
Activity Report 2013

# Project-Team MAESTRO

## Models for the performance analysis and the control of networks

RESEARCH CENTER
**Sophia Antipolis - Méditerranée**

THEME
**Networks and Telecommunications**

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**Keywords:** Markovian Model, Game Theory, Control Theory, Network Modeling, Delay Tolerant Networks, Cellular Networks, Smart Grids

*In collaboration with LIA, Univ. of Avignon (UAPV).* MAESTRO *is member of the joint laboratory between Inria and Alcatel-Lucent Bell Labs, and member of the French-Indian international joint unit* UMI *in applied mathematics between Inria,* CNRS*, and the Indian Institute of Science, Bangalore, India.*

*Creation of the Project-Team:* 2003 October 01.

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# 2. Overall Objectives

## 2.1. Presentation of MAESTRO

MAESTRO is an Inria project-team whose members are located in Sophia Antipolis (S. Alouf, K. Avrachenkov, P. Nain, G. Neglia), at LIA (Lab. of Informatics of Avignon) in Avignon (E. Altman) and at LIRMM (Lab. Informatics, Robotics and Microelectronics of Montpellier) in Montpellier (A. Jean-Marie). MAESTRO is concerned with the modeling, performance evaluation, optimization and control of stochastic Discrete-Event Dynamical Systems (DEDS), with a particular emphasis on networks and their applications. The scientific contributions are both theoretical, with the development of new modeling formalisms, and applied, with the development of software tools for the performance evaluation of DEDS, and the patenting of new methods jointly with industrial partners.

## 2.2. Highlights of the Year

The book by K. Avrachenkov, J. Filar and P. Howlett, "Analytic Perturbation Theory and Its Applications" [68] has been completed and published in December 2013. The book provides a unifying treatment of analytic perturbations with particular emphasis on singular perturbations. The applications considered in the book include: linear and non-linear optimization, Markov chains, Markov Decision Processes.

G. Neglia got the one-minute madness award at the conference IFIP 12th Intl. Conference on Networking (IFIP Networking 2013), for his one-minute presentation of the paper [49].
BEST PAPERS AWARDS :
[58] **Signaling Game-based Approach to Power Control Management in Wireless Networks in ACM PM2HW2N - 8th Workshop on Performance Monitoring and Measurement of Heterogeneous Wireless and Wired Networks**. K. IBRAHIMI, E. ALTMAN, M. HADDAD.
[60] **On Optimal Packet Routing in Deterministic DTNs in IEEE VTC - 77th Vehicular Technology Conference**. G. NEGLIA, X. ZHANG, J. KUROSE, D. TOWSLEY, H. WANG.

# 3. Research Program

## 3.1. Research Directions

MAESTRO follows six main research directions: network science, wireless networks, network engineering games, green networking and smart grids, content-oriented systems, and advances in methodological tools. These directions are very connected: network engineering games find applications in many networking fields, and methodological advances are typically motivated by applications.

### *3.1.1. Network Science*

MAESTRO contributes to this new fast growing research subject. "Network Science" or "Complex Network Analysis" aims at understanding the structural properties and the dynamics of a variety of large-scale networks in telecommunications (e.g. the graph of autonomous systems, the Web graph), social science (e.g. community of interest, advertisement, reputation, recommendation systems), bibliometrics (e.g. citations, co-authors), biology (e.g. spread of an epidemic, protein-protein interactions), and physics. It has been observed that the complex networks encountered in these areas share common properties such as power law degree distribution, small average distances, community structure, etc. It also appears that many general questions/applications (e.g. community detection, epidemic spreading, search, anomaly detection) are common in various disciplines which study networks. In particular, we aim at understanding the evolution of complex networks with the help of game theoretical tools in connection with Network Engineering Games, as described below. We design efficient tools for measuring specific properties of large scale complex networks and their dynamics. More specifically, we work on the problem of distributed optimization in large networks where nodes cooperatively solve an optimization problem relying only on local information exchange.

### *3.1.2. Wireless Networks*

The amazing technological advances in wireless devices has led networks to become heterogeneous and very complex. Many research groups worldwide investigate performance evaluation of wireless technologies. MAESTRO's specificity relies on the use of a large variety of analytic tools from applied probability, control theory and distributed optimization to study and improve wireless network functionalities.

### *3.1.3. Network Engineering Games*

The foundations of *Network Engineering Games* are currently being laid. These are games arising in telecommunications engineering at all the networking layers. This includes considerations from information and communications theory for dealing with the physical and link layers, along with cross layer approaches. MAESTRO's focus is on three areas: *routing games*, *evolutionary games* and *epidemic games*. In routing games we progress on the theory for costs that are not additive over links (such as packet losses or call blocking probabilities). We pursue our research in the stochastic extension of evolutionary game theory, namely the "anonymous sequential games" in which we study the total expected costs and the average cost. Within epidemic games we study epidemics that compete against each other. We apply this to social networks, considering in particular the coupling between various social networks (e.g. propagation strategies that combine Twitter, FaceBook and other social networks).

### *3.1.4. Green Networking and Smart Grids*

The ICT (Information and Communications Technology) sector is becoming one of the main energy consumers worldwide. There is awareness that networks should have a reduced environmental footprint. Our objective is to have a systematically "green" approach when solving optimization problems. The energy cost and the environmental impact should be considered in optimization functions along with traditional performance metrics such as throughput, fairness or delay. We aim at contributing to the design and the analysis of future green networks, in particular those using renewable energy.

Researchers envision that future electricity distribution network will be "smart", with a large number of small generators (due to an extensive use of renewable energies) and of consumer devices able to adapt their energy needs to a time-varying offer. Generators and devices will be able to locally communicate through the electrical grid itself (or more traditional communication networks), in order to optimize production, transport and use of the energy. This is definitely a new application scenario for MAESTRO, to which we hope to be able to contribute with our expertise on analytic models and performance evaluation.

### *3.1.5. Content-Oriented Systems*

We generally study problems related with the placement of data in communication networks. We are particularly interested in In-network caching, a widely adopted technique to provide an efficient access to data or resources on a world-wide deployed system while ensuring scalability and availability. For instance, caches are integral components of the Domain Name System, the World Wide Web, Content Distribution Networks, or the recently proposed Information-Centric Network (ICN) architectures. We analyze network of caches, study their optimal placement in the network and optimize data placement in caches/servers.

### *3.1.6. Advances in Methodological Tools*

MAESTRO has a methodological activity that aims at advancing the state of the art in the methodological tools used for the general performance evaluation and control of systems. We contribute to such fields as perturbation analysis, Markov processes, queueing theory, control theory and game theory. Another objective is to enhance our activity on general-purpose modeling algorithms and software for controlled and uncontrolled stochastic systems.

## 3.2. Scientific Foundations

The main mathematical tools and formalisms used in MAESTRO include:

- theory of stochastic processes: Markov process, renewal process, branching process, point process, Palm measure, large deviations, mean-field approximation, fluid approximation;
- theory of dynamical discrete-event systems: queues, pathwise and stochastic comparisons, random matrix theory;
- theory of control and scheduling: dynamic programming, Markov decision process, game theory, deterministic and stochastic scheduling;
- theory of singular perturbations.

# 4. Application Domains

## 4.1. Main Application Domains

MAESTRO's main application area is networking, to which we apply modeling, performance evaluation, optimization and control. Our primary focus is on protocols and network architectures, and recent evolutions include the study of the Web and social networks, as well as models for Green IT.

- Wireless (cellular, ad hoc, sensor) networks: WLAN, WiMAX, UMTS, LTE, HSPA, delay tolerant networks (DTN), power control, medium access control, transmission rate control, redundancy in source coding, mobility models, coverage, routing, green base stations,
- Internet applications: social networks, content distribution systems, peer-to-peer systems, overlay networks, multimedia traffic, video-on-demand, multicast;
- Information-Centric Networking (ICN) architectures: Content-Centric Network (CCN, also called Content-Oriented Networks);
- Internet infrastructure: TCP, high speed congestion control, voice over IP, service differentiation, quality of service, web caches, proxy caches.

# 5. New Results

## 5.1. Network Science

**Participants:** Eitan Altman, Konstantin Avrachenkov, Mahmoud El Chamie, Julien Gaillard, Philippe Nain, Giovanni Neglia, Marina Sokol.

### *5.1.1. Epidemic models of propagation of content*

In [15], E. Altman and P. Nain, in collaboration with Y. Xu (MAESTRO member at the time of submission) and A. Shwartz (Technion, Israel), focus on the propagation of content in peer-to-peer (P2P) networks. They first study the transient behavior of some P2P networks whenever information is replicated and disseminated according to epidemic-like dynamics. They then use the insight gained from the previous analysis in order to predict how efficient could measures taken against P2P networks be. They first introduce a stochastic model which extends a classical epidemic model, and characterize the P2P swarm behavior in presence of free riding peers. They then study a second model in which a peer initiates a contact with another peer chosen randomly. In both cases the network is shown to exhibit phase transitions: a small change in the parameters causes a large change in the behavior of the network. The authors show, in particular, how phase transitions affect measures of content providers against P2P networks that distribute non-authorized music, books or articles, and what is the efficiency of counter-measures. In addition, this analytic framework can be generalized to characterize the heterogeneity of cooperative peers.

### *5.1.2. The design of recommendation systems (RS) for social networks*

Recommendation systems take advantage of products and users information in order to propose items to targeted consumers. In [50], J. Gaillard, E. Altman, M. El Bèze and E. Ethis (both from Univ. Avignon) propose a framework to overcome the usual scalability issues of nowadays systems. The system includes a dynamic adaptation to enhance the accuracy of rating predictions by applying a new similarity measure. They perform several experiments on films data from Vodkaster, showing that systems incorporating dynamic adaptation improve significantly the quality of recommendations compared to static ones.

In [51] the same authors propose new modifications of the recommendation algorithm that allow not only to present a recommendation but also to propose a list of words which appeared frequently in recommendations of other people who watched that film and who have been identified to have similar preferences, according to their opinions on common movies.

### *5.1.3. Network centrality measures*

A class of centrality measures called betweenness centralities reflects degree of participation of edges or nodes in communication between different parts of the network. The original shortest-path betweenness centrality is based on counting shortest paths which go through a node or an edge. One of shortcomings of this metric is that it ignores the paths that might be one or two hops longer than the shortest paths, while the edges on such paths can be important for communication processes in the network. To rectify this shortcoming a current flow betweenness centrality has been proposed. Similarly to the shortest-path betweenness, it has prohibitive complexity for large size networks. In [42] K. Avrachenkov, N. Litvak (Univ. of Twente, the Netherlands), V. Medyanikov (St. Petersburg State Univ., Russia) and M. Sokol propose and analyze two regularizations of the current flow betweenness centrality, $\alpha$-current flow betweenness and truncated $\alpha$-current flow betweenness, which can be computed fast and correlate well with the original current flow betweenness. In particular, the new centrality measures indicate well vulnerability of a network.

