INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team Mascotte

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

Sophia Antipolis - Méditerranée

THEME COM

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1. Team

MASCOTTE *is a joint team between INRIA Sophia Antipolis - Méditérranée 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

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Vice-head

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Olivier Dalle [Associate Professor UNSA, Délégation INRIA since 01/09/06]
Joanna Mouliérac [Associate Professor UNSA since 01/09/07]
Michel Syska [Associate Professor UNSA]

External collaborators

Afonso Ferreira [Research Director (DR) CNRS (on leave at COST Office, Brussels), HdR]
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Alexandre Laugier [Engineer Orange Labs, part time within CRC CORSO 2]

Engineers

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Fabrice Peix [Expert Engineer, IST-FET AEOLUS]

Post-doctoral fellows

Luc Hogie [Post Doc INRIA since 01/12/07]
Gurvan Huiban [Assistant Professor (ATER) until 31/08/07]
Olga Gerber [Post-Doc INRIA, until 30/11/07]
Dimitri Michail [Post Doc ERCIM since 01/10/07]
Marie-Emilie Voge [Assistant Professor (ATER) until 31/08/07]

PhD Students

Marie Asté [MENRT, since 01/10/07, 1st year]
Omid Amini [Allocataire X until 01/10/07, defense 28/11/07]
Cristiana Gomes [Grant Brazil, since 01/09/06, 2d year]
Florian Huc [BDI CNRS/Région, since 01/10/05, 3d year]
Christelle Molle [Grant DGA/CNRS, since 01/10/06, 2d year]
Nelson Morales [Grant CONICYT Chile, until 28/02/07, defense 26/01/07]
Julian Monteiro [CORDI, since 01/10/07, 1st year]

Napoleao Nepomuceno [BDE Région/3-ROAM, since 01/12/07, 1st year]
Jean-Paul Perez Seva [Cifre Thales, since 01/01/06, 3rd year]
Patricio Reyes Valenzuela [Grant CONICYT Chile, since 01/02/06, 2nd year]
Ignasi Sau Valls [BDO CNRS/Région, since 01/10/06, 2d year]

Invited Researchers

Jorge Amaya [Santiago, Chili, January 16-30 2007 (2 weeks)]
Binh Minh Bui Xuan [LIRMM, Montpellier, February 12-16 2007 (1 week)]
Claudio Casetti [Polytech Torino, June 15-30 2007 (2 weeks)]
Ricardo Correa [U. Federal do Ceara, Fortaleza, Brazil, January 1st - June 30 2007 (6 months)]
Rok Erman [Ljubljana University, Slovenia, December 2007 (1 week)]
Louis Esperet [LABRI, Bordeaux, France, February 2007 (1 month)]
Luisa Gargano [Salerno Italy, July 15 - August 31 2007 (1.5 months)]
Simon Griffiths [Cambridge University, April 2007 (1 week), July 2007 (1 week), October 2007 (1 week)]
Jan van den Heuvel [London School of Economics, United Kingdom, February 2007 (1 month)]
Sulamita Klein [U. Federal do Rio de Janeiro, Brazil, January 23 - February 15 2007 (3 weeks)]
Daniel Král' [Charles University, Prague, Czech Republic, September 2007 (1 week) and November 2007 (1 week)]
Bernard Lidicky [Charles University, Prague, Czech Republic, November 2007 (1 week)]
Claudia Linhares Sales [Universidade Federal do Ceara, Fortaleza Brazil, January-July 2007 (7 months)]
Tobias Müller [Eindhoven Technical University, The Netherlands, July 17-25 2007 (two weeks)]
Lucca Moscardelli [L'Aquila, Italy, March 5-9 2007 (1 week)]
Nicolas Nisse [LRI, Univ. Paris-Sud, January 3-8 2007 (1 week)]
Joseph Peters [S.F.U. Vancouver, Canada, April 21 - May 15 2007 (3 weeks)]
Diana Piguet [Charles University, Prague, Czech Republic, February 3-17 2007 (2 weeks)]
Saket Saurabh [Bergen Univ., Norway, March 4-10 2007 (1 week)]
Jean-Sébastien Sereni [Charles University, Prague, Czech Republic, September 2007 (1 week)]
Riste Škrekovski [Ljubljana University, Slovenia, September 2007 (2 weeks)]
Ladislav Stacho [S.F.U Vancouver, Canada, April 21 - May 5 2007 (2 weeks)]
Fabrice Theoleyre [CITI, Lyon, February 27 - March 2 2007 (1 week)]
Andrew Thomason [Cambridge University, United Kingdom, April 2007 (two weeks) and July 2007 (two weeks)]
Stéphan Thomassé [LIRMM, Montpellier, February 2007 (1 week), July 2007 (1 week)]
Ugo Vaccaro [Salerno Italy, July 15 - August 31 2007 (1.5 months)]
Gabriel Wainer [Carleton University, Ottawa, Canada, June 2007 (2 weeks)]
Paul Wollan [Hamburg, Germany, July 22-28 2007 (1 week)]
Joseph Yu [S.F.U Vancouver, Canada, January 20 - April 15 (3 months)]
Janez Zerovnik [Maribor Univ, Slovenia, July 16-31 2007 (2 weeks)]

Internships

Marie Asté [Master 2 MDFI Marseille 01/04/07- 31/08/07 (5 months)]
Federico Felizzi [Cambridge (England) 01/07/07 -31/08/07 (2 months)]
Juan-Carlos Maureira [Chili, 20/01/07 - 20/03/07 (2 months)]
Dorian Mazauric [Master 1 STIC and EPU 2, UNSA, France, July-September 2007, 3 months]
Gianlucca Quercini [Pre Doc, Genova, Italy, 23/04/07-22/10/07 (6 months)]
Judicael Ribault [Master 2 STIC "ISI", UNSA, March-September 2007, 6 months]
Marco Servetto [Grant Leonardo, Genova, Italy, 05/03/07 - 04/09/07 (6 months)]
Sigurd Teigen [BSc. Ithaca College, Ithaca, NY, June-August 2007 (2.5 months)]

2. Overall Objectives

2.1. Overall Objectives

MASCOTTE is a joint team between INRIA Sophia Antipolis and the laboratory I3S (Informatique Signaux et Systèmes de 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 Orange Labs (research and development of France Telecom) in Sophia Antipolis via the CRC CORSO (2003-2005) and CORSO2 (2006-2008). Its research fields are Algorithmics, Discrete Mathematics Combinatorial optimization and Simulation, with applications to telecommunication or transportation networks.

The objectives of the MASCOTTE project-team are to design networks or communication algorithms. In order to meet these objectives, the team studies various theoretical tools, such as Discrete mathematics, Graph theory, or Algorithmics and develops applied techniques and tools, especially for Combinatorial optimization and Computer simulation. In particular MASCOTTE used in the last year both these theoretical and applied tools for the design of various networks, such as WDM, SDH, wireless, satellites, overlay, peer-to-peer and even transportation networks (several being combined sometimes).

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

All these researches (and developments) are done with other groups in France and all over the world, MASCOTTE aiming at being a leader and attractive project in its field. In particular MASCOTTE is strongly implied in the European project IST FET AEOLUS (http://aeolus.ceid.upatras.gr/), where it is the leader of sub-project 2 on resource management and work-package WP2.2: Sharing Critical Resources [81]. MASCOTTE is also strongly involved in European project COST: 293 GRAAL. MASCOTTE has official partnerships in particular with Simon Fraser University, Vancouver (MASCOTTE is a joint team INRIA/S.F.U), Montreal, and Ottawa in Canada, Fortaleza and Sao Paolo in Brazil, London and Oxford in England, Politecnico di Torino and University of Genova and Torino and Udine in Italy.

The main results are detailed in the next sections. The activity of MASCOTTE can be measured via the softwares developed, the contracts obtained and the publications. The full list of publications of the project can be found at the following url: http://www-sop.inria.fr/mascotte/Publications/

3. Scientific Foundations

3.1. Scientific Foundations

Keywords: *Algorithmics*, *Combinatorial optimization*, *Discrete mathematics*, *Formal semantics of programming languages*, *Graph theory*, *Simulation*.

The project develops tools and theory in the following domains: Discrete mathematics (in particular Graph theory), Algorithmic, Combinatorial optimization and Simulation, Formal semantics of programming language.

Typically, a telecommunication network (or an interconnection network) is modeled by a graph. A vertex may represent either a processor or a router or any of the following: a switch, a radio device, a site or a person. An edge (or arc) corresponds to a connection between the elements represented by the vertices (logical or physical connection). We can associate more information both to the vertices (for example what kind of switch is used, optical or not, number of ports, equipment cost) and to the edges (weights which might correspond to length, cost, bandwidth, capacity) or colors (modeling either wavelengths or frequencies or failures) etc. According to the application, various models can be defined and have to be specified. This modeling part is an important task. To solve the problems, we manage, when possible, to find polynomial algorithms. For example, a maximum set of disjoint paths between two given vertices is by Menger's theorem equal to the minimum cardinality of a cut. This problem can be solved in polynomial time using graph theoretic tools or flow theory or linear

programming. On the contrary, determining whether in a directed graph there exists a pair of disjoint paths, one from s_1 to t_1 and the other from s_2 to t_2, is an NP-complete problem, and so are all the problems which aim at minimizing the cost of a network which can satisfy certain traffic requests. In addition to deterministic hypothesis (for example if a connection fails it is considered as definitely down and not intermittently), the project started recently to consider probabilistic ones.

