per unit of time.

In [12] we propose an in-depth study of the reconfiguration problem in multi-fiber WDM networks. It consists in defining how to adapt the optical layer to changing traffic patterns. Our objective is to treat the problem globally. We consider arbitrary mesh topologies, all-to-all traffic and multi-hop routing. However, we restrict ourselves to prevision: the traffic evolutions are foreseen. We propose a compact Mixed Integer Linear Programming model, enabling us to solve medium instances. We define several metrics to evaluate the performance of a solution. We also propose some mathematical cuts and a lower bound for the problem. We make extensive experiments based on this model, in order to investigate the influence of different parameters, such as the metric chosen or the cut formulation. To do so, many instances are solved with different networks.

We have modelled a reconfiguration problem in which we want to switch from a routing R_1 to a routing R_2 using the minimum number of simultaneous temporary routes. In this model, a request may be switch to a temporary route before reaching its final routing in R_2, thus make use of extra resources of the network. In [83] we have proved that the problem is in general NP-complete and give an approximation for planar graphs. In [13], we establish some similarities and differences with two other known problems: the pathwidth and the pursuit problem. Then we give the solutions for some classes of graphs, in particular complete d-ary trees and grids. This lead us to study in [28], [61], [58] the pathwidth of planar and outerplanar graphs (see below).

6.2.2.2. Pathwidth of planar and outerplanar graphs

Motivated by our work on routing reconfiguration in WDM networks, we were interested in [28] in the relation between the pathwidth of a biconnected outerplanar graph and the pathwidth of its (geometric) dual. After Bodlaender and Fomin proved that the pathwidth of every biconnected outerplanar graph is always at most twice the pathwidth of its (geometric) dual plus two, they conjectured that there exists a constant c such that the pathwidth of every biconnected outerplanar graph is at most c plus the pathwidth of its dual. They also conjectured that this was actually true with c being 1 for every biconnected planar graph. Fomin proved that the second conjecture is true for all planar triangulation. First, we construct for each $p \geq 1$ a biconnected outerplanar graph of pathwidth $2p+1$ whose (geometric) dual has pathwidth $p+1$, thereby disproving both conjectures. Next, we also disprove two other conjectures (one of Bodlaender and Fomin, implied by one of Fomin). Finally we prove, in an algorithmic way, that the pathwidth of every biconnected outerplanar graph is at most twice the pathwidth of its (geometric) dual minus one. A tight interval for the studied relation is therefore obtained, and we show that all the gaps within the interval actually happen.

In [58] we improve a result of Fomin and Thilikos saying that the pathwidth of every 3-connected planar graph G satisfies: $\mathtt{pw}(G^*) \leq 6\mathtt{pw}(G) + c$, for some constant c. We show that the dual of a 3-connected planar graph has pathwidth at most 3 times the pathwidth of the primal plus two ($3\mathtt{pw}(G) + 2$). For 4-connected planar graphs, we obtain a multiplicative factor of two.

6.2.3. Traffic Grooming

In a WDM network, routing a request consists in assigning it a route in the physical network and a wavelength. If each request uses at most $1/C$ of the bandwidth of the wavelength, we will say that the grooming factor is C. That means that on a given edge of the network we can groom (group) 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 (shortly ADM) used in the network (related to the cost of the nodes).

We have 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 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. In prior work, using tools of graph and design theory, we optimally solved the problem for rings for practical values and infinite congruence classes of values for a given C.

In [43], [74] we have modeled the problem on bidirectional rings. The main difference with previous studies is that the routing has now to be taken into account. We have established a general lower bound for all grooming factors and improve bounds for $C = 2$ and $C = 3$ when $N = 4t + 3$. Then we have obtained good upper bound constructions.

In [42] we give an optimal solution to the Maximum All Request Path Grooming (MARPG) problem motivated by a traffic grooming application. The MARPG problem consists in finding the maximum number of connections which can be established in a path of size N, where each arc has a capacity or bandwidth C (grooming factor). We present a greedy algorithm to solve the problem and an explicit formula for the maximum number of requests that can be groomed. In particular, if $C = s(s + 1)/2$ and $N > s(s - 1)$, an optimal solution is obtained by taking all the requests of smallest length, that is of length 1 to s. However, this is not true in general since anomalies can exist. We give a complete analysis and the exact number of such anomalies.

The book chapter [20] is a survey of the main results on traffic grooming problems.

6.3. Fault tolerance

Participants: Omid Amini, Jean-Claude Bermond, David Coudert, Afonso Ferreira, Frédéric Giroire, Frédéric Havet, Florian Huc, Stéphane Pérennes, Bruce Reed, Hervé Rivano, Jean-Sébastien Sereni, Marie-Emilie Voge, Joseph Yu.

Network fault tolerance (or survivability) is a key issue in the design and management of networks. Basic tools used in this context come from graph theory, in particular connectivity and flow studies. On the applied side we have pursued our investigation on a problem posed by Alcatel Space Technologies (now Alenia) on satellite boarded fault tolerant networks (Traveling Tube amplifiers Redundancy). We have also considered extensively the fault tolerance and protection in backbone networks like WDM networks (in collaboration with France Telecom). A simple strategy (of protection) consists in associating to each request one (or more) extra disjoint path of protection. In fact new problems have been emphasized by considering multi-layer networks. Indeed a failure at one level (for example the optical network) might induce many failures at an upper level (for example the virtual graph on which are established the communications). This new area was also investigated in the context of the ACI Sécurité PRESTO. All these studies concern mainly static networks with a centralized knowledge; we have also addressed some problems in the case of distributed computing and started with France Telecom researches on the reliability problem where each edge has a probability of failure. This appears to be a promising area in particular in the context of SLA (Service Level Agreement).

6.3.1. Minimum cost k-connected graphs

In [76] we present new structural results about the existence of a subgraph when the degrees of the vertices are prespecified. Further, we use these results to prove a 16-edge weighting version of a conjecture of Karonski, Luczak, and Thomason, an asymptotic 2-edge weighting version of the same conjecture, and a 7/8 version of Louigi's conjecture.

6.3.2. Multi commodity flows.

Given an undirected network, the multi-terminal network flows analysis consists in determining the all pairs maximum flow values. In [17], we consider an undirected network in which some edge capacities are allowed to vary and we analyze the impact of such variations on the all pairs maximum flow values. We first provide an efficient algorithm for the single parametric capacity case, and then propose a generalization to the case of multiple parametric capacities. Moreover, we provide a study on Gomory-Hu cut-tree relationships.

We also studied highly Linked Parity Graphs. A graph G is k-linked if G has at least $2k$ vertices, and for any $2k$ vertices $x_1, x_2, \cdots, x_k, y_1, y_2, \cdots, y_k$, G contains k pairwise disjoint paths $P_1, \cdots, P_k$ such that P_i joins x_i and y_i for $i = 1, 2, \cdots, k$. We say that G is parity-k-linked if G is k-linked and, in addition, the paths $P_1, \cdots, P_k$ can be chosen such that the parities of their length are prescribed. Thomassen was the first to prove the existence of a function $f(k)$ such that every $f(k)$-connected graph is parity-k-linked if the deleting of any $4k-3$ vertices leaves a non bipartite graph. In [82], we show that the above statement is still valid for $50k$-connected graphs. This is the first result that the linear function of the connectivity guarantees the Erdos-Posa type result for parity-k-linked graphs.

6.3.3. Satellite boarded fault tolerant networks.

ALCATEL SPACE INDUSTRIES asked us to consider the following problem. Signals arriving at a telecommunication satellite (via input links) have to be routed through a network to amplifiers (outputs, also called *Travelling Wave Tube Amplifiers*, i.e. TWTA). The links of the networks are made of wave guides.

The problem comes from the fact that the amplifiers may fail during the satellite's lifetime and cannot be repaired. So one needs to have more amplifiers than the number of signals. One wants to be able to route the arriving signals to valid amplifiers, that is to find link disjoint paths between the inputs and valid outputs in the interconnection network.

The networks are made of links and expensive switches, hence we want to minimize the number of switches subject to the following conditions: each input and each output is connected to exactly one switch; each switch is adjacent to exactly four links; there are $p+\lambda$ inputs and $p+k$ outputs; p signals arrive on the $p+\lambda$ inputs and among the $p+k$ outputs, k can fail permanently; and finally all the input signals should be sent to valid amplifiers, i.e. outputs, via disjoint paths.

The problem can be modeled as follows. A $(p,\lambda,k)-$network is an undirected graph with $p+\lambda$ inputs, $p+k$ outputs and internal vertices of degree four. A $(p,\lambda,k)-$network is *valid* if for any choice of p inputs and p outputs, there exist p edge-disjoint paths from the inputs to the outputs. In the special case $\lambda = 0$, a $(p,\lambda,k)-$network is already known as a *selector*. We wish to determine $N(p,\lambda,k)$, the minimum number of nodes in a valid $(p,\lambda,k)-$network.

In a still unpublished manuscript we have build a theory for the case $\lambda = 0$ which reduces the problem to verify a simple condition on an associated bipartite graph called the kernel. Using that we solve completely the case $k = 4$ and give very tight bounds for k small. Furthermore we have been able to build (using MASCOPT) a software which verify easily the validity of networks until $p = 100$.

In [63], we studied a variation of this problem where the switches have 6 links. The minimum number of switches is determined when $k \leq 6$.

For general λ we present validity certificates from which derive lower bounds for $N(p,\lambda,k)$. We also provide constructions, and hence upper bounds, based on expanders. The problem is very sensitive to the order of λ and k. For instance, when λ and k are small compared to p, the question reduces to avoid certain forbidden local configurations. For larger values of λ and k, the problem is to find graphs with a good expansion property for small sets. This lead us to introduce a new parameter called *robustness*. In many cases, we provide asymptotically tight bounds for $N(p,\lambda,k)$ [57], [38].

In [22], [31], we studied a variation of this problem where p of the input signals called priorities must be routed to the p amplifiers providing the best quality of service in presence of f faults. Let $R(n,p,f)$ be the minimum number of switches of such a network. We prove in [22] that $R(n,p,f) \leq \frac{n+f}{2}\lceil \log_2 p \rceil + \frac{5}{2}(n-p) + g(f)$

with g a function depending only on f. In [31], we show that $R(n,p,f) \leq 18n + 34(p+f)$. We then compute $R(n,p,f)$ exactly for a few small values of p and f.

6.3.4. Protection

6.3.4.1. Protection in WDM networks.

We study the problem of designing a survivable WDM network based on covering the communication requests with subnetworks that are protected independently from each other. The subnetworks are chosen to be loops (cycles) in order to minimize the complexity of the routing problem with full survivability.The advantage is that a loop (cycle) is secured by its reverse loop. Given the failure of any single link, we can reroute the traffic going through the failed link via the other part of the cycle. (More precisely one can associate two wavelengths to each cycle of the covering: one for the normal traffic and another as a spare one.)

The survivability problem mentioned above consists of finding a cycle partition or covering of the edges of I with an associated routing over the graph G which should satisfy the Disjoint Routing constraint, or *DR constraint*, i.e:the requests involved in a cycle of the covering are routed via vertex disjoint paths (equivalently, their routings form an elementary cycle in the physical graph G).

The aim is to minimize the cost of the network; that is a very complex function depending on the size of the ADM's put in each node, the number of wavelengths (associated to the subnetworks) in transit in each optical node and a cost of regeneration and amplification of the signal. In a first approximation, some authors reduce it to minimize the number of cycles of the covering (which is related to the problem of minimizing the number of wavelengths used and the cost of transmission); other minimize the sum of the number of vertices of the rings; other insist on using very small cycles in the covering (short cycles are easier to manage and in case of failures, rerouting is easier). One can also want to minimize the total load (using or not shortest paths).

We have obtained exact results when the logical graph I is K_n, which corresponds to the instance of communication called total exchange or all-to-all, where each vertex wants to communicate with all the others simultaneously, and when the the physical graph G is C_n, a cycle of length n or a torus $T(n)$ of size n by n [23].

6.3.4.2. Shared Risk Resources group

Failure resilience is a desired feature of the Internet. Most traditional restoration architectures are designed assuming single failure cases, which is not adequate in present day multilayer networks. Multiple link failure models, such as Shared Risk Link Groups (SRLG), Shared Risk Node Groups (SRNG), and more generally Shared Risk Resource Groups (SRRG), are becoming critical in survivable network design. These shared risk models have been unified through the notion of *colored graphs*.

In [60], [55], [14] we focus on complexity and approximability issues of optimization problems in colored graphs, and on the evolutions of the relationships among these problems in these settings. We introduce the notions of colored cut and colored spanning tree and prove the hardness and non-approximability of colored path, cut and spanning tree optimization problems. We also investigate specific polynomial cases and provide a MILP formulation for colored cut problems and heuristic algorithms for the Minimum Color Path and Minimum Color st-Cut problems. We emphasized the main differences between colored combinatorial questions and their counterparts in classical graph theory. In particular we show that the Max Flow - Min Cut like relationships do not hold in colored graphs.

In [49] we provide an efficient MILP formulation for the minimum color path problem which is related to finding a path of maximum reliability in a multilayer network and is thus an essential issue of network survivability. We also proved new polynomial cases.

In [56], [14] we investigate further the transformation of a multilayer network into a colored graph. Indeed the transformation is not unique and has a huge impact on the complexity of the problems and thus on the quality of the solutions. In particular if the transformation is not well chosen, we turn from a tractable polynomial problem to an NP-hard one.

6.4. Resource sharing in wireless and sensor networks

Participants: Jean-Claude Bermond, Ricardo Correa, Afonso Ferreira, Jérôme Galtier, Guillaume Méheut, Nelson Morales, Stéphane Pérennes, Hervé Rivano, Joseph Yu.

6.4.1. Medium access

6.4.1.1. CDMA networks

The UMTS technologies offer a large range of possible transmission rate and power to the mobile users. Setting these values in an adaptive, fair, and optimal way is a challenging issue. After carefully analyzing the system of equations, and applying appropriate changes of variables, we find in [52] a formulation where the constraints for capacity are convex. We take advantage of a known analytical solution of the problem for the powers to reformulate the problem on the rates. Then we extract properties from the Kuhn-Tucker conditions to derive an algorithm having almost linear complexity with the number of users. This case turns to be very useful in practice and the algorithm very simple and efficient.

6.4.1.2. Analysis of the slotted non-persistent CSMA protocol

In [53], we analyze the slotted non-persistent CSMA protocol when the packet size follows a poissonian distribution. To that purpose, we use a semi-Markov representation of the protocol and derive a closed form for the saturation throughput. The method can apply to a very large family of protocols and therefore unifies lots of results. The new formula for non-persistent CSMA with non unitary packet size present many interesting aspects.

6.4.2. Bandwith allocation

6.4.2.1. Radio networks: Internet in villages.

Within the CRC CORSO with France Telecom, we have studied the problem of designing efficient strategies to provide Internet access using wireless devices. Typically, in one village several houses wish to access a gateway (a satellite antenna) and to use multi-hop wireless relay routing to do so.

In particular we address the problem of gathering information in a specific node (or *sink*) of a radio network, where interference constraints are present. We take into account the fact that, when a node transmits, it produces interference in an area bigger than the area in which its message can actually be received. The network is modeled by a graph; a node is able to transmit one unit of information to the set of vertices at distance at most d_T in the graph, but when doing so it generates interference that does not allow nodes at distance up to d_I ($d_I \geq d_T$) to listen to other transmissions. Time is synchronous and divided into time-steps in each of which a round (set of non-interfering radio transmissions) is performed.

In [45], [21], [59], we give general lower bounds on the number of rounds required to gather into a sink of a general graph, and present an algorithm working on any graph, with an approximation factor of 4. We also show that the problem of finding an optimal strategy for gathering is NP-HARD, for any values of d_I and d_T. If $d_I > d_T$, we show that the problem remains hard when restricted to the uniform case where each vertex in the network has exactly one piece of information to communicate to the sink.

In [41], we consider the case $d_T = 1$ and give algorithms and lower bounds on the minimum number of rounds for this problem, when the network is a path and the destination node is either at one end or at the center of the path. The algorithms are shown to be optimal for any d_I in the first case, and for $1 \leq d_I \leq 4$, in the second case.

In [44] we consider the general case for d_T, and obtain *good* approximations in some specific topologies, like the path, balanced stars and the 2 dimensional grid. In all these cases we provide algorithms whose performance differs only by an additive constant from the theoretical minimum.

6.4.2.2. Resource allocation for a geostationary satellite

In [15] we present an algorithm for resource allocation in satellite networks. It deals with planning a time/frequency plan for a set of terminals with a known geometric configuration under interference constraints. Our objective is to minimize the size of the frequency plan while ensuring that the different types of demands are satisfied, each type using a different bandwidth. The proposed algorithm relies on two main techniques. The first generates admissible configurations for the interference constraints, whereas the second uses mixed linear/integer programming with column generation. The obtained solution estimates a possible allocation plan with optimality guarantees, and highlights the frequency interferences which degrade the construction of good solutions.

6.4.2.3. Fair power and transmission rate control in wireless networks

In third generation mobile networks, transmission rates can be assigned to both real time and non real time applications. We address in this paper the question of how to allocate transmission rates in a manner that is both optimal and fair. As optimality criterion we use the Pareto optimality notion, and as fairness criterion we use a general concept of which the max-min fairness (which is the standardized fairness concept in ATM networks) and the proportional fairness (which characterizes fairness obtained by some transport protocols for the Internet) are special cases. We show in [37] that the problem is a joint optimization system of the transmission rate and the power. We formulate the fair allocation problem as an optimization problem and propose both exact as well as approximating solutions. We consider both uplink and downlink problems and study also macrodiversity.

6.4.3. Theoretical tools for evaluation

6.4.3.1. Dynamic Networks and Evolving Graphs

The highly dynamic behavior of wireless networks make them very difficult to evaluate, e.g. as far as the performance of routing algorithms is concerned. However, some of these networks, such as intermittent wireless sensors networks, periodic or cyclic networks, and low earth orbit (LEO) satellites systems have more predictable dynamics, as the temporal variations in the network topology are somehow deterministic.

Unfortunately, the temporal variations in the topology of dynamic networks are hard to be effectively captured in a classical graph model. Recently, a graph theoretic model the evolving graphs was proposed to help capture the dynamic behavior of these networks, in view of the construction of least cost routing and other algorithms [79]. In particular we used evolving graphs 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

We further investigated the connected components problem in dynamic networks with special topologies. In a dynamic setting, the topology of a network derives from the set of all the possible links, past and future. We proved that the strongly connected components problem is still NP-complete when the topology is composed of unit disc graphs and the nodes are placed on a grid [81]. On the other hand, we also gave a polynomial-time algorithm, by dynamic programming, in order to compute a maximum strongly connected components when the topology is a tree

We also investigated the concepts of journeys in Evolving Graphs, which captures both space and time constraints in routing problems. Journeys where formalized in [77], [78], [80] 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.

The algorithms and insights obtained through this model are theoretically very efficient and intriguing. However, there is no study on the uses of these theoretical results into practical situations. Therefore, the objective of this work is to analyze the applicability of the evolving graph theory in the construction of efficient routing protocols in realistic scenarios.

In [51], we used the NS2 network simulator to first implement an evolving graph based routing protocol, and then to evaluate such protocol compared to three major ad-hoc protocols (DSDV, DSR, AODV). Interestingly, our experiments showed that evolving graphs have all the potentials to be an effective and powerful tool in the development of algorithms for dynamic networks, with predictable dynamics at least. In order to make this model widely applicable, however, some practical issues still have to be addressed and incorporated into the model, like stochastically predictable behavior. We also discuss such issues in this paper, as a result of our experience.

6.4.3.2. Capacity evaluation of ad-hoc and hybrid networks

Evaluating the capacity of a radio network is a challenging issue of quality of service guaranteed networks design [72]. Two approaches are investigated, with the objective of developing tools combining both mathematical optimization and stochastic evaluation. Assuming a given network topology and a routing protocol, a first approach [54], [70] is focused on the capacity evaluation of routing protocols based on either a self-organization scheme or a flat approach. To reach this goal, we propose to use linear-programming formulation to model radio resource sharing as linear constraints. Four models are detailed to evaluate the capacity of any routing scheme in wireless multihops networks. First, two models of fairness are proposed: either each node has a fair access to the channel, or the fairness is among the radio links. Besides, a pessimistic and an optimistic scenarios of spatial re-utilization of the medium are proposed, yielding a lower bound and an upper bound on the network capacity for each fairness case. Finally, using this model, we provide a comparative analysis of some flat and self-organized routing protocols.

A second approach [69], [73] focuses on existential bounds on the transport capacity of random networks. The literature providing tight lower and upper bounds of order $\frac{1}{\sqrt{N}}$ with non-realistic communication and media access models. Our work extends these results to more realistic CSMA/CA 802.11 like media access control layer and random communication pattern. We have investigated on the capacity that is reachable by localized routing protocols. We have developed localized geometrical protocols and conducted a competitive experimental and analytical analysis against centralized shortest path based algorithms. Preliminary results suggest that localized information makes impossible to distribute efficiently the load of the networks, hence increasing the practical lower bound to $\frac{1}{\sqrt{N \log N}}$. Nevertheless, these results are merely hints and the question is still open.

6.5. Graph colourings and applications

Participants: Frédéric Havet, Bruce Reed, Jean-Sébastien Sereni, Stephan Thomassé.

6.5.1. Channel assignment and improper coloring.

Satellites send information to receivers on earth, each of which is listening on a frequency. Technically it is impossible to focus the signal sent by the satellite exactly on receiver. So part of the signal is spread in an area around it creating noise for the other receivers displayed in this area and listening on the same frequency. A receiver is able to distinguish the signal directed to it from the extraneous noises it picks up if the sum of the noises does not become too big, i.e. does not exceed a certain threshold T. The problem is to assign frequencies to the receivers in such a way that each receiver gets its dedicated signal properly. We investigate this problem in the fundamental case where the noise area at a receiver does not depend on the frequency and where the "noise relation" is symmetric that is if a receiver u is in the noise area of a receiver v then v is in the noise area of u. Moreover the intensity I of the noise created by a signal is independent of the frequency and the receiver. Hence to distinguish its signal from noises, a receiver must be in the noise area of at most $k = \left\lfloor \frac{T}{I} \right\rfloor$ receivers listening to signals on the same frequency. Moreover, due to some practical reasons (as, for instance, the specific environment of a receiver), the frequency at each receiver must be chosen among a list of allowed ones for that receiver.

Hence one needs to find a k-improper coloring of the noise graph: its vertices are the receivers and two of them are joined by an edge if they interfere.

The receivers being on earth, the noise graphs are planar-like and in particular have bounded density. Hence, in [32], [13], we give some results for graphs with bounded density. They generalize and improve previous known results about improper choosability of planar graphs and graphs of higher genus.

Furthermore, the noise area may often be modeled by a disk. Hence, in [33], [13], we investigate improper coloring for unit disk graphs and random unit disk graphs to generalize results of McDiarmid and Reed (1999), McDiarmid (2003), and McDiarmid and Müller (2006). We are also concerned about complexity issues of improper coloring of unit disk graphs, and weighted improper coloring of subgraphs of the triangular lattice.

6.5.2. Channel assignment and coloring with constraints at distance 2

The channel assignment problem in radio networks is the following: 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 large enough. In [65], we investigated the case when two stations interfering must get wavelengths (integers) that are at least p apart.

In a closer to reality model, if two stations are close (but not too close), then they must receive different channels. Such problems may be modeled by $L(p,1)$-labelings. An $L(p,1)$-labeling of a graph G is an integer assignment f to the vertex set $V(G)$ such that $|f(u)-f(v)| \geq d$ if $d_G(u,v)=1$ and $|f(u)-f(v)| \geq 1$ if $d_G(u,v)=2$.

$L(1,1)$-labelings of a graph are exactly the colorings of its square. Since plane graphs are of particular interests because the transmitters are laid out on earth, we study coloring of squares of plane graphs [64]. In [66], [13], we investigate 3-facial colorings of plane graphs which is a closely related notion. Indeed in such a coloring, two vertices must get different colors if they are at distance at most three and around the same face.

In [16], we survey the results obtained concerning a related conjecture of Erdos and Nešetřil on colouring the squares of line graphs.

6.5.3. Vertex-Coloring Edge Weightings

A weighting on the edges of a graph induces a coloring where the color of a vertex is the sum of the weights of the edges containing it. We show in [75] that the edges of any connected graph with three or more vertices can be weighted using integers between 1 and 30 so as to obtain a proper coloring (i.e. no edge is monochromatic).

6.5.4. Arc-coloring and function theory

Let f and g be two functions from a finite set E into a set F. If f and g never coincides (i.e. $f(x) \neq g(x)$ for all $x \in E$), we seek for the minimum number of (f,g)-independent sets to cover E, where a set $I \subset E$ is (f,g)-independent if $f(I) \cap g(I) = \varnothing$. This problem may be transformed into an arc-coloring problem of some graph. Hence, motivated by function theory, we study [24] the maximum value $\Phi^{\vee}(k,l)$ of the arc-chromatic number over the digraphs in which a vertex has either outdegree at most k or indegree at most l.

6.5.5. Circuits in graphs and digraphs

Digraphs are used to model various networks in which orientation plays a role. One of the most common basic problem is to find disjoint circuits or short circuits. Two celebrated conjectures give outdegree conditions ensuring the existence of short circuits: Bermond-Thomassen Conjecture asserts that every digraph in which every vertex has outdegree at least $2k-1$ contains k disjoint circuits and Caccetta-Häggkvist conjecture asserts that every digraph on n vertices and with minimum outdegree n/k has a circuit of length at most k. These two conjecture are somehow related because they are both implied by Hoang-Reed conjecture. As these conjectures are very difficult for digraphs, we first try to establish it for tournaments which are orientation of complete graphs. In [67], we establish Hoang-Reed conjecture for tournaments, and in [46] we settle Bermond-Thomassen conjecture for regular tournaments. In [26], we disprove a conjecture which, if true, would have implied Cacetta-Häggkvist conjecture.

In [25], we studied a similar problem for undirected graphs. We give some conditions for a multipartite graphs to contain a triangle.

We also studied the minimum feedback arc set problem in which one wants to find the minimum number of arcs that should be removed from a digraph to leave it acyclic. In [27], we show that this problem is NP-hard for tournament.

6.5.6. Other results

With a new method based on the notion of genetic algorithm and the explicit enumeration of orders, we prove in [18], [39], [13] that all orders on at most 10 elements are circle orders. This theorem represents the best partial result on Sidney-Sidney-Urrutia Conjecture.

In [30] we prove a new bound on the mixing time of a Markov chain by considering the conductance of its connected subsets.

6.6. Overlay Network and Global Computing

Participants: Raphael Chand, Michel Cosnard, Luigi Liquori.

Entities in Arigatoni are organized in *Colonies*. A Colony is a simple virtual organization composed by exactly one *leader*, offering some broker-like services, and some set of *Individuals*. Individuals are SubColonies of Individuals, or basic units called *Global Computers*. Global Computers communicate by first registering to the Colony and then by mutually asking and offering services. The leader, called *Global Broker*, has the job to analyze service requests/responses coming from its own Colony or arriving from a surrounding Colony, and to route requests/responses to other Individuals. After this discovery phase, Individuals get in touch with each others without any further intervention from the system, typically in a P2P fashion.

Symmetrically, the leader of a Colony can arbitrarily unregister an Individual from its Colony, because, e.g. of its bad performance when dealing with some requests, or because of its high number of "embarrassing" requests for the Colony. This mechanism/strategy reminiscent of the roman *do ut des*, is nowadays called, in Game Theory, *"tit-for-tat"*. The strategy is commonly used in economics, social sciences, and it has been implemented by a computer program as a winning strategy in a chess-play challenge against humans (see also the well known *prisoner dilemma*). In computer science, the tit-for-tat strategy is the main principle of BitTorrent[4] P2P protocol.

Once a Global Computer has issued a request for some services, the system finds some Global Computers (or, recursively, some SubColonies) that can offer the resources needed , and communicates their identities to the (client) Global Computer as soon as they are found.

The model also offers some mechanisms to dynamically adapt to *dynamic topology changes* of the Overlay Network, by allowing an Individual (Global Computer or SubColony) to log/delog in/from a Colony. This essentially means that the process of routing request/responses may lead to failure, because some Individuals delogged or because they are temporarily unavailable (recall that Individuals are not *slaves*). This may lead to temporarily *denials of service* or, more drastically, to the complete delogging of an Individual from a given Colony in the case where the former does not provide enough services to the latter.

The fact that the Arigatoni model only deals with Resource Discovery has one important advantage: the complete generality and independence of any given requested resource. Arigatoni can fit with various scenarios in the Global Computing arena, from classical P2P applications, like file sharing, or band-sharing, to more sophisticated GRID applications, like remote and distributed big (and small) computations, until possible, futuristic *migration computations*, i.e. transfer of a non completed local run in another GCU, the latter scenario being useful in case of catastrophic scenarios, like fire, terrorist attack, earthquake etc, in the vein of a Global programming languages à la Obliq or Telescript.

[4] See http://www.bittorrent.com

The main units in Arigatoni are:

- a *Global Computer Unit, GCU*, i.e. the basic peer of the Global computer paradigm; typically it is a small device, like a PDA, a laptop or a PC, connected with any IP network, unrelated to the media used, wired or wireless, etc;
- a *Global Broker Unit, GBU*, is the basic unit devoted to register and unregister GCU s, to receive service queries from client GCU s, to contact potential servants GCU s, to negotiate with the latter the given services, to trust clients and servers and to send all the informations useful to allow the client GCU, and the servants GCU s to be able to communicate. Every GCU can register to only one GBU, so that every GBU controls a *colony* of collaborating Global Computers. Hence, communication intra-colony is initiated via only one GBU, while communication inter-colonies is initiated through a chain of GBU-2-GBU message exchanges. In both cases, when a client GCU receives an acknowledgment for a request service (with related trust certificate) from the proper GBU, then the client will enjoy the service directly from the servant(s) GCU, i.e. without a further mediation of the GBU itself;
- a *Global Router Unit, GRU* is a simple basic unit that is devoted to send and receive packets of the Global Internet Protocol and to forward the payload to the units which is connected with this router. Every GCU and every GBU have one personal GRU. The connection between router and peer is ensured via suitable API.