### *5.1.4. Average consensus protocols*

Information can flow in a network through communication links connecting the nodes. Not all the links have the same importance and it is common in complex networks to distinguish "weak" links/ties and "strong" ones. Depending on the specific network, the strength of a link connecting two nodes can be quantified by its transmission capacity, the inter-meeting rate between the two nodes, the level of mutual trust of the two nodes, etc.. The topology of connections and the strength of the links are two factors that affect the speed of spread of information in the network. In [63], M. El Chamie and G. Neglia in collaboration with L. Severini (student at Univ. of Nice Sophia Antipolis, France) have shown that the topology can have stronger effect on the information spread than the strength of the links. In particular, they have considered an iterative belief propagation process as in average consensus protocols where each node in the network has a certain belief (a real number) that is updated iteratively by the weighted average of the nodes' belief and the ones they connected to. They have shown by simulations on random graphs that a topological optimization can have a significant faster spread of beliefs than any weight selection optimization techniques. They have also given a 2-hop message averaging that performs faster convergence than standard algorithms.

The activity on "Reducing communication overhead of average consensus protocols", described in MAESTRO's 2012 activity report has lead to the publication [49].

## 5.2. Wireless Networks

**Participants:** Eitan Altman, Philippe Nain, Giovanni Neglia, Oussama Habachi.

### *5.2.1. Delay Tolerant Networks*

We have pursued our study of optimal control in delay tolerant network. We studied the trade-off between delivery delay and energy consumption in a delay tolerant network in which a message (or a file) has to be delivered to each of several destinations by epidemic relaying. In addition to the destinations, there are several other nodes in the network that can assist in relaying the message. The optimal control policy was obtained in the mean-field limit of large number of mobiles by C. Singh, E. Altman, A. Kumar and R. Sundaresan in [33].

Our analysis of DTNs so far was done with mobility models in which all individuals move independently of each other. In [61]. S. Patil, M. Kumar and E. Altman have studied through simulations the multicast time in DTNs where the mobility of individuals follow dependent movement such as the one of flocking birds. This model is typical to cooperative movement and could be useful to describe a rescue team in an area hit by a disaster. We showed the impact of the parameters defining the mobility on the multicast time. If instead of broadcasting packets one first codes them (using network coding) then one can obtain substantial gain in the performance. This is shown in the case that all packets that are to be sent are available for coding before transmission. In [16], E. Altman studies in collaboration with F. de Pellegrini (CREATE-NET) and L. Sassatelli how to optimally decide on the amount of coded packets to create as a function of time in the case that the information to be coded is not available before transmission. This allows to optimize the system performance for the case of real-time traffic.

In [11], A. Ali, M. Panda, T. Chahed and E. Altman design and study a reliable transport protocol for DTNs consisting of both unicast and multicast flows. The improvement in reliability is brought in by a novel Global Selective ACKnowledgment (G-SACK) scheme and random linear network coding (RLC). The motivation for using network coding and G-SACKs comes from the observation that one should take the maximum advantage of the contact opportunities which occur quite infrequently in DTNs. Network coding and G-SACKs perform "mixing" of packet and acknowledgment information, respectively, at the contact opportunities and essentially solve the randomness and finite capacity limitations of DTNs. In contrast to earlier work on network coding in DTNs, we observe and explain the gains due to network coding even under an inter-session setting. Our results from extensive simulations of appropriately chosen "minimal" topologies quantify the gains due to each enhancement feature. In a related publication [67], A. Ali, L. Sassatelli, E. Altman and T. Chahed present an overview of theoretical background that is used for evaluating transport protocols in DTNs.

In [13], E. Altman formulates in collaboration with A. P. Azad, T. Başar (Univ. Illinois at Urbana Champain) and F. De Pellegrini (CREATE-NET) a problem where both transmission and activation of mobile terminals are controlled as a linear optimal control problem. They solve the problem by making use of this linearity in order to obtain explicit expressions for the objective function as a function of the control actions trajectories (rather than as a function of both actions and state trajectories). This allows them to compute the optimal strategies explicitly.

In [26], E. Altman studies in collaboration with D. Fiems (Ghent Univ.) a class of Markov-modulated stochastic recursive equations. This class includes multi-type branching processes with immigration as well as linear stochastic equations. Conditions are established for the existence of a stationary solution and expressions for the first two moments of this solution are found. Furthermore, the transient characteristics of the stochastic recursion are investigated: the first two moments of the transient solution are obtained as well. Finally, to illustrate the approach, the results are applied to the performance evaluation of packet forwarding in delay-tolerant mobile ad-hoc networks.

In [34], G. Neglia in collaboration with X. Zhang, H. Wang (both from Fordham Univ., Bronx, USA), J. Kurose and D. Towsley (both from Univ. of Massachusetts at Amherst, USA) has also investigated the benefits of applying Random Linear Coding (RLC) to unicast application in DTNs. Under RLC, nodes store and forward random linear combinations of packets as they encounter each other. For the case of a single group of packets originating from the same source and destined for the same destination, they have proved a lower bound on the probability that the RLC scheme achieves the minimum time to deliver the group of packets. Although RLC achieves a significant reduction in group delivery delay, it fares worse in terms of average packet delivery delay and network transmissions. When replication control is employed, RLC schemes reduce the group delivery delay without increasing the number of transmissions. In general, the benefit achieved by RLC is more significant under stringent resource (bandwidth and buffer) constraints, limited signaling, highly dynamic networks, and when it is applied to packets from same flow. For more practical settings with multiple continuous flows in the network, the researchers have shown the importance of deploying RLC schemes with a carefully tuned replication control in order to achieve reduction in average delay.

In [60], the same authors investigated the problem of determining the routing that minimizes the maximum/average delivery time or the maximum/average delivery delay for a set of packets in a deterministic

Delay Tolerant Network, i.e. in a network for which all the nodes' transmission opportunities are known in advance. While the general problem with multiple sources and multiple destinations is NP-hard, they have presented a polynomial-time algorithm that can efficiently compute the optimal routing in the case of a single destination or of a single packet that needs to be routed to multiple destinations.

In [59], P. Nain in collaboration with D. Towsley (Univ. of Massachusetts at Amherst, USA), A. Bar-Noy and F. Yu (both from City Univ. of New York, USA), P. Basu (Raytheon BBN Technologies, USA), and M. P. Johnson (Univ. of California, Los Angeles, USA) consider the problem of estimating the end-to-end latency of intermittently connected paths in disruption/delay tolerant networks. While computing the time to traverse such a path may be straightforward in fixed, static networks, doing so becomes much more challenging in dynamic networks, in which the state of an edge in one timeslot (i.e., its presence or absence) is random, and may depend on its state in the previous timeslot. The authors compute the expected traversal time (ETT) for a dynamic path in a number of special cases of stochastic edge dynamics models, and for three different edge failure models, culminating in a surprisingly nontrivial yet realistic "hybrid network" setting in which the initial configuration of edge states for the entire path is known. The ETT for this "initial configuration" setting can be computed in quadratic time (as a function of path length), by an algorithm based on probability generating functions. Several linear-time upper and lower bounds on the ETT are provided and evaluated using numerical simulations.

### *5.2.2. Interference coordination in wireless networks*

In [47], R. Combes, E. Altman and Z. Altman (Orange Labs, Issy les Moulineaux) model a LTE wireless network with Inter-Cell Interference Coordination (ICIC) at the flow level where users arrive and depart dynamically, in order to optimize quality of service indicators perceivable by users such as file transfer time for elastic traffic. They propose an algorithm to tune the parameters of ICIC schemes automatically based on measurements. The convergence of the algorithm to a local optimum is proven, and a heuristic to improve its convergence speed is given. Numerical experiments show that the distance between local optima and the global optimum is very small, and that the algorithm is fast enough to track changes in traffic on the time scale of hours. The proposed algorithm can be implemented in a distributed way with very small signaling load.

In [46], the same authors introduce self-organizing mechanisms as control loops, and study the conditions for stability when running control loops in parallel. Based on control theory, they propose a distributed coordination mechanism to stabilize the system. In certain cases, coordination can be achieved without any exchange of information between control loops. The mechanism remains valid in the presence of noise via stochastic approximation. Instability and coordination in the context of wireless networks are illustrated with two examples. The paper is essentially concerned with linear systems, and the applicability of our results for non-linear systems is discussed.

### *5.2.3. Streaming over wireless*

The Quality of Experience (QoE) of streaming service is often degraded by playback interruptions. To mitigate these, the media player prefetches streaming contents before starting playback, at a cost of delay. In [66], Y. Xu, S. E. Elayoubi, E. Altman and R. El-Azouzi study the QoE of streaming from the perspective of flow dynamics. First, a framework is developed for QoE when streaming users join the network randomly and leave after downloading completion. They compute the distribution of prefetching delay using partial differential equations, and the probability generating function of playout buffer starvation using ordinary differential equations. Second, they extend the framework to characterize the throughput variation caused by opportunistic scheduling at the base station in the presence of fast fading. This study reveals that the flow dynamics is the fundamental reason of playback starvation. The QoE of streaming service is dominated by the average throughput of opportunistic scheduling, while the variance of throughput has very limited impact on starvation behavior.

### *5.2.4. Dynamic coverage of mobile sensor networks*

B. Liu (Univ. of Massachusetts at Lowell, USA), O. Dousse (Nokia Research Center, Switzerland), P. Nain, and D. Towsley (Univ. of Massachusetts at Amherst, USA) study in [30] the dynamic aspects of the coverage

of a mobile sensor network resulting from continuous movement of sensors. As sensors move around, initially uncovered locations may be covered at a later time, and intruders that might never be detected in a stationary sensor network can now be detected by moving sensors. However, this improvement in coverage is achieved at the cost that a location is covered only part of the time, alternating between covered and not covered. The authors characterize area coverage at specific time instants and during time intervals, as well as the time durations that a location is covered and uncovered. They further consider the time it takes to detect a randomly located intruder and prove that the detection time is exponentially distributed. For mobile intruders, a game theoretic approach allows to derive optimal mobility strategies for both sensors and intruders. The optimal sensor strategy is to choose the direction uniformly at random between 0 and $2\pi$. The optimal intruder strategy is to remain stationary. This solution represents a mixed strategy which is a Nash equilibrium of the zero-sum game between mobile sensors and intruders.

#### 5.2.5. Wireless network security

The activity on "Fast and secure rendezvous protocols for mitigating control channel DoS attacks" described in MAESTRO's 2012 activity report has lead to the publication [35].

## 5.3. Network Engineering Games

**Participants:** Eitan Altman, Konstantin Avrachenkov, Ilaria Brunetti, Julien Gaillard, Majed Haddad, Manjesh Kumar Hanawal, Alexandre Reiffers.

#### 5.3.1. Association problem

In [32], A. Silva, in collaboration with H. Tembine, E. Altman and M. Debbah, study a non-cooperative association game where mobiles associate to Base Stations. The authors solve the problem using the theory of optimal transportation after incorporating in it the effect of network congestion. They are able to find a closed form expression for its solution. The authors also solve a global optimization problem for minimizing the total power needed by the mobile terminals over the whole network.

#### 5.3.2. Cognitive radio

In [52] O. Habachi considers a non-cooperative Opportunistic Spectrum Access (OSA) where Secondary Users (SUs) access opportunistically the spectrum licensed for Primary Users (PUs) in TV white spaces (TVWS). As sensing licensed channels is time and energy consuming, the author considers a hierarchical Cognitive Radio (CR) architecture, where CR base stations sense a subset of the spectrum in order to locate some free frequencies. Thereafter, a SU that needs to communicate through TVWS sends a request to a CR base station for a free channel. The author models the problem using a Partially Observable Stochastic Game (POSG), and he takes into consideration the energy consumption of CR base stations and the Quality of Service of SUs. Since solving POSG optimally may require a significant amount of time and computational complexity, the author then models the OSA problem using a game theoretical approach, and proposes a symmetric Nash equilibrium solution concept. Finally, the simulations that validate the theoretical findings are provided.

In [24], J. Elias (Univ. Paris Descartes), F. Martignon (Univ. Paris Sud), L. Chen and E. Altman address the joint pricing and network selection problem in cognitive radio networks. The problem is formulated as a Stackelberg game where first the Primary and Secondary operators set the network subscription price to maximize their revenue. Then, users perform the network selection process, deciding whether to pay more for a guaranteed service, or use a cheaper, best-effort secondary network, where congestion and low throughput may be experienced. They use the Nash equilibrium concept to characterize the equilibria for the price setting game. On the other hand, a Wardrop equilibrium is used in the network selection game.

#### 5.3.3. Cooperative games in wireless networks

We have pursued this year our new activity on cooperative games in wireless communications. We have pursued our work on coalition games and started working on the area of matching games. In [56], E. Altman, C. Hasan and J.-M. Gorce (both from Inria project-team SOCRATE) have addressed the problem of association of mobiles to base stations which can be viewed as a coalition game. They formulated the game using a stochastic geometric approach (one Poisson point process representing the base stations and another one representing the mobiles) and studied the impact of switching off base stations (for energy efficient operation).

An important class of games within cooperative games is the matching games. They have been used in stable marriage games (in which a bi-partite graph called matching is to be proposed between a group of men and women based on mutual ranking between this group). A second well-known application of matching games is the college admission problem in which students are assigned to colleges based on their preferences as well as on the preferences of the colleges. We introduced and solved two matching games in wireless communication using the theory of matching games. In [55] the same authors study a game similar to the above ones to match pairs of mobiles where one mobile serves as a relay for the other in the absence of a good direct channel to the base station. The utilities studied here are the outage probabilities. In [65], R. Vaca-Ramirez, E. Altman, J. S. Thompson and V. Ramos-Ramos propose a distributed algorithm for energy efficient virtual Multiple-input/Multiple-output coalition formation. They model cooperation as a game derived from the concept of stable marriage with incomplete lists. Single antenna devices such as mobile and relay stations cooperate in order to improve the user's and system's energy efficiency. In both problems above, the performance of the equilibrium is shown to be close to the social optimum and yet the complexity for achieving the equilibrium is only polynomial (whereas that of computing a global optimal matching is NP hard).

In [40] K. Avrachenkov, L. Cottatellucci (EURECOM) and L. Maggi (CREATE-NET, Italy) study multiple access channels whose channel coefficients follow a quasi-static Markov process on a finite set of states. The authors address the issue of allocating transmission rates to users in each time interval, such that optimality and fairness of an allocation are preserved throughout a communication, and moreover all the users are consistently satisfied with it. First, it is shown how to allocate the rates in a global optimal fashion. The authors provide a sufficient condition for the optimal rates to fulfill some fairness criteria in a time-consistent way. Then the authors utilize the game-theoretical concepts of time consistent Core and Cooperation Maintenance. It is demonstrated that in the model the sets of rates fulfilling these properties coincide and they also coincide with the set of global optimal rate allocations. The relevance of the presented dynamic rate allocation to LTE systems is also shown.

### *5.3.4. Bayesian games in networking*

K. Veeraruna, E. Altman, R. El-Azouzi and S. Rajesh have studied in [29] a power control problem in which a base station allocates power according to the channel state as reported by the mobiles. The paper addresses the question of how to allocate the power, given that the channel reported by some non-cooperative mobile may be unreliable. They obtain the equilibrium allocation after formulating the problem as a Bayesian game.

In [38], E. Altman and T. Jiménez consider both a cooperative as well as non-cooperative admission into an M/M/1 queue. The only information available is a signal that says whether the queue size is smaller than some value L or not. They first compute the globally optimal and the Nash equilibrium stationary policy as a function of L. They compare the performance to that of full information and of no information on the queue size. They identify the value of L that optimizes the equilibrium performance.

In [58], K. Ibrahimi, E. Altman and M. Haddad introduce a signaling game approach to power control. They consider two players named player I and player II. They assume that player I only knows his channel state without any information about the channel state of player II and vice-versa. Player I moves first and sends a signal to player II which can be accurate or distorted. Player II chooses his power control strategy based on this information and his belief about the nature of the informed player's information. In order to analyze such a model, the proposed scheme game is transformed into an equivalent 4x4 matrix game. The authors establish the existence of Nash equilibria and then derive it numerically and study its properties.

In [53], M. Haddad and E. Altman, in collaboration with P. Wiecek and H. Sidi, present a Bayesian game theoretic framework for determining the decision to which cell a given mobile user should associate in LTE two-tier Heterogeneous Networks. Users are assumed to compete to maximize their throughput by picking the best locally serving cell with respect to their own measurement, their demand and a partial statistical channel state information of other users. In particular, the authors investigate the properties of a hierarchical game, in which the macro-cell BS is a player on its own. They derive analytically the utilities related to the channel quality perceived by users to obtain the equilibria. They show in the Stackelberg formulation, how

the operator, by dynamically choosing the offset about the state of the channel, can optimize its global utility while end-users maximize their individual utilities.

### 5.3.5. Network neutrality and collusion

Representatives of several Internet access providers have expressed their wish to see a substantial change in the pricing policies of the Internet. In particular, they would like to see content providers pay for use of the network, given the large amount of resources they use. This would be in clear violation of the "network neutrality" principle that had characterized the development of the wireline Internet. We proposed and studied possible ways of implementing such payments and of regulating their amount. M. K. Hanawal and E. Altman have pursued in [54] working on network neutrality studying various ways of collusion between an ISP and a content provider and in particular, another form of non-neutrality in which a content provider signals to an ISP information on the popularity of its content and hides this information from other ISPs. They define and compute the price of collusion and study the impact of such signalling on the ISP that is in collusion as well as on the other ones.

In the situation just described, the demand is modelled to be elastic. In contrast, in [62], A. Reiffers and E. Altman study in collaboration with Y. Hayel pricing issues in non-neutral network with non-elastic traffic. A Stackelberg equilibrium is derived and the price of collusion is computed.

Our research on network neutrality started already on 2010 with a research report [83] that has now been published in [14]. We already reported on this publication in 2011 when it became available electronically.

### 5.3.6. Competition over popularity in social networks

In [39] E. Altman, P. Kumar, S. Venkatramanan and A. Kumar consider a situation where several content producers send their content to some subscriber of a social network. These posts appear on the subscriber's timeline which is assumed to have finite capacity. Whenever a new post arrives to the timeline, an older post leaves it. Therefore to be visible, a source has to keep sending contents from time to time. Each source is modelled as a player in a non-cooperative game in which one trades between the utility for being visible on the timeline and the cost (or effort) for keeping sending content. This game is solved in a Markovian setting the performance measures of interest are computed.

In [37], E. Altman in cooperation with F. De Pellegrini (CREATE-NET), D. Miorandi, T. Jiménez and R. El-Azouzi study situations in which subscribers of a social network take the decision whether to access or not some content, based on the number of views that the content has. Their analysis aims at understanding the way in which information about the quality of a given content can be deduced from view counts when only part of the viewers that access the content are informed about its quality. In this paper they present a game formulation for the behavior of individuals using a mean-field model: the number of individuals is approximated by a continuum of atomless players and for which the Wardrop equilibrium is the solution concept. They derive conditions on the problem's parameters that result in the emergence of threshold equilibria policies. But they also identify some parameters in which other structures are obtained for the equilibrium behavior of individuals.

### 5.3.7. Evolutionary games

Evolutionary game theory is a relatively young mathematical theory that aims at formalizing in mathematical terms evolution models in biology. In recent years this paradigm has penetrated more and more into other areas such as the linguistics, economics and engineering. The current theory of evolutionary game makes an implicit assumption that the evolution is driven by selfishness of individuals who interact with each other. In mathematical terms this can be stated as "an individual equals a player in a non-cooperative game model". This assumption turns out to be quite restrictive in modeling evolution in biology. It is now more and more accepted among biologist that the evolution is driven by the selfish interests of large groups of individuals; a group may correspond for example to a whole beehive or to an ants' nest. In [43] and [71], I. Brunetti and E. Altman propose an alternative paradigm for modeling evolution where a player does not necessarily represent an interacting individual but a whole class of such individuals. In [71] in particular, they use Markov Decision Evolutionary Games (MDEG) to allow a parent and a child represent the same individual at different states.

This is yet another enhancement in what we understand as a player. An important contribution is in the study of the Hawk and Dove game in these new frameworks.

In [27], M. Haddad, J. Gaillard, E. Altman and D. Fiems (Ghent Univ.) study an evolutionary game in the MDEG framework of power control. Aging is taken into account by assuming that as the battery of the mobile becomes empty, high power is not available anymore. The goal of a mobile is to use power that maximizes the amount of traffic it can transmit during its lifetime. We restrict in this work to policies that are state independent and compute the equilibrium.

## 5.4. Green Networking and Smart Grids

**Participants:** Sara Alouf, Eitan Altman, Nicaise Choungmo Fofack, Delia Ciullo, Alain Jean-Marie, Giovanni Neglia.

### *5.4.1. Stochastic geometry methods for wireless design issues*

In [64] the issue of energy efficiency in Orthogonal Frequency-Division Multiple Access (OFDMA) wireless networks is discussed by D. Tsilimantos, J.-M. Gorce (Inria project-team SOCRATE) and E. Altman. Their interest is focused on the promising concept of base station (BS) sleep mode, introduced recently as a key feature in order to dramatically reduce network energy consumption. The proposed technical approach fully exploits the properties of stochastic geometry, where the number of active cells is reduced in a way that the outage probability, or equivalently the signal to interference plus noise (SINR) distribution, remains the same. The optimal energy efficiency gains are then specified with the help of a simplified but yet realistic BS power consumption model. Furthermore, the authors extend their initial work by studying a non-singular path loss model in order to verify the validity of the analysis and finally, the impact on the achieved user capacity is investigated. In this context, the significant contribution of this paper is the evaluation of the theoretically optimal energy savings of sleep mode, with respect to the decisive role that the BS power profile plays.

### *5.4.2. Analysis of base stations with autonomous energy supply*

S. Alouf, A. Jean-Marie and D. Ciullo have started the modeling of wireless communication base stations with autonomous energy supply (solar, wind). One challenge is to account for the random and non-stationary input of energy. A second challenge is to find the correct time and space granularity of the model, so as to ensure both the practical relevance of the model and numerical tractability. The activity will be backed up by a measurement campaign on the Com4Innov platform (http://www.com4innov.com/), that will provide information on energy consumption of different traffic patterns.

### *5.4.3. Demand-response system*

Energy demand aggregators are new actors in the energy scenario: they gather a group of energy consumers and implement a demand-response paradigm. When the energy provider needs to reduce the current energy demand on the grid, it can pay the energy demand aggregator to reduce the load by turning off some of its consumers loads or postponing their activation. Currently this operation involves only greedy energy consumers like industrial plants. In [48], [78] A. Jean-Marie and G. Neglia in collaboration with G. Di Bella, L. Giarré, M. Ippolito and I. Tinnirello (all from Univ. of Palermo, Italy) have studied the potential of aggregating a large number of small energy consumers like home users as it may happen in smart grids. In particular they have addressed the feasibility of such approach by considering which scale the aggregator should reach in order to be able to control a significant power load. The challenge of the study derives from residential users' demand being much less predictable than that of industrial plants. For this reason they have resorted to queuing theory to study analytically the problem and quantify the trade-off between load control and tolerable service delays.

## 5.5. Content-Oriented Systems

**Participants:** Sara Alouf, Konstantin Avrachenkov, Nicaise Choungmo Fofack, Delia Ciullo, Alain Jean-Marie, Philippe Nain, Giovanni Neglia, Marina Sokol.

### 5.5.1. Performance evaluation of hierarchical TTL-based cache networks

N. Choungmo Fofack, P. Nain and G. Neglia, together with D. Towsley (Univ. of Massachusetts at Amherst, USA) have revisited and extended the work that has appeared in [82]. They consider caches that implement an expiration-based eviction policy to manage contents in their memory. These caches are called Time-To-Live (TTL)-based caches. These TTL-based caches can be used to model caches running classical replacement policies such as Least Recently Used (LRU) and Random Replacement (RND). The main characteristic of the latter TTL-based cache models is that they (re)initialize the TTL of a content at both cache hit and cache miss. In a paper that is currently under review, the case of a network of caches where requests for each content are routed as a polytree is analyzed and a framework to evaluate the performance of such general TTL-based cache networks is proposed.

### 5.5.2. Modeling modern DNS caches

Motivated by the recent behavior of Domain Name System (DNS) caches that do not respect the timeout marked (by Authoritative DNS servers) on resource records, N. Choungmo Fofack and S. Alouf propose in [44] a theoretical model based on renewal arguments to describe this modern behavior. The proposed model for a cache taken in isolation is validated with real traces collected by Inria's IT service at Sophia-Antipolis at one of the Inria's DNS caches. The model of a network of caches is validated by event-driven simulations. This study suggests that, when inter-request times have a concave cumulative distribution function, client caches (those caches that are fed directly by users requests) should keep each resource record for a constant duration (that may depend on its popularity). However, core caches should draw their timeout values for each record from a distribution which has as high coefficient of variation as possible.

### 5.5.3. An approximate analysis of general and heterogeneous cache networks

Jointly with M. Dehghan, D. L. Goeckel and D. Towsley (Univ. of Massachusetts at Amherst, USA), N. Choungmo Fofack proposes a simple, accurate, and computationally efficient framework to assess performance of network of caches with arbitrary topology, requests described by renewal processes, and caches running Least Recently Used (LRU), First-In First-Out (FIFO), or Random Replacement (RND) policies. Their framework is based on the characteristic time approximation of LRU, RND and FIFO caches that helps to model the latter as TTL-based caches. Classical results of the theory of (renewal) point processes (e.g. approximation of general point processes by renewal processes, thinning a renewal point process, aggregating/merging independent renewal processes) are used as well as theoretical results established in [82] and [44] on TTL-based caches (e.g. calculation of metrics of interest such hit and occupancy probabilities, characterization of miss streams).

### 5.5.4. Data placement

Jointly with J.-C. Bermond (Inria project-team COATI), D. Mazauric (Univ. Aix-Marseille) and J. Yu (UFV Vancouver), A. Jean-Marie has pursued the study of combinatorial designs that solve the problem of replicating optimally data over unreliable servers, with the objective of minimizing the variance of the availability of documents. In a forthcoming revision of [81], they use results from Design Theory, particularly the existence of "large triple systems" to solve multiple instances of the problem.

### 5.5.5. Semi-supervised learning with application to P2P systems

Semi-supervised learning methods constitute a category of machine learning methods which use labelled points together with unlabelled data to tune the classifier. The main idea of the semi-supervised methods is based on an assumption that the classification function should change smoothly over a similarity graph, which represents relations among data points. This idea can be expressed using kernels on graphs such as graph Laplacian. Different semi-supervised learning methods have different kernels which reflect how the underlying similarity graph influences the classification results. In [41] K. Avrachenkov, P. Gonçalves (Inria project-team DANTE) and M. Sokol analyze a general family of semi-supervised methods, provide insights about the differences among the methods and give recommendations for the choice of the kernel parameters and labelled points. In particular, it appears that it is preferable to choose a kernel based on the properties of the

labelled points. They illustrate our general theoretical conclusions with an analytically tractable characteristic example, clustered preferential attachment model and classification of content in P2P networks.

## 5.6. Advances in Methodological Tools

**Participants:** Konstantin Avrachenkov, Alain Jean-Marie, Philippe Nain.

### *5.6.1. Perturbation analysis*

In [21] K. Avrachenkov and J.-B. Lasserre (LAAS-CNRS) investigate the analytic perturbation of generalized inverses. Firstly the authors analyze the analytic perturbation of the Drazin generalized inverse (also known as reduced resolvent in operator theory). The approach is based on spectral theory of linear operators as well as on a new notion of group reduced resolvent. It allows one to treat regular and singular perturbations in a unified framework. The authors provide an algorithm for computing the coefficients of the Laurent series of the perturbed Drazin generalized inverse. In particular, the regular part coefficients can be efficiently calculated by recursive formulae. Finally, the authors apply the obtained results to the perturbation analysis of the Moore-Penrose generalized inverse in the real domain.

### *5.6.2. Markov processes*

In [20] K. Avrachenkov, L. Cottatellucci (EURECOM), L. Maggi (CREATE-NET, Italy) and Y.-H. Mao (Beijing Normal Univ., China) consider both discrete-time irreducible Markov chains with circulant transition probability matrix $P$ and continuous-time irreducible Markov processes with circulant transition rate matrix $Q$. In both cases they provide an expression of all the moments of the entropy mixing time. In the discrete case, they prove that all the moments of the mixing time associated with the transition probability matrix $\alpha P + (1-\alpha)P^*$ are maximum in the interval $0 \leq \alpha \leq 1$ when $\alpha = 1/2$, where $P^*$ is the transition probability matrix of the time-reversed chain. Similarly, in the continuous case, they show that all the moments of the mixing time associated with the transition rate matrix $\alpha Q + (1-\alpha)Q^*$ are also maximum in the interval $0 \leq \alpha \leq 1$ when $\alpha = 1/2$, where $Q^*$ is the time-reversed transition rate matrix.

In [23] K. Avrachenkov, in collaboration with A. Piunovskiy and Z. Yi (both from Univ. of Liverpool, UK), study a general homogeneous continuous-time Markov process with restarts. The process is forced to restart from a given distribution at time moments generated by an independent Poisson process. The motivation to study such processes comes from modeling human and animal mobility patterns, restart processes in communication protocols, and from application of restarting random walks in information retrieval. The authors provide a connection between the transition probability functions of the original Markov process and the modified process with restarts. Closed-form expressions for the invariant probability measure of the modified process are derived. When the process evolves on the Euclidean space there is also a closed-form expression for the moments of the modified process. The authors show that the modified process is always positive Harris recurrent and exponentially ergodic with the index equal to (or bigger than) the rate of restarts. Finally, the general results are illustrated by the standard and geometric Brownian motions.

### *5.6.3. Queueing theory*

In [22] K. Avrachenkov, P. Nain and U. Yechiali (Tel Aviv Univ., Israel) consider two independent Poisson streams of jobs flowing into a single-server service system having a limited common buffer that can hold at most one job. If a type-$i$ job ($i = 1, 2$) finds the server busy, it is blocked and routed to a separate type-$i$ retrial (orbit) queue that attempts to re-dispatch its jobs at its specific Poisson rate. This creates a system with three dependent queues. Such a queueing system serves as a model for two competing job streams in a carrier sensing multiple access system. We study the queueing system using multi-dimensional probability generating functions, and derive its necessary and sufficient stability conditions while solving a Riemann-Hilbert boundary value problem. Various performance measures are calculated and numerical results are presented. In particular, numerical results demonstrate that the proposed multiple access system with two types of jobs and constant retrial rates provides incentives for the users to respect their contracts.

### 5.6.4. Control theory

In conjunction with E. Della Vecchia and S. Di Marco (both from National Univ. Rosario, Argentina), A. Jean-Marie has pursued the studies on the Rolling Horizon procedure and other approximations in stochastic control problems. Inspired by the work of A. Ruszczyński, they have considered Markov Decision problems where the metric to be optimized is a risk measure, a metric which generalizes the mathematical expectation and takes risk aversion of agents into account. For infinite-horizon, risk-averse discounted Markov Decision Processes, they have proved approximation bounds which imply the convergence of approximate rolling horizon procedures when the horizon length tends to infinity. They have also analyzed the effects of uncertainties on the transition probabilities, the cost functions and the discount factors [77].

In [17] K. Avrachenkov, U. Ayesta (LAAS-CNRS), J. Doncel (LAAS-CNRS) and P. Jacko (BCAM, Spain) address the problem of fast and fair transmission of flows in a router, which is a fundamental issue in networks like the Internet. They focus on the relaxed version of the problem obtained by relaxing the fixed buffer capacity constraint that must be satisfied at all time epoch. The relaxation allows one to reduce the multi-flow problem into a family of single-flow problems, for which one can analyze both theoretically and numerically the existence of optimal control policies of special structure. In particular, it is shown that the control can be represented by so-called index policies, but not always by threshold policies. The simulation and numerical results show that the index policy achieves a wide range of desirable properties with respect to fairness between different TCP versions, across users with different round-trip-time and minimum buffer required to achieve full utility of the queue.

