



INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team MAESTRO

*Models for Performance Analysis and
Control of Networks*

Sophia Antipolis - Méditerranée

THEME COM

Activity
R *eport*

2007

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2. Overall Objectives

2.1. Overall Objectives

MAESTRO is an INRIA project-team whose all members are located in Sophia Antipolis except E. Altman who is located at Laboratoire Informatique d'Avignon (LIA) in Avignon, and A.-E. Baert and A. Jean-Marie who are both located at LIRMM in Montpellier. MAESTRO is concerned with the modeling, performance evaluation, optimization and control of 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.

Research activities in 2007 have focused on the following issues:

- performance evaluation of wireless, mobile, ad hoc and sensor networks, within the IST project BIONETS, a grant from FRANCE TELECOM R&D and the support of CEFIPRA (French-Indian collaboration);
- analysis of the WIMAX protocol within the ANR grant WINEM;
- design and evaluation of a software for the tracking of multimedia content published on the Web within the ANR grant SPI3-PRO;
- analysis of sized-based scheduling schemes, and performance evaluation of peer-to-peer protocols using stochastic models with the support of FRANCE TELECOM R&D and Network of Excellence EURO-NFI;
- singularly perturbed Markov chains and time-average optimal control in the framework of the French-Australian grant LINKAGE INTERNATIONAL.

3. Scientific Foundations

3.1. Scientific Foundations

The main mathematical tools and formalisms used in MAESTRO include:

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

4. Application Domains

4.1. Application Domains

Our main application area is networking and in particular, modeling, performance evaluation, optimization and control of protocols and network architectures. It includes:

- Internet infrastructure: TCP, high speed congestion control, voice over IP, service differentiation, quality of service;
- Internet applications: multicast, content distribution systems, peer-to-peer systems, overlay networks, multimedia traffic;
- Wireless (cellular, ad hoc, sensor) networks: WLAN, WIMAX, UMTS, delay tolerant networks, power control, medium access control, transmission rate control, redundancy in source coding, mobility models, coverage, routing.

5. Software

5.1. Software

5.1.1. *Web Graph Analyzer*

Participants: Konstantin Avrachenkov, Danil Nemirovsky, Elena Smirnova.

In 2007, K. Avrachenkov, D. Nemirovsky and E. Smirnova have continued to develop the software “Web Graph Analyzer” for the investigation of Web Graph properties. In particular, during 2007 we have added a visualization module to the software.

5.1.2. *Autonomous Engine for Image Search*

Participants: Konstantin Avrachenkov, Huyen Do, Elaine Isnard, Philippe Nain.

In collaboration with CANON we have developed a Web Crawler for crawling images from targeted Web Sites. This Crawler is used by CANON in a software which helps independent photographers to detect uncopyright use of their material. Distinctive features of our Crawler are: efficient sub-optimal refresh policy, extracting images from Flash based Web sites, managing several http connections inside one Java thread.

This work was supported by ANR grant SPI3-PRO (see Section 7.3).

6. New Results

6.1. Congestion control and IP traffic characterization

Keywords: AIMD, AQM router, TCP, TCP Westwood+, long/short-lived flows, uniform sampling.

Participants: Eitan Altman, Alain Jean-Marie, Konstantin Avrachenkov.

6.1.1. *Performance of TCP in general topologies*

Participants: Eitan Altman, Konstantin Avrachenkov.

In [24] E. Altman and K. Avrachenkov, in collaboration with C. Barakat (INRIA project-team PLANETE) and K. Chandrayana (Rensselaer Polytechnic Institute, Troy, USA) have proposed an analytical model for the calculation of the network load and the drop probabilities in a TCP/IP network with a general topology. This model does not require the predefinition of bottleneck links. The model is first formulated as a Non-linear Complementarity Problem (NCP), then transformed into two equivalent formulations: fixed-point formulation and non-linear programming formulation. Existence and uniqueness of the solution of this NPC is proved by casting it into the well-known utility optimization framework.

6.1.2. TCP fairness issues

Participants: Eitan Altman, Konstantin Avrachenkov.

In [46] E. Altman and K. Avrachenkov, jointly with C. Barakat (INRIA project-team PLANETE) and N. Möller (KTH, Stockholm, Sweden), have investigated the the inter-protocol fairness between TCP Westwood+ and TCP New Reno. By means of analytical modeling and ns-2 simulations, they demonstrate that the two protocols get different shares of the available bandwidth in the network. The main result is that the bandwidth sharing between both protocols depends on one crucial parameter: the ratio between the bottleneck router buffer size and the bandwidth delay product. