INRIA, Evaluation of Theme Networks and Telecommunications

Project-team MASCOTTE

March 20-23, 2012

Project-team title:

Méthodes Algorithmiques, Simulation, Combinatoire et OpTimisation pour les TElécommunications

Scientific leader:

Until March 15 2011: Jean-Claude Bermond
Since March 15 2011: David Coudert

Research center:

Sophia Antipolis – Méditerranée

Common project-team with:

I3S (UMR 7271 CNRS/UNS)

1 Personnel

Personnel (November 2007)

	Misc.	INRIA	CNRS	University	**Total**
DR (1) / Professors			1	1	**2**
CR (2) / Assistant Professors		2	3	3	**8**
Permanent Engineers (3)					**0**
Temporary Engineers (4)	1				**1**
PhD Students	5	1	2	1	**9**
Post-Doc.	1	2			**3**
Total	**7**	**5**	**6**	**5**	**23**
External Collaborators	2		2		**4**
Visitors ($>$ 1 month)					**9**

(1) "Senior Research Scientist (Directeur de Recherche)"
(2) "Junior Research Scientist (Chargé de Recherche)"
(3) "Civil servant (CNRS, INRIA, ...)"
(4) "Associated with a contract (Ingénieur Expert or Ingénieur Associé)"

Personnel (March 20-23, 2012)

	Misc.	INRIA	CNRS	University	**Total**
DR / Professors			2		**2**
CR / Assistant Professor		2	2	4	**8**
Permanent Engineer			1/3		**1/3**
Temporary Engineer		2			**2**
PhD Students	5	4	1	2	**12**
Post-Doc.	3	1			**4**
Total	**8**	**9**	**5+1/3**	**6**	**28+1/3**
External Collaborators					
Visitors ($>$ 1 month)					

Changes in staff

DR / Professors CR / Assistant Professors	Misc.	INRIA	CNRS	University	Total
Arrival		1	1	1	3
Leaving		1	1	1	3
Transit		1	2		3

Comments:

- **Arrivals**
  - Frédéric Giroire, CR CNRS, joined the team in Sept. 2008;
  - Nicolas Nisse, CR INRIA, joined the team in Sept. 2009;
  - Luc Hogie is Research Engineer (IR CNRS) at the *pôle COMRED* of the I3S laboratory since Feb. 2010, assigned for 30% of his time to MASCOTTE;
  - Christelle Caillouet-Molle, Assistant Professor at IUT Nice Côte d'Azur, joined the team in Sept. 2011.
- **Promotion**
  - Stéphane Pérennes has been promoted DR CNRS in 2010.
- **Transit**
  - Bruce Reed, DR CNRS, joined the team in Sept. 2008 and is now on leave at McGill University, Montréal Canada, since Sept. 2009;
  - Afonso Ferreira, DR CNRS, returned to the team in Sept. 2009 after 5 years at the COST office of the European Commission. He was also responsible of international cooperations for CNRS section 7 (part time position) till Sept. 2010. He is since on leave at European Commission for the FET Open programme;
  - Philippe Mussi, CR INRIA, has returned in Sept. 2009, after serving for 4 years at the External Relation and Valorization office of INRIA Sophia Antipolis. Since May 2011 he is in charge of animation of European Institute of Technology' Knowledge & Innovation Community (KIC) ICT Labs for the Nice Sophia Antipolis area. He also manages the Sophia co-location center. Members of the KIC in Sophia include INRIA, UNS, EURECOM, and the *pôle de compétitivité Solutions Communicantes Sécurisées* (SCS) cluster.

- **Departures**
  - Luigi Liquori, CR INRIA, has launched the new INRIA team LogNet in January 2008;
  - Michel Cosnard, Prof. UNS, left the team in January 2008 and he is currently PDG of INRIA;
  - Hervé Rivano, CR CNRS, moved to the CITI laboratory in Lyon in Sept. 2009.

Current composition of the project-team (March 20, 2012):

Head of the project-team		
David Coudert	CR INRIA	HDR
Vice-head of the project-team		
Frédéric Havet	CR CNRS	HDR
INRIA researcher		
Nicolas Nisse	CR INRIA	
CNRS researchers		
Jean-Claude Bermond	DR CNRS	Emeritus
Frédéric Giroire	CR CNRS	
Stéphane Perennes	DR CNRS	HDR
UNS researchers		
Christelle Caillouet-Molle	Assistant Prof. UNS	
Olivier Dalle	Assistant Prof. UNS	
Joanna Moulierac	Assistant Prof. UNS	
Michel Syska	Assistant Prof. UNS	
CNRS engineer		
Luc Hogie	IR CNRS	part time (30%)
Assistants		
Sandra Devauchelle	AI CNRS	part time (25%)
Patricia Lachaume	TR INRIA	part time (50%)
Post-doc		
Gianlorenzo D'Angelo	INRIA	since Sep. 2011
Frantisek Kardos	ANR	since Oct. 2011
Yaning Liu	ANR	since Apr. 2011
Emilio Mancini	ANR	since Mar. 2011

Expert engineer

Grégory Morel	ANR	since Oct. 2011
Van Dan Nguyen	ADT INRIA	since Jan. 2011

PhD students

Leonardo Sampaio Rocha	CAPES/Brazil	since Oct. 2009
Issam Tahiri	CORDI/APRF	since Nov. 2009
Mikaila Toko Worou	CIFRE Orange labs	since Nov. 2009
Julio Araujo	MESR	since Dec. 2009
Remigiusz Modrzejewski	BDO Région/CNRS	since Nov. 2010
Ronan Pardo Soares	CORDI-S	since Dec. 2010
Aurélien Lancin	CORDI/FP7	since Jan. 2011
Sébastien Felix	CIFRE Orange labs	since Jan. 2011
Ana Karolinna Maia de Oliveira	CAPES/Brazil	since Sep. 2011
Alvinice Kodjo	BDE Région/3Roam	since Oct. 2011
Bi Li	BDO Région/INRIA	since Oct. 2011
Khoa Truong Phan	MESR	since Oct. 2011

Current position of former project-team members (including PhD students during the (2008-2011) period):

	MASCOTTE	Current position
Former PhD students		
Marie Asté	PhD 2007-2008	Teacher (Toulouse, France)
Christelle Caillouet-Molle	PhD 2006-2009	Assistant Prof. (UNS, MASCOTTE)
Nathann Cohen	PhD 2008-2011	Post-Doc (ULB, Belgium)
Philippe Giabbanelli	PhD 2010	PhD Biomedical Physiology (SFU, Canada)
Cristiana Gomes	PhD 2006-2009	Post-Doc (UFC, Brazil)
Florian Huc	PhD 2005-2008	Post-Doc (EPFL, Switzerland)
Dorian Mazauric	PhD 2008-2011	Post-Doc (U. Columbia, NY, USA)
Juan-Carlos Maureira Bravo	PhD 2008-2011	Post-Doc (Santiago, Chile)
Julian Monteiro	PhD 2007-2010	Founded a startup (Sao Paulo, Brazil)
Napoleão Nepomuceno	PhD 2007-2010	Assistant Prof. (UNIFOR, Brazil)
Brice Onfroy	PhD 2009-2010	Engineer (Avisto, Sophia Antipolis)
Jean-Paul Perez Seva	PhD 2006-2009	Software Engineer (Kontron, Toulon)
Patricio Reyes Valenzuela	PhD 2006-2009	Post-Doc (U. Carlos III, Madrid, Spain)
Judicael Ribault	PhD 2008-2011	Post-Doc (U. Carleton, Ottawa, Canada)
Ignasi Sau Valls	PhD 2006-2009	CR CNRS (LIRMM, Montpellier)
Former Post-doc and Engineers		
Janna Burman	Post-Doc 2010-2011	Post-Doc (LRI, France)
Frédéric Giroire	Post-Doc 2007-2008	CR CNRS MASCOTTE

Luc Hogie	Post-Doc 2008-2009	IR CNRS (I3S, Sophia Antipolis)
Dimitrios Michail	Post-Doc 2007-2008	Assistant Prof. (U. Athens, Greece)
Gianpiero Monaco	Post-Doc 2009-2010	Assistant Prof (U. L'Aquila, Italy)
Nicolas Nisse	Post-Doc 2008-2009	CR INRIA MASCOTTE
Fabrice Peix	Engineer 2004-2009	IR CNRS (Lab. GéoAzur, Sophia Antipolis)
Orestis Telelis	Post-Doc 2010	Research Assistant (U. Liverpool, UK)

Last INRIA enlistments

- Nicolas Nisse is CR2 INRIA since Sept. 2009, and CR1 INRIA since Dec. 2011.

Other comments:

Since March 2011, David Coudert is the scientific leader of MASCOTTE in replacement of Jean-Claude Bermond (Now Emeritus). Furthermore, Frédéric Havet is now the vice-head of MASCOTTE in replacement of David Coudert.

2 Work progress

2.1 Keywords

Tools: Algorithmics, Discrete mathematics, Graph theory, Combinatorial optimization, Simulation.

Applications: Network design and routing for telecommunication networks: backbone, wireless backhaul and mesh, overlay, peer-to-peer, and transportation networks.

Software: OSA, DRMSim, Grph

2.2 Context and overall goal of the project

MASCOTTE is a joint team between INRIA Sophia Antipolis - Méditerranée and the laboratory I3S (Informatique Signaux et Systèmes de Sophia Antipolis) which itself belongs to CNRS (Centre National de la Recherche Scientifique) and UNS (University Nice Sophia Antipolis). Its research fields are algorithmics, discrete mathematics (in particular graph theory), combinatorial optimization, and simulation, with applications to telecommunication networks.

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

The objectives of MASCOTTE are to design networks and communication algorithms. In order to meet these objectives, the team studies various theoretical tools, such as Discrete Mathematics, Graph Theory, or Algorithmics and develops applied techniques and tools, especially for Combinatorial Optimization and Computer Simulation. The theoretical results can be applied to various situations and technologies. In particular, MASCOTTE used in the last years both these theoretical and applied tools for the design and optimization of wired (WDM, SDH, MPLS, etc.), wireless (sensors, mesh, backhaul, etc.), and logical (peer-to-peer, etc.) networks.

This results also in the production of advanced softwares such as DRMSim (Dynamic routing models simulator), Grph (a graph optimization library), the MASCOPT library (MASCOTTE optimization), and ambitious software projects such as the OSA (Open Simulation Architecture) Computer Simulation Architecture.

All these researches have been 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, in the last four years, MASCOTTE has been involved in various European projects (IST FET CRESCCO, FP7 STREP EULER, and COST 293 Graal). MASCOTTE has official partnerships with, among others, Simon Fraser University, Vancouver (joint-team until 2009) and Ottawa (joint-team since 2011) in Canada, Fortaleza (joint-team 2009-2011) and Sao Paolo in Brazil, RWTH Aachen in Germany, Charles University in Prague, and Sun Yat-sen University in Taiwan. Furthermore, MASCOTTE has strengthen or started new collaborations with several industrial partners such as Alcatel-Lucent, Orange labs, and SMEs 3Roam, Avisto, and UbiStorage.

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/

2.3 Objectives for the evaluation period

2.3.1 Cut & Paste of the objectives of 2007

Based upon our analysis of the state-of-the-art research and industrial activities, we believe that our team could take part into major scientific and technological breakthrough in the application fields detailed hereafter.

Our ongoing research contracts give rise to a strong structure on our research which should keep what MASCOTTE is renowned for, being the engine of a virtuous cycle between applied networking problems, theoretical basic tools, and software development: we tackle networking problems with theoretical tools, the understanding of the former need improvement of the latest, even building new tools, that we validate with software, refine our models and identify new problems, and loop.

Our forthcoming research should be settled on the following items.

1. **Design and deployment of access networks:** new access network technologies yields specific optimization issues that have not been addressed when backbone net-

works were investigated in the last ten years. In particular, since the subject is the last miles to the user, the traffic is not groomed and there are no statistical effects that validate usual "average case hypothesis". One should be able to provide for efficient and survivable network design while the communication demand is uncertain with significant variance. There are huge lacks in the state-of-the-art combinatorial optimization theory for addressing such problems.