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

Theoretical results are described after, with more emphasise on those of graph theory (Section 6.6) and formal semantics (Section 6.7).

4. Application Domains

4.1. Application Domains

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

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

MASCOTTE is mainly interested in the design of heterogeneous networks. The project has kept working on the design of backbone networks in particular optical ones (see Section 6.1), but has considerably increased his research on wireless (see Section 6.2) and overlay networks (see Section 6.3).

We have also pursued our research on fault tolerance, reliability, and disponibility (see Section 6.4).

These researches are done inside the CRC CORSO 2, and the ANR (program for young researchers) OSERA on optimization and simulation of ambient networks.

We have also developed two cooperations with SME's. The first one is on data storage in peer-to-peer networks with the SME UBISTORAGE and the second is one on radio networks with the SME 3-ROAM. The proposal SPREADS (Safe P2P reliable Architecture for Data Storage) with UBISTORAGE and other partners has been funded by ANR. The proposal WISDOM (Wireless IP Service Deployment Optimization and Monitoring) with 3 SME's and leaded by 3-ROAM is still in discussion with ANR ; anyway a first PhD will start in December 2007 funded by the province PACA and the SME.

5. Software

5.1. Prototype Software

- MASCOPT (http://www-sop.inria.fr/mascotte/mascopt/)
  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 Orange Labs on the design of telecommunication backbone networks.

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

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

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

  The Open Simulation Architecture (OSA) [96] 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 Protocol 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 Protocol of Arigatoni networks.

  We have also implemented an overlay architecture relying on a vehicular network, called *Arigatoni on wheels* (Ariwheels for short). Ariwheels in the *Omnet++* simulator, coding the overlay part and exploiting the existing wireless underlay network modules. In the underlay we used IEEE 802.11 at the MAC layer and the DYMO routing protocol (an AODV-like reactive routing protocol).

  We tested the performance of Ariwheels in a vehicular environment. We used a realistic mobility model generated by the tool VanetMobiSim, developed in Eurecom, whose ouput (mobility traces) was fed to the *Omnet++* simulator. Vehicles travel in a 1-km-wide city section over a set of urban roads, which include several road intersections regulated by traffic lights or stop signs. In particular, we adopt the IDM-IM microscopic car-following model, which allows us to reproduce real-world traffic dynamics as queues of vehicles decelerating and/or coming to a full stop near crowded intersections.

6. New Results

6.1. Backbone networks

Participants: Omid Amini, Jean-Claude Bermond, Michel Cosnard, David Coudert, Jérôme Galtier, Florian Huc, Gurvan Huiban, Alexandre Laugier, Dorian Mazauric, Joanna Mouliérac, Fabrice Peix, Stéphane Pérennes, Hervé Rivano, Ignasi Sau Valls, Michel Syska, Marie-Emilie Voge.

Network design is a very wide subject which concerns all kinds of networks. For telecommunications networks it can be either physical networks (backbone, access, wireless, ...) or virtual (logical) ones. The objective is to design a network able to route a (given, estimated, dynamic, ...) traffic under some constraints (e.g. capacity) and with some quality of service (QoS) requirements. Usually the traffic is expressed as a family of requests with parameters attached to them. In order to satisfy these requests, we need to find one (or many) paths between their end nodes. The set of paths is chosen according to the technology, the protocol or the QoS constraints. For instance, optical backbones use the WDM technology to take better advantage of the capacity of the optical fibers often already installed. This is achieved through the multiplexing of several wavelength channels onto the same fiber. In that case a resource allocation is an optical channel, which consists of a path and a wavelength assigned on each link along the path, and is called a *lightpath*. If wavelength translation is performed in optical switching, then each channel may be assigned different wavelengths on each link along the path; otherwise the wavelength continuity constraint must be satisfied on all links along the path. Of course, two lightpaths sharing a link must use different wavelengths on that link. The design can be done at the conception of the network (i.e. when conceiving a virtual network in MPLS where we have to establish virtual paths) or to adapt the network to changes (failures, new link, updates of routers, variation of traffic, ...). Finally there are various optimization criteria which differ according to the point of view: for a network user they are related to its satisfaction (minimizing delays, increasing available bandwidth, ...), while for a network operator, economics criteria like minimizing deployment and operating costs are more important.

This very wide topic is considered by a lot of academic and industrial teams in the world. Our approach is to attack these problems with tools from discrete mathematics and to consider mainly telecommunications networks. This approach is shared by other teams in Europe, most of them being part of European projects IST FET AEOLUS (where MASCOTTE is leader of sub-project *SP2 Resource management*) and COST 293 Graal (where MASCOTTE is leader of working group *WG-A broadband and optical networks*). Outside Europe, many teams have also this approach and sometimes we have direct collaborations with them: Vancouver (EA RESEAUXCOM), Montréal, Fortaleza,...

6.1.1. Traffic Grooming

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

We have first addressed the problem of traffic grooming in WDM rings or paths with All-to-All uniform unitary traffic. The goal is to minimize the total number of ADMs required. We have shown that this problem corresponds to a partition of the edges of the complete graph into subgraphs, where each subgraph has at most C edges (where C is the grooming ratio) and where the total number of vertices has to be minimized. Using tools of graph and design theory, we optimally solved the problem for practical values and infinite congruence classes of values for a given C. We give optimal constructions on unidirectional rings when $C \geq N(N-1)/6$ and when $C = 3, 4, 5, 6, 12$, on paths when $C = 2$ [24], give good upper bounds on bidirectional rings for $C = 2, 3$, and propose an approximate construction for all-to-all traffic on unidirectional rings [82]. We also showed how to improve lower bounds by using refined counting techniques, and how to determine the maximum number of connections which can be established in a path of size N or in a DAG [48]. Furthermore,

we have established the first in-approximability result on traffic grooming [44], [43], [79] using a study of the parametrized complexity of the smallest degree constraint subgraph problem [80]. Finally, we provide in [43] an approximation algorithm for ring and path networks with approximation factor of $O(n^{1/3}\log^2 n)$, independent of the grooming factor.

6.1.2. Multicast aggregation

Traditional IP Multicast has been proposed in order to manage group communications over the Internet in a bandwidth efficient manner. Although this proposition has been well studied, there are still many issues to deal with before its deployment. In [47], we propose a new algorithm, mQMA, that deals with two important problems of traditional IP multicast, i.e., multicast forwarding state scalability and multi-constrained QoS routing. The mQMA algorithm builds few trees and maintains few forwarding states for the groups thanks to the technique of multicast tree aggregation, which allows several groups to share the same delivery tree. Moreover, mQMA builds trees satisfying multiple QoS constraints. We show, through extensive simulations, that mQMA leverages the same QoS performance as Mamcra which is the main multi-constrained multicast routing algorithm. Moreover, mQMA dramatically reduces the number of trees to be maintained.

6.1.3. Information dissemination

In the broadcasting problem, one node needs to broadcast a message to all other nodes in a network. If nodes can only communicate with one neighbor at a time, broadcasting takes at least $\lceil \log_2 N \rceil$ rounds in a network of N nodes. In the neighborhood broadcasting problem, the node that is broadcasting needs to inform only its neighbors. In a binary hypercube with N nodes, each node has $\log_2 N$ neighbors, so neighborhood broadcasting takes at least $\lceil \log_2 \log_2 (N+1) \rceil$ rounds. In [25], we present asymptotically optimal neighborhood broadcast protocols for binary hypercubes.

6.1.4. Reconfiguration in WDM networks

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

In this context, we have been investigating two kinds of problems. The first one is to find the most suitable route for incoming connection requests with eventual rerouting of pre-established connections. To cope with this objective, we proposed a model, with MILP formulation, that captures the trade-off between network performance and number of reconfigurations applied to the virtual topology. We have also studied the influence of several parameters and metrics on networks with foreseen traffic evolutions. Finally, we proposed a simulated annealing based heuristic algorithm [68].

The second approach is to develop tools to switch connections from a pre-computed routing to another in a transparent way for end users, that is without service disruption. We thus concentrated on the reoptimization phase of the network. We have modeled this problem as a scheduling problem in a digraph with cycles, and then established some similarities and differences with two other known problems: the *pathwidth* and a particular *graph searching problem* [85]. Cycles are broken through the use of temporary routes (called "agents" in the model) that have to be minimized. Then, we gave optimal scheduling for some classes of graphs, in particular complete d-ary trees, grids, k-connected graphs... This has led us to study the pathwidth of planar and outerplanar graphs [32], thus answering open questions on the notion of pathwidth itself.

6.1.5. Routing minimizing or bounding delays

Data networks are subject to congestion, thereby the delay to go across the network may be large enough in order to dishearten customers to keep on using such a network. In [37] we address the problem of determining in a given network a routing which minimizes the delay or keeps it under a certain bound. We explain which cases of our problem are NP-complete. Using a duality theory and a special form of column generation for semi-definite programming we show new formulations of this problem that can lead to better results.

6.2. Wireless networks

Participants: Jean-Claude Bermond, David Coudert, Afonso Ferreira, Jérôme Galtier, Cristiana Gomes, Florian Huc, Gurvan Huiban, Alexandre Laugier, Claudia Linhares-Sales, Christelle Molle, Julian Monteiro, Nelson Morales, Fabrice Peix, Stéphane Pérennes, Patricio Reyes, Hervé Rivano.

This year, MASCOTTE has persue is study of *ad hoc* and sensor networks and wireless mesh networks within international and national collaborations with academic and industrial partners, as mentioned below.
In particular, we have studied radio networks with a focus on combinatorial optimization, graph theoretic, and algorithmic properties. The approach privileged in the team, based on the aforesaid theoretic tools, with a network design flavor, is complementary with those developed in other INRIA project-teams such as PLANETE, MAESTRO, ARES or POPS. At the international level, our researches are comparable and collaborative with some groups in renowned research centers such as CTI of Patras in Greece, Universities of Roma or Salerno in Italy, the Technion Institute in Israël, SFU in Vancouver, Canada, Arizona State University in USA, or the University of Sao Paulo in Brazil.

We studied a wide range of issues of wireless networks, from the design of efficient medium access techniques or energy aware protocols, to the development of theoretical tools for analyzing and evaluating dynamic networks. We are also developing a specific focus on the design of radio access networks, such as radio data gathering networks, that are recently known as *Wireless Mesh Networks*. Some graph coloring problems motivated by channel assignment in wireless networks are detailed in Section 6.6.

6.2.1. Medium access control and routing

We have proposed several alternatives to improve the collision reduction protocol of WiFi networks. We have introduced a simple regulation based on tournaments and related to the tree algorithms of Capetanakis, used in a different way, to improve significantly the spectral efficiency with specific cards and protocols. In particular, we show that minimizing the collision probability reduces to a problem of approximating a function by Riemann integral [62].

Permutation routing is used as one of the standard tests of routing algorithms. We have studied permutation routing algorithms that work on finite convex subgraphs of basic grids, under the store-and-forward Δ-port model, modeling wireless networks. We have considered algorithms implemented independently at each node, without assuming any global knowledge about the network. We have described optimal distributed permutation routing algorithms for subgraphs of triangular and square grids that need ℓ_{max} (the maximum over the length of the shortest path of all packets) routing steps, and shown that there is no such algorithm on the hexagonal grids. Furthermore, we have shown that these algorithms are oblivious and translation invariant [73].

6.2.2. Energy awareness

One of the main problems investigated in the settings of wireless communication is to minimize the energy consumption of the devices. Designing so-called *energy aware* protocols and systems yields many challenges, in particular for sensor networks. We studied energy aware broadcast protocols from the complexity and approximability viewpoint.

In particular, the performance of the Minimum Spanning Tree heuristic for the Minimum Energy Broadcast Routing (MEBR) problem has been investigated. We first proved that, for any number of dimension $d \geq 2$, the approximation ratio of the heuristic does not increase when the power attenuation coefficient α, that is the exponent to which the coverage distance must be raised to give the emission power, grows. Moreover, we have shown that, for any fixed instance and when α tends to infinity, the ratio tends to the lower bound of Clementi et al., and Wan et al., given by the d-dimensional kissing number, thus closing the existing gap between the upper and the lower bound. We then introduce a new analysis allowing us to establish a 7.45-approximation ratio for the 2-dimensional case, thus significantly decreasing the previously known 12 upper bound. Finally, we extend our analysis to any number of dimensions $d \geq 2$ and any $\alpha \geq d$, obtaining a general approximation ratio of $3d^{-1}$, again independent of α. The improvements of the approximation ratios are specifically significant in comparison with the lower bounds given by the kissing numbers, as these grow at least exponentially fast with respect to d [34], [35].

6.2.3. Wireless mesh networks design and provisioning

Wireless Mesh Networks (WMNs) are cost-effective and provide an appealing answer to connectivity issues of ubiquituous computing. Unfortunately, wireless networks are known for strong waste of capacity when their size increases. Thus, a key challenge is to provide guaranteed quality of service. Maximizing network capacity requires to optimize jointly the Access Points (AP) placement, the routing and the link scheduling taking interference into account. We have addressed this question by providing MILP models for computing optimal 802.11a or 802.16 WMN design [64], [65], [86].

A fundamental issue of WMNs is to gather data packets at one gateway, taking radio interferences into account. Considering a synchronous TDMA network yields a call scheduling problem for which we gave lower bounds on the number of rounds and approximations algorithms in the general case, as well as optimal results on specific cases. We have investigated a relaxation of the scheduling called the call weighting problem and provide linear models, hardness study and approximation algorithms for maximizing the transport capacity of the network [20].

We have also investigated the problem of minimizing the size of routers queues while ensuring a fair bandwidth allocation. This has motivated the introduction and study of a new combinatorial problem, the proportional coloring. Given a graph G with positive weights associated to its edges, we want to find a colouring which preserves the proportion given by the weights associated to each edge. If such colouring exists, we want to find one using a minimum number of colours. We have proved that deciding if a weighted graph admits a proportional colouring is polynomial while determining its proportional chromatic index is NP-hard, provided a lower bound and an upper bound for this parameter, and identified classes of graphs for which we can exactly determine the proportional chromatic index [67].

6.2.4. Theoretical tools for evaluation

We introduced a graph theoretic model some years ago, the evolving graphs. It helps to capture the dynamic behavior of networks that have predictable dynamics. Recently, we have investigated routing algorithms and protocols, and validated them through comparison with state-of-the art ad-hoc routing protocols [60], [61].

Concerning Wireless mesh networks, we combined various approaches for understanding the capacity behavior of these networks. In particular, we have conducted multi-objective analysis of mesh networks based on column-generation optimization algorithms for call scheduling and routing. We have proposed a multi-objective approach that deal with two objective functions. The first one is to minimize the load over the routers, it increases the security in case of failure and minimizes the cost with memory in each node. The second objective is to minimize the time of the communication. Using Column generation, we have identified the Pareto frontier of the problem, hence capturing the trade-off generated by using these two conflicting objective functions [63], [93].

6.3. Overlay networks

Participants: Michel Cosnard, Luigi Liquori, Raphael Chand.

The explosive growth of the Internet, wireless, and *ad hoc* networks gives rise to the possibility of designing large *overlay networks* and *self-organizing virtual organizations* consisting of connected computer units, able to provide a rich functionality of services that make use of aggregated computational power, storage, information resources, etc.

This new MASCOTTE's research vein started in 2006 with the arrival of Luigi Liquori and consists in studying theoretical foundations and pragmatical simulations and implementations of *programmable overlay networks* and *overlay network computing systems*. Such overlays are built over a large number of distributed *computational individuals* or *global computers*, virtually self-organized in *colonies*, and ruled by a leader or *global broker* who is elected or imposed by system administrators. We designed, validated through simulation, and implemented these foundations in a programmable overlay computer system, called *Arigatoni*. Our vision can also be summarized by Jan Bosch's (Nokia labs) slogan: *"Computer is moving on the edge of the Network"*.

The *Arigatoni* overlay network computer [94], [95], [28], [72], [53], [55], [71], [90], [91], developed since 2006 in the MASCOTTE Project Team by Luigi Liquori and Michel Cosnard, is a structured multi-layer overlay network which provides resource discovery with variable guarantees in a virtual organization where peers can appear, disappear, and self-organize themselves dynamically.

Every individual asks the broker to log in the colony by declaring the resources that can be offered (with variable guarantees). Once logged in, an individual can ask the broker for other resources. Colonies can recursively be considered as *evolved individuals* who can log in an outermost colony governed by another super-leader. Communications and routing intra-colonies go through a broker-2-broker *PKI*-based negotiation. Every broker routes intra- and inter- *service requests* by filtering its *resource routing table*, and then forwarding the request first inside its colony, and second outside, via the proper super-leader (thus applying an *endogenous-first-estrogen-last* strategy).

Theoretically, queries are formulæ in first-order logic equipped with a small program used to *orchestrate* and *synchronize* atomic formulæ. When the client individual receives notification of all (or part of) the requested resources, then the real resource exchange is performed directly by the server(s) individuals, without any further mediation of the broker, in a pure peer-to-peer fashion. The proposed overlay promotes an *intermittent* participation in the colony, since peers can appear, disappear, and organize themselves dynamically. Therefore, the routing process may lead to *failures*, because some individuals have quit, or are temporarily unavailable, or they were logged out by the broker due to their poor performance or greediness.

In the first versions of *Arigatoni*, the network topology was tree- or forest-based. But since global computers are not slaves, multiple registrations are in principle possible and unavoidable. This weaves the network topology into a *dynamic graph*. As an immediate consequence, *Arigatoni*'s protocols deal with multiple registrations of the same individual in different colonies, with the natural consequence of resource overbooking, routing table update loops, and resource discovery loops (when a resource request comes back to the individual that generates the request itself). This phenomenon is well known in the telecommunications industry, such as in the "frame-relay" world, and in the domain of transportation and hotel reservations.

Arigatoni features essentially two protocols: the *resource discovery protocol* dealing with the process of a global broker to find and negotiate resources to serve an individual request in its own colony, and the *virtual intermittent protocol* dealing with (un)registrations of individuals to colonies.

Dealing essentially with resource discovery and peers' intermittence has one important advantage: the complete generality and independence of any offered and requested resource. *Arigatoni* can fit with various scenarios in the global computing arena, from classical *P2P* applications (file- or bandwidth-sharing), to new *Web2.0* applications, to new *V2V* and *V2I* over *MANET* applications, to more sophisticated *Grid* applications (distributed large computations), until possible, futuristic *migration computations*, *i.e.* transfer of a non-completed local run to another global computer, the latter being useful in case of catastrophic scenarios, like fire, terrorist attack, earthquake, etc.

Summarizing, *Arigatoni* is *parametric*, or *universal* in the sense of universal Turing Machines, or *generic* as the von Neumann computer architecture. In one sentence and to our little knowledge: "*Arigatoni* is the first fully programmable overlay network computer".

6.4. Fault tolerance

Participants: Omid Amini, Jean-Claude Bermond, David Coudert, Jérôme Galtier, Frédéric Havet, Florian Huc, Alexandre Laugier, Fabrice Peix, Stéphane Pérennes, Bruce Reed, Hervé Rivano, Michel Syska, Marie-Emilie Voge.

Network fault tolerance (or survivability) is a key issue in the design and management of networks and involves many aspects. Indeed a failure can impact a local characteristic of the network but also has repercussions on many parameters. Our previous studies concerned mainly static networks with a centralized knowledge and permanent failures (for example a broken fiber link or a part of an equipment no more working). Basic tools used in this context come from graph theory, in particular, flow studies and connectivity.

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). This problem has also been considered by several teams, like ZIB (Germany), but mainly from an applied point of view, and we are the first to propose a theoretical framework for such study.

We have also extensively considered the fault tolerance and protection in backbone networks like WDM network (in collaboration with Orange Labs).

Considering backbone networks, the industrial experience shows that the classic graph connectivity approach does not fit the economic constraints of telecommunication operators and are not relevant in the settings of modern multilayered networks. We have therefore investigated the notion of Shared Risk Resource Group (SRRG) [101] which capture network survivability issues where a failure may break a whole set of resources. Secondly we have also addressed some problems motivated by the interest of France Telecom research in Service Level Agreements (SLA), such as terminal or service reliability issues.

6.4.1. 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 *Travel ling 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 objective consists in minimizing the number of switches subject to restrictive conditions.

In the past we have obtained various practical constructions for small cases and define a new theory to solve the problem and also provide asymptotically tight bounds. In [49] we consider the case where we can use use only a certain number of ports; indeed, as the satellite is rotating, all the ports are not well oriented and hence not available. We present validity certificates from which derive lower bounds and we also provide constructions of optimal (or quasi optimal) networks for practical values.

6.4.2. Shared Risk Resource Group.

This notion has been formalized as *colored graphs*, where a set of resources is represented by a set of edges with same color. For example in a multilayer network, a failure at one level (e.g. the optical network) might induce many failures at the above level (e.g. the virtual topology on which are established the communications). We have considered the analogous of classical optimization problems in the context of SRRG, such as determining paths or cuts with the minimum numbers of colors or color disjoint paths. We proved that these optimization problems are much more difficult than their counterparts in classical graph theory. In particular standard relationship such as the Max Flow - Min Cut equality do not hold any longer. We have established a classification of hardness and (non)approximability results for many optimization problems in colored graphs [31]. We have also identified cases where these problems can be solved in polynomial time [84], for example when the edges of a given color form a connected subgraph and other cases arising in practical situations. Finally, in [83] we investigate the minimization of the average reliability of connections in multilayer networks under both SRRG and costs constraints.

6.4.3. Protection by cycle.

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. The survivability problem mentioned above consists of finding a cycle partition or covering of the edges of a logical graph with an associated routing over the physical graph 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).

We have obtained in [26] exact results when the logical graph is the complete graph which corresponds to the instance of communication called total exchange or all-to-all, and when the the physical graph is a torus minimizing various cost functions like 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) or the total load (using or not shortest paths).

6.5. Simulation and optimization tools

Participants: Olivier Dalle, Juan-Carlos Maureira, Cyrine Mrabet, Julian Monteiro, Fabrice Peix, Judicael Ribault, Marco Servetto, Michel Syska.

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

6.5.1. Discrete-Event Simulation

In the domain of discrete-event simulation, our development efforts on the Open Simulation Architecture (OSA) are going on [57]; we are still exploring various original techniques and tools, such as Aspect Oriented Programming [58] or Component-Based Software Engineering [56], to find new ways of dealing with important methodological issues: ensuring re-usability of both the simulation software and the simulation models, ensuring reproducibility of results, supporting large scale distributed executions, fully dissociating modeling and experimental concerns, or providing user-friendly and collaborative development support. To our knowledge, except maybe for a few commercial tools, but whose internals details are not disclosed, no other discrete-event simulation software tool worldwide is both freely available and open-source and fully supports all the activities involved in a simulation study.

Several new collaborations have also been started: at the national level, O. Dalle and J. Ribault visited several times the ADAM project-team in Lille and J. Ribault stayed one month in LIP6-Regal project team; at the international level, Prof. G. Wainer stayed 2 weeks in Sophia with MASCOTTE in June and O. Dalle stayed one month at Carleton University (Canada), visiting back Prof. G. Wainer, in October. Following, several formal collaboration proposals have been or are soon to be submitted, as well as new reasearch issues addressed [59]. One of the main research direction targetted by these collaborations is large-scale distributed simulation. Some preliminary work on distributing the OSA architecture using the FractalRMI Framework have been started [92].

Concerning the development of the MASCOPT library, we claim that this work is unique in the sense that on the one hand the library provides higher level tools in comparison with existing linear programming or graph tools. On the other hand, MASCOPT is dedicated to network combinatorial optimization, not to the detailed modelling and tuning of complex real networks as it is the case for some existing commercial optimization softwares. The level of abstraction of the network is different here. The MASCOPT library shares a lot of objectives with SNDlib (See http://sndlib.zib.de/ for more details on SNDlib), a library of test instances for telecommunication network design. Both projects aim at providing sources for testing, evaluating, and comparing network design models and algorithms. In the case of SNDlib, only data are considered, in the case of MASCOPT, we consider program as well. In both cases, it is possible to repeat again an experiment, either with new data set or with different algorithms and then to compare results.

6.5.2. Combinatorial network optimization

The MASCOPT [97] library has reached maturity and is intensively used inside the team for testing and evaluation of optimization programs. During the last year we have pursued its development and the work of [83], [65], [64] has been validated by implementing the algorithm with MASCOPT.

(see Section 5.1 and http://www-sop.inria.fr/mascotte/mascopt)

6.6. Graph theory

Participants: Omid Amini, Marie Asté, Jean-Claude Bermond, David Coudert, Frédéric Havet, Florian Huc, Stéphane Pérennes, Gianlucca Quercini, Bruce Reed, Ignasi Sau-Valls.

MASCOTTE principally investigates applications in telecommunications via graph theory (see other objectives). However it also studies a number of theoretical problems of general interest. Our research mainly focused on three topics which are studied by lots of teams: graph colouring, graph decomposition and digraphs.

- Graph colouring is a hot topic in graph theory. It is one of the oldest problem in combinatorics (with the 4-colour problem), has a central position in discrete mathematics and a huge number of applications. Lots of new results have been obtained the last ten years with the fast development of new technics (structural and probabilistic). In MASCOTTE we studied graph colouring problems via these new methods (probabilistic method, discharging method).
- Since the seminal sery of papers of Robertson and Seymour (*Graph Minors*), tree decomposition and analogous graph decompositions have attracted lot of attention because of its structural and algorithmic importance. First because most of the intractable problems (NP-hard problems) become polynomial when restricted to bounded width. Secondly, because the width w of a decomposition is related to the size g of a large grid-like minor. Hence important proof or algorithms are based on the fact that either the width is small and we can solve the problem or there is a large grid and we also can solve the problem. However this relation is loose. Typically $g \leq w \leq 2^g$. Hence algorithm obtained by this method are non-practical and the result obtained far from optimal. An objective of MASCOTTE is to sharpen the relation between these two parameters and also to get analogous results for digraphs.
- Paths and cycles/circuits are of the simplest and most commonly used objects in graph theory. In undirected graphs they are fairly well understood, whereas they are not in digraphs. There are lots of natural easily stated conjectures regarding paths and circuits in digraphs which are open for several decades: Caccetta-Häggkvist Conjecture (*Every digraph with minimum outdegree n/k contains a circuit of length at most* k), Bermond-Thomassen Conjecture (*Every digraph with minimum outdegree* $2k-1$ *contains* k *disjoint circuits*), Burr Conjecture (*Every digraph with chromatic number* $2k-2$ *contains every oriented tree of order* n). MASCOTTE tried to tackle these hard conjectures.

6.6.1. Graph colouring

We mainly investigated two generalisations of usual graph colouring, improper colouring and $L(p,q)$-labellings. They both are motivated by channel assignment.

A *k-improper colouring* is a mapping c from its vertex set into a set of colours such that every vertex has at most k neighbours with the same colour. We investigated improper colouring of graphs which usually arise in channel assignment problems: random graphs, unit disk graphs, graphs with bounded density (including planar graphs). In [87], we gave combinatorial bounds and approximate algorithms for k-improper colouring graphs of unit disk graphs and in [50], we investigate a weighted version of the problem (a vertex must receive several colors) for induced subgraphs of the triangular lattice which is a widely used subclass of unit disk graphs as they give optimal coverage.

An *$L(p,q)$-labelling of G* is an integer assignment f to the vertex set $V(G)$ such that $|f(u)-f(v)| \geq p$, if u and v are adjacent, and $|f(u)-f(v)| \geq q$, if u and v have a common neighbour. Such a concept is a modelling of a simple channel assignment, in which the separation between channels depends on the distance. More precisely, it has to be at least p if they are very close and q if they are close (but not very close). We gave various results on such labellings [76], [88]. The main result in these area is the proof [66] of Wegner's Conjecture (1977). It asserts that the number of colours required in an $L(1,1)$ labelling of a planar graph is at most $\frac{3}{2}\Delta + o(\Delta)$. This proof has been generalised to $L(p,q)$-labelling for any $p \geq q$. In addition, it makes an extensive use of the probabilistic method and so provide new evidence of the power of the new tools in this method (Local Lemma, concentrations bounds, hardcore distributions,...).

Marginally, we also investigated various graph colouring problems. We give [45] a sufficient condition on the lists given to vertices to have a proper list colouring, we studied edge weightings which induce a vertex colouring [21] and colouring of hypergraphs [54].

6.6.2. Digraph structure

We show [22] that every digraph of chromatic number n contains every oriented path with two blocks of order n. This is the first non-trivial optimal result regarding Burr Conjecture since Gallay-Roy Theorem (1968) which motivated this conjecture. Furthermore, the proof uses an interesting Lemma unifying the existence of a small circuit and Bondy's theorem showing the existence of a circuit of length at least the chromatic number.

In [42], we give a necessary condition for a digraph to contain a directed cycle of length 4. Contrary to the undirected case in which an obvious necessary condition is the number of edges one cannot expect such an easy condition for digraphs. Therefore we introduce the suitable parameter: the mixing property.

6.6.3. Graph decomposition

Our main result is the unification [78] of all the duality theorems of the graph decompositions in the frame of submodular functions. This gives a better understanding of these major aspects and may yield new results. We obtained a newer result relating the pathwidth of an outerplanar [32] graphs to the pathwidth of its dual. It yields a better efficient approximation algorithm for finding the pathwidth of such graphs. Finally, we started [52], [27] to study the relation between treewidth and of a new kind of grid-like graphs which may yield to tighter relations than the existing ones.

Pathwidth and treewidth are very strongly related to graph searching games. Roughly speaking, graph searching problems look for the smallest number of searchers that are sufficient to capture a fugitive in a graph. In [75] we studied non-deterministic graph searching in trees. On one hand, we give tight upper bounds on the number of queries required to search a tree when the number of searchers is fixed. We also prove that this number can be computed in linear time when two searchers are used. On the other hand, our main result consists in the design of a simple polynomial time algorithm that computes a 2-approximation of $s_q(T)$, for any tree T and any $q \geq 0$. This algorithm becomes exact if $q \in \{0, 1\}$, which proves that the decision problem associated to s_1 is polynomial in the class of trees.

6.6.4. Miscellaneous

In [33], we study the ratio between the minimum size of an odd cycle vertex transversal and the maximum size of a collection of vertex-disjoint odd cycles in a planar graph. We show that this ratio is at most 10. For the corresponding edge version of this problem, Král and Voss recently proved that this ratio is at most 2; we also give a short proof of their result.

In [69], we provide a linear algorithm to compute the crossing number of a graph which is the minimum number of edge crossings of a graph in any planar drawing.

In [80], we initiate the study of finding an induced subgraph of size at most k with minimum degree at least d. For $d = 2$, it corresponds to finding a shortest cycle of the graph. The problem is strongly related to the DENSE K-SUBGRAPH problem and is of interest in practical applications. We show that these problems are fixed parameter intractable for $d \geq 3$ in general graphs by showing it to be W[1]-hard by a reduction from MULTI-COLOR CLIQUE. On the algorithmic side, we show that the problems are fixed parameter tractable in graphs which excluded minors and graphs with bounded local tree-width so in particular, in planar graphs, graphs of bounded genus and graphs with bounded maximum degree.

6.7. Formal semantics of Programming Language

Participant: Luigi Liquori.

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

- With A. Ciaffaglione and M. Miculan (University of Udine, Italy), we illustrate 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* [30].
- 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 [39].
- With S. Ronchi della Rocca (University of Turin, Italy), we present a fully typed λ-calculus based on the intersection-type system discipline, which is a counterpart à la Church of the type assignment system as invented by Coppo and Dezani. The relationship between this calculus and the intersection type assignment system is the standard isomorphism between typed and type assignment system, and so the typed language inherits from the untyped system all the good properties, like subject reduction and strong normalization. Moreover both type checking and type reconstruction are decidable [41].
- With B. P. Serpette (INRIA Sophia), we propose an imperative version of the Rewriting-calculus, a calculus based on pattern-matching, pattern-abstraction, and side-effects, which we call imprho. We formulate a static and a big-step *call-by-value* operational semantics of imprho. The operational semantics is deterministic, and immediately suggests how to build an interpreter for the calculus. The static semantics is given via a first-order type system based on a form of product-types, which can be assigned to terms-like structures (*i.e.*, records). The calculus is *à la* la Church, *i.e.*, pattern-abstractions are decorated with the types of the free variables of the pattern. Imprho is a good candidate for a core of a pattern-matching imperative language, where a (monomorphic) typed store can be safely manipulated and where fixed-points are built-in into the language itself. Properties such as determinism of the interpreter and subject-reduction are completely checked by a machine-assisted approach, using the Coq proof assistant. Progress and decidability of type-checking are proved by pen and paper [98].
- With Arnaud Spiwack (LIX), in the context of *statically-typed, class-based languages*, we investigate classes that can be extended with *trait* composition. A trait is a collection of methods without state; it can be viewed as an *incomplete stateless class*. Traits can be composed in any order, but only make sense when imported by a class that provides state variables and additional methods to disambiguate conflicting names arising between the imported traits. We introduce FeatherTrait Java, a conservative extension of the simple lightweight class-based calculus Featherweight Java with *statically-typed traits*. In FeatherTrait Java, classes can be built using traits as basic behavioral bricks; method conflicts between imported traits must be resolved *explicitly* by the user either by (i) aliasing or excluding method names in traits, or by (ii) overriding explicitly the conflicting methods in the class or in the trait itself. We present an operational semantics with a lookup algorithm, and a sound type system that guarantees that evaluating a well-typed expression never yields a *message not understood* run-time error nor gets the interpreter stuck. We give examples of the increased expressive power of the trait-based inheritance model. The resulting calculus appears to be a good starting point for a rigorous mathematical analysis of typed class-based languages featuring trait-based inheritance [100].

We also introduce FeatherTrait Java with Interfaces, where traits need to be typechecked only once, which is necessary for compiling them in isolation, and considering them as regular types, like Java-interfaces with a behavioral content [99].

7. Contracts and Grants with Industry

7.1. 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 and 2006-2008.

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

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

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

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

8. Other Grants and Activities

8.1. National Collaborations

8.1.1. Color Ariwheels with Politecnico di Torino, 2007

Arigatoni on wheels. The goal of the project is the definition of an info-mobility system capable of proposing new development paradigms that focus on the maximization of communication efficiency and information exchange in Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) communication. Such goals can be pursued without devising new communication technologies, but, rather, by aiming at a drastic technological upgrading of existing infrastructures and at devising a lightweight overlay network called Arigatoni, designed at INRIA Sophia Antipolis in Mascotte Project Team and mathematically investigated in Maestro Project Team. The "Arigatoni-On-Wheels" project will therefore specify and investigate models, algorithms and protocols that can promote an efficient interactivity among all the elements of traffic systems (vehicles, roadside infrastructures and service centres).

(http://www-sop.inria.fr/mascotte/Luigi.Liquori/ARIGATONI/Ariwheels.htm)

8.1.2. Color GenOpt with Genova University, 2007

Design and implementation of new graph algorithms, especially in the fields of network optimization and graph representation. The objective is to use advanced techniques in combinatorial optimization and graph theory to improve the existing solutions to these problems, while implementing the resulting algorithms in the MASCOPT library developed at MASCOTTE team.

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

8.1.3. ANR Jeunes Chercheurs OSERA, 2005-2008

On optimization and simulation of ambient networks.

(http://golgoth.inria.fr/wiki/Contrats/ANR-JCOSERA)

8.1.4. ARC CARMA, 2007-2008

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

(http://golgoth.inria.fr/wiki/Contrats/ARCINRIACARMA/)

8.1.5. Action ResCom, 2006-...

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

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

8.1.6. ANR SPREADS with UbiStorage

The project SPREADS (Safe P2p-based REliable Architecture for Data Storage) with industrial applications has been recently approved by ANR. The leader is the SME UBISTORAGE. other partners are the project REGAL at INRIA Rocquencourt Eurecom and LACL Paris XII.

It has got the approbation and label of the "pôle de compétitivité" SCS.

(http://golgoth.inria.fr/wiki/Contrats/SPREADS)

8.2. European Collaborations

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

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

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

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

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

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

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

8.2.2. European Action COST 293 Graal, 2004-2008

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

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

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

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

8.2.4. Alliance program with Royal Holloway College (London) 2007

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

8.2.5. FP6, Tempus Erasmus Mundus, JEP_41099_2006

TEMPUS DEUSK: (Joint European Projects 2007-2009) "Doctoral School Towards European Knowledge Society" - Reform of Curriculum Content of Doctoral Studies at the University of Novi Sad and the University of Belgrade, coordinated by the University of Udine (Italy). The aim of the project proposal is to restructure, revise and update the Doctoral Studies in Informatics of the University of Novi Sad and of the University of Belgrade, in accordance with the process of legal reform of the Higher Education System in the Republic of Serbia. The project and all the costs related to mobility for academic and administrative staff will be supported and financed by the European Commission.

8.3. International Collaborations

8.3.1. Join team "RESEAUXCOM", 2003-2007

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

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

8.3.2. INRIA OPTINET, 2007

Cooperation with Concordia University, Montreal, Canada, granted by the joint team program of INRIA, on optimization of dynamic optical networks.

8.3.3. INRIA-FAPESP MOBIDYN, 2003-2007

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

8.4. Guests

Jorge Amaya: Santiago, Chili January 16-30 2007 (2 weeks).

Stefano Annese: CSP INLAB, Torino, Italy, February 26-27 2007.

Diego Borsetti: Politech Torino, Italy, February 26-27 2007 & August 29-31 2007.

Kim Bruce: Pomona College, USA, July 7-8 2007.

Binh Minh Bui Xuan: LIRMM, Montpellier, February 12-16 2007 (1 week).

Claudio Casetti: Polytech Torino, June 15-30 2007 (2 weeks)

Ricardo Correa: U. Federal do Ceara, Fortaleza, Brazil, January 1st - June 30 2007 (6 months)

Rok Erman: Ljubljana University, Slovenia, December 2007 (1 week).

Louis Esperet: LABRI, Bordeaux, France, February 2007 (1 month).

Luisa Gargano: Salerno Italy, July 15 - August 31 2007 (1.5 months).

Paolo Giaccone: Politech Torino, Italy, February 26-27 2007

Simon Griffiths: Cambridge University, April 2007 (1 week), July 2007 (1 week), October 2007 (1 week).

Robert Harper: CMU, USA, July 7-8 2007.

Jan van den Heuvel: London School of Economics, United Kingdom, February 2007 (1 month).

Furio Honsell: UNIUD, Udine, Italy, July 7-8 2007.

Sulamita Klein: U. Federal do Rio de Janeiro, Brazil, January 23 - February 15 2007 (3 weeks).

Daniel Král': Charles University, Prague, Czech Republic, September 2007 (1 week) and November 2007 (1 week).

Pierre Lescanne: LIP, ENS Lyon, July 7-8 2007.

Bernard Lidicky: Charles University, Prague, Czech Republic, November 2007 (1 week).

Claudia Linhares Sales: Universidade Federal do Ceara, Fortaleza Brazil, January-July 2007 (7 months).

Tobias Müller: Eindhoven Technical University, The Netherlands, July 17-25 2007 (two weeks).

Lucca Moscardelli: L'Aquila, Italy, March 5-9 2007 (1 week).

Nicolas Nisse: LRI, Univ. Paris-Sud, January 3-8 2007 (1 week).

Cesare Pautasso: ETH, Zurich, Suisse, January 15-16 2007.

Joseph Peters: S.F.U. Vancouver, Canada, April 21 - May 15 2007 (3 weeks).

Diana Piguet: Charles University, Prague, Czech Republic, February 3-17 2007 (2 weeks).

Saket Saurabh: Bergen Univ., Norway, March 4-10 2007 (1 week).

Jean-Sébastien Sereni: Charles University, Prague, Czech Republic, September 2007 (1 week).

Riste Škrekovski: Ljubljana University, Slovenia, September 2007 (2 weeks).

Arnaud Spiwack: LIX, July 7-8 2007.

Ladislav Stacho: S.F.U Vancouver, Canada, April 21 - May 5 2007 (2 weeks).

Fabrice Theoleyre: CITI, Lyon, February 27 - March 2 2007 (1 week).

Andrew Thomason: Cambridge University, United Kingdom, April 2007 (two weeks) and July 2007 (two weeks).

Stéphan Thomassé: LIRMM, Montpellier, February 2007 (1 week), July 2007 (1 week).

Ugo Vaccaro: Salerno Italy, July 15 - August 31 2007 (1.5 months).

Gabriel Wainer: Carleton University, Ottawa, Canada, June 2007 (2 weeks).

Paul Wollan: Hamburg, Germany, July 22-28 2007 (1 week).

Joseph Yu: S.F.U Vancouver, Canada, January 20 - April 15 (3 months).

Janez Zerovnik: Maribor Univ, Slovenia, July 16-31 2007 (2 weeks).

8.5. Visits of Mascotte members to other research institutions

M. Asté: Charles University, Prague, Czech Republic, July 2007 (2 weeks) and November 2007 (2 weeks).

O. Amini: London School of Economics, August 2007 (1 week); University of Bergen, September 2007 (1 week)

J-C. Bermond: CTI, Patras, Greece, June 2007 (1 month); Fordham Univ., New York, USA, December 2007 (1 week).

M. Cosnard: CTI Patras, Greece, June 2007 (1 week); SFU Vancouver, BC, Canada, July 27 - August 15 2007 (3 weeks).

D. Coudert: Univ. of Maribor, Slovenia, January 31 - February 6; Concordia University, Montreal, Canada, April 11 - May 27 2007 (1.5 months); CITI, INSA-Lyon, France, July 9-11 2007 and November 19 2007; LIRMM, Montpellier, France, December 18-19 2007.

O. Dalle: V2B (SME), Marseille, March 29 2007; INRIA/ADAM, Lille, April 24-25 2007; LIMOS, Clermont-Ferrand, August 9 2007; Carleton University (plus invited talk), Ottawa, Canada, October 1st - October 31st 2007; University of Oslo, Norway, November 1-4 2007;

A. Ferreira: Univ. Sao Paolo, Brazil, March 29 - April 15 2007.

J. Galtier: Univ. of Maribor, Slovenia, January 31 - February 6 2007.

F. Havet: LIAFA, Paris, January 2007(1 week); Charles University, Prague, Czech Republic, October 2007 (1 week)

F. Huc: LIRMM Montpellier, France, May 1-5 may (1 week); Concordia University, Montreal, Canada, June 2 - July 2 (1 month); LSE, London, UK, August 2007 (1 week).

L. Liquori: University of Turin, Italy, March 07, (2dd); Politech Turin, Italy, March+July 07, (1 week); Project Protheo, Loria (tot 9dd); IBM Zurich, March 2007, (2dd); Univ. Lugano, Switzerland, November 07, (3dd); School of Engineering of the University of Rome "La Sapienza", October 2007 (1dd), Univ. Genova, Italy, December 07, (3dd); Politech Turin, Italy, December 07, (3dd); Univ. Udine, Italy, December 07, (3dd).

C. Molle: Visit to POPS project CNRS-INRIA-Univ. Lille 1 involved in ARC CARMA, Lille, France, December 10-18, 2007.

J. Moulierac: Visit to RIM project, CRISTAL Laboratory Tunis, Tunisia in February 2007 (1 week).

C. Mrabet: INRIA/ADAM, Lille, April 24-25 2007.

S. Perennes: SFU Vancouver, BC, Canada, June 10 - July 11 2007.

J. Ribault: INRIA/ADAM, Lille, April 24-25 2007; INRIA/ADAM, Lille, July 16-20 2007 (1 week); INRIA/REGAL, Paris, October 8-31 2007 (3.5 weeks).

H. Rivano: LIFL, Lille, France, February 26 - March 2 2007 (1 week);

I. Sau Valls: Research Group on Graph Theory and Combinatorics, DMA IV, UPC Barcelona, Spain, July 2007 (1 month); Computer Science Department, Technion, Haifa, Israel, June 2007 (3 weeks); Department of Theoretical Computer Science, IMFM, Ljubljana, Slovenia, September 2007 (3 weeks) and December 2007 (2 weeks).

9. Dissemination

9.1. Leadership within the scientific community

9.1.1. Participation in Committees

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

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, WG-A “broadband and optical networks”); expert for ANR Telecom; member of the management committee of *pôle ResCom du GDR ASR du CNRS*; expert for the National Sciences and Engineering Research Council of Canada (NSERC);

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;

A. Ferreira: member of the Panel Signal and Systems of the Swedish Research Council in 2007;

J. Galtier: member of the COST Action 293 Management Committee, expert senior in Orange Labs, member of the jury for new senior experts in July 2007 in Orange Labs, scientific leader for the CORSO2 common action between Orange Labs and INRIA.

F. Havet: member of the "Commission de Spécialistes de la 27^{e} section" University Montpellier 2; member of the "Commission de Spécialistes de la 25^{e} section" University Lyon 1; member of the I3S commitee.

L. Liquori: member of the "Commission de Spécialistes de la 27^{e} section" University Nice and Institut National Polytecnique de Lorraine.

H. Rivano: substitute member of the I3S laboratory Committee; member of the CUMIR.

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.

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

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

9.1.3. Steering Committees

D. Coudert: annual summer school ResCom; AlgoTel;

B. Reed: Canadian Conference on Discrete Mathematics;

9.1.4. Workshop organization

O. Amini, J-C. Bermond, F. Huc, P. Lachaume, M-E. Voge: AEOLUS Workshop on Scheduling, Nice, France, March 8-9, 2007. http://www-sop.inria.fr/mascotte/WorkshopScheduling/

O. Dalle: organized a Special Session on CBSE techniques applied to Simulation at the AIS-CMS 2007 International Conference (Buenos Aires, Feb 8-10 2007); *Journé des Poles Info d'I3S*, July 6 2007; Club InTech'Sophia: *Les réseaux Pair-à-Pair* (peer-to-peer), Sophia Antipolis December 17 2007.

F. Havet: organized GALET'07, 2nd *Journées Graphes, ALgorithmes ET toute cette sorte de choses...* , Sophia-Antipolis, France, December 11-12 2007. http://www-sop.inria.fr/mascotte/Galet/

J. Galtier : organized the mini-syposium on non-convex programming for telecommunications, at the international conference on Non Convex Programming, dec 17, 2007, Rouen.

L. Liquori organized in july 2007 at INRIA Lorraine a *Journée sur les Langages et les Preuves*, program on http://www-sop.inria.fr/mascotte/Luigi.Liquori/HDR/Peter.Pan.html

9.1.5. Participation in program committees

J-C. Bermond: TPC chair of the AEOLUS Workshop on Scheduling, Nice, France, March 8-9, 2007.

D. Coudert: TPC co-chair of AlgoTel'07 [16], Ile d'Oléron, May 29 - June 1 2007.

O. Dalle: TPC member of the 7th French-speaking Conference on Modeling and Simulation (MOSIM'08), Paris, March 31st - April 2nd 2008; TPC Member of the 2007 Industrial Simulation Conference (ISC'2007), Delft, NL, June 11-13 2007; TPC Member of the Workshop on Network Simulation Tools 2007 (NSTools'07), in Conjunction with VALUETOOLS'07, Nantes, France, October 2007; TPC member of the 2007 High Performance Computing & Simulation Conference (HPC&S), Prague, June 4-6 2007; TPC Chair of the Modeling and Simulation Methodologies track (METH) of the 21st European Conference on Modeling and Simulation (ECMS07), Prague, June 4-6 2007;

J. Galtier: PC member of the 6th international workshop on the Design of Reliable Communication Networks (DRCN'07), in La Rochelle, October 2007, of the 9ème rencontres francophones sur les aspects algorithmiques de télécommunications (AlgoTel 2007), Ile d'Oleron, may/june 2007, of the international conference on Non Convex Programming (NCP07), Rouen, December 2007.

L. Liquori: PC Member of ECOOP 07, European Conference on Object Oriented Programming, Aarhus, Denmark; PC Member of FOOL/WOOD 07, International Workshop on Foundations and Developments of Object-Oriented Languages; PC Member of SC 08, International Symposium on Software Composition 2008; PC Member of HotP2P 08, Fifth International Workshop on Hot Topics in Peer-to-Peer Systems.

H. Rivano: PC member of Algotel 2007.

9.2. Teaching

9.2.1. HdR

F. Havet [18]: Graph colouring and applications, HDR thesis, UNSA, December 12, 2007.

L. Liquori [19]: *Peter, le langage qui n'existe pas...* (Peter, the language that does not exists...). Habilitation Thesis, Institut National Polytechnique de Lorraine (INPL), 6 Juillet, 2007.

9.2.2. Theses

9.2.2.1. Theses defended in 2007

O. Amini [17]: *Algorithmique des décompositions de graphes: applications aux réseaux de télécommunications*. PhD thesis, Ecole Polytechnique, November 28, 2007;

N. Morales [20]: *Algorithmique des réseaux de communication radio modélisés par des graphes*. PhD thesis, Ecole doctorale STIC, Université de Nice-Sophia Antipolis, January 26, 2007.

9.2.2.2. Theses in preparation

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

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.

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

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

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

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

I. Sau Valls: *Groupage de trafic*, since October 2006;

9.2.3. Participation in thesis Committees

J-C. Bermond: PhD committee (member) of Nelson Morales, ED STIC, UNSA, January 26 2007; PhD committee (chair) of Yannick Bréhon, ENST Paris, May 11 2007; PhD committee (member) of Bertrand Estellon, Univ. Marseille, November 30 2007; PhD committee (member) of Omid Amini, Ecole Polytechnique, November 28 2007.

D. Coudert: PhD referee of Fernando Solano Donado, U. Girona, Spain, December 4 2007 ; PhD committee of Benoit Darties, LIRMM Montpellier, France, December 14 2007.

O. Dalle: PhD opponent (referee) of Erek Götkürk, U. Oslo, Norway, November 2007.

A. Ferreira: Phd Committee: Arnaud Casteigts, LABRI, Bordeaux, September 27 2007.

J. Galtier: PhD committee (member) of Alexandre Skoda, Univ. of Paris 6, November 29 2007.

L. Liquori: PhD committee of Romain Pechoux, Institut National Polytechnique de Lorraine, Nancy, France, November 15 2007.

9.2.4. Internships

D. Coudert and F. Huc: supervised the internship of D. Mazauric (Master 1 STIC and EPU 2, UNSA, France), July-September 2007 (3 months).

O. Dalle: supervised the internships of Juan-Carlos Maureira (Chile),20/01/07 - 20/03/07 (2 months); Judicael Ribault (Master 2 STIC "ISI", U. Nice-Sophia Antipolis), April-September 2007 (6 months); Sigurd Teigen (B.Sc. Ithaca College, Ithaca, NY, June-August 2007 (2.5 months);

J. Galtier: supervised the intership of Federico Felizzi (Cambridge, England), 01/07/07 -31/08/07 (2 months).

F. Havet: supervised the internship of M. Asté (Master 2 MDFI, University of Provence, France), April-June 2007 (3 months).

M. Syska: supervised the internships of Gianlucca Quercini (Pre Doc, Genova, Italy), 23/04/07-22/10/07 (6 months); Marco Servetto (Grant Leonardo, Genova, Italy), 05/03/07 - 04/09/07 (6 months);

9.2.5. 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

O. Amini: Afternoon of Combinatorics, London, 30 August 2007.

F. Havet: Seminar of LIAFA, 23 January 2007; Graph Theory Conference, Fredericia, Denmark December 2007.

F. Huc: Afternoon of Combinatorics, London, 30 August 2007.

A. Ferreira:

- COST in the 7th Framework Programme, Canada-EU Research Opportunities Info Days. Toronto, Ottawa, and Montreal, March 2007.
- Foreseeing the unexpected: how the Digital Revolution is changing the world, Conference The Good, the Bad, and the Unexpected, Moscow, May 2007.
- Research Opportunities in ICT: Europe 2007-2013 and Beyond, 6th IEEE International Symposium on Network Computing and Applications, Boston, July 2007.

– Future societal challenges in ICT, Workshop Shaping Future FET Proactive Initiatives. European Commission, Belgium, September 2007.

J. Galtier: Journees Franciliennes de Recherche Operationnelle (JFRO), June 15 2007.

9.3.2. Participation in scientific meetings

Joint COST 293 GRAAL / COST 295 DYNAMO Workshop, Maribor, Slovenia, Jan. 31 - Feb. 4, 2007.
Attended by D. Coudert, J. Galtier, I. Sau Valls.