Communication over the behavioral units of the model are performed by a simple communication protocol, the Global Internet Protocol (GIP), on the top of TCP or UDP protocol. Basic global computers can communicate by first registering to a brokering service and then by mutually asking and offering services, in a way that is reminiscent to Rapoport's "tit-for-tat" strategy of co-operation based on reciprocity. In the model, resources are encapsulated in the intranet in which they reside, and requests for resources located in another intranet traverse a broker-2-broker negotiation using classical PKI mechanisms.

- In [40], we design a lightweight communication model, called Arigatoni, with related architecture, that is suitable to deploy the "Global Computing Paradigm" i.e. computation via a seamless, geographically distributed, open-ended network of bounded resources by agents (called *Global Computers*) acting with partial knowledge and no central coordination. The paradigm provides uniform services with variable guarantees. Aggregating many Global Computers sharing similar or different resources leads to a *Virtual Organization*, also called *Overlay Computer*[5]. Finally, organizing many Overlay Computers, using, e.g. tree- or graph-based topology leads to an *Overlay Network*, i.e. the possibility of programming a *collaborative Global Internet* over the *plain Internet*. Discovering dynamic resources must be scalable in number of resources and users and hence, as much as possible, fully decentralized. It should tolerate intermittent participation and dynamically changing status/availability. The model is suitable to fit with various global scenarios from classical P2P application, like file sharing, or band-sharing, to more sophisticated GRID application, like remote and distributed big (and small) computations, to possible, futuristic real migrating computations;
- We then study [47] how single resources, offered by the Global/Overlay Computers are discovered. The process is often called *Resource Discovery*: it requires an *up-to-date* information about widely-distributed resources. This is a challenging problem for very large distributed systems particularly when taking into account the continuously changing state of resources offered by Global/Overlay Computers and the possibility of tolerating intermittent participation and dynamically changing status/availability of the latter.

6.7. Formal semantics of Programming Language

Participant: Luigi Liquori.

[5]Overlay Computer: abstraction that can be implemented on top of a Global Computer to yield another Global Computer

Although not related with the main research themes of MASCOTTE, Luigi LIQUORI is still active in his prior research domain. In particular:

- With A. Ciaffaglione and M. Miculan (University of Udine, Italy), he illustrates in [34], [68] a methodology for formalizing and reasoning about Abadi and Cardelli's object-based calculi, in (co)inductive type theory, such as the *Calculus of (Co)Inductive Constructions*, by taking advantage of *Natural Deduction Semantics* and *coinduction* in combination with *weak Higher-Order Abstract Syntax* and the *Theory of Contexts*. With F. Honsell and M. Lenisa we introduce a *General Logical Framework*, called GLF, for defining Logical Frameworks, based on dependent types, in the style of the well known Edinburgh Logical Framework LF. The framework GLF features a generalized form of lambda abstraction where β-reductions fire provided the argument satisfies a logical predicate and may produce an n-ary substitution. The type system *keeps* track of when reductions have yet to fire. The framework GLF subsumes, by simple instantiation, LF as well as a large class of generalized constrained-based lambda calculi, ranging from well known restricted lambda calculi, such as Plotkin's call-by-value lambda calculus, to lambda calculi with patterns. But it suggests also a wide spectrum of completely new calculi which have intriguing potential as Logical Frameworks. Also with Honsell, Lenisa and Redamalla, we investigate a lambda calculus with patterns where reductions are allowed in patterns. Because of sophisticated pattern matching facilities this language is suitable for verification and manipulation of HXML documents;
- With D. Dougherty (WPI, USA) and P. Lescanne (ENS Lyon) we present in [29] a formalism called *Addressed Term Rewriting Systems,* which can be used to model implementations of theorem proving, symbolic computation, and programming languages, especially aspects of sharing, recursive computations and cyclic data structures. Addressed Term Rewriting Systems are therefore well suited for describing object-based languages, and as an example we present a language, incorporating both functional and object-based features;
- With C. Kirchner, H. Cirstea, B. Wack (LORIA, Nancy), we continues in [35], [48] our exploration on the new rewriting calculus. A web page describing our complete development can be found at http://rho.loria.fr. A number of paper dealing with various type systems has been delivered in 2005-2006, mostly dealing with polymorphic type features, or imperative features of the framework. A running (coq certified) interpreted has been released.

7. Contracts and Grants with Industry

7.1. Contract CRE France Telecom R&D

Keywords: *Design of telecommunication networks*, *Matching*, *Protection*, *Routing*.

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

7.2. Contract CRC France Telecom R&D

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

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

As mentioned earlier, we have a strong collaboration with France Telecom R&D inside the CRC CORSO. This means that some researchers of MASCOTTE on one side and engineers of France Telecom R&D 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.

8. Other Grants and Activities

8.1. National Collaborations

8.1.1. Action MobiVip, 2004-2006

MobiVIP is a PREDIT project funded by Ministries of Research, Transportation, Industry and Environment, together with ANVAR and ADEME. In this program, 5 research laboratories and 7 SMEs work in collaboration to experiment, demonstrate and evaluate a new transportation system for cities, based on intelligent small urban vehicles. Mascotte will develop methods for traffic estimation based on instrumentation of those vehicles.

(http://www-sop.inria.fr/mobivip/)

8.1.2. ANR Jeunes Chercheurs OSERA, 2005-2008

On optimization and simulation of ambient networks.

8.1.3. ACI sécurité informatique 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/PRESTO/)

8.1.4. Action ResCom, 2006-...

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

8.2. European Collaborations

8.2.1. European project IST CRESCCO, 2002-2006

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).

8.2.2. European project IST AEOLUS, 2005-2009

On algorithmic principles for building efficient overlay computers, in collaboration with 21 European universities and coordinated by University of Patras, Greece.

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

8.2.3. 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.

D. Coudert for INRIA and J. Galtier for France Telecom R&D are in the management committee of this action.

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

8.2.4. European COST 355

P. Mussi has joined COST Action 355 **"Changing behavior towards a more sustainable transport system"**. The main objective of this COST Action is to develop a more rigorous understanding of the conditions under which the process of growing unsustainable transport demand could be reversed, by changing travelers , shippers and carriers behavior.

(http://www.cost.esf.org/index.php?id=240&action_number=355)

8.2.5. Royal Society Grant with King's College London, 2004-2006

Bilateral Cooperation, 04/2004-03/2006, on "Web Graphs and Web Algorithms", in collaboration with the Department of Computer Science, King's College London, funded by the Royal Society, U.K.

8.3. International Collaborations

8.3.1. Cooperation INRIA–Brazil Regal and Mobidyn, 2003-2006

On algorithmic problems for telecommunication networks, in collaboration with the Federal University of Ceara (Fortaleza, Brazil); also funded by the PACA province (06/04-06/06).

Cooperation with the university of Sao Paolo (resp A. Goldman) projet commun Mobidyn INRIA-FAPESP on combinatorial models for dynamic networks.

8.3.2. Join team "RESEAUXCOM", 2003-2006

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/)

8.3.3. Cooperation FQNRT/INRIA DynOpt, 2006

Cooperation FQNRT/INRIA with Concordia University, Montreal, Canada: "DynOpt", on optimization of dynamic optical networks. We aim to strengthen this collobaration.