2. **Routing and network provisioning:** even though routing and network provisioning has been quite intensively studied, new issues are emerging where intensive research is required. In particular, dynamic routing and re-routing algorithms have to be developed: previously over-provisioned topologies are to be tightly provisioned: indeed the bandwidth consumption is continuously growing and would not stop, while former national monopolistic operators are being scattered into small atomistic operators which are not able to expand the network infrastructure. Another issue is the optimization of operating cost and energetic sustainability. New optimization strategies and algorithms are required for minimizing the energetic consumption of the networks.

3. **Modeling and simulation of virtual networks:** With the rise of the Peer-to-Peer applications, a new galaxy of *virtual* networks, dedicated to a particular service or application have emerged. These virtual networks introduce new kinds of demands and trafics on the underlying conventional networks. On one hand, new analytical and simulation models are needed to gain a better understanding of their impact on the underlying networks. On the other hand, such models are also needed in order to make commercial applications based on such virtual networks more robust, predictable and following, more competitive on a rapidly evolving international market. In parallel with this modeling effort, the reflexions about methodological issues in simulation, and more generally about empirical results obtained by means of software tools should be pursued.

4. **Programmable overlay networks:** in sync with the new INRIA strategic plan, we plan to study semantics and pragmatics of *self-organizing overlay networks*. In particular, we will focus on foundations of *pervasive, programmable overlay network computing systems* that are *universal* in the sense of Turing Machines, or *generic* as the von Neumann computer architecture is.

To achieve those objectives, we need to develop and adapt classical methods in graph theory. Finally we have a crucial need for software development engineers, especially for the development of the MASCOPT library and OSA architecture.

2.3.2 Evolution of the objectives during the evaluation period

Globally we have fulfilled the objectives announced in 2007. In particular we have kept the virtuous cycle described above with a balance between theoretical basic tools and applied networking problems with software developments. We have also pursued our international implication with two new strong collaborations with Brazil and Canada (Joint teams), and another with Taiwan (international ANR).

It is worth noting that our research is influenced by two parameters: the changes in staff and the contracts signed during the last four and a half years.

As example L. Liquori left MASCOTTE in January 2008 to create his own project, LogNet, and therefore the domain (4) he was leading on programmable overlay networks is not mentioned in this evaluation (it is central in LogNet's project where successful

results have been obtained). On the other hand, the arrival of F. Giroire reinforced the topic Peer-to-Peer Networks (domain 3) with in particular studies on data placement and streaming systems which were not planned in 2007.

Similarly, with the departure of H. Rivano in September 2009 to the CITI laboratory in Lyon, we put slightly less emphasis than planned on wireless mesh networks (with WiFi connections). However, during the last period, we obtained strong results on the gathering problem and its relaxed version (weighted routing problem). We also investigated with MAESTRO the call scheduling problem in presence of interferences, thanks to the co-supervision of a PhD student who agreed to work within the two teams using the tools of both projects. Furthermore, we considerably strengthened the collaboration initiated in 2007 (domain 1) with the SME 3Roam on microwave backhaul networks, a very interesting topic on which we obtained very nice results (1 thesis passed and 2 on-going, plus an industrial contract involving also the SME Avisto). We will continue to investigate this topic of backhaul networks with perspectives related to energy efficiency and the study of how to design and operate a backhaul network when sets of links are simultaneously experiencing a reduction of their capacities due to changes in the environmental conditions (e.g., rain).

Concerning domain(2), the new collaboration with Alcatel Lucent Bell Belgium (bilateral contract followed by the European STREP Euler) and the recruitment of N. Nisse made the domain of routing in complex networks become a central topic of MASCOTTE. We have to face the huge size of the considered networks and this leads to consider new algorithmics and structural properties of large graphs. Clearly, this topic still need to be developed with both theoretical algorithmics and simulation tools.

As we expected, minimizing the power consumption of networks, in particular backbone networks, became a hot topic and we contributed to it (with the ANR DIMAGREEN). Energy efficiency will remain one of our research domains in the COATI's project-team (in backbone networks as well as in the above-mentioned backhaul networks).

Simulation (domain 3) has remained an important topic in MASCOTTE. We have significantly contributed to new tools and models or developed new ones when necessary. We also fulfilled our objectives by contributing methodological advances through the Open Simulation Architecture, by completing 2 PhD theses, by obtaining new contracts, and by setting up a strong collaboration with University of Carleton in Ottawa (EA DISSIMINET). In the future, this topic will be transferred in the OASIS project-team where O. Dalle is moving.

Finally, MASCOTTE has pursued his research in Discrete Mathematics (mainly graph theory) with the proof of longstanding conjectures and new emphasis on exponential and fixed parameterized algorithms (ANR AGAPE). On this topic, COATI intends to remain a leader in France and to continue having a strong international impact.

2.4 Objective i : Backbone and broadband network

2.4.1 Personnel

Permanent researchers: Jean-Claude Bermond, David Coudert, Frédéric Giroire, Joanna Moulierac, Nicolas Nisse, Stéphane Pérennes, Hervé Rivano.
Post-docs: Gianpiero Monaco, Fabrice Peix
PhD students: Nathann Cohen, Florian Huc, Dorian Mazauric, Napoleão Nepomuceno, Brice Onfroy, Ignasi Sau Valls, Issam Tahiri.

2.4.2 Project-team positioning

Network design is a very wide subject which concerns all kinds of networks. In telecommunications, networks can be either physical (backbone, access, wireless, ...) or virtual (logical). 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.

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, in particular our partners in European contracts (see Section 2.4.4).

Outside Europe, many teams have similar approaches and sometimes we have direct collaborations with them: Vancouver (EA RESEAUXCOM), Montreal, Fortaleza (EA EWIN),... It is worth noting that on some specific problems (e.g. traffic grooming), MASCOTTE is considered as one of the leader teams in the world.

2.4.3 Scientific achievements

Traffic grooming. In a WDM network, each connection request is assigned a lightpath (i.e., a route in the physical network and a wavelength). When each request uses at most $1/C$ of the bandwidth of a wavelength, C requests can be assigned the same wavelength on a given link. C is called the *grooming factor*. In this setting, we aim at minimizing either the number of wavelengths (related to the transmission cost) or the number of Add/Drop Multiplexers (ADM) used in the network (related to the cost of the nodes).

During the evaluation period, we established the first non-approximability result on traffic grooming using a study of the smallest degree-constrained subgraph problem [J27, Ci137, Ci138]. Using tools of graph and design theory, we have proposed approximate constructions for all-to-all traffic on unidirectional rings for any value of C [J4], on bidirectional rings for $C = 2, 3$ [J79], and provided a $O(n^{1/3} \log^2 n)$-approximation algorithm for general traffic on ring and path networks. We have also proposed an *a priori* placement of ADMs in unidirectional WDM rings allowing to satisfy any set of requests with bounded degree d [Ci189, Ci155]. We then optimally solved the problem for all-to-all traffic on bidirectional rings when $C = 1, 2, 3$ and $C = k(k+1)/2$ $(k \geq 1)$ for infinite

congruence classes [J79], and on unidirectional rings with the extra constraints that the traffic between a subset of vertices must be served with grooming factor C' [J53]. Moreover, we studied on-line traffic grooming on the path [R295], proposed a 4-approximation algorithm for general instances on the path for a variant of the problem [Ci177], and proposed a new framework, based on linear programming with column generation, for shared segment protection in WDM networks with grooming capability [Ci217, Ci250]. Finally, we contributed to a large survey on traffic grooming [Ch129].

A related problem is the optimization of the number of labels used to forward packets in GMPLS networks, in particular when using the All-Optical Label Switching (AOLS) technology where each label involves a specific device. We proved that the minimization problem is NP-hard and APX-hard when using *label-stacking* techniques, and proposed approximation and dynamic programming algorithms [J107, Ci163, Ci164]. We also considered *label-stripping* techniques and proposed a heuristic algorithm performing tradeoffs between the stack size and the waste of bandwidth [Ci201].

Reconfiguration in WDM networks. In production networks, traffic evolution, failures and maintenance operations force to adapt regularly the current configuration of the network (virtual topology, routing of connections). The routing reconfiguration problem in WDM networks consists of scheduling the *migration* of established lightpaths from current routing to a new pre-computed one while minimizing service disruptions. We have shown in the past the relations between this problem and the *graph searching problem* (see Section 2.8) and established NP-completeness and inapproximability results.

During the evaluation period, we have studied the necessary trade-offs between the total and simultaneous numbers of service disruptions that occurs during the reconfiguration process [J84, Ci208, Cn266, T346], investigated the problem with the extra constraints that some connections should never be interrupted (particular service level agreement), and proposed heuristic algorithms [Ci171, Cn261]. We have also started investigating the influence of physical layer impairment constraints on the reconfiguration problem [Cn272]. Last, we have extended our investigation to networks with shared bandwidth (e.g., GMPLS), proving that the reconfiguration problem becomes even harder [Ci172].

This work has motivated several theoretical studies in graph searching [J84, J87, J102] (see Section 2.8).

Green networking. The minimization of ICT energy consumption has become a priority with the recent increase of energy cost and the new sensibility of the public, governments and corporations towards energy consumption. ICT alone is responsible of 2% to 10% (depending on the estimations) of the world power consumption. For example, it is estimated that switches, hubs and routers account for 6 TWh per year in the US.

Several studies exhibit that the traffic load of the routers has only a small influence on their energy consumption. Hence, the power consumption relies on the number of active network elements (e.g., interfaces, line cards, base chassis, etc.). We proposed a modeling of the problem of minimizing the (weighted) number of active network elements ensuring the routing of the traffic, proved that it is not in APX (i.e., there is no polynomial-time constant-factor approximation scheme), and proposed heuristics. We formally studied the problem on specific topologies such as trees and complete graphs, providing bounds that can be exploited for real topologies. We also investigated trade-offs between the energy consumption and the stretch of the routing, as well as the impact on some protection mechanisms [Ci212, Cn276, T346].

As a use case, we investigated further potential energy savings in fixed broadband wireless networks by selectively turning off idle communication devices in low-demand scenarios [Ci234, Cn275, T343]. Experimental validation is scheduled with SME 3Roam

and Orange Labs.

Other topics We have also investigated several problems related to routing (see Section 2.8), survivability, etc. In particular, we have proposed: a $(1+\frac{5}{3}\varepsilon) \simeq 1.61$-approximation algorithm for the path-coloring problem in bounded-degree trees [J57]; an IP multicast aggregation schemes to optimize bandwidth usage [J3], and proposed the Xcast6 Treemap Island [R311] to overcome the scaling limitations of existing IP multicast protocols; mathematical models for optimizing routing reliability in networks with *shared risk link groups* [Ci142]; methods for determining survivable routing in multi-layer networks taking into account operational constraints [P288, P289] (patents); new algorithms ensuring traveling time with a certain accuracy in time-dependent graphs [Ci243]. Last, we analyzed traffic traces collected on an enterprise VPN to model the behavior of end-users in different environments [Ci144, Ci162, P288, P289] and to detect botnets [Ci180, P287].

2.4.4 Collaborations

We had strong collaborations with many academic partners: ASU, Tempe, USA; Concordia U., Montréal, Canada; McGill U., Montréal, Canada; UPC Barcelone, Spain; Weissmann Inst., Rehovot, Israel; SFU, Vancouver, Canada; Univ. of Patras and CTI, Greece; and others. We also collaborate with companies: Orange labs, Alcatel-Lucent Bell labs, and SME 3Roam.

2.4.5 External support

National: ANR JCJC OSERA, Color LARECO, ANR JCJC DIMAGREEN
European: IST FET AEOLUS, COST 293 Graal, PHC PROCOPE with RWTH Aachen
International: EA RESEAUXCOM with SFU Vancouver, EA EWIN with Fortaleza
Industrial: CRC CORSO 2 with Orange labs, ADR HiMa with Alcatel-Lucent.

2.4.6 Self assessment

\+ Joint publications with researchers from many different labs and countries;

\+ Successful collaboration with SME 3Roam on the design and management of fixed wireless backhaul networks (3 PhDs, one defended in 2010);

+/- Collaboration with Alcatel-Lucent on the dynamic evolution of the virtual topology and its reconfiguration in the context of the joint lab INRIA/Alcatel-Lucent. The work slowed down after the involved PhD student stopped his PhD.