### 5.6.5. Game theory

In [18] K. Avrachenkov, L. Cottatellucci (EURECOM) and L. Maggi (CREATE-NET, Italy) consider simple Markovian games, in which several states succeed each other over time, following an exogenous discrete-time Markov chain. In each state, a different simple static game is played by the same set of players. The authors investigate the approximation of the Shapley-Shubik power index in simple Markovian games (SSM). The authors prove that an exponential number of queries on coalition values is necessary for any deterministic algorithm even to approximate SSM with polynomial accuracy. Motivated by this, the authors propose and study three randomized approaches to compute a confidence interval for SSM. They rest upon two different assumptions, static and dynamic, about the process through which the estimator agent learns the coalition values. Such approaches can also be utilized to compute confidence intervals for the Shapley value in any Markovian game. The proposed methods require a number of queries, which is polynomial in the number of players in order to achieve a polynomial accuracy.

In [19] K. Avrachenkov, L. Cottatellucci (EURECOM) and L. Maggi (CREATE-NET, Italy) study multi-agent Markov decision processes (MDPs) in which cooperation among players is allowed. They find a cooperative payoff distribution procedure (MDP-CPDP) that distributes in the course of the game the payoff that players would earn in the long run game. They show under which conditions such a MDP-CPDP fulfills a time consistency property, contents greedy players, and strengthen the coalition cohesiveness throughout the game. Finally, the authors refine the concept of Core for Cooperative MDPs.

# 6. Bilateral Contracts and Grants with Industry

## 6.1. Bilateral Contracts with Industry

MAESTRO members are involved in the Inria Alcatel-Lucent Bell Labs joint laboratory and participate in several ADRs (Action de Recherche/Research Action). The joint laboratory consists of three ADRs in its first phase (2008–2012) and six ADRs in its second phase (starting October 2012).

### 6.1.1. ADR "Semantic Networking" (January 2008 – April 2013)

**Participants:** Sara Alouf, Eitan Altman, Konstantin Avrachenkov, Oussama Habachi, Philippe Nain, Marina Sokol.

Coordinators are Isabelle Guérin Lassous (Inria project-team RESO) for Inria and Ludovic Noirie for Alcatel-Lucent.

The new paradigm of "semantic networking" for the networks of the future brings together "flow-based networking", "traffic-awareness" and "self-management" concepts to get "plug-and-play" networks. The natural traffic granularity is the flow. MAESTRO's task is to elaborate on the scheduling of flows in routers having in mind the fairness among flows with different round-trip times. A joint Inria Alcatel-Lucent patent has been filed in 2009 (inventors for Inria: S. Alouf, K. Avrachenkov, D. Carra, P. Nain). Two other patents (inventors for Inria: S. Alouf, K. Avrachenkov, A. Blanc) were filed in 2010 but withdrawn later by Alcatel-Lucent.

### *6.1.2. ADR "Self-Organized Networks in Wireless" (October 2012 – )*

**Participants:** Eitan Altman, Majed Haddad, Manjesh Kumar Hanawal, Nessrine Trabelsi.

Coordinators are Bruno Gaujal (head of Inria project-team MESCAL) for Inria and Laurent Roullet for Alcatel-Lucent.

This ADR is a follow-up of the ADR "Self Optimizing Wireless Networks" from the first phase. Two joint Inria Alcatel-Lucent patents have been filed during the first phase, one in 2011 (inventors for Inria: E. Altman, S. Ramanath) and one in 2012 (inventors for Inria: E. Altman). Two joint Inria Alcatel-Lucent patents have been filed during the second phase, in 2013 (inventors for Inria: E. Altman, M. Haddad).

Majed Haddad and Eitan Altman have been working with Alcatel-Lucent on mobility issues in cellular networks. Various models have been proposed and developed in close collaboration with the business unit of Alcatel-Lucent.

### *6.1.3. ADR "Network Science" (January 2013 – January 2016)*

**Participants:** Konstantin Avrachenkov, Jithin Kazhuthuveettil Sreedharan, Philippe Nain, Giovanni Neglia, Marina Sokol.

Coordinators are Philippe Nain and Konstantin Avrachenkov for Inria and Philippe Jacquet for Alcatel-Lucent.

"Network Science" aims at understanding the structural properties and the dynamics of various kind of large scale, possibly dynamic, networks in telecommunication (e.g., the Internet, the web graph, peer-to-peer networks), social science (e.g., community of interest, advertisement, recommendation systems), bibliometrics (e.g., citations, co-authors), biology (e.g., spread of an epidemic, protein-protein interactions), and physics. The complex networks encountered in these areas share common properties such as power law degree distribution, small average distances, community structure, etc. Many general questions/applications (e.g., community detection, epidemic spreading, search, anomaly detection) are common in various disciplines and will be analyzed in this ADR "Network Science".

## 6.2. Bilateral Grants with Industry

### *6.2.1. "Data Communication Network Performance" (December 2013 – December 2015)*

**Participants:** Sara Alouf, Konstantin Avrachenkov, Philippe Nain, Giovanni Neglia.

Contractor: ALSTOM Transport (http://www.alstom.com/transport/)

Participants: Pierre Cotelle, Pierre Dersin, Sébastien Simoens.

The objective of this study is to build a simulation platform and and develop an evaluation methodology for predicting Quality of Service and availability of the various applications supported by the data communication system of train networks.

P. Nain is responsible for Inria.

# 7. Partnerships and Cooperations

## 7.1. National Initiatives

### *7.1.1. ANR Marmote*

**Participants:** Alain Jean-Marie, Issam Rabhi.

ANR Program: Modèles Numériques (MN) 2012

Project title: MARkovian MOdeling Tools and Environments

Duration: January 2013 - December 2016

Coordinator: Alain Jean Marie (Inria)

Partners: Inria (project-teams DYOGEN, MAESTRO and MESCAL), Univ. Versailles-Saint-Quentin (PRiSM lab.), Telecom SudParis (SAMOVAR lab.), Univ. Paris-Est Créteil (LACL), and Univ. Pierre-et-Marie-Curie (LIP6)

Abstract: ANR MARMOTE aims at realizing the prototype of a software environment dedicated to modeling with Markov chains. It brings together seven partner teams, expert in Markovian analysis, who will develop advanced solution algorithms and applications in different scientific domains: reliability, distributed systems, biology, physics and economics.

https://wiki.inria.fr/MARMOTE/Welcome

## 7.2. European Initiatives

### *7.2.1. FP7 Projects*

#### *7.2.1.1. CONGAS*

**Participants:** Eitan Altman, Konstantin Avrachenkov, Yonathan Portilla, Alexandre Reiffers.

Project title: Dynamics and coevolution in multi level strategic interaction games

Type: COOPERATION

Challenge: Future and Emerging Technologies

Instrument: Specific Targeted Research Project

Objective: FET Proactive: Dynamics of Multi-Level Complex Systems (DyM-CS)

Duration: October 2012 - September 2015

Coordinator: Francesco De Pellegrini (CREATE-NET)

Scientific Coordinator: Eitan Altman (Inria)

Other partners: Center for Research and Telecommunication Experimentation for Network Communities (Italy), Univ. d'Avignon et des Pays de Vaucluse (France), Technische Universiteit Delft (The Netherlands), Imperial College of Science, Technology and Medicine (United Kingdom), Univ. di Pisa (Italy) and Technion - Israel Institute of Techonology (Israel)

Inria contact: Konstantin Avrachenkov

Abstract: CONGAS will develop new mathematical models and tools, rooted in game theory, for the analysis, prediction and control of dynamical processes in complex systems. It will provide a coherent theoretical framework for understanding the emergence of structure and patterns in these systems, accounting for interactions spanning various scales in time and space, and acting at different structural and aggregation levels.

MAESTRO's task is to develop game theoretic models to model (a) the formation of technological and social network; (b) the routing for competing agents; and (c) the competition of information in social networks.

http://www.congas-project.eu/

### *7.2.2. Collaborations in European Programs, except FP7*

Program: PHC Tournesol FL - Belgium

Project title: Stochastic modelling of dissemination and epidemic processes on complex networks

Duration: January 2013 - December 2013

Coordinator: B. Prabhu (LAAS-CNRS) is coordinator for French side and D. Fiems is coordinator for Belgian side

Other partners: CNRS, LAAS (France); Ghent University, TELIN (Belgium)

More info: The role of MAESTRO is to work on information propagation models in online social network with directed links.

### *7.2.3. Collaborations with Major European Organizations*

European Space Operations Centre: European Space Agency, Darmstadt (Germany)

Application of a BitTorrent-like data distribution model to mission operations. In the framework of this project with ESA we cooperate with Thales-Alenia Space (France) and with Teletel S.A. (Greece).

## 7.3. International Initiatives

### *7.3.1. Inria Associate Teams*

#### *7.3.1.1. GANESH*

**Participants:** Eitan Altman, Konstantin Avrachenkov, Manjesh Kumar Hanawal, Parmod Kumar.

Title: GAmes, OptimizatioN and Analysis of NEtworkS THeory and Applications

Inria principal investigator: Eitan Altman

International Partners (Institution - Laboratory - Researcher):

IISc Bangalore (India) - Electrical Communication Engineering - Anurag Kumar

IIT Bombay (India) - Department of Electrical Engineering - D. Manjunath

IIT Madras (India) - Electrical Engineering - Venkatesh Ramaiyan

Duration: 2012 - 2014

See also: http://www-sop.inria.fr/members/Eitan.Altman/Ganesh/Home.html

This project aims at producing outstanding contributions to the foundations of the theory of networks, in game theory, team theory, optimization and analysis. Three areas in networking will be used to apply these: (a) economy of networks and network neutrality, (b) scheduling in wireless networks, and (c) distributed optimization issues in ad-hoc networks.

### *7.3.2. Inria International Partners*

#### *7.3.2.1. Informal International Partners*

MAESTRO has continued collaborations with researchers from GERAD, Univ. Montreal (Canada), Flinders Univ. (Australia), National Univ. of Rosario (Argentina), Technion – Israel Institute of Technology (Israel), Univ. of Arizona (USA), Univ. of Illinois at Urbana-Champaign (USA), Univ. of Liverpool (UK), Univ. of Massachusetts at Amherst (USA), Univ. of Palermo (Italy), and Univ. of Twente (The Netherlands); cf. Sections 7.4.1.1 and 7.4.2.

## 7.4. International Research Visitors

### *7.4.1. Visits of International Scientists*

*7.4.1.1. Professors / Researchers*

**Koen De Turck**

Subject: Information Dissemination in Directed Online Social Networks

Date: from 25 Nov 2013 until 27 Nov 2013

Institution: Ghent Univ. (Belgium)

**Jocelyne Elias**

Subject: Network Covering

Date: from 29 Nov 2013 until 28 Dec 2013

Institution: Paris Descartes Univ. (France)

**Dieter Fiems**

Subject: Information Dissemination in Directed Online Social Networks

Date: from 25 Nov 2013 until 27 Nov 2013

Institution: Ghent Univ. (Belgium)

**Vladimir Gaitsgory**

Subject: Singular Perturbations in Markov Decision Processes

Date: from 30 Nov 2013 until 6 Dec 2013

Institution: Flinders University (Australia)

**Jasper Goseling**

Subject: Random Access with Physical-layer Network Coding

Date: from 13 Oct 2013 until 16 Oct 2013

Institution: Univ. of Twente (Netherlands)

**Roberto Lucchetti**

Subject: Application of Cooperative Games to Networks

Date: from 10 Jul 2013 until 12 Jul 2013

Institution: Politecnico di Milano (Italy)

**Natalia Markovich**

Subject: Modeling Clusters of Extreme Values in Random Walk Processes

Date: from 1 Jul 2013 until 15 Aug 2013

Institution: Russian Academy of Sciences (Russia)

**Fabio Martignon**

Subject: Network covering

Date: from 29 Nov 2013 until 28 Dec 2013

Institution: Paris Sud Univ.(France)

**Vladimir Mazalov**

Subject: Networking Games and Cloud Computing Market

Date: from 17 Sep 2013 until 18 Oct 2013

Institution: Petrozavodsk State Univ. (Russia)

**Leon Petrosian**

Subject: Game Theoretic Models in Network Formation

Date: from 2 Aug 2013 until 9 Aug 2013

Institution: St. Petersburg State Univ. (Russia)

**Bruno Ribeiro**

Subject: Online Myopic Network Covering

Date: from 12 Jun 2013 until 19 Jun 2013

Institution: Univ. Massachusetts, Amherst (USA)

**Don Towsley**

Subject: Randomness and Wireless Security

Date: from 15 Apr 2013 until 19 Apr 2013

Institution: Univ. Massachusetts, Amherst (USA)

**Kavitha Voleti Veeraruna**

Subject: Performance Analysis of Social Networks Using Game Theoretical Tools

Date: from 28 May 2013 until 7 Jun 2013

Institution: IIT Bombay (india)

**Piotr Wiecek**

Subject: Evolutionary Game Models

Date: from 16 Sep 2013 until 27 Sep 2013

Institution: Wrocław Univ. of Technology (Poland)

**Sulan Wong**

Subject: European Approach to Net Neutrality

Date: from 1 Dec 2013 until 15 Jan 2014

Institution: Univ. de A Coruña (Spain)

**Uri Yechiali**

Subject: A Retrial System with Two Input Streams and Two Orbit Queues

Date: from 21 Apr 2013 until 4 May 2013

Institution: Tel Aviv Univ. (Israel)

*7.4.1.2. Ph.D. students*

**Giovanni Accongiagioco**

Subject: Game theoretic models applied to the Internet Economy

Date: from 14 Jan 2013 until 13 Jul 2013

Institution: Pisa Univ. (Italy)

**Liudmila Ostroumova**

Subject: Epidemic models on directed networks

Date: from 26 May 2013 until 9 Jun 2013

Institution: Yandex and Moscow State Univ. (Russia)

**Cristina Rottondi**

Subject: Privacy in smart grids

Date: from 1 Nov 2013 until 30 Nov 2013

Institution: Politecnico di Milano (Italy)

**Rodrigo Vaca Ramirez**

Subject: Vertical handover framework towards energy efficiency

Date: from 23 Nov 2012 until 12 Mar 2013

Institution: Univ. of Edinburgh (UK)

*7.4.1.3. Internships*

**Xinwei Bai**

Subject: Optimization of spatial caches

Date: from 15 Sep 2013 until 14 Dec 2013

Institution: Univ. of Twente (Netherlands)

**Grégoire Beaudoire**

Subject: Complexity Analysis of the Network Coverage Problem

Date: from 10 Jun 2013 until 26 Jul 2013

Institution: ENS Lyon (France)

**Kumar Chippala**

Subject: Numerical comparison of various multi-armed bandit algorithms

Date: from 2 May 2013 until 23 Jul 2013

Institution: IIT Bombay (India)

**Engin Eljez**

Subject: Congestion games with cost that decrease in the congestion

Date: from 1 Jun 2013 until 29 Jul 2013

Institution: Politecnico di Torino (Italy)

**Simon Forest**

Subject: Graphes aléatoires : génération, épidémies, applications

Date: from 10 Jun 2013 until 2 Aug 2013

Institution: ENS Paris (France)

**Sushma Hanawal**

Subject: Creation, Simulation and Multidiscipline Evaluation of Dynamic Mobility Models in Complex Systems

Date: from 25 Aug 2012 until 25 Mar 2013

Institution: SJCE Mysore (India)

**Denys Korostii**

Subject: Polls in online social networks

Date: from 1 Mar 2013 until 31 Aug 2013

Institution: Univ. Nice Sophia Antipolis (France)

**Vasily Medyanikov**

Subject: Graph-theoretic Models for Evolution of Social Networks

Date: from 22 Jul 2013 until 11 Aug 2013

Institution: St. Petersburg State Univ. (Russia (Russian Federation))

**Tanmay Vashistha Sharma**
Subject: Diffusion Processes in Networks
Date: from 6 May 2013 until 12 Jul 2013
Institution: IIT Bombay (India)

**Xiuhui Ye**
Subject: Raise of influential individuals in Online Social Networks
Date: from 15 May 2013 until 15 Nov 2013
Institution: Politecnico di Torino (Italy)

#### *7.4.2. Visits to International Teams*

MAESTRO members have visited (the)

- GERAD, Univ. Montreal, Canada in the period 20 October – 10 November 2013 (**A. Jean-Marie**);
- Ghent Univ., Belgium in the period 21–22 November 2013 (**K. Avrachenkov**);
- Flinders Univ., Australia in the period 20 March – 20 April 2013 (**K. Avrachenkov**);
- National Univ. of Rosario, Argentina in the period 4 – 15 March 2013 (**A. Jean-Marie**);
- Petrozavodsk State Univ., Russia in the period 26 – 28 June 2013 (**K. Avrachenkov**);
- Technical Univ. of Darmstadt, Germany in the period 5–6 October 2013 (**G. Neglia**);
- Technion – Israel Institute of Technology, Tel Aviv, Israel in the period 19–28 April 2013 (**E. Altman**);
- Univ. of Arizona, USA in the period 31 March – 2 June 2013 (**M. K. Hanawal**);
- Univ. of Illinois at Urbana-Champaign, USA in the period 1 October 2013 – 31 January 2014 (**M. El Chamie**);
- Univ. of Liverpool, UK in the period 6 – 14 February 2013 (**K. Avrachenkov**);
- Univ. of Massachusetts at Amherst, USA in the periods 1 September – 30 October 2013 (**N. Choungmo Fofack**) 1–10 May 2013 and 25–30 October 2013 (**P. Nain**);
- Univ. of Twente, The Netherlands in the period 19 – 20 June 2013 (**K. Avrachenkov**);
- Yandex Research and Institute of Control Problems, Russia in the period 21 – 30 October 2013 (**K. Avrachenkov**);

# 8. Dissemination

## 8.1. Scientific Animation

### *8.1.1. Editorial activities*

MAESTRO members are

Editor-in-Chief of

- *Performance Evaluation* (PEVA) (**P. Nain** since 1 January 2008);

Associate Editors of (in alphabetical order)

- *Dynamic Games and Applications* (DGAA) (**E. Altman** since 2011);
- *IEEE Transaction on Control of Networks* (TCNS) (**E. Altman** since 2013);
- *IEEE/ACM Transaction on Networking* (ToN) (**E. Altman** since 2013);
- *Journal of Economic Dynamics and Control* (JEDC) (**E. Altman** since 2001);
- *Performance Evaluation* (PEVA) (**K. Avrachenkov** since 2008);

Guest editors of Special Issues of

- *Dynamic Games and Applications* (DGAA) on "Dynamic Games for Networks" [69] (**E. Altman**);
- *Performance Evaluation* (PEVA) on "Selected Papers from the 9th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2011)" [70] (**E. Altman**).

### *8.1.2. Conferences, meetings and tutorial organization*

MAESTRO members were

in the Steering Committee of

- 7th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2013, Turin, Italy) (**E. Altman**);
- 31st Intl. Symposium on Computer Performance, Modeling, Measurements and Evaluation (IFIP WG 7.3 Performance 2013, Vienna, Austria) (**P. Nain**);
- 11th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2013, Tsukuba, Japan) (**E. Altman** as chair).

General Co-chair of

- IEEE Intl. Workshop on Self-Organizing Networks (SONETs 2014, Istanbul, Turkey) (**M. Haddad**);
- 4th Intl. Workshop on Indoor and Outdoor Small Cells (IOSC 2013, Tsukuba, Japan) (**E. Altman**, **M. Haddad**).

Publicity Co-chair of

- ACM Intl. Conference on Measurement and Modeling of Computer Systems (ACM SIGMETRICS 2014, Austin, Texas, USA) (**S. Alouf**);
- 33rd IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2014, Toronto, Canada) (**G. Neglia**).

Organizer of

- a stream of sessions "Random Graphs and Complex Networks" at the 17th INFORMS Applied Probability Society Conference 2013 (Costa Rica) (**K. Avrachenkov**).

Workshops chair of

- 11th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2013, Tsukuba, Japan) (**M. Haddad**).

### *8.1.3. Participation in technical program committees (TPC)*

MAESTRO members were in the TPC of (in alphabetical order)

1. 8th ACM MobiCom Workshop on Challenged Networks (CHANTS 2013, Miami, Florida, USA) (**G. Neglia**);
2. ACM Intl. Conference on Measurement and Modeling of Computer Systems (ACM SIGMETRICS 2013, Pittsburgh, Pennsylvania, USA) (**A. Jean-Marie**);
3. 9th Advanced Intl. Conference on Telecommunications (AICT 2013, Rome, Italy) (**K. Avrachenkov**);
4. 33rd IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2014, Toronto, Canada) (**G. Neglia**);
5. 4th Intl. Conference on Access Networks (ACCESS 2013, Nice, France) (**K. Avrachenkov**);
6. 20th Intl. Conference on Analytical and Stochastic Modelling Techniques and Applications (ASMTA 2013, Ghent, Belgium) (**K. Avrachenkov**);
7. 7th Intl. Conference on Game Theory and Management (GTM 2013, St. Petersburg, Russia) (**E. Altman**);
8. 13th Intl. Conference on Next Generation Wired/Wireless Networking (NEW2AN 2013, St. Petersburg, Russia) (**K. Avrachenkov**);
9. 7th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2013, Turin, Italy) (**S. Alouf**, **G. Neglia**);

10. 28th Intl. Symposium on Computer and Information Sciences (ISCIS 2013, Paris, France) (**A. Jean-Marie**);
11. 11th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2013, Tsukuba, Japan) (**D. Ciullo**);
12. 25th Intl. Teletraffic Conference (ITC 2013, Shanghai, China) (**S. Alouf**, **G. Neglia**);
13. 1st Intl. Workshop on Modeling, Measurements and Optimization of Video Performance over Wireless Networks (WiVid 2013, Tsukuba, Japan) (**O. Habachi**);
14. 6th Intl. Workshop on Multiple Access Communications (MACOM 2013, Vilnius, Lithuania) (**K. Avrachenkov**);
15. Intl. Workshop "Networking Games and Management" (Petrozavodsk, Russia) (**E. Altman**, **K. Avrachenkov**);
16. 9th Intl. Workshop on Resource Allocation, Cooperation and Competition in Wireless Networks (RAWNET/WNC3 2013, Tsukuba, Japan) (**O. Habachi**);
17. Joint Workshop on Pricing and Incentives in Networks and Systems (W-PIN+NetEcon 2013, Pittsburgh, Pennsylvania, USA) (**E. Altman**).
18. 15èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications (AlgoTel 2013, Pornic, France) (**G. Neglia**);
19. 10th Workshop on Algorithms and Models for the Web Graph (WAW 2013, Cambridge, Massachusetts, USA) (**K. Avrachenkov**);
20. 15th Workshop on Mathematical Performance Modeling and Analysis (MAMA 2013, London, UK) (**A. Jean-Marie**, **P. Nain**);

### *8.1.4. Leadership within the scientific community*

- E. Altman is a fellow member of IEEE (Class of 2010).
- E. Altman, A. Jean-Marie and P. Nain are (elected) members of IFIP WG7.3 on "Computer System Modeling".
- P. Nain is the vice-Chair of the IFIP WG7.3 working group on "Computer System Modeling" (since June 30, 2007).