8.4. Visitors

- *Luigi Addario-Berry*, McGill University, Montreal, Canada, June 2006 (1 week).
- *Stéphane Bessy*, Univ. of Montpellier, April 2006 (1 week).
- *Pierre Charbit*, Univ. Of Lyon, April 2006 (1 week).
- *Ricardo Correa*, Universidade Federal do Ceará, Brazil, April 2006 (1 month).
- *Fedor Fomin*, Univ. Of Bergen, Norway, July 2006 (1 week).
- *Luisa Gargano*, University of Salerno, Italy, July-August 2006 (1 month).
- *Frédéric Giroire*, INRIA Rocquencourt, February 2006 (2 weeks).
- *Alfredo Goldman*, Universidade of Saõ Paulo, Brazil, November 2006 (2 weeks);
- *MohammadTaghi Hajiaghayi*, Carnegie Mellon University, December 11-15, 2006 (1 week).
- *Julian Monteiro*, Universidade of Saõ Paulo, Brazil, November-December 2006 (6 weeks);
- *Brigitte Jaumard*, Concordia University, Montreal, Canada, June 2006 (1 week).
- *Ross Kang*, Oxford University, United Kingdom, May 7-19 and October 2-6 2006 (3 weeks).
- *Benjamin Leveque*, Laboratoire Leibniz, IMAG, Grenoble, France, July 2006 (1 week).
- *Claudia Linhares Sales*, Universidade Federal do Ceara', Fortaleza Brazil, August-December 2006 (4 months).
- *Frédéric Maffray*, CNRS, Leibniz, Grenoble, July 2006 (1 week).
- *Tobias Müller*, Oxford University, United Kingdom, May 12-25 2006 (2 weeks).
- *Nicolas Nisse*: LRI, Université Paris-Sud, December 18-22 2006 (1 week).
- *Cesare Pautasso*, ETZ, Zurich, Switzerland, November 27-28 2006 (2 days);
- *Gianluca Quercini*, University of Genova, Italy, December 5-7 2006 (2 days).

- *Joseph Peters*, Simon Fraser University, Vancouver, Canada. June-july 2006 (1 month).
- *Riste Škrekovski*, University of Ljubljana, Slovenia, 19 June – 05 July 2006 (2 weeks).
- *Arnaud Spiwack*, ENS Cachan, June 2006 (1 week).
- *Ladislav Stacho*, Simon Fraser University, Burnaby BC, Canada. June-July 2006 (3 weeks).
- *Ugo Vaccaro*, University of Salerno, Italy, July-August 2006 (1 month).
- *Anders Yeo*, Royal Holloway College, London, UK, March 2006 (1 week).
- *Joseph Yu*, Simon Fraser University, Vancouver, Canada. June-july 2006 (1 month).

8.5. Visits of Mascotte members to other research institutions

- *O. Amini*: Bergen University, Norway, November 19-24 2006 (1 week); LIRMM, Montpellier, November 27-30 2006 (1 week);
- *J.-C. Bermond*: Greece, June 2006 (1 month); Simon Fraser University, Vancouver, BC, Canada, September 2006 (2 weeks).
- *D. Coudert and H. Rivano*: LIFL, Lille, France, March 2006 (1 week); Concordia University, Montreal, Canada, April-May 2006 (2 weeks).
- *D. Coudert and M.-E. Voge*: LIFO, Orléans, France, April 10-11 2006.
- *F. Havet*: University of Ljubljana, Slovenia, 19–24 February 2006 (1 week); LIRMM, University of Montpellier II, May 2006 (1 week); Charles University, Prague, 22-29 November 2006 (1 week).
- *F. Huc*: Concordia University, Montreal, Canada, April 23 - Mai 25 and December 10-21 2006 (1.5 month); Cambridge university, Cambridge, England, June 5-10 2006 (1 week).
- *G. Huiban*: Federal University of Minas Gerais, January, 1st to July 28th.
- *L. Liquori*: University of Turin, March and November 2006 (1 week); University of Udine, April 2006 (1 week); Project Protheo, LORIA, 5 two-three days visits in 2005-2006; Project Focal, LIP6, Paris VI, 5 times visits of 1J in 2005-2006.
- *N. Morales*: LaBRI, Universite Bordeaux I, February, June and October 2006 (1 month).
- *B. Reed*: National Institute of Informatics, Tokyo, Japan, August 2006 (1 month); Oxford University, England, October 27 - November 9 2006 (collaboration with C. MCDiarmid and L. Addario-Berry); Charles University, Prague, Czech Republic, November 22-29 2006 (collaboration with D. Kral and J-S. Sereni); University of Toronto, Toronto, Canada, December 7-10 2006 (collaboration with Mike Molloy); Montréal, Canada, December 11-16 2006 (collaboration with Paul Seymour, Princeton); Simon Fraser University, Vancouver, BC, Canada, December 16-31 2006 (collaboration with A. Flaxman, Microsoft, and B. Mohar, SFU).
- *H. Rivano*: CITI lab, Lyon, France, March, September and November 2006 (2 weeks).
- *J.-S. Sereni*: University of Ljubljana, Slovenia, 19 February – 04 March 2006.
- *M. Syska*: Simon Fraser University, Burnaby BC, Canada. May 16th - June 16th 2006 (1 month).
- *M.-E. Voge*: Laboratoire Leibniz, Grenoble, France, March 2006 (2 days); LIRMM, Montpellier, France, April 2006 (2 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 (Italy, Canada, Israel); president of the scientific committee of LIRMM (Montpellier), January 2006; member of the "Commission de Spécialistes de la 27^{e} section" of UNSA; member of the I3S Project Committee; member of the PhD committee of Marseille; President of the recruiting committee of INRIA Junior Researchers (CR2) at Sophia Antipolis; member of the best thesis award committe of Telecom Valley (Provence Alpes Côte d'Azur province).
- *M. Cosnard*: members of a lot of committees mainly in relation with its direction of INRIA
- *D. Coudert*: member of the COST Action 293 Management Committee (working group learder); expert for ANR Telecom; member of the management committee of "pôle ResCom du GDR ASR du CNRS ";
- *O. Dalle* : member of the “Commission de Spécialistes 27^{e} section” of UNSA; member of the “Commission du Développement Logiciel” de l'INRIA Sophia Antipolis; member of the “Comité Informatique” of I3S; member of working group "Vers une théorie de la Simulation" (http://www.lsis.org/versim/);
- *A. Ferreira*: member of the RNRT commission 3; member of the CNRT Telius board; member of the Technical Commission on Network Architectures and Telecommunication Systems of the French National Research Agency (RNRT/ANR) in 2006; member of the Panel Signal and Systems of the Swedish Research Council in 2006;
- *J. Galtier*: member of the COST Action 293 Management Committee.
- *F. Havet*: member of the I3S laboratory Committee, of the "Commission de Spécialistes de la 25^{e} et 26^{e} section" of the University of Lyon 1, and of the "Commission de Spécialistes de la 27^{e} section" of the University of Montpellier II;
- *A. Laugier*: referee for ACI "Nouvelles interfaces des mathématiques".
- *L. Liquori*: participated to the kickoff meeting in Juin 2006 of the *Internazionalizzazione del Sistema Universitario*, a common joint PhD project between the University of Udine, Sienne, Pise (Italie), Valencia (Espagne), UNSA, Hyderabad (Inde). He also write the proposition that was refereed by the Italian Ministry of Research and Education. The Italian Ministry, the INRIA and the EPU will finance this project;
- *P. Mussi*: head of the ReV department (public relations, international and industrial partnerships) of INRIA Sophia Antipolis; member of commission de spécialistes 27^{e} section of l'UNSA; member of Comité Technique Paritaire and Conseil Scientifique of l'INRIA; member of working group "Modélisation Multiple et Simulation" (GdR MACS, http://mad3.univ-bpclermont.fr/), and working group "Vers une théorie de la Simulation" (http://www.lsis.org/versim/);
- *B. Reed*: member of the Research Committee of the Canadian Mathematical Society; Chair of the Doctoral Prize Selection Committee of the Canadian Mathematical Society;
- *H. Rivano*: substitute member of the I3S laboratory Committee;
- *M. Syska*: member of the technical committee of european project IST FET AEOLUS; member of the "Commission de Spécialistes de la 27e section CNU" of the University of Avignon, head of the "Commission Informatique" of the I3S Laboratory; member of the I3S laboratory committee.

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;
- *M. Cosnard*: Editor-in-Chief of Parallel Processing Letters (until 2006).

- *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

- *D. Coudert*: annual summer school ResCom;
- *A. Ferreira*: AlgoTel (2000-2006), ACM Dial M for Mobility (2000-2006);
- *B. Reed*: Journal of Combinatorial Theory(B); member of the Steering Committee for the Canadian Conference on Discrete Mathematics;

9.1.4. Workshop organization

- *O. Amini and F. Havet*: organized JCALM, Sophia-Antipolis, France, October 20 2006. http://www-sop.inria.fr/mascotte/JCALM/
- *M. Cosnard*: Chairman of the EURO-PAR 2006 Workshop on Parallel Numerical Algorithms
- D. Coudert and H. Rivano: local organization chairs of InterSense'06, Nice, France, Mai 30-31 2006.
- *O. Dalle*: organized the Versim WorkGroup annual meeting, Sophia Antipolis, France, june 16 2006.
- *H. Rivano* (chair) and *J.-S. Sereni* organized ResCom summer school, Porquerolles, France, June 11-16 2006. http://www.i3s.unice.fr/ResCom2006/.
- *F. Havet*: organized GALET, Sophia-Antipolis, France, july 05-06 2006. http://www-sop.inria.fr/mascotte/Galet/
- *L. Liquori*: co-chair of the Third Workshop on the Rho-Calculus, King's College London, UK, October 23-24 2006. http://rho.loria.fr/workshop2006.html;
- *B. Reed*: Co-Organizer of the combinatorics session of the first joint meeting of the Mexican Mathematical Society and the Canadian Mathematical Society held in Guanajuto Mexico in September 2006.
- *P. Reyes*: volunteer student at InterSense'06, Nice, France, Mai 30-31 2006.

9.1.5. Participation in program committees

- *M. Cosnard*: Member of the Program Committee of the 2006 International Conference (ACM, IEEE, IFIP) on Parallel Architectures and Compilation Techniques, PACT 2006; Member of the Program Committee of the 2006 (IEEE) International Parallel and Distributed Processing Symposium , IPDPS 2006.
- *D. Coudert*: member of the programme committee of AlgoTel'06, Trégastel, France, Mai 9-12 2006; co-chair of the program committee of the summer school ResCom'06, Porquerolles, France, June 12-16 2006.
- *O. Dalle*: is member of the Intl. Program Committee of the High Performance Computing & Simulation Conference (HPC&S)
- *A. Ferreira*: member of the programme Committee of the 3-rd IEEE International Workshop on Mobility Management and Wireless Access, 2006; member of the programme Committee of the 7th Latin-American Theoretical Informatics Conference (LATIN 06).
- *J. Galtier*: member of the program committee of Networking 2006 and AlgoTel 2006.
- *F. Havet*: was a member of the programme committee of WG06, Bergen, June 06.
- *L. Liquori*: PC Member of ECOOP 05 and 07, European Conference on Object Oriented Programming; PC Member of FTFJP 05, International Workshop on Formal Techniques for Java-like Programs; PC Member of FOOL 07, International Workshops on Foundations of Object-Oriented Languages ; Co-chair of the Third Workshop on the Rho-Calculus, King's College London, UK, October 23-24 2006.

- *B. Reed*: Member of the program committee for SODA 2006.

9.2. Teaching

9.2.1. Theses

- The following theses have been defended in 2006:
  - *G. Huiban*: Le problème de la reconfiguration dans les réseaux WDM multifibres. Ph.D Thesis. Ecole doctorale STIC, Université de Nice Sophia Antipolis, July 28 2006. [12].
  - *J.-S. Sereni*: Colorations de graphes et applications. PhD thesis, Ecole doctorale STIC, Université de Nice-Sophia Antipolis, July 5 2006. [13]
  - *M.-E. Voge*: Optimisation des réseaux de télécommunications: réseaux multicouches, tolérance aux pannes et surveillance de trafic. PhD thesis, École doctorale STIC, Université de Nice-Sophia Antipolis, November 17 2006 [14].
- The following theses are in preparation:
  - *O. Amini*: Conception des réseaux tolérants aux pannes et graphes d'expansion locale, since October 2005.
  - *C. Gomez*: Optimisation des réseaux dynamiques de quatrième génération, since September 2006.
  - *F. Huc*: Conception de réseaux dynamiques tolérants aux pannes, since October 2005.
  - *C. Molle*: Structures combinatoires et simulation des réseaux radio maillés, since October 2006.
  - *N. Morales*: Méthodes d'approximation pour les problèmes de réseaux de télécommunications avec de contraintes économiques et de traffic incertain, since October 2003; defense planed early 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.
  - *I. Sau Valls*: Groupage de trafic, since October 2006;

9.2.2. Member of thesis Committees

- *J-C. Bermond*: Member of PhD thesis committees of J-S. Sereni, July 05, 2006; PhD committee of M-E. Voge, supervisor, UNSA, November 17, 2006; PhD committee of F. Giroire, Rocquencourt, November 29, 2006.
- *M. Cosnard*: Member of so many Ph.D. and HDR thesis Committees that he does not remember them.
- *D. Coudert*: PhD committee of S. Lahoud, ENST Bretagne, April 14 2006; PhD committee of M-E. Voge, UNSA, November 17, 2006;
- *F. Havet*: PhD committee of J.-S. Sereni, co-supervisor, Sophia Antipolis, July 5 2006;
- *L. Liquori*: PhD referee of Mme Rekka Redamalla, University of Udine, Italy, December 2006.
- *B. Reed*: PhD committee of J.F. Culus (referee), Universite de Toulouse Le Mirial, June 2006; PhD committee of Louigi Addario-Berry, supervisor, McGill University, Montreal, Canada, September 2006.

9.2.3. Internships

- *J-C. Bermond and D. Coudert*: supervised the internship of I. Sau-Valls (UPC Barcelone), september 2005 - February 2006.
- *J-C. Bermond and S. Thomassé*: supervised the internship of Alex Popkin (Vanderbilt University, U.S.A.)
- *D. Coudert*: supervised two internships of F. Ben-Hfaiedh (PFE INSAT Tunis and Master 2 STIC RSD), september 2005-February 2006 and March-June 2006.
- *O. Dalle and S. Perennes*: supervised the intership of Duc Phong LE (IFI Hanoi, Vietnam), March-September 2006 (7 months)
- *O. Dalle*: supervised the internship of Violeta Doneva (Master 2 STIC "PMLT", U. Nice-Sophia Antipolis), March-September 2006 (7 months)
- *O. Dalle*: supervised the internship of Judicael Ribault (Master 1 STIC "Informatique", U. Nice-Sophia Antipolis), May-July 2006 (2.5 months)
- *L. Liquori*: supervised the internship of A. Patel Sept. 2005, Feb. 2006 (KTH, Sweden)
- *H. Rivano*: supervised the internship of F. Kaabi (INSAT Tunis), september 2005-February 2006.
- *H. Rivano*: supervised the internship of G. Méheut (Polytechnique), april-june 2006.
- *H. Rivano*: supervised the internship of C. Molle (Master 2 UPMC), april-july 2006.
- *M. Syska*: supervised the internship of P. Pastorelli (Master 1, U. of Genoa), July-November 2006.

9.2.4. Teaching

The members of MASCOTTE are heavily involved in teaching activities at undergraduate level (DEUG, IUT, Master 1 and 2, Engineering Schools like ESSI). 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. 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 Master STIC RSD. 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. Altogether that represents around 200 hours per year.