\+ Collaboration with Orange labs at Sophia Antipolis on power-consumption measurement of various devices on an experimental network. We have also 2 joint PhD with a CIFRE contract;

\+ Patents with Intel research [P287] and Sprint labs [P288, P289];

\- We obtained less results than expected on survivability.

In the future, we will continue our research activity on the design and management of backbone and broadband networks with emphasis on the design of networks topology and adaptive routing mechanisms allowing to optimize the usage of networks resources and to realize acceptable trade-offs with the energy consumption. We will conduct both fundamental research to develop appropriate tools and methodology, and experimental research in collaboration with industrial partners.

2.5 Objective ii : Wireless networks

2.5.1 Personnel

Permanent researchers: Jean-Claude Bermond, Christelle Caillouet-Molle, David Coudert, Afonso Ferreira, Jérôme Galtier, Frédéric Giroire, Luc Hogie, Joanna Moulierac, Nicolas Nisse, Stéphane Pérennes, Hervé Rivano;
Post-docs: Fabrice Peix;
PhD students: Nathann Cohen, Cristiana Gomes, Florian Huc, Dorian Mazauric, Julian Monteiro, Juan-Carlos Maureira Bravo, Napoleão Nepomuceno, Ronan Pardo Soares, Patricio Reyes Valenzuela, Issam Tahiri.

2.5.2 Project-team positioning

In the last years, MASCOTTE has conducted a research effort on wireless access networks, from mesh (or multi-hop cellular) networks to ad-hoc and sensor networks. Considering this field, MASCOTTE has been involved in international and national collaborations with academic and industrial partners, as mentioned below.

Using combinatorial optimization and centralized algorithmic with a network design flavor, fast data gathering, call scheduling, transport capacity and energy consumption of the networks have been studied. Using distributed algorithmic with a protocol flavor, fast data gathering and call scheduling are investigated. Our approach is complementary with the network protocol designer and information theory analyst points of view developed in other INRIA project-teams such as PLANETE, MAESTRO, SWING (ex ARES), or POPS. The complementarity has been exploited through an ARC collaboration with ARES and POPS, a joint Ph.D. between MAESTRO and MASCOTTE [T346], through an ANR VERSO project ECOSCELLS in which MAESTRO, MASCOTTE, and SWING are involved, and through regular collaborations with 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, RWTH Aachen in Germany, Universities of Roma or Salerno in Italy, the Technion Institute in Israël, SFU in Vancouver, Canada, Arizona State University in USA, UFC Universidade Federal do Ceará, Fortaleza in Brazil, or the University of São Paulo in Brazil.

We studied a wide range of issues of wireless networks, from the design of efficient cross-layer medium access, call scheduling and routing techniques to energy efficient optimization. We developed theoretical tools for integrating dynamic characteristics of the networks in the optimization models, and analyzing and evaluating dynamic networks. Several other topics that are related to wireless networks have been investigated in the last years in MASCOTTE. More detailed information can be found in the last activity reports or in other sections of this report. In particular, some graph coloring problems have been motivated by channel assignment in wireless networks, and this topic encourages the development of optimization techniques and wireless simulation tools.

2.5.3 Scientific achievements

Backhaul networks. We have investigated network optimization problems related to the design and configuration of fixed wireless microwave backhaul - the portion of the network infrastructure that provides interconnectivity between the access and the core networks. We have presented mathematical models to generate power-efficient radio configurations as a function of the network traffic [J61, Ci173, Cn262]. We also concentrated

on conceiving reliable fixed broadband wireless networks under outage probability constraints, using a chance-constrained programming approach [Ci232, Ci233]. In addition, in collaboration with the SME 3Roam, we have developed an optimization tool, 3Link, for helping the design of microwave links [T343].

Wireless mesh networks. We addressed the problem of computing the transport capacity of wireless mesh networks dedicated to Internet access [T338, J70]. A fundamental issue of wireless mesh networks is to gather data packets at one or several gateways, taking radio interferences into account [Cn252]. We investigated a relaxation of the scheduling, called the round weighting problem, and provided linear models, hardness study and approximation algorithms for maximizing the transport capacity of the network [J16, Ci145, Ci153, Cn256, Cp278]. We gave exact or almost exact bounds for the same problem in the specific case of regular grids [Cn253]. In [J82, Ci152, Ci206, Cn255], a more sophisticated linear model is proposed, transforming the maximum flow problem into a minimum cut problem using duality theory. Minimizing the size of routers queues while ensuring a fair bandwidth allocation motivated the introduction and study of a new combinatorial problem, the proportional coloring [Ci149]. [J71, Ci193, Cn257] are dedicated to a specific work about the impact of the MAC layer type on the capacity of wireless mesh networks. We have now started developing a robust optimization model to deal with the dynamic features of the network [Cn273]; in other words, we are considering uncertainty of traffic demand.

Protocols. Several works of MASCOTTE deal with gathering (data collection) in wireless multi-hop networks when interferences constraints are present. The goal is to find the minimum number of rounds needed to achieve such a gathering and design algorithms achieving this minimum. We gave algorithms and lower bounds on several topologies like paths [J28], trees with and without buffering in intermediate nodes [J54, J56, Ci140, Ci141], grids [Ci165, Cn260], and general graphs [Ci229]. [T340, Ci229] concerned the general study of the algorithmic and the complexity of the gathering problem in radio networks and wireless sensor networks. We also considered the use of mobile sinks in a wireless sensor network and studied the trade-off between energy consumption and delay of data collection [Ci230, Cn274].

Computing an optimal distributed call scheduling with local information in wireless networks is a challenging problem to tackle, even when interferences are not considered. The goal is to ensure the stability of the queueing system, bounding the average number of awaiting messages in the network assuming random arrivals [R290]. We designed the first fully distributed local algorithm with the following properties: it works for any arbitrary binary interference model; it has a constant number of mini-slots of control (independent of the size of the network and the values of the queues); and it needs no knowledge [Ci249]. We also studied the stability of a localized algorithm for routing packets between undifferentiated sources and sinks in a network modeled by a multigraph [Ci205]. [Cn259] considered a weaker stability objective, but coped with interferences.

Energy Awareness. One of the main problems investigated in the settings of wireless communication is to minimize the energy consumption of the devices. In fixed broadband wireless networks, we investigated the problem of determining feasible radio configurations focusing on power efficiency [Ci173], and by selectively turning off idle communication devices in low-demand scenarios [Ci234, Cn275]. In wireless sensor networks, we performed a scalability analysis over a novel integer programming model devoted to optimize power consumption efficiency [Ci135]. [Ci200] focuses on the energy consumption of ad-hoc and

sensor networks through the viewpoint of congestion. Congestion not only causes packet loss and increases queueing delay, but also leads to unnecessary energy consumption.

Other topics. Broadcasting across delay tolerant networks [Ci147], maximizing the number of nodes reached, minimizing the duration of the process, and minimizing the bandwidth utilized. We analyzed the applicability of the evolving graph theory in the construction of efficient routing protocols in realistic scenarios. Using the NS2 network simulator to first implement an evolving graph based routing protocol, we then use it as a benchmark when comparing the four major ad-hoc routing protocols (AODV, DSR, OLSR and DSDV) [J66, Ci154]. Moreover, we investigated the class of distributed storage systems whose content may evolve over time [Ci158].

Using linear programming, we have also provided mathematical models to reach an optimal and fair solution of the rate allocation problem for downlink in a Multi-hop Cellular Network [Ci182], and to compute upper and lower bounds on the capacity of a CSMA-CA based network according to a physical topology and a given routing protocol [J72].

We have additionally investigated on the feasibility of providing network connectivity to vehicles over a predefined trajectory (trains, metros, urban buses, etc.) [T345, Ci190]. We introduced a new system that allows fast handover between an on-board, fast moving IEEE 802.11 device and a series of 802.11 Access Points regularly placed along the road or track.

2.5.4 Collaborations

This topic has enhanced fruitful collaborations with national and international partners. In France, we have collaborated with other INRIA teams: MAESTRO (Sophia Antipolis), POPS (Lille), and SWING (Lyon). We also had strong collaboration with international researchers from Italy (Universities of Roma and Salerno), Germany (RWTH Aachen), USA (Columbia University), Canada (SFU Vancouver), and Brazil (UFC Universidade Federal do Ceará in Fortaleza, and University of São Paulo).

2.5.5 External support

National: ARC CARMA, ANR DIMAGREEN, ECOSCELLS, and OSERA
European: IST/FET AEOLUS, PHC Procope (with RWTH Aachen)
International: *Equipe associée* RESEAUX-COM
Industrial: CRC CORSO 2 with France Telecom, APRF RAISOM with SMEs 3Roam and AVISTO

2.5.6 Self assessment

\+ Strong cooperation with the SME 3ROAM on backhaul access microwave networks (PhDs, contracts);

\+ Nice results on mesh radio networks (capacity evaluation, gathering, weighted routing problem, ...);

+/− Departure of H. Rivano who contributed to the topic, but this leads to a collaboration with SWING in Lyon;

\+ Collaboration with MAESTRO (1 joint PhD);

− The call scheduling problem is not completely solved (we hope to obtain strong results in the future).

2.6 Objective iii : P2P and overlay networks

2.6.1 Personnel

Permanent researchers: Jean-Claude Bermond, Olivier Dalle, Afonso Ferreira, Frédéric Giroire, Stéphane Pérennes
Post-doc: Yaning Liu
PhD students: Julio Araújo, Dorian Mazauric, Julian Monteiro, Remigiusz Modrzejewski

2.6.2 Project-team positioning

Traditional means to store data are dedicated servers or magnetic tapes. These solutions are reliable but expensive. Recently, hard disks and bandwidth have become cheaper and widely available, allowing new forms of data storage on distributed, peer-to-peer (P2P) architectures. To achieve high durability, these P2P systems encode the user data in a set of redundant fragments and distribute them among the peers. These systems are cheap to operate, but their highly distributed nature raises questions about reliability, durability, availability, confidentiality, and routing of the data. An abundant literature exists on the topic of P2P storage systems. Several efforts to build large-scale self-managing distributed systems have been done, among others, Intermemory, Ocean Store, Freenet, PASTRY, CFS, Total Recall. However, few analytical models have been proposed to estimate the behavior of the system (the data durability, resource usage, e.g., bandwidth) and understand the trade-offs between the system parameters. Furthermore, in almost all these models, the behavior of a single block is modeled and the block failures are considered to be independent. We showed that this assumption can lead to severe errors of estimation on the behavior of a system subject to peer failures [Ci174]. Therefore the need of new more complex analytical models to describe the systems.

Several international teams work on storage systems as well as teams at INRIA, mainly ASAP in Rennes and MAESTRO in Sophia. MASCOTTE is one of the rare team working on all aspects of such systems from experiments with real code to fluid models for large systems. We collaborated with the startup UbiStorage and the University of Amiens inside the Spreads ANR to provide them with models of storage systems and to do experimentations with their code. We are participating in a discussion group on distributed storage systems with Technicolor, Eurecom, Polytechnico di Torino (Workshop in September 2011 in Technicolor Rennes).

2.6.3 Scientific achievements

Performance Analysis In P2P storage systems, peers fail continuously, hence, the necessity of self-repairing mechanisms to achieve high durability. In [T342, Ci213, Cn269], we propose and study analytical models that assess the bandwidth consumption and the probability to lose data of storage systems that use erasure coded redundancy. We show by simulations that the classical stochastic approach found in the literature, that models each block independently, gives a correct approximation of the system average behavior, but fails to capture its variations over time. These variations are caused by the simultaneous loss of multiple data blocks that results from a peer failing (or leaving the system). We then propose in [Ci174, Cn263] a new stochastic model based on a fluid approximation that better captures the system behavior. In addition to its mean, it gives a correct estimation of its standard deviation. In [R308], we assess the speed of the reconstruction process of P2P storage systems. We propose a new analytical framework, based on queuing models, to estimate the repair time and the probability of data loss. This model takes into account

the correlation of concurrent repairs. The models are validated by mathematical analysis and experimentation using the Grid'5000 test-bed platform.

Data Placement In [R296, Ci181, Ci213], we study the impact of different data placement strategies on the system performance when using erasure codes redundancy schemes. We compare three policies: two of them local, in which the data are stored in logical neighbors, and the other one global, in which the data are spread randomly in the whole system. We focus on the study of the probability to lose a data block and the bandwidth consumption to maintain enough redundancy. We provide mathematical analysis in [Ci207, Cn265, Ci213]. Finally, we propose a new external reconstruction strategy and a suitable degree of locality that could be introduced in order to combine the efficiency of the global policy with the practical advantages of a local placement.

In collaboration with MAESTRO, we consider this data placement problem as a graph design problem. In [R304], we show that there exists an optimal placement policy minimizing the variations of the network bandwidth if and only if a "well balanced" design exists. The existence of well balanced designs is a difficult problem as it contains as subproblem the existence of Steiner systems. We provided constructions solving the problem for some system parameters.

Codes Distributed or peer-to-peer storage solutions rely on the introduction of redundant data to be fault-tolerant and to achieve high reliability. Recently, the Regenerating Codes were proposed as an improvement over classical replication and erasure codes to introduce redundancy. These codes make a better use of the available bandwidth when reconstructing the missing information. In [Ci223], we propose a new code based on a hybrid approach, Double Coding, and compare it to existing codes from the point of view of availability, durability and storage space.

Streaming Systems We also considered an other family of P2P systems, namely systems for video streaming. P2P videos amount for a significant amount of the overall Internet traffic. We tried to lower the impact of P2P videos on operator backbones. In [J110], we introduced a network-friendly zapping system for P2P IPTV. In [Ci244], we study time-shifted streaming (or catch-up TV) which allows viewers to watch their TV programs within an expanded time window. We propose a new system based on a multiple-interval graph model which reduces the traffic at the server side.

2.6.4 Collaborations

We had strong collaboration with EPI MAESTRO and SME UbiStorage on P2P storage. In particular, we used company's code to carry out experimentation on the Grid 5000 platform which allowed us to validate the assumptions of our mathematical models. We also had a fruitful collaboration with Telecom Bretagne (Brest) and Technicolor (Rennes) on P2P streaming.

2.6.5 External support

National: ANR SPREADS, ANR USS-SimGrid
European: IST FET AEOLUS

2.6.6 Self assessment

+ Study of a new topic in Mascotte: building an efficient distributed storage system.
+ To tackle the problem, we combined mathematical analysis, simulations, and experimentations.
+ Active collaboration with a startup, UbiStorage
− Study of systems that in practice did not really catch on. There exist lots of experimental systems, but very few are really working in practice (maybe Wuala, but it is not purely P2P).

We are currently trying to adapt methods and analysis used for storage systems to several other domains, e.g. P2P live streaming, Video-on-demand and more recent problematics as Content Delivery Networks (CDNs). We are also actually developing new methods to design energy efficient distributed systems by combining our two different kind of expertise in energy efficient networks and in distributed systems.

2.7 Objective iv : Simulation and optimization tools

2.7.1 Personnel

Permanent researchers: Olivier Dalle, Luc Hogie, Michel Syska;
Post-docs: Emilio Mancini, Fabrice Peix;
PhD students: Aurélien Lancin, Juan-Carlos Maureira Bravo, Julian Monteiro, Judicael Ribault, Issam Tahiri.

2.7.2 Project-team positioning

Research on network design, protocols and communication issues extensively (but not only) relies on both simulation experiments and implementation of combinatorial optimization algorithms. Since MASCOTTE aims at addressing challenging problems, the existing tools for tackling these problems are often inexistent or insufficient. Concerning simulation, there are mainly two reasons for which existing tools happen not to be sufficient: the size of the problem being addressed, or the lack of proper simulation models. As far as combinatorial network optimization is concerned, the existing MASCOPT library allowing simple implementation of linear programs or algorithms still appears to be a unique free java library.

With respect to the size of the problem, the challenging problems addressed in MASCOTTE include large Peer-to-Peer networks having millions of Peer nodes, large wireless (IEEE 802.11) networks having several thousands of WiFi access points, routing protocol simulations in large IP networks and large sensor networks. With respect to the simulation models, even though some simulators may prove to be usable for a particular study, they often lack sufficiently detailed models.

Aside these research and development efforts on applied simulation techniques, the team had a significant involvement on fundamental research in simulation. This involvement is motivated for two reasons: first, the simulation tools and techniques are continuously evolving and solving new challenging networking problems requires to solve equally challenging issues in simulation. Second, as emphasized in the perspectives of our last evaluation period, the methodology and practices in networking simulation still need to be improved, especially in terms of reproducibility and traceability of simulation results. Hence, MASCOTTE is actively involved in projects and research in this area, in particular through the OSA (Open Simulation Architecture) software project (see 3.2.3 software, page 30) and the DISSIMINET Associated Team (further described below).

2.7.3 Scientific achievements

Fundamental research on simulation – Many issues need to be addressed in order to improve the methodology and practises when conducting research studies based on computer simulations. In [Ci157], we show that the combined use Aspect Oriented Programming and Architecture Description Languages can help to build new patterns of reuse in the definition of simulation scenarios. This layered approach allow for the definition of more sophisticated scenarios while still ensuring the reuse without change of existing (and validated) simulation code. In the context of the BROCCOLI Collaborative Action, we applied similar programming and software engineering techniques to produce an advanced Instrumentation Framework for simulations called OSIF [Ci219]. Following our success in these two dimensions of the simulation methodology, the layering technique have been generalized to all aspects of OSA which lead to a new layered design that is not found in any other simulation architecture. We also investigated the possibility of porting the

concept of shared component found in the Fractal Component Model to the DEVS simulation formalism [Ci143]. In order for the new suggested practices to reach practictioners, some communication efforts have been done, like we did in [J62, J91, J92].

Simulation of very large scale systems: the P2P case – The research works lead in MASCOTTE on peer-to-peer systems, especially in the context of the SPREADS ANR project, have raised challenging technical issues in terms of simulation. When the SPREADS ANR project started, in 2007, existing simulators available from the research community were either limited to simulations of a few thousands of realistic peer nodes, or to hundreds of thousands of simplistic nodes. Our major achievement was to provide tools and solutions for simulating very large scale P2P systems, using realistic models. This research problem was addressed both in the BROCCOLI ARC project, in the SPREADS ANR project, and in the AEOLUS FET project. The results are a parallel version of the OSA platform that can run on thousands of computing nodes on a grid computing facility such as Grid5K. Scalability experiences demonstrated that the simulator is able to scale up (at least) to 500K peers [T347], which represents several millions of Fractal Components (one of the largest Fractal-based application ever deployed). Although still unpublished, promising simulation experiments where conducted using the actual code used for the peers in production by the UbiStorage SME. As part of the ANR USS-SIMGRID project, we developed a toolchain for modeling P2P systems within the SimGrid platform [Ci245] and monitoring tools to characterize and build models of the workloads in large distributed computing platforms [Ci235].

Contributions to new or existing simulation software tools – Beside the OSA platform [Cp283], we also pay a particular attention to the design and software engineering of simulation tools in general [Ci185]. We also made significant contributions to existing simulators such as Omnet++ [Ci190, Ci191]. In [Ci220], for example, we extended the Omnet++ INET Framework with the capability of modeling directional and asymmetrical wireless antennas.

We also developed new simulators for specific needs. Dynamic Routing Model Simulator (DRMSim [Ci216]), addresses the specific problem of large-scale simulations of (inter-domain) routing models on large networks. DRMSim is a discrete-event simulator that comes with a generic routing models and implementations of BGP as well as of State-of-the-Art compact routing protocols. MANETs have also been studied using simulations: mobility issues have been studied in [Cp281, Cp282] and routing protocols for MANETs with known connectivity patterns using evolving graphs in [J66].

Combinatorial network optimization – The MASCOPT library has reached maturity and is intensively used inside the team and with partners for testing and evaluation of optimization programs. During the last period, the following research has been validated by implementing the algorithm with MASCOPT. In [T338] several algorithms on the optimization of the capacity of wireless mesh networks have been implemented and tested. In [Ci193], the study of the effects of the acknowledgment traffic on the capacity of wireless mesh networks has been modeled in a linear programming formulation. The implementation in MASCOPT was solved using the column generation process.

Within the cadre of the AGAPE ANR project, J-F. Lalande and V. Levorato (LIFO) have implemented some exponential or parameterized graph algorithms such as the chromatic number, the maximum independent set problem, the minimum directed feedback vertex set, the minimum vertex cover or the minimal ab-separators.

2.7.4 Collaborations

International collaborations: University of Rostock (Germany), University of Carleton, Ottawa (Canada), University of Arizona (USA).
National collaborations: UbiquitousStorage (SME), INRIA EPI ADAM (Lille), Institut Telecom Evry (ACMES), LIRMM AlGCo and LIFO.

2.7.5 External support

National: ANR AGAPE, ARC BROCCOLI, ANR OSERA, and ANR SPREADS, ANR USS-SIMGRID
International: *Equipe associée* DISSIMINET
Industrial: APRF RAISOM with SMEs 3Roam and AVISTO.

2.7.6 Self assessment

+ Joint publications with researchers from Carleton University (Canada), University of Arizona (USA), University of Rostock (Germany);

+ Successful collaboration with the SME UbiStorage on the design implementation of simulations of their actual Peer-to-peer backup system;

+ International recognition through active participation in collective publications and standardization efforts (about the DEVS formalism), guest editorship of multiple Special Issues of Journals and international conference organization involvement;

– Limited actual interactions between the fundamental research on simulation and the other MASCOTTE research topics;

– With the leave of Fabrice Peix, the development and distribution of MASCOPT has been limited;

+ The ANR AGAPE has relaunched the interest for MASCOPT;

– The lack of performances (which was intentionally ignored in the initial design of the library) penalizes the use of MASCOPT for the new research interests in the team;

+ A lot of the design and interfaces of MASCOPT are reused in the development of the new software being developed in MASCOTTE.

In the future, we will continue to use simulations as a privileged tool for supporting our studies, but the fundamental research effort on simulation will be stopped within MASCOTTE and transferred to another EPI where it find tighter interactions. The development of MASCOPT will be pursued but with focus on the linear programming interface part.

2.8 Objective v : Algorithms

2.8.1 Personnel

Permanent researchers: David Coudert, Afonso Ferreira, Jérôme Galtier, Frédéric Giroire, Frédéric Havet, Nicolas Nisse, Stéphane Pérennes, Bruce Reed, Hervé Rivano;
Post-docs: Janna Burman, Gianlorenzo D'Angelo, Frantisek Kardos, Gianpiero Monaco;
PhD students: Julio Araújo, Nathann Cohen, Philippe Giabbanelli, Florian Huc, Dorian Mazauric, Ronan Pardo Soares, Jean-Paul Perez Seva, Leonardo Sampaio Rocha, Ignasi Sau Valls.

2.8.2 Project-team positioning

In the last years, MASCOTTE has conducted an intense research effort on the algorithmic aspects of graph theory. We are mainly interested in understanding how structural properties of networks can lead to the design of efficient algorithms. In general we try to find the most efficient algorithms, either exact algorithms or approximation ones, to solve various problems of graph theory, often with applications in telecommunication networks. We are involved in many international and national collaborations with academic and industrial partners

We mainly focus on three topics: parameterized complexity, distributed algorithm and pursuit-evasion.

- Parameterized complexity is a recent approach to deal with intractable computational problems having some parameters that can be relatively small with respect to the input size. This area has been developed extensively during the last decade and new techniques have been developed (bidimensionality, kernelization, graph minors theory). We design FPT algorithms for various problems of graph theory and contribute developing these new methods.

- In complex (large-scale) networks like the Internet or social networks, the size and the dynamicity are difficult problems to be handled. On way is to propose distributed and/or fault tolerant (or even self-stabilizing) algorithms. We consider problems that involve mobile agents in distributed environment. We also investigate the power of a communication model using only localized information.

- During last decade, an intense research effort has been dedicated to the pursuit-evasion problems, where a team of *cops* must capture a fugitive in a graph. We are strongly involved in this area that finds motivations through its relationship with graph decompositions and has implications in optical network reconfiguration (see Section 2.4).

2.8.3 Scientific achievements

Algorithmic of graphs. Most of graph problems that we consider are NP-hard and most of them are even hard to approximate. Hence, to solve them efficiently, we aim at designing general exponential-time algorithms as well as polynomial-time algorithms for special classes. For decision problems with input size n and parameter k (generally this parameter represents a structural property of the input graph), one goal of parameterized complexity theory is to design an algorithm with running time $f(k)P(n)$, where$f$ is a

super-polynomial (very often exponential) function in k and P a polynomial in n. Problems having such an algorithm are said to be fixed-parameter tractable (FPT).

We consider several problems related to the disjoint-paths problem that asks whether there exist pairwise-disjoint paths to be assigned to all requests. For instance, given k pairs of vertices $\{(s_i, t_i)\}_{i \leq k}$ (i.e., k requests) in an n-node graph, the disjoint-path packing aims at finding a set of paths P_i from s_i to t_i, $i \leq k$, such that each vertex is in at most two of these paths. We propose a $O(n \log n)$-time algorithm for this problem for fixed k [Ci150], improving a result of Kleinberg. In [J43, Ci187], we consider the disjoint-paths problem with parity constraint on the length of the paths. In [J41], we propose a polynomial-time algorithm that, given ℓ requests, finds ℓ disjoint paths in a symmetric directed graph. This generalizes the result in the case of undirected graph [Robertson and Seymour, 1995], while the case of directed graph is known to be NP-hard for $\ell \geq 2$ [Fortune et al. 1980].

We also consider a general class of problems that consists in finding some particular subgraph H or minor in a weighted graph G. We present various algorithms for this problem depending on the structure of the host graph G and of what must be optimized in H (e.g., maximum number of edges, etc.). For instance, in [T341, Ci199], we present subexponential parameterized algorithms on planar graphs for finding largest subgraph with bounded maximum degree. In this works, we use bidimensionality theory to obtain combinatorial bounds, combined with dynamic programming techniques over a branch decomposition of the input graph.

We design efficient algorithms for many other graph problems such as coloring (see Section 2.9), path vertex problem, hull number, etc.

Sage (implementations). Sage (see `http://www.sagemath.org`) is a free open-source mathematics software system licensed under the GPL. Sage aims to provide to mathematicians, researchers, and students the tools they need to perform calculations. The members of MASCOTTE implicated in the Sage project have already contributed to more than 100 graph algorithms; they have also added bridges to some linear-programming solvers, and actively contributed to the improvement of the documentation [Ch127, Ch128].

Distributed Algorithms. We investigated algorithmic problems arising in complex networks like the Internet, social networks or mobile sensor networks. In any distributed communication network it is important to deliver quickly messages between pairs of nodes. We consider the key problem of computing and updating small routing tables. E.g., in [Ci195], we present a compact routing scheme that achieves a constant stretch in a particular class of graphs. This algorithm has been implemented using DRMSim (Sec. 3.2.2).

We study various models of distributed computing via the paradigm of mobile agents [Ci204, Ci226, Ci239]. We also study the power of a communication model using only localized information. In [Ci228], we have investigated the question of determining which graph properties can or cannot be computed using only local information.

Pursuit-evasion games. Pursuit-evasion encompasses a wide variety of combinatorial problems related to the capture of a fugitive residing in a network by a team of searchers. The goal consists in minimizing the number of searchers required to capture the fugitive in a network and in computing the corresponding capture strategy. We investigated several variants of these games because, on one hand they provide an algorithmic way to understand structural properties of graphs, and, on the other hand, they are related to various applications in telecommunication networks. For instance, we introduce and study a generalized variant of graph searching that leads to a unified view of graph decompositions [J26], generalizing some results of the Graph Minors theory. A surprising application

of "Cops-and-Robber"-like games is the problem for a web-browser to download documents in advance while an internaut is surfing on the Web [R307].

2.8.4 Collaborations

The works described in this section have been done in collaboration with more than 80 partners from french or foreign labs from more than 10 countries. In France, we have strong collaborations with researchers from Bordeaux (LaBRI), Marseille (LIF), Montpellier (LIRMM), Orléans (LIFO), Orsay (LRI), Paris (LIAFA), etc. We also have strong collaboration with Canada (McGill, Simon Fraser University), Brazil (Fortaleza), Chile (Universidad de Chili, Univ. Adolfo Ibañez, Santiago), Czech Republic (Charles University, Prague), Denmark (Univ. of Southern Denmark, Odense), Greece (Athens, Patras), Italy (L'aquila), Israel (Technion), Norway (Univ. of Bergen), Slovakia, etc.

2.8.5 External support

National: ANR AGAPE, ANR JCJC DIMAGREEN
European: IST FET AEOLUS, COST 293 Graal, FP7 EULER
International: EA EWIN (UFC Fortaleza)
Industrial: CRC CORSO 2 with Orange labs, DCR with Alcatel-Lucent Belgium, Cifre Orange Labs Sophia antipolis

2.8.6 Self assessment

+ joint publications (27 journals and 27 international conferences) with researchers from more than 10 countries;

+ Collaboration with Alcatel-Lucent Belgium on the dynamic compact routing. This work continues through the EULER project. Two on-going PhD on this topic.

+ Our involvement in Sage implementation and documentation serves the dissemination of MASCOTTE's algorithmic results. In addition, we will use Sage both for research and teaching purposes. MASCOTTE aim at continuing this effort by proposing Sage implementations of new algorithms for inclusion into future releases.

2.9 Objective vi : Graph theory

2.9.1 Personnel

Permanent researchers: Jean-Claude Bermond, David Coudert, Frédéric Giroire, Frédéric Havet, Nicolas Nisse, Bruce Reed;
Post-docs: Frantisek Kardos;
PhD students: Julio Araújo, Marie Asté, Nathann Cohen, Florian Huc, Ana Karolinna Maia de Oliveira, Dorian Mazauric, Leonardo Sampaio Rocha, Ignasi Sau Valls.

2.9.2 Project-team positioning

MASCOTTE principally investigates applications in telecommunications via graph theory. But it also studies a number of theoretical problems of general interest. Such problems are studied by lots of teams around the world and we collaborate with many of them.

We mainly focused on three topics: graph coloring, graph decomposition and digraphs.

- Graph coloring is a central topic in graph theory. It is one of the oldest problem in combinatorics (with the 4-color 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 study graph coloring problems and contribute developing these new methods (probabilistic method, discharging method).

- Decomposing graph is a natural approach to both capture their complexity and design algorithms. In particular, since the seminal series of papers of Robertson and Seymour, tree decomposition and analogous graph decompositions have attracted lot of attention because of its structural and algorithmic importance. We are interested in a better knowledge of this decomposition and would like to get analogues for directed graphs.

- For many reasons, a lot less is known about directed graphs than about undirected graphs. MASCOTTE aims at developing the theory of directed graphs and making progress on some long-standing conjectures and problems.

2.9.3 Scientific achievements

Globally, our main contribution is on graph coloring. Two third of our publications in graph theory deal with this topic. We obtained many new results in this area, and in particular on those modeling channel assignment and on-line coloring algorithms.

We settle a famous conjecture on $L(p,q)$-labelings. An *$L(p,q)$-labeling of a graph 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. This models some channel assignment problem in radio networks. we are interested in finding $L(p,q)$-labeling with minimum *span* (the difference between the largest and the smallest labels plus one). In 1992, Griggs and Yeh conjectured that every graph with maximum degree $\Delta \geq 2$ has an $L(2,1)$-labeling with span at most Δ^2+1. In [Ci146], we proved this conjecture when D is sufficiently large and extend the result to $L(p,q)$-labelings [R292].

We also made a significant advance toward the Acyclic Edge Coloring Conjecture due to Fiamčik in 1978: *Every graph of maximum degree Δ has an acyclic edge-coloring with $\Delta+2$ colors.* An *acyclic edge-coloring* is an edge-coloring that is proper (adjacent edges get distinct colors) and that has the property that every cycle contains edges of at least three distinct colors. In [J76], we settled this conjecture for planar graphs with girth at least 5

and showed that every planar graph of maximum degree Δ has an acyclic edge-coloring with $\Delta + 12$ colors. The previous result bound for planar graphs was $2\Delta + 29$.

Beyond all the results we obtained, we also contributed to develop graph coloring techniques and in particular, the probabilistic method (see the book *Graph colouring and the probabilistic method*) and the discharging method. For example, the proof of Griggs and Yeh's conjecture is probabilistic and show how a semi-random method may be used after decomposing the graph into quasi-cliques and a set of low degree vertices, when the problem can be easily solved on cliques. We also introduce new variants of the discharging method: in [J60] we use some global discharging rule whereas they are usually local; in [J69], we use local discharging rules but on an auxiliary graph instead of the graph itself.

Although less numerous, our results on width parameter and digraphs should not be neglected, as some of them are significant. For example, in [R300], we propose a new proof of the duality between the bramble-number of a graph and its tree-width. Our approach is based on a new definition of submodularity on partition functions which naturally extends the usual one on set functions. The proof does not rely on Menger's theorem, and thus greatly generalizes the original one. It thus provides a dual for matroid tree-width. One can also derive all known dual notions of other classical width-parameters from it.

2.9.4 Collaborations

We had fruitful collaboration with many people of around twenty teams. We only list below the strongest.

- Federal University of Ceara, Brazil on all topics: 15 joint publications, 5 co-supervised PhD thesis (1 defended and 4 on-going), another former PhD student in Mascotte is in postdoc there.
- Charles University, Prague Czech Republic, on graph coloring: 8 joint publications, one former PhD student in Mascotte did his postdoc there.
- University of Ljubljana, mainly on graph coloring: 7 joint publications.
- LIRMM, Montpellier on all topics: 8 joint publications, organization of JCALM together (also with Marseille and now Barcelone).

2.9.5 External support

National: Color Pagro, ANR Agape;
European: FET Aeolus, PICS CNRS Prague, PHC Alliance, PHC Econet, PHC Proteus;
International: ANR International Taiwan GraTel, EA EWIN.

2.9.6 Self assessment

+ Lots of publications, many of them with researchers from many different labs and countries;

+ Resolution of longstanding conjectures.

+/− Study of theoretical problems sometimes far away from practical problems.

In the future, we will continue our research in graph theory. However, more efforts should be put on digraphs for which most problems are notoriously more difficult than for undirected graphs.

3 Knowledge dissemination

3.1 Publications

	2008	2009	2010	2011	Total
PhD Thesis	1	5	2	4	12
H.D.R (*)	1		2		3
Journal	22	26	25	28 (+13)	101 (+13)
Conference proceedings (**)	37	52	30	32 (+2)	151 (+2)
Book chapter	2		5	3	10
Book (written)					
Book (edited)	4	2	3		9
Patent	3				3
General audience papers					
Technical report					
Deliverable	2	7	4	11	24

(*) HDR Habilitation à diriger des Recherches
(**) Conference with a program committee

We mainly publish our theoretical results in Journals in the field of Discrete mathematics and Algorithmic. We present our more applied results in many different conferences to ensure a wide dissemination of the results and to establish fruitful contacts with other researchers.

Major journals. In what follows we list the main Journals which are well established in our field.

- Algorithmica: 5
- Combinatorica: 1
- Combinatorics, Probability and Computing: 2
- Computer communications: 3
- Computer networks: 1
- Discrete Mathematics: 7
- Discrete Applied Mathematics: 17
- European Journal of Combinatorics: 3
- IEEE Communication Letters: 1
- IEEE Transactions on Computers: 2
- IEEE/ACM Transactions on Networking: 0
- IEEE/OSA Journal of Optical Communication & Networking: 0
- Information and Computation: 2
- Journal of Combinatorial Theory Ser B: 4
- Journal of Computer and System Sciences: 1

- Journal of Graph Theory: 3
- Networks: 3
- SIAM Journal on Discrete Mathematics: 9
- Simulation & Gaming: 1
- Theoretical Computer Science: 14
- Wireless networks: 2

International conferences

- AdHoc-NOW (International Conference on AD-HOC Networks & Wireless): 4
  General Chair in 2008
- DISC (International Symposium on Distributed Computing): 1
- ESA (European Symposium on Algorithms): 1
- Eurocomb (European Conference on Combinatorics, Graph Theory and Applications): 5
- GLOBECOM (IEEE Global Communications Conference): 1
- GreenCom (IEEE/ACM International Conference on Green Computing and Communications): 1
- ICALP (International Colloquium on Automata, Languages and Programming): 0
- ICC (IEEE International Conference on Communications): 2
- INFOCOM (IEEE International Conference on Computer Communications): 1
- IPEC (International Symposium on Parameterized and Exact Computation, formerly IWPEC): 2
- IWOCA (International Workshop on Combinatorial Algorithms): 2
- LAGOS (Latin-American Algorithms, Graphs, and Optimization Symposium): 5
- Networking (IFIP International Conferences on Networking): 1
- P2P (IEEE International Conference on Peer-to-Peer Computing): 1
- PADS (ACM/IEEE/SCS Workshop on Principles of Advanced and Distributed Simulation): 1
- PODC (ACM SIGACT-SIGOPS Symposium on Principles of Distributed Computing): 2
- SIGMETRICS (ACM annual conference of the Special Interest Group (SIG) for the computer systems performance evaluation community): 1
- SIMUTools (International Conference on Simulation Tools and Techniques): 1
- SIROCCO (Intl. Conference on Structural Information and Communication Complexity): 6

- SODA (ACM-SIAM Symposium on Discrete Algorithms): 4
- STACS (International Symposium on Theoretical Aspects of Computer Science): 1
- STOC (ACM Symposium on Theory of Computing): 1
- WG (Intl. Workshop on Graph-Theoretic Concepts in Computer Science): 4
- WSC (Winter Simulation Conference): 4
- WoWMoM (IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks): 1

National conferences We would like to highlight the french speaking conference AlgoTel (Rencontres Francophones sur les aspects Algorithmiques des Télécommunications) in which we participate in both organization and programs, and where we present our new results (21 papers during the evaluation period). This conference is very important to disseminate results within the french community. Furthermore it has now reach maturity with a selection rate of 1/3.

We also would like to emphasize the "Journées Graphes et Algorithmes". This annual event gather all the french researchers interested in graph theory and graph algorithms. Although there are no published proceedings, it is an invaluable meeting for us to exchange with our french colleagues. Each year, we give several talks on our most recent works in this conference.

- AlgoTel (Rencontres Francophones sur les aspects Algorithmiques des Télécommunications): 21
  Organization in 2011
- CFIP (Colloque francophone sur l'ingénierie des protocoles): 1
  (**best student paper**)
- JDIR (Journées Doctorales en Informatique et Réseaux): 4
  General chair in 2010
- ROADEF (congrès annuel de la ROADEF): 1

3.2 Software

3.2.1 Grph, a graph optimization library

- **Classification:** A-3, SO-3, SM-3, EM-3, SDL-4, OC: DA-4, CD-4, MS-4, TPM-4
- **Grph web site:** http://www-sop.inria.fr/mascotte/software/grph/

The main objective of Grph is to provide researchers and engineers with a library suited to the experimentation of graph algorithms, and facilitating the integration of such algorithms into large software (in particular DRMSim). Grph can be seen as a successor to the MASCOPT optimization library, from which it reuses many features and ideas. The motivation for developing a new library lies in the context of the recent research projects conducted at MASCOTTE, which are mostly concerned with large graphs. Indeed, MASCOPT was not designed for processing such instances and has shown performance limitations. As it appeared that improving the performance of MASCOPT would have required too deep changes, we opted for injecting the experience gained along the MASCOPT project into a fresh and targeted library.

Grph can be differentiated from other Java graph libraries in at least two ways: First Grph is geared towards performance. At every stage, it is designed to be efficient, both in terms of computation time and in terms of memory requirements. It allows to handle large dynamic graphs in the order of millions of nodes. Such large instances could hardly be dealt with in Java before. Second its graph model is made to be general. In practice this model supports mixed graphs composed of directed (or not) simple- and hyper-edges. Grph comes with a collection of base graph algorithms which is regularly augmented.

In order to achieve best performance, Grph resorts to a number of strategies. First it represents vertices and edges via 32-bits native integers. Also, Grph uses the inherent parallelism of multi-core processors and multi-processor computers whenever possible, and performs caching of the results of graph algorithms in order to avoid re-computations (this is particularly useful in the context of network simulation). Grph also integrates a bridge to native code (libraries or external applications) which allows the implementation of critical algorithms in C/C++. In order to do this, Grph uses on-the-fly compilation. Finally, through the Jalinopt toolkit, it benefits from the effectiveness of linear programs solvers (currently CPLEX is supported).

So far, most known users of the Grph library are part of INRIA project teams AOSTE and MASCOTTE, and of the FP7 STREP EULER project. Grph has been registered on August, 1st 2011 with the French "Agence pour la Protection des Programmes" (APP)[1]. It has currently an INRIA proprietary license, to keep full control of developments made by external users. This license allows free usage and access to the source code.

Other graph libraries in the Java world include Graphstream, JGraphT and Jung. These libraries are not competing Grph since they all have their own targets (OO model, graph rendering, etc.) and none of them aims at performance.

Current and future plans include the design of a distributed infrastructure for the execution of graph algorithms as well as the development of new advanced algorithms including bridging-centrality, hyperbolicity, group betweenness, etc.

3.2.2 Dynamic routing models simulator, DRMSim

- **Classification:** A-3, SO-3, SM-3, EM-3/4, SDL-3, OC: DA-4, CD-4, MS-4, TPM-4
- **DRMSim web site:** http://drmsim.gforge.inria.fr

The objective of DRMSim is to provide a routing model simulator to the scientific "networking" community. DRMSim does not aim at performing accurate simulations at the "forwarding level". Instead it focuses on the underlying routing layer itself, by exposing a clear and dedicated Application Programming Interface (API) to its users. In other words, it is devoted to the construction of routing tables and so to the evaluation of the behavior and performances of various distributed routing schemes (performance metrics are: stretch, size of routing tables, number of messages, adaptativity to topological modifications, etc.). Simulations are modeled according to the discrete-event paradigm.

Many researchers willing to conduct experimentations on the routing layer opt for widespread solutions like *ns-2*, OMNet++, etc. However, these complex simulators do not permit easy access to their routing models since they are designed to provide reasonable accuracy of the physical layer, and maximum accuracy of the MAC one. The cost of such care for accuracy has a negative impact on the overall performance of their simulation engines. The DRMSim routing model for physical and MAC layer is designed as a compromise between performance and detail. In particular, performance is always prioritized

[1] Grph APP number IDDN.FR.001.310007.000.S.P.2011.000.31235.

as long as the routing models are respected. Therefore, DRMSim enables its users to conduct simulations on large network instances that cannot be handled with other simulators. In particular, when coupled with the Grph library (see Section 3.2.1), it enables the simulation of networks composed of more than 10 000 nodes. Also, its API simplifies the experimentation of novel routing schemes such as NSR [Ci195], under various scenario including dynamic evolution of the topology and of the routing policies.

The problem of routing simulation has motivated the design and development of numerous tools. Most relevant tools include CBGP, SimBGP, and SIMROT, which are BGP-specific simulators, and cannot be used to investigate other protocols. CBGP aims at computing the outcome of BGP decision process in networks composed of thousands routers. It is designed for static topologies and so it has no temporal dimension. SimBGP is designed for simulating the behavior of BGP at a microscopic level. SIMROT is a lightweight simulator capable of capturing the routing dynamics on networks with thousands nodes, and so the impact of various topology parameters on BGP dynamics.

DRMSim is entirely written in Java, and relies on the Grph library (see Section 3.2.1). The core of DRMSim consists of about 60,000 lines of code. DRMSim is developed in cooperation with Alcatel-Lucent Bell and the LaBRI (Laboratoire Bordelais de Recherche en Informatique, Bordeaux, France). It is currently targeted to the FP7 STREP EULER project partners, but as soon as it will have reached a good level of maturity, it will be made available to a larger scientific community. To this end, DRMSim is already distributed under the terms defined by the General Public License v3.

Preliminary experiments showing the possibilities of DRMSim have been presented in [Ci216].

3.2.3 Open Simulation Architecture, OSA

- **Classification:** A-3, SO-4, SM-3, EM-3/4, SDL-4, OC: DA-4, CD-4, MS-4, TPM-4
- **OSA web site:** http://osa.inria.fr
- **OSA forge:** http://osa.gforge.inria.fr

OSA is a federating platform for the simulation community, designed to favour the integration of new or existing contributions at every level of its architecture and to allow for extensive reuse of contributed elements. The platform core supports discrete-event simulation engine(s) built on top of the ObjectWeb Consortium's Fractal component model.

In OSA, the systems to be simulated are modeled and instrumented using Fractal components. Using an innovative layered design, OSA properly separates the many concerns of in silico experiments based on discrete event simulations. Since these concern are contained in independent and reusable layers, this approach allows for an unprecedented level of reuse, which in turns allows for better experimental practices. The layered approach has not yet been used in any other simulator to our best knowledge. However, many simulators use similar approach to provide architectures based on components. James II, for example, developed at University of Röstock, explores a more conventional approach that combines component-based modeling with plugin-based based architecture (instead of layered). Since OSA puts a strong emphasis on reuse of existing parts of simulator software, in the latest version, the OSA architecture accepts JamesII plugins which in turns, allows OSA to run almost all the simulation models supported by JamesII. Another similar merge has recently started to allow OSA simulations to run with code reused from the NS3 network simulator despite the programming language are different.

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) 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 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).

Many discrete-event simulators are developed concurrently, but with identical or similar purpose. Another goal of OSA is to favor the reuse and integration of simulation software components and models. To favor reuse, OSA uses a layered approach to combine the modeling, simulation, and related concerns, such as instrumentation or deployment. This ability is demonstrated by the successful integration and reuse of third- party components, such as Scave, the analysis module of Omnet++, or a large number of the James II plugins developed by the University of Rostock. OSA is both a testbed for experimenting new simulation techniques and a tool for real case studies.

OSA is developed in Java (80%) and XML, AspectJ, etc. It consists of 20k lines of code and represents the work of about 8 man/year.

OSA, through the OSIF (Open Simulation Instrumentation Framework) prototype, also addresses the issue of simulation instrumentation. In most existing simulators, the outputs of a simulation run consist either in a simulation report generated at the end of the run and summarizing the statistics of interest, or in a (set of) trace file(s) containing raw data samples produced and saved regularly during the run, for later post-processing. We address issues related to the management of these data and their on-line processing, such as: (i) the instrumentation code is mixed in the modeling code; (ii) the amount of data to be stored may be enormous, and often, a significant part of these data are useless while their collect may consume a significant amount of the computing resources; and (iii) it is difficult to have confidence in the treatment applied to the data and then make comparisons between studies since each user (model developer) builds its own ad-hoc instrumentation and data processing. We propose a new component-based instrumentation framework designed to solve the above mentioned issues based on several mature software engineering techniques and frameworks, such as COSMOS, Fractal and its ADL, and Aspect-Oriented Programming. OSIF consists of 3k lines of code.

3.2.4 Tools

- **Classification:** A-3, SO-3, SM-3, EM-3, SDL-4, OC: DA-4, CD-4, MS-4, TPM-4

To cope with the separation of concerns, most of the softwares of MASCOTTE externalize concerns that are not part of their functional domain. When they are relevant, these concerns are exported to specific sofware projects. This is the case for solving linear programs, the integration into the UNIX environment, job farming, the generation of plots, etc.

- **Jalinopt** is an interface to use external linear programming solvers from Java (http://www-sop.inria.fr/members/Luc.Hogie/jalinopt/);

- **Java4unix** simplifies the integration of java applications in UNIX environments (http://www-sop.inria.fr/members/Luc.Hogie/java4unix/).

3.3 Valorization and technology transfert

DCR – Contract with Alcatel-Lucent Bell (Antwerpen, Belgium), 12/2008-12/2010.
On Dynamic Compact Routing Schemes for the autonomous system of the Internet, in collaboration with LABRI (Bordeaux)
(http://www-sop.inria.fr/mascotte/projets/DCR/).

This contract was originally intended for one year but has been extended for a second year in order to pursue our work and to prepare the proposal for FP7 FIRE STREP EULER project. We were successful and the project has started in 10/2010.

Thanks to this contract, we have intensify research activities on compact routing schemes and on algorithms for large dynamic graphs. It has also provided the roots for the development of the Grph graph optimization library (Section 3.2.1) and of the DRMSim dynamic routing schemes simulators (Section 3.2.2).

CRC CORSO2 with France Télécom R&D (now Orange labs), 2006-2008.
This collaborative research contract was the successor of the contract we had for the period 2003-2005.

Within this contract, some researchers from MASCOTTE and some engineers from France Télécom R&D were working together on specified subjects related to the design of telecommunication networks: fault tolerance, how to use radio networks for bringing Internet in places where there is no ADSL, etc.

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

This contract has been followed by two PhD grants (CIFRE).

SME 3Roam, since 2007.
The collaboration has been supported by 2 PhD grants (joint funding 3Roam and PACA province), the APRF contract RAISOM also involving SME Avisto, and the ANR ECOSCells project.

We have investigated various aspects of microwave backhaul networks with 3Roam: radio links configuration, frequency and bandwidth reservation, routing, power consumption, etc.

Napoleão Nepomuceno contributed to the development of the software 3Link on the radio link configuration (choice of equipments, transmission power, modulation, coding, etc.). 3Link is distributed by 3Roam.

3.4 Teaching

MASCOTTE teaching activities are conducted both by full researchers (INRIA or CNRS), assistant professors (UNS) and PhD students. All the participants are involved from licence to doctorate level, with main objective to appeal students for internships in our fields of interest.

Teaching conducted by UNS assistant professors at the licence level (about 800 hours per year):

- Introduction to Algorithms and Complexity;

- Introduction to Networks, Advanced Networking;
- Introduction to Operating Systems, Bash Scripting, Advanced Programming in Unix Environment, Linux System Administration;
- Object-Oriented Programming;
- Database and advanced Information System;
- IT Tools.

Teaching conducted by CNRS or INRIA researchers at licence level:

- Computer science, 20h, Level L1 (classe préparatoire MPSI), Lycée International de Valbonne (since 2011);
- Functionnal programming with scheme, 18h, Level L1, UFR Sciences, UNS;
- Introduction to Algorithms and programming, 35h, Cycle Initial Polytechnique 2, École Polytech'Nice, UNS;
- Discrete Mathematics, 64h, Level L3, Ecole Polytech'Nice, UNS;

Teaching conducted at the master level:

- Graph Theory, 24h, M1 PENSUNS, UNS;
- Graph Combinatorics, 25h, and Discrete Mathematics for Telecommunications, 25h, Level M2, Master MDFI, Université de la Méditerranée, Faculté des sciences de Luminy;
- Algorithms for telecommunications, 42h, Level M2, Master IFI (international stream Ubinet), UNS (since 2009).
- Probabilistic Methods, 18h, Master 2 Mathematics, Lebanese University, Beyruth, Lebanon (2011);

Teaching responsibilities:

- Collaboration INRIA-Lycée International de Valbonne: N. Nisse is co-responsible of the Computer Science course of MPSI (since 2011);

- IUT Nice Côte d'Azur: M. Syska is responsible of the Computer Science Department of IUT since september 2011 and was responsible of the licence LP SIL degree before then;

- Ubinet, Master IFI:
  - J-C. Bermond is member of the scientific committee;
  - J. Moulierac was responsible of the International stream Ubinet, Master IFI (http://ubinet.unice.fr), until August 2011;
  - F. Giroire is responsible of the Internships within international stream Ubinet, Master IFI (http://ubinet.unice.fr), since October 2011;
- International Master 1: J.-C. Bermond is member of the scientific committee of the international track of the M1.

Education Committees:

- D. Coudert in member of the scientific board of the GIS ENSL-UNS (CNRS, ENSL, INRIA, UNS) since 2011;
- Reviewers and examiners of many PhD thesis in France and outside France (Spain, Italy, Lebanon, etc.); ...

3.5 General Audience Actions

"Science et culture au Lycée": talks in high schools.

- J-C. Bermond and D. Mazauric have presented "les métiers de la recherche" at the Conferences 2GT and 1S STI STL in the Lycée de La rouvière Toulon (April 29, 2010);
- F. Havet presented general audience scientific results at Lycée Vauvenargues, Aix en Provence, 2010, and Lycée du rempart, Marseille, 2011. Slides available at: http://www-sop.inria.fr/members/Frederic.Havet/FeteScience/grand-public.html

Science participative: "*Modéliser les échanges au sein des réseaux, ou comment faire se promener les écolières de sorte que jamais les écolières ne soient ensemble de jour en jour*", in 2010. Video available at:
http://www.youtube.com/watch?v=BSNeYXnDXmM

Short movie on J-C. Bermond made by Foundation EADS when he was the recipient of the "Grand Prix Fondation EADS 2010" granted by the french academy of science.
http://www.youtube.com/watch?v=S0vrQc2nnn8

J-C. Bermond has been invited at the "19/20 France 3 Côte d'Azur" of December 20 2010, after he was the recipient of the 2010 EADS Prize.
http://www.cote-azur.cnrs.fr/Breves/Deux-chercheurs-azureens-a-l-honneur-sur-France-3-Cote-d-Azur/

Participation of F. Havet to "Fête de la science" in Rians, Var, France. 4 days in October 2010 and 4 days in October 2011. Materials available at:
http://www-sop.inria.fr/members/Frederic.Havet/FeteScience/Fete-Science.html

"Journées Méditerranéennes du Logiciel Libre": M. Syska has presented "MASCOPT *une boite à outils de manipulation de graphe*", Polytech'Nice-Sophia (November 26, 2010).
http://jm2l.linux-azur.org/conference/mascopt-une-boite-à-outils-de-manipulation-de-graphe;

Seminar of F. Havet on "Les grands problèmes mathématiques de l'antiquité" at "Café des Sciences de Rians" (Monthly general audience seminar in Rians) on December 12, 2010. Slides available at:
http://www-sop.inria.fr/members/Frederic.Havet/FeteScience/Cafe-10-12-10.pdf

Seminar of F. Havet on "Mathémagique" at "Gouter des Sciences de Rians" (Science seminar dedicated to children) on March 20, 2011.

Seminar of J-C. Bermond on "*Graphes, hypergraphes et réseaux*" at Colloquium Jacques Morgenstern on May 12 2011. Video available at:
http://www-sop.inria.fr/colloquium/intervenant.php?nom=Bermond&prenom=Jean-Claude

3.6 Visibility

Editorial boards: Combinatorics Probability and Computing; Computer Science Reviews; Discrete Mathematics; Discrete Applied Mathematics; Discrete Mathematics, Algorithms and Applications (2009-); Discrete Mathematics and Theoretical Computer Science; Journal of Combinatorial Theory, Series B; Journal of Graph Theory; Journal Of Interconnection Networks; Journal of Parallel and Distributed Computing; Mathématiques et Sciences Humaines; Networks; Parallel Processing

Letters; the SIAM book series on Discrete Mathematics; Transactions on Network Optimization and Control; Wireless Networks; ...

Participations in Conference Organisation Committees (General Chair, Local Chair): ADHOCNOW'08; AEOLUS Workshop 08; AdhocAmC'08; JCALM'08; JGA'08; NMS'08; PhD-NOW'08; SIMUTools'08; Workshop on Graph Colouring 08; AGAPE'09; 2nd Bellairs Workshop on Probabilistic Combinatorics and WVD 09; CRM workshop on Combinatorics, Randomized Algorithms and Probability 09; Czech-Slovenian-French Workshop on Graph Colouring 09 and 10; IMAGINE'09; JCALM'09; Valuetools'09; Workshop on Probabilistic and Extremal Combinatorics 09; JDIR'10; OMNeT++'10; ACM/IEEE/SCS PADS'11; AlgoTel'11; CC'11; TERA-NET'11; ...

Participations in Conference Program Committees: ACM CoNEXT shadow PC 08; ACM CoNEXT student workshop 08; ADHOC-NOW'08; ASSESS'08; AlgoTel'08, 09, 10, and 11; ECMS-METH'08; ESA'08; JDIR'08 and 10 (PC chair); JGA'08, 09, 10, and 11; MCO'08; SIMUTools'08 (PC chair) and 09; WNS2'08; Workshop on Optimization Issues in Grid and Parallel Computing Environments 08; ACM Mobility'09; HPCS'09; LAGOS'09; NSTOOLS'09; 8FCC'10; DEVS'10; FUN'10; HPCS'10; IEEE CoMetS'10 and 11; MajecSTIC'10; Omnet++'10 and 11; SEA'10 and 11; WG'10; APDCM'11; DEVS/TMS'11; FCT'11; SIMTIM'11; TERA-NET'11; ...

Steering Committees: ISPAN 08 and 09; IMAGINE 08 and 09; Canadian Conference on Discrete Mathematics 08; Pacific Institute for Mathematical Sciences Scientific Review Committee (till 09). AlgoTel; SIMUTools; JCALM; JGA; Pôle ResCom du GDR ASR du CNRS; GT Graphes du GDR IM du CNRS; ...

Membership in recruiting committees: *Commissions de spécialistes 27^e section* of Univ. Nice Sophia Antipolis and Univ. Avignon till 08; *Comités de sélections 27^e section* at Univ. of Nice Sophia (09, 10, 11 for PRs, MCFs, and ATERs), Univ. Marseille 2 (08, 11), Univ. Méditerranée (11), Univ. Claude Bernard de Lyon (10), and Univ. Montpellier II (11); *Comités de sélections 61^e section* at Univ. Nice Sophia Antipolis (09 for MCFs and PRs); Recruiting committee of a CNRS engineer for the *Pôle ComRed* of I3S;

Various Committees: INRIA committees: *comité du suivi doctoral*, Commission for software development, CUMIR, and various ad-hoc working groups; Responsible of *Pôle ComRed* of I3S till 11; Elected and nominated members of I3S laboratory committee; Nominated member of CITI laboratory committee (since 09); Elected member of the Comité National de la Recherche Scientifique (CoNRS); Member of selection committee of several CNRS programmes (eg PICS, conventions, LIAs, GDRIs...); Member of scientific committee of the STIC AmSud programme; Member of Working Groups for the monitoring of FP7 and the preparation of FP 8 for the French Ministry of Research; Expertizes at national level for AERES, ANR, ANRT, DRTT, RNRT, CIR applications (Credit Impot Recherche), etc.; Expertizes at European level for the distribution of European Structural Funds with the Czech Ministry of Research, the Slovakia VEGA programme, European commission, FET-Open programme, EC PARADISO project; Expertizes at international level for Canada (FQNRT, NSERC,...), Qatar;

4 External Funding

The table to be filled up has no consistency and is misleading. Indeed we think that it is important to emphasize the contracts and projects of a team and we describe them in details after. It might also be interesting for experts to know the funding of the contract and to distinguish between "big" contracts which include salaries and management time and "small" ones. But it has no meaning to mix salaries and external other resources. Not only that should not appear in a scientific report, but if one wants to do it properly it should include the salaries of all types (in particular those of the permanent people) and it should be done as a "consolidated budget" including hosting costs etc .... Finally most of the salaries of PhD, Post Docs or AI we mention here are of course not included in one of the contracts, but they are mainly paid by INRIA, CNRS, University or various French Ministries and cannot be considered as real external funding. However basic resources given by these organisms are not mentioned (they are not so high if we compared with the contract but are important as they are the only resources without precise objectives).

So we split the table in two parts. In the first table when the funding part of MASCOTTE is clearly identified we have indicated the amount in Keuros; otherwise we put a $\oplus$ to indicate there has been some funding (most of the time it consists in reimbursement of travels and stays).

(k euros)	2008	2009	2010	2011
INRIA Research Initiatives				
ARC Carma (†)	25			
ARC Broccoli (†)	20	20		
Color Lareco (†)	8			
Color Pagro (†)	6			
National initiatives				
ANR Osera	30			
ANR Spreads	73	73	71	
ANR Dimagreen		21	63	63
ANR Agape		13	53	53
ANR Ecocells			2	2
ANR USS-SimGrid			13	27
Action Rescom	$\oplus$	$\oplus$	$\oplus$	$\oplus$
Action Graphes	$\oplus$	$\oplus$	$\oplus$	$\oplus$
Action OSA				$\oplus$
European projects				
FET Aeolus	92	62		
COST 293 Graal	$\oplus$			
FP7 Strep Euler			29	116
Associated teams and International projects				
Ea RéseauxCom Sfu Vancouver Canada	8			
Ea Ewin Fortaleza Brazil		20	22	10
Ea Dissiminet Carleton U. Canada				18
PHC Alliance London	3			
Inria Fapesp Mobidyn	5			
Econet	13			
PHC Proteus		2	2	
PICS CNRS Prague		5	6	6
ANR International Taiwan GRATEL			20	20
PHC Procope AAchen				4
Industrial contracts				
Crc France Telecom	$\oplus$			
Thales (CIFRE)	5			
France Telecom (CIFRE)			7	7
France Telecom (CIFRE)				6
Alcatel Lucent Bell Labs Belgium	5	63	62	
APRF PACA FEDER RAISOM		42	63	63
Joint Lab Alcatel Lucent Bell Labs ADR Hima			27	
Total	**293**	**321**	**440**	**395**

(k euros)	2008	2009	2010	2011
Scholarships				
PhD (*)	336	285	267	324
Post Doc (*)	45	82	111	57
AI (+)				50
Total	**381**	**367**	**378**	**431**

† INRIA Cooperative Research Initiatives
‡ Large-scale Initiative Actions
∗ other than those supported by one of the above projects
+ junior engineer supported by INRIA
# engineer supported by INRIA

ARCs

- CARMA with ARES, POPS, Drakkar, 2007-2008.

  (CApacité des Réseaux MAillés) is a project lead by MASCOTTE and involves 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.

  Funded by INRIA in 2008 with 25.000€.

- ARC BROCCOLI, 2008-2009.

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

  Funded by INRIA with 20.000€ in 2008 and 20.000€ in 2009.

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

- Color LARECO, 2008.

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

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

  Funded by INRIA Sophia Antipolis - Méditerranée with 8.000€.

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

- Color PAGRO, 2008.

  (PArtition de GRaphes Orientés) with LIRMM, Montpellier.

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

  Funded by INRIA Sophia Antipolis - Méditerranée with 6.000€.

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

National initiatives

- ANR Jeunes Chercheurs OSERA 12/2005-11/2008.

  On optimization and simulation of ambient networks.

  Funded by ANR with 98.100€ ; it has got the approbation and label of the "pôle de compétitivité" SCS.

- ANR SPREADS with UbiStorage 12/2007-12/2010.

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

  Funded by ANR with 217.299€ ; it has got the approbation and label of the "pôle de compétitivité" SCS.

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

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

  Funded by ANR with 188.931€ .

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

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

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

  Funded by ANR with 211.348€ .

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

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

  The ECOSCells (Efficient Cooperating Small Cells) project aims at developing the algorithms and solutions required to allow Small Cells Network (SCN) deployment. The consortium gathers industrial groups, together with 3 SMEs and 6 research institutes: Alcatel-Lucent Bell Labs (leader), Orange Labs, 3-ROAM, Sequans, Siradel, INRIA teams MAESTRO, MASCOTTE and SWING, Université d'Avignon et des Pays de Vaucluse, Laboratoire des Signaux et Systèmes / Supelec, LAAS and Eurecom.

  Funded by ANR with 5.270€ .

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

- ANR USS-SimGrid, 07/2010-10/2012.

  The USS-SimGrid project aims at Ultra Scalable Simulations with SimGrid. This tool is leader in the simulation of HPC settings, and the main goal of this project is to allow its use in the simulation of desktop grids and peer-to-peer settings.

  Funded by ANR with 59 662€ .

  (http://uss-simgrid.gforge.inria.fr/)

- Action ResCom 2006-.

  Réseaux de communications, working group of Gdr Asr CNRS.

  (http://rescom.asr.cnrs.fr/)

- Action Graphes 2006-.

  Action Graphes, working group of Gdr IM CNRS.

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

European projects

- FET Aeolus European Project, 09/2005-08/2009 prolongated to 02/2010.

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

  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/)

  Funded with 368.640€.

- COST 293 Graal European action, 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 cooperation 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.

  David Coudert for INRIA and Jérôme Galtier for France Telecom R&D were in the management committee of this action. David Coudert was also leader of working group WG-A "broadband and optical networks".

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

  Funds cover the participation of various members of MASCOTTE to the annual meetings and scientific visits to partners labs.

- FP7 STREP EULER, 10/2010-09/2013.

  EULER (Experimental UpdateLess Evolutive Routing) is part of FIRE (Future Internet Research and Experimentation) objective of FP7.

  EULER gathers 7 partners: Alcatel-Lucent Bell (leader) (Antwerp, Belgique), IBBT (Ghent, Belgium), UCL (Louvain, Belgium), RACTI (Patras, Grece), UPC (Barcelona, Spain), UPMC (ComplexNetworks, Paris 6), INRIA (MASCOTTE, GANG, CEPAGE).

MASCOTTE is the leader of WP3 on Topology Modelling and Routing scheme experimental analysis.

It aims at finding new paradigms to design, develop, and validate experimentally a distributed and dynamic routing scheme suitable for the future Internet and its evolution.

(http://www.euler-fire-project.eu)

Funded with 346.837€.

Associated teams and other international projects

- EA Sfu with the Network Modeling Group "RESEAUXCOM", 2004-2006+2007-2009.

  One of the main objectives is to strengthen our collaboration with SFU, Vancouver, Canada. Many reciprocal visits have been performed.

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

  Funded by INRIA with 8.000€ in 2008.

- EA Joint team "EWIN", 01/2009-12/2011

  Joint team EWIN (Efficient algorithms in WIreless Networks) with the Departamento de Computação of Universidade Federal do Ceará of Fortaleza (Brazil). The research themes are the design of exact or approximate algorithms for solving problems in networks, in particular wireless networks. The problems that we will consider can be modelled as graph coloring or graph decomposition problems. More specifically, we studied the following problems: channel assignment in radio networks which can be modelled by various graph coloring problems, dynamic routing in wireless networks using microwave links, and routing reconfiguration in MPLS or WDM networks, certain models of which are closely related to graph searching problems and tree and path decompositions.

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

  Funded by INRIA with 20.000€ in 2009, 22.000€ in 2010 and 10.000€ in 2011.

- EA Joint team 'DISSIMINET", 01/2009-12/2011

  Joint team with Carleton University (Canada) Laboratory: Advanced Real-Time Simulation Laboratory. This Franco-Canadian team will advance research on the definition of new algorithms and techniques for component-based simulation using a web-services based approach. The results of this common research will be integrated into the discrete-event distributed simulators of both teams: the CD++ simulator at Carleton University and the simulation middle-ware developed in MASCOTTE, called OSA, whose developments are supported by an INRIA ADT since January 2011.

  (http://www-sop.inria.fr/members/Olivier.Dalle/wiki/Main/Dissiminet)

  Funded by INRIA with 15.000€ in 2011.

- Alliance program with Royal Holloway College (London) 2007-2008.

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

  Funded by the french Ministry of Foreign and European Affairs with 3.000€ and by the British Research Council with 2.000£ in 2008.

- INRIA-FAPESP MOBIDYN, 2003-2008

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

  Funded by the Paca province with 11.800€, INRIA with 13.100€ and the CNRS with 4.600€, so overall 29.600€.

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

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

  Funded by the french Ministry of Foreign and European Affairs with 13.000€ in 2008.

- PHC Proteus (with Ljubljana) 01/2009-12/2010

  On Graph colouring: theoretical and algorithmic aspects.

  Funded by the french Ministry of Foreign and European Affairs with 2.000€ in 2009 and 2.000€ in 2010.

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

  On Graph colouring: theoretical and algorithmic aspects.

  Funded by the CNRS with 5.000€ in 2009, 6.000€ in 2010 and 6.000€ in 2011.

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

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

  Funded by the french Ministry of Foreign and European Affairs with 4.000€ in 2011

- ANR International Taiwan GRATEL, 01/2010 – 12/2013

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

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

  Funded with 60.892€.

Industrial contracts

- Crc CORSO2 France Télécom R&D, 2006-2008.

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

  *Contrat de recherche collaborative (*crc*) with France Télécom R&D.*

  We had a strong collaboration with France Télécom R&D inside 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 France Télécom R&D on the other side work together on

specified subjects approved by a "Comité de pilotage". Among these subjects we can cite the design of telecommunication networks, the study of fault tolerance and the use of radio networks for bringing Internet in places where there is no ADSL.

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

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

  Keywords: Accompanying contract for Ph.D. grant of Jean-Paul Perez Seva.

  Funded by Thales with 15.000€.

- Orange Labs Sophia antipolis, 11/2009-11/2012.

  Keywords: Accompanying contract for Ph.D. grant of Mikaila Toko Worou.

  Funded by Orange with 21.000€.

- Orange Labs Sophia antipolis, 02/2011-01/2014.

  Keywords: Accompanying contract for Ph.D. grant of Sébastien Félix.

  Funded by Orange with 21.000€.

- DCR -Contract with Alcatel-Lucent bell-labs (Antwerpen, Belgium), 12/2008-12/2010.

  On Dynamic Compact Routing Schemes in collaboration with LABRI (Bordeaux)

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

  Funded by Alcatel-Lucent bell-labs Belgium with 130.000€.

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

  On Wireless IP Service Deployment optimization and monitoring.

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

  Funded by the province PACA and the European fund FEDER with 189.245€.

- Alcatel-Lucent Bell-Labs -ADR HiMa, joint laboratory INRIA / Alcatel-Lucent Bell-labs France, 10/2009 -12/2012

  MASCOTTE is part of the joint laboratory INRIA / Alcatel-Lucent Bell-labs France within the ADR HiMa (research action on High Manageability) and works on autonomous dynamic management of virtual topologies (the ADR finances the first 9 months of a Ph.D. student, Philippe Giabbanelli, who decided to return to Canada, for an amount of 27.000€).

  (http://inria.bell-labs.commonlab.homeip.net/index.php/High_Manageability)

Other funding,

5 Objectives for the next four years

Since 2000, the MASCOTTE project-team has conducted high level research activities in discrete mathematics and combinatorial optimization for telecommunication networks. It has also been active in the development on discrete-event simulation methodology and tools.

The methodology of MASCOTTE was on the one side to conduct fundamental researches in graph theory, combinatorial optimization, and algorithmic for which the group

has an international visibility. Significant advances have been made for instance on graph coloring problems and graph decomposition methods. On the other side, MASCOTTE addressed practical problems issued from telecommunication networks using tools from discrete mathematics in collaboration with industrial partners. Indeed, MASCOTTE has established several strong collaborations with companies such as Orange labs, Alcatel-Lucent Bell labs (France and Belgium), SMEs 3Roam and Avisto in Sophia Antipolis, and SME UbiStorage.

Before the end of MASCOTTE in 2012, we propose to build a new project-team called Coati (Combinatorics, Optimization, and Algorithms for Telecommunications), that will be a joint project-team between INRIA and the I3S laboratory (UMR 7271 CNRS/UNS). Coati will keep the successful ingredients of MASCOTTE that are strong international collaborations, and a good balance between theoretical research in discrete mathematics and industrial collaborations on telecommunication networks (wired and wireless). But Coati will differ from MASCOTTE in the studied topics. Some topics will disappear completely, like the development of discrete-event simulation tools and methodology (indeed, Olivier Dalle, who was running these activities will join some other team) although we will continue to use them; some will be kept like graph decomposition methods or optimization algorithms for network design; some will be developed like compact routing, green networking, and moderately exponential algorithms.

- Proposal and presentation slides:
  - http://www-sop.inria.fr/members/David.Coudert/COATI/
- Status of the Coati proposal:
  - We obtained the initial "GO" from INRIA, I3S, CNRS and UNS;
  - 20/10/2011: Short presentation (20 min) to the scientific committee of CRISAM;
  - 01/12/2011: Short presentation (20 min) to the scientific committee of I3S;
  - 16/03/2012: Long presentation (1 h) to the scientific committee of CRISAM.

Olivier Dalle will join the OASIS project-team to build with them a new project-team in which he will pursue his research activities on simulation methodology and tools.

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