ARC CARMA kickoff meeting, LIFL, Lille, France, Feb. 28 - March 2, 2007.
Attended by D. Coudert, C. Molle, H. Rivano.

IST FET AEOLUS Workshop on Scheduling, Nice, France, March 8-9, 2007
Attended by many members of MASCOTTE.

INRIA/Alcatel-Lucent workshop, Paris, France, March 9, 2007.
Attended by D. Coudert.

4th *Journées du Pôle ResCom du GDR ASR*, LIP6, Paris, France, March 15-16, 2007.
Attended by D. Coudert, H. Rivano, P. Reyes, M.-E. Voge.

Workshop on Graph Colouring problems arising in telecommunications, Banff, Canada, March 19-23 2007.
Attended by F. Havet.

Workshop on Probabilistic Graph Theory, Bellairs Institute, Barbados, March 24-30, 2007.
Attended by F. Havet.

Workshop on Graph Theory, Oberwolfach, March 25-31 2007.
Attended by O. Amini.

1st *Journées Statistiques du Sud*, Nice, France, April 11-13 2007.
Attended by J. Galtier and I. Sau Valls.

COST 295, 1st Workshop On Dynamic Networks, Salerno, Italy, May 7-8, 2007.
Attended by O. Gerber.

Colloque des doctorants ED STIC et SFA, Sophia Antipolis, France, May 10-15, 2007.
Attended by O. Amini, F. Huc, C. Molle

COST 293, 9th COST 293 Workshop, Castiglioncello (LI), Italy, June 4-6, 2007.
Attended by D. Coudert.

Journée des Poles Info d'I3S, Sophia Antipolis, July 5 2007.
Attended by many member of MASCOTTE.

ARC CARMA workshop, INSA Lyon, France, July 9-11, 2007.
Attended by D. Coudert, H. Rivano.

Workshop on Parametrized Complexity, Dagsthul, Germany, July 2007.
Attended by F. Havet.

5th *Journées du Pôle ResCom du GDR ASR*, ENSEEIHT, Toulouse, France, Sept. 20-21, 2007.
Attended by D. Coudert, C. Molle, H. Rivano.

2nd *Journées nationales des ARC*, Rennes, October 1-2 2007.
Attended by H. Rivano.

AEOLUS technical committee meeting, Athens, October 1-2, 2007.
Attended by J-C. Bermond, D. Coudert, L. Liquori.

DEUKS, kick-off meeting European project TEMPU DEUKS, Novi Sad, Serbia, October 23-25 2007.
Attended by L. Liquori.

Journée Optimisation des Réseaux, Paris, France, October 25, 2007.
Attended by C. Molle

10th COST 293 GRAAL meeting, Rome, Italy, October 29-31, 2007.
Attended by D. Coudert, J. Galtier, C. Molle, J. Moulierac, I. Sau Valls.

IST FET AEOLUS second year evaluation workshop, Sophia Antipolis, France, November 7-8, 2007.
Attended by many members of MASCOTTE.

JGA'07, 9th *Journées Graphes et Algorithmes*, November 8-9, 2007.
Attended by O. Amini, M. Asté, F. Havet, F. Huc and I. Sau Valls.

INRIA COM B evaluation workshop, Paris, France, November 13-14, 2007.
Attended by J-C. Bermond, M. Cosnard, D. Coudert, O. Dalle, J. Galtier, F. Havet, J. Moulierac, H. Rivano, M. Syska.

ARC CARMA meeting, INSA Lyon, France, November 19, 2007.
Attended by D. Coudert, H. Rivano.

40th anniversary celebration of INRIA, LIFL, Lille, France, December 10-11, 2007.
Attended by D. Coudert, O. Dalle, C. Molle, H. Rivano

Journées GALET, 2nd *Journées Graphes, ALgorithmes ET toute cette sorte de choses...*, Sophia-Antipolis, France, December 11-12 2007.
Attended by most of the members of MASCOTTE.

Séminaire Intech'Sophia, "*Les réseaux Pair-à-Pair* (Peer to Peer)", Sophia Antipolis, December 17 2007.
Attended by many members of MASCOTTE.

9.3.3. Participation in conferences

AIS-CMS 2007 Conference, Buenos Aires, February 8 - 10, 2007.
Attended by O. Dalle (Speaker) [56].

ARCS'07 Architecture of Computing Systems Swiss Federal Institute of Technology (ETH) Zurich, Switzerland March 12-15, 2007.
Attended by L. Liquori (Speaker) [53].

IPDPS'07, IEEE International Parallel & Distributed Processing Symposium, March 26-30 2007.
Attended by M. Cosnard (Speaker) [48].

EW'07, 13th European Wireless Conference, Paris, France, April 1-4, 2007
Attended by C. Molle.

Combinatorial Optimization into the Future: A Celebration of Bill Pulleyblank's fifty Nine and One Half Birthday, April 1st- 8th , Bellairs Institute, Barbados, 2007.
Attended by O. Amini.

INOC'07, International Network Optimization Conference, Spa, Belgium, April 22-25 2007
Attended by I. Sau Valls (Speaker) [73].

OON'07, 4th Workshop on Optimization of Optical Networks, Montreal Canada, Mai 2-3, 2007
Attended by D. Coudert.

SBRC'07, 25th Brazilian Symposium on Computer Networks and Distributed Systems, Belem, Brazil, May 28–June 01, 2007
Attended by J. Monteiro (Speaker) [61].

AlgoTel'07, 9th *rencontres francophones sur les aspects algorithmiques des télécommunications*, Ile d'Oléron, May 29 - June 1 2007
Attended by D. Coudert (Co-Chair), F. Huc (Speaker) [50], G. Huiban, C. Gomes, C. Molle (Speaker) [65], P. Reyes, H. Rivano, I. Sau Valls (Speaker) [44].

SIROCCO'07, 14th International Colloquium on Structural Information and Communication Complexity, Castiglioncello (LI), Italy, June 6-8, 2007
Attended by D. Coudert.

ECMS 2007, European Conference on Modeling and Simulation, Prague, Czech Republic, June 4-6 2007.
Attended by O. Dalle (Track Chair).

WoWMoM'07, IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks, Helsinki, Finland, June 18-21 2007
Attended by G. Quercini (Speaker).

EURO'07, 22nd European Conference on Operational Research EURO XXII, Prague, Czech Republic, July 8-11, 2007
Attended by C. Molle (Speaker) [64].

SCSC'07, Summer Computer Simulation Conference, San Diego, CA, USA, July 15-18, 2007
Attended by O. Dalle (Speaker) [57].

ICSNC'07 International Conference on Services and Networks Communications, Cap Esterel, France, August 25-31, 2007
Attended by J. Galtier (Speaker) [62].

EUROSIM Congress, Ljubjana, Slovenia, September 9-13, 2007
Attended by O. Dalle (Speaker) [58].

DRCN'07, 6th International Workshop on Design and Reliable Communication Networks, La Rochelle, October 7-10 2007
Attended by G. Huiban (Speaker) [68] and F. Huc.

MASCOTS'07, 15th IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems, Istanbul, Turkey, October 24-26, 2007
Attended by C. Gomes (Speaker) [63].

TGC'07 Symposium on Trustworthy Global Computing, Sophia-Antipolis, November 5-6, 2007.
Attended by L. Liquori (Speaker) [71].

LAGOS'07, 4th Latin-American Algorithms, Graphs and Optimization Symposium, Puerto Varas, Chile, November 24-29 2007
Attended by F. Huc (Speaker) [42], [45], [67].

CoNext'07, 3rd International Conference on emerging Networking EXperiments and Technologies, New York, USA, December 10-13 2007.
Attended by J-C. Bermond.

Graph Theory Conference, Fredericia, Denmark December 2007.
Attended by F. Havet (Invited Speaker).

9.3.4. Participation in schools

IT'07, IEEE Winter School on Coding and Information Theory, La Colle sur Loup, France, March 12-16 2007
Attended by C. Gomes, C. Molle, H. Rivano, I. Sau Valls.

JCALM, *Journées Combinatoire et Algorithmes du Littoral Méditerranéen*, Montpellier, France, April 26-27 2007.
Attended by O. Amini, M. Aste, O. Gerber, C. Gomes, F. Havet, F. Huc, G. Huiban, G. Quercini, M.-E. Voge.

Ecole de Printemps d'Informatique Théorique, Fréjus, France, June 3-8, 2007.
Attended by F. Havet.

ResCom'07, 2nd summer school ResCom, Calcatoggio, Corse, France, June 16-23 2007
Attended by D. Coudert, C. Gomes, G. Huiban, C. Molle, H. Rivano

10. Bibliography

Major publications by the team in recent years

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

[2] O. AMINI, F. GIROIRE, F. HUC, S. PÉRENNES. *Minimal selectors and fault tolerant networks*, in "Networks", To appear, 2007, ftp://ftp-sop.inria.fr/mascotte/Publications/AG+07.pdf.

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