### *8.1.5. Research administration*

S. Alouf

- was member of the recruitment committee for a *Maître de Conférences* position at Polytech'Tours.

E. Altman

- is co-responsible of one of the five themes of the SFR (Structure Fédérative de Recherche) AGORANTIC (in which Inria is a founding member) entitled "Digital Culture and Virtual Societies."
- is Scientific coordinator of the European project CONGAS.

K. Avrachenkov

- together with Arnaud Legout (DIANA team) and Fabien Gandon (WIMMICS team) is co-responsible of the multi-disciplinary research theme (Action Transversale) "Semantic and Complex Networks" at Inria Sophia Antipolis - Méditerranée.

A. Jean-Marie

- is the scientific coordinator of Inria activities in Montpellier (since 2008); as part of this duty, he represents Inria in the Scientific Board of the Univ. of Montpellier 2, at the Scientific Council of the Doctoral School "Sciences and Agrosciences" of the Univ. of Avignon, at the Regional Conference of Research Organisms (CODOR), at the Regional Consulting Committee for Research and Technological Development (ARAGO Committee);

- is member of the managing sub-committee of the Project-Team Committee of the Inria Sophia Antipolis – Méditerranée research center (since July 2010);
- is a member of the Steering Committee of the GDR RO, a national research initiative on Operations Research sponsored by the CNRS;
- is president of the Technical and Industrial Orientation Council for Information Technologies (COSTI TIC) of the Transferts LR association (since 2009);
- has presided the 2013 recruitment committee for junior Inria researchers (CR2) for the Inria Sophia-Antipolis – Méditerranée research center.

P. Nain

- is Chairman of Inria's Evaluation Committee since 1 September 2012 (http://www.inria.fr/en/institute/organisation/committees/evaluation-committee); as part of this duty he has presided the 2013 recruitment committee for senior Inria researchers (DR2) and was member of the 2013 recruitment committee for junior Inria researchers (CR2) for the Inria Nancy Grand Est center.
- is Head of project-team MAESTRO.

MAESTRO members are in the following committees of Inria Sophia Antipolis - Méditerranée

- CC (Comité de Centre): General Information Commission (**N. Choungmo Fofack** as PhD Student Representative, until May 2013); **G. Neglia** since September 2013);
- ComRes: Commission Restauration (**N. Choungmo Fofack** as PhD Student Representative, until May 2013);
- CSD: Doctoral Committee (**S. Alouf**, since February 2006);
- NICE: Invited Researchers Committee (**K. Avrachenkov**, since 2010);

and in charge of the following tasks for the research center:

- Supervision and validation of the project-teams' yearly activity reports (**K. Avrachenkov**, since 2010);
- Accounting for the monthly Project-Team Committee meetings (**S. Alouf**, since February 2012);
- Organizing MAESTRO internal meetings (**N. Choungmo Fofack**, since November 2011).

## 8.2. Teaching - Supervision - Juries

### *8.2.1. Teaching*

Licence:

S. Alouf, "Probability and Statistics", 45H, 1st year Water Engineering degree (L3), Univ. of Nice Sophia Antipolis (UNS), France.

E. Altman, "Culture and Internet", 32H, 3rd year of Communication and Culture studies (L3), Univ. of Avignon (UAPV), France.

N. Choungmo Fofack, "Stochastic processes for Signal Processing", 64H, 1st year Electronic Engineering degree (L3), Univ. of Nice Sophia Antipolis (UNS), France.

M. El Chamie, "Databases", 20H, Computer Science Methods applied to the Enterprise Management Program (L3), Univ. of Nice Sophia Antipolis (UNS), France.

M. El Chamie, "Networks", 15H, Computer Science Program (L3), Univ. of Nice Sophia Antipolis (UNS), France.

Master:

S. Alouf, "Performance Evaluation of Networks", 31.5H, M2 IFI Ubinet, Univ. of Nice Sophia Antipolis (UNS), France.

E. Altman, “Analysis of social Networks”, 8H, Venezuelan Informatics School (EVI), Master in Computer Engineering, Merida, 30 Sept – 4 October, Merida, Venezuela.

M. El Chamie, “Internet and Networks”, M1 International in Computer Science, Univ. of Nice Sophia Antipolis (UNS), France.

G. Neglia, “Performance Evaluation of Networks”, 31.5H, M2 IFI Ubinet, Univ. of Nice Sophia Antipolis (UNS), France.

Doctorat:

A. Jean-Marie, “Advanced Markov Modeling”, 18H, Univ. of Montpellier 2, France.

### *8.2.2. Supervision*

PhD:

Richard Combes, “Self-organizing functionalities in radio networks,” Univ. Pierre and Marie Curie, 15 February 2013, advisors: Eitan Altman and Zwi Altman (Orange Labs) and Sylvain Sorin (Univ. Pierre and Marie Curie).

Eugenio Della Vecchia, “Contribution to the solution of problems in stochastic control and games”, National Univ. of Rosario, Argentina, 12 March 2013, advisors: Silvia Di Marco (National Univ. of Rosario, Argentina) and Alain Jean-Marie.

Manjesh Kumar Hanawal, “Resource allocation and learning algorithms in small cells wireless networks,” Univ. of Avignon (UAPV), 6 November 2013, advisors: Eitan Altman and Rachid El-Azouzi (Univ. of Avignon).

Cengis Hasan, “Optimization of resource allocation for small cells networks,”, INSA Lyon, 29 August 2013, advisors: Eitan Altman and Jean-Marie Gorce (Inria project-team SOCRATE).

Yuhui Wang, “On the use of network coding and multicast for enhancing performance of wired networks”, Telecom SudParis, 17 May 2013, advisors: Eitan Altman, Tijani Chahed and Eric Gourdin (Telecom SudParis).

PhD in progress:

Alberto Benegiamo, “Mathematical tools for smart grids,” 1 November 2013, advisors: Patrick Loiseau (Eurecom) and Giovanni Neglia.

Ilaria Brunetti, “Cooperative and competitive content dissemination in social networks,” 1 October 2012, advisor: Eitan Altman.

Nicaise Choungmo Fofack, “Performance Evaluation of TTL-based resource networks,” 1 October 2010, advisors: Sara Alouf and Philippe Nain.

Mahmoud El Chamie, “Belief propagation in complex networks,” 1 October 2011, advisors: Konstantin Avrachenkov and Giovanni Neglia.

Julien Gaillard, “Creation, simulation and multidiscipline evaluation of dynamic mobility models in complex systems,” 1 October 2011, advisors: Eitan Altman, Marc El Bèze (Univ. of Avignon) and Emmanuel Ethis (Univ. of Avignon).

Jithin Kazhuthuveettil Sreedharan, “Diffusion processes in complex networks,” 23 July 2013, advisor: Konstantin Avrachenkov.

Yonathan Portilla, “Analysis of social networks,” 1 January 2012, advisor: Eitan Altman.

Alexandre Reiffers, “Modelling competition and cooperation in telecommunication networks,” 15 October 2012, advisor: Eitan Altman.

Marina Sokol, “Clustering and learning techniques for traffic/user classification,” 1 October 2009, advisors: Paulo Gonçalves (Inria project-team DANTE) and Philippe Nain.

Abdoulaye Tall, “Self organization in wireless networks,” 1 December 2012, advisors: Eitan Altman and Zwi Altman (Orange Labs).

### 8.2.3. Juries

MAESTRO members participated in the Habilitation (HDR) thesis committees of (in alphabetical order):

- Marc Chaumont: 23 July 2013, Univ. of Montpellier 2 (**A. Jean-Marie** as jury member);
- Yezekael Hayel: 4 December 2013, Univ. of Avignon (UAPV) (**E. Altman** as advisor and **A. Jean-Marie** as jury president);
- Raphaël Soubeyran: 13 November 2013, Univ. Montpellier 1 (**A. Jean-Marie** as jury member);

and in the PhD thesis committees of (in alphabetical order):

- Richard Combes: 15 February 2013, Pierre and Marie Curie Univ. (**E. Altman** as advisor);
- Manjesh Kumar Hanawal: 6 November 2013, Univ. of Avignon (**E. Altman** as advisor);
- Mathieu Leconte: 18 December 2013, Telecom ParisTech (**A. Jean-Marie** as jury president);
- Cédric Mauclair: 13 June 2013, Univ. Toulouse (**A. Jean-Marie** as jury member);
- Alexandre Salch: 29 November 2013, INPG (**A. Jean-Marie** as reviewer and **P. Nain** as jury member);
- Romain Tajan: 5 December 2013, Univ. Cergy-Pontoise (**Eitan Altman** as jury member);
- Yuhui Wang: 17 May 2013, Telecom SudParis (**E. Altman** as advisor).

## 8.3. Popularization

Activities are presented in chronological order:

- The article titled "Internet" (interview of S. Alouf by E. Kuntzelmann, as reported in the 2012 activity report) has appeared in Savoirs Jeunes (14 January 2013). It is available here: http://www.savoirs.essonne.fr/sections/ressources/questions-a/resource/internet/.
- E. Altman and A. Reiffers participated in a round-table on the network economy in France, organized at the National Assembly in Paris (28 February 2013).
- A short publication [80] by M. Cosnard and E. Altman has appeared in 01Business on the network neutrality debate in France (11 July 2013). It is intended for a large audience and presents advantages in legislating on this topic.
- E. Altman presented a talk at the 9th Mediterranean rendez-vous entitled: "The new networks - Cradle of globalized culture in the Mediterranean Area" at Marseille, with the participation of leading political and economical figures from Mediterranean and Middle Eastern countries (9 November 2013).
- S. Alouf delivered a conference titled "Internet ou Web ?" at Inria, Sophia Antipolis, for a group of high school students (22 November 2013).