The members of MASCOTTE supervise on the average severals internships each year at all levels (Master 1 and 2, Engineering Schools). 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

- *D. Coudert*: 3rd Workshop on Optimization of Optical Networks (OON 06), Montreal Canada, April 27-28 2006; IEEE-LEOS ICTON/COST 293 GRAAL, Nottingham, UK, June 18-22 2006.
- *A. Ferreira*: Integrated Internet Ad hoc and Sensor Networks Conference (InterSense'06), Nice, May 2006; Colloquium France - Amerique Latine: Concurrence et Cooperation, Paris, June 2006.
- *F. Havet*: International Conference on Discrete Mathematics, Bangalore, India, December 15-18 2006
- *L. Liquori*: "A Framework for Defining Logics", 3rd Workshop on Rewriting Calculus, London UK, October 2006.
- *J.-S. Sereni*: Pathwidth of outerplanar graphs, Graph Theory seminar, University of Ljubljana, 02 March 2006.

- *B. Reed*:
  - Two talks at the SIAM conference on Discrete Mathematics, Victoria, Canada, June 2006: 1) in the minisymposium on Probabilistic Combinatorics, and 2) in the minisymposium on Graph Minors;
  - Plenary talk at the Analysis of Algorithms Conference, Alt Biesen, Belgium, July 2006.
  - Horizon of Combinatorics Summer School in Budapest, Hungary, July 2006.
  - Plenary talk at the Horizons of Combinatorics Conference at Lake Balaton, Hungary, July 2006.
  - Plenary talk at the Krakow workshop on graph theory in September 2006.
  - Workshop on Flexible Betwork Design, Bertinoro, Italy, October 2006.
  - Workshop on tree decompositions and graph searching, Anogia, Crete, October 2006.
  - Tohoku University, Sendai, Japan, August 2006.
  - Charles University, Pragues, November 2006.

9.3.2. Participation in scientific meetings

- *O. Amini, D. Coudert, F. Huc and H. Rivano*: 3rd Journées ResCom, Paris, France, September 25-26 2006.
- *O. Amini, F. Havet and F. Huc*: 8th Journées Graphes et Algorithmes, Orléans, 9-10 November 2006.
- *J-C. Bermond*: review meeting of the associate team program, Rocquencourt, November 27 2006.
- *J-C. Bermond, D. Coudert, H. Rivano and M-E. Voge*: meeting of ACI-SI PRESTO, September 5, 2006
- *J-C. Bermond, D. Coudert and L. Liquori*: AEOLUS technical committee meeting, Athens, October 13-14 2006.
- *J-C. Bermond and L. Liquori*: AEOLUS first year evaluation in Lucca, Italy, November 2006.
- *D. Coudert, J. Galtier and H. Rivano*: COST 293 & 295 Workshop, Les Ménuires, France, January 16-17 2006.
- *D. Coudert, H. Rivano and M-E. Voge*: 2nd Journées ResCom, Lille, France, March 6-7 2006.
- *D. Coudert*: 5th Management Committee meeting, European Action COST 293 Graal, Budapest, Hungary, March 19-24, 2006.
- *D. Coudert and J. Galtier*: 6th Management Committee meeting, European Action COST 293 Graal, Nottingham, June 18-22, 2006; 7th COST 293 workshop and Management Committee meeting in Zurich, Switzerland, September 8-10 2006.
- *L. Liquori, S. Pérennes and M. Syska*: AEOLUS technical committee meeting, Roma, Italy, March 15-17 2006.
- *L. Liquori*: kickoff meeting in Juin 2006 of the *Internazionalizzazione del Sistema Universitario*, a common joint PhD project between the University of Udine, Sienne, Pise (Italie), Valencia (Espagne), UNSA, Hyderabad (Inde). He also write the proposition that was refereed by the Italian Ministry of Research and Education. The Italian Ministry will finance the project with 125.100 EUROS for three years was given for this projet.

9.3.3. Participation in conferences

- All the members of Mascotte attended the Journees GALET, Sophia-Antipolis, France, july 05-06 2006.
- Members of MASCOTTE attended the Journées CALM, Sophia Antipolis, October 20 2006 and the

- *O. Amini*: IPM Combinatorics II, Design Theory, Graph Theory, and Computational Methods, Tehran, Iran, April 22-27, 2006
- *O. Amini, D. Coudert, C. Molle, N. Morales, H. Rivano and M.-E. Voge*: Algotel 2006, Tregastel, France, May 9-12 2006.
- *O. Amini, D. Coudert and B. Reed*: GRASTA'06, Anogi, Crete Island, Greece, October 9-12 2006;
- *O. Amini and F. Huc*: Horizon of Combinatorics, Budapest, Hungary, July 16-22 2006
- *O. Amini, F. Havet and F. Huc*: Journée Graphes et Algorithmes, Orléans, November 8-10 2006
- *R. Chand and L. Liquori*: 6th International Workshop on Innovative Internet Community Systems (I2CS 06), Neuchâtel, Switzerland, June 2006.
- *M. Cosnard*: IPDPS 2006, Rhodes (Greece), April 2006.
- *D. Coudert*: PaRISTIC, Nancy 22-24 2006;
- *D. Coudert, J. Galtier and H. Rivano*: WONS'06, Les Ménuires, France, January 18-20 2006.
- *D. Coudert, F. Huc and H. Rivano*: OON'06, Montreal, Canada, April 27-28 2006.
- *D. Coudert, P. Reyes and H. Rivano*: InterSense'06, Nice, France, May 30-31 2006.
- *D. Coudert, J. Galtier and M.-E. Voge*: ICTON 2006, Nottingham, UK, June 18-22 2006.
- *O. Dalle*: ECMS 2006, Bonn, Germany, May 28th-31st, 2006.
- *J. Galtier*: IEEE Globecom 2006, San Francisco, CA, USA, November 29 - December 1 2006;
- *F. Havet*: WG06, Bergen, Norway, June 22-24 2006.
- *L. Liquori*: JFLA 06, Pauillac, March 2006; DCM 06, Venice, Italy, July 2006; JVA 06, Sophia, Bulgaria, October 2006; Formal Description Of Programming Concepts IFIP WG 2.2 40th Anniversary Meeting 11-13 September 2006 University of Udine, Italy, where the paper “A Framework to build Logical Frameworks” by Honsell, Lenisa and Liquori was presented; 3rd workshop on Rewriting Calculus, London, UK, October 2006.
- *J.P. Perez Seva*: attended PACT 06, Seattle, WA, USA, September 2006.
- *N. Morales*: attended PerCom 2006, Pisa, Italy, March 13-17 2006.
- *H. Rivano*: attended IEEE International Workshop on Wireless Ad-hoc and Sensor Networks (IWWAN), New-York, USA, June 28-30 2006.

9.3.4. Participation in schools

- *O. Amini and F. Huc*: attended Horizon of Combinatorics, Budapest, Hungary, July 10-15 2006
- *O. Amini and S. Perennes*: attended COST 295 Dynamo Training School, Lisboa, Portugal, June 28 - July first 2006.
- *O. Amini, D. Coudert, J. Galtier, F. Havet, F. Huc, P. Reyes, H. Rivano and J.-S. Sereni*: attented ResCom summer school, Porquerolles, France, June 11-16 2006.
- *D. Coudert and I. Sau Valls*: attended the ADONET/COST spring school on Combinatorial Optimization of Communication Networks, Budapest, Hungary, March 20-24 2006.
- *J. Galtier*: presented the advanced course "Reliability in Networks" in the ResCom summer School, Porquerolles, June 12-16, 2006.
- *C. Molle and S. Perennes*: AEOLUS School on Algorithmic Game Theory, Patras, Greece, December 18 - 19, 2006.

10. Bibliography

Major publications by the team in recent years

[1] S. ALOUF, E. ALTMAN, J. GALTIER, J.-F. LALANDE, C. TOUATI. *Quasi-Optimal Resource Allocation in Multi-Spot MFTDMA Satellite Networks*, in "Combinatorial Optimization in Communication Networks", M. CHENG, Y. LI, D.-Z. DU (editors). , chap. 12, Kluwer Academic Publishers, 2006, p. 325-366.

[2] 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", vol. 3, n° 2, 2000, p. 335–348.

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