S. Alouf is a member of MASTIC, a commission in charge of popularization and regional and internal scientific animation (since November 2011).

## 8.4. Participation in scientific events

### 8.4.1. Keynotes, tutorials and invited talks

MAESTRO members gave the following keynote lectures (in alphabetical order):

- *Admission control to an M/M/1 queue with partial information*, at the 20th Intl. Conference on Analytical & Stochastic Modelling Techniques & Applications (ASMTA), Ghent, Belgium, 8 July 2013 (**E. Altman**);
- *Dynamic game models in complex systems*, at the 17th Intl. Conference On Principles Of Distributed Systems (OPODIS), Nice, France, 17 December 2013 (**E. Altman**);

the following tutorials (in alphabetical order):

- *Tutorial on Stochastic Games*, at Game Theory Workshop of Politecnico di Milano, Italy , 23–24 May 2013 (**K. Avrachenkov**).

and the following invited talks (in alphabetical order):

- *Analysis of Social Networks*, at the Seminar on interactions of computer science and mathematics in the LIP6 laboratory of the Pierre and Marie Curie Univ., France, 18 October 2013 (**E. Altman**);
- *Competition over popularity in social networks*, at KAIST, Seoul, 21 May 2013 (**E. Altman**);
- *Cooperative Game Theory for Markovian quasi-static multiple access channels*, at the Workshop "Networking Games and Management", Petrozavodsk, Russia, 24 June 2013 (**K. Avrachenkov**);
- *Game theoretic models for competition over popularity in social networks*, University of California at Berkeley, USA, 26 July 2013 (**E. Altman**);
- *Graph-based semi-supervised learning methods: Comparison and tuning*, at the Yandex Workshop on Random Graphs and their Applications, Moscow, Russia, 25 October 2013 (**K. Avrachenkov**);
- MAESTRO*'s activities on smart grids*, at the JRC-TUM Partnership Event "Emerging Smart Electricity Systems", 20–21 March 2013, Munich, Germany (**G. Neglia**);
- *Modeling Energy Demand Aggregators for Residential Consumers*, at the Centre de Mathématiques Appliquées de l'Ecole des Mines, Sophia Antipolis, France, 2 April 2013 (**G. Neglia**);
- *Modern DNS cache network*, at Boston Univ., Boston, Massachusetts, USA, 23 September 2013 (**N. Choungmo Fofack**);
- *Online Myopic Network Covering*, at the Mathematics Department of the University of Liverpool, UK, 8 February 2013 (**K. Avrachenkov**);
- *Pay Few, Influence Most - Online Myopic Network Coverage*, at the Technical Univ. of Darmstadt, Germany, 6 September 2013 (**G. Neglia**);
- *Singular Perturbations in Optimization*, at GeoLMI 2013 Conference, Luminy, France, 12 November 2013 (**K. Avrachenkov**);
- *Weight Selection in Consensus Protocols*, at Univ. of Illinois at Urbana-Champaign (UIUC), Champaign, Illinois, USA, 24 October 2013 (**M. El Chamie**).

### *8.4.2. Conferences and workshops*

MAESTRO members gave presentations at the following scientific events (in alphabetical order):

- Conf. on Empirical Methods in Natural Language Processing (EMNLP), 18–21 October 2013, Seattle, Washington, USA (**J. Gaillard**);
- Dagstuhl Scheduling Seminar, 11 March 2013, Dagstuhl Castle, Germany (**K. Avrachenkov**);
- 52nd IEEE Conf. on Decision and Control (CDC), 10–13 December 2013, Florence, Italy (**I. Brunetti**, **G. Neglia**);
- 32nd IEEE Intl. Conf. on Computer Communications (INFOCOM), 14–19 April 2013, Turin, Italy (**E. Altman**);
- IEEE Wireless Communications and Networking Conf. (WCNC), 7–10 April 2013 Shanghai, China (**O. Habachi**);
- 12th IFIP Intl. Conf. on Networking (Networking), 22–24 May 2013, Brooklyn, New York, USA (**G. Neglia**);
- 20th Intl. Conf. on Analytical and Stochastic Modelling Techniques and Applications (ASMTA), 8–10 July 2013, Ghent, Belgium (**E. Altman**);
- 9th Intl. Conf. on Data Mining (DMIN), 22–25 July 2013, Las Vegas, Nevada, USA (**J. Gaillard**);
- 7th Intl. Conf. on Performance Evaluation Methodologies and Tools (VALUETOOLS), 10–12 December 2013, Turin, Italy (**N. Choungmo Fofack**);

- 11th Intl. Symp. on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), 13–17 May 2013, Tsukuba, Japan (**E. Altman**, **M. Haddad**, **M. K. Hanawal**);
- 25th Intl. Teletraffic Conference (ITC), 10-12 September 2013, Shanghai, China (**M. Haddad**);
- 15èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications (AlgoTel), 28–31 May 2013, Pornic, France (**M. El Chamie**, **A. Reiffers**);
- 10th Workshop on Algorithms and Models for the Web Graph (WAW), 14–15 December 2013, Cambridge, Massachusetts, USA (**K. Avrachenkov**);
- Workshop of the ANR CLEANER, 31 January–1 February 2013, Annecy, France (**A. Jean-Marie**);
- 9th Workshop of the Intl. Society of Dynamic Games (ISDG), 5–6 July 2013, Barcelona, Spain (**I. Brunetti**).

### *8.4.3. Technical program committee meetings*

MAESTRO members have participated in the following TPC meetings:

- 33rd IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2014), 16 November 2013, Toronto, Canada (**G. Neglia**).

### *8.4.4. Schools and students workshops*

MAESTRO members have attended the following summer schools:

- Summer school ResCom on “Content-oriented networks, Internet evolution or revolution?” (30H), 13–17 May 2013, Porquerolles, France (**I. Brunetti**, **N. Choungmo Fofack**).

# 9. Bibliography

## Major publications by the team in recent years

[1] S. ALOUF, V. MANCUSO, N. CHOUNGMO FOFACK. *Analysis of power saving and its impact on web traffic in cellular networks with continuous connectivity*, in "Pervasive and Mobile Computing", October 2012, vol. 8, n$^{o}$ 5, pp. 646-661 [*DOI :* 10.1016/J.PMCJ.2012.04.001], http://hal.inria.fr/hal-00729082

[2] E. ALTMAN, T. BASAR, F. DE PELLEGRINI. *Optimal Control in Two-Hop Relay Routing*, in "IEEE Transactions on Automatic Control", March 2011, vol. 56, n$^{o}$ 3, pp. 670-675, http://dx.doi.org/10.1109/TAC.2010.2095930

[3] E. ALTMAN, P. NAIN, J.-C. BERMOND. *Distributed Storage Management of Evolving Files in Delay Tolerant Ad Hoc Networks*, in "Proc. of IEEE INFOCOM 2009", Rio de Janeiro, Brazil, April 2009, pp. 1431-1439, http://dx.doi.org/10.1109/INFCOM.2009.5062059

[4] E. ALTMAN, P. NAIN, A. SHWARTZ, Y. XU. *Predicting the Impact of Measures Against P2P Networks on the Transient Behaviors*, in "Proc of IEEE INFOCOM 2011", Shanghai, China, April 2011, pp. 1440-1448, http://dx.doi.org/10.1109/INFCOM.2011.5934931

[5] E. ALTMAN, F. DE PELLEGRINI. *Forward correction and fountain codes in delay-tolerant networks*, in "IEEE/ACM Transactions on Networking", February 2011, vol. 19, n$^{o}$ 1, pp. 1-13, http://dx.doi.org/10.1109/TNET.2010.2091968

[6] K. AVRACHENKOV, D. LEBEDEV. *PageRank of Scale Free Growing Networks*, in "Internet Mathematics", 2006, vol. 3, n$^{o}$ 2, pp. 243-267, http://projecteuclid.org/euclid.im/1204906139

[7] K. AVRACHENKOV, B. RIBEIRO, D. TOWSLEY. *Improving Random Walk Estimation Accuracy with Uniform Restarts*, in "Proc. of 7th Workshop on Algorithms and Models for the Web Graph (WAW 2010)", Stanford University, CA, USA, Lecture Notes in Computer Science, December 2010, vol. 6516, pp. 98-109, http://dx.doi.org/10.1007/978-3-642-18009-5_10

[8] X. ZHANG, G. NEGLIA, J. KUROSE, D. TOWSLEY. *Performance Modeling of Epidemic Routing*, in "Elsevier Computer Networks", July 2007, vol. 51, n$^{o}$ 10, pp. 2867-2891, http://dx.doi.org/10.1016/j.comnet.2006.11.028

[9] H. ZHANG, G. NEGLIA, D. TOWSLEY, G. LO PRESTI. *Stability and Efficiency of Unstructured File Sharing Networks*, in "IEEE Journal on Selected Areas in Communications", September 2008, vol. 26, n$^{o}$ 7, pp. 1284-1294, http://dx.doi.org/10.1109/JSAC.2008.080925

## Publications of the year

### Doctoral Dissertations and Habilitation Theses

[10] M. K. HANAWAL. , *Analysis of Spatial and Economical Effects in Communication Networks*, Université d'Avignon, November 2013, Ph.D. Thesis, http://hal.inria.fr/tel-00937510

### Articles in International Peer-Reviewed Journals

[11] A. ALI, M. PANDA, T. CHAHED, E. ALTMAN. *Improving the transport performance in delay tolerant networks by random linear network coding and global acknowledgments*, in "Ad Hoc Networks", November 2013, vol. 11, n$^{o}$ 8, pp. 2567-2587 [*DOI :* 10.1016/J.ADHOC.2013.07.004], http://hal.inria.fr/hal-00916916

[12] E. ALTMAN. *A stochastic game approach for competition over popularity in social networks*, in "Dynamic Games and Applications", June 2013, vol. 3, n$^{o}$ 2, pp. 313-323 [*DOI :* 10.1007/S13235-012-0057-4], http://hal.inria.fr/hal-00681959

[13] E. ALTMAN, A. P. AZAD, T. BASAR, F. DE PELLEGRINI. *Combined Optimal Control of Activation and Transmission in Delay-Tolerant Networks*, in "IIEEE/ACM Transactions on Networking", April 2013, vol. 21, n$^{o}$ 2, pp. 482-494 [*DOI :* 10.1109/TNET.2012.2206079], http://hal.inria.fr/hal-00918695

[14] E. ALTMAN, P. BERNHARD, S. CARON, G. KESIDIS, J. ROJAS-MORA, S. WONG. *A model of network neutrality with usage-based prices*, in "Telecommunication Systems", February 2013, vol. 52, n$^{o}$ 2, pp. 601-609, Available electronically by Springer since 2011 [*DOI :* 10.1007/S11235-011-9504-6], http://hal.inria.fr/hal-00926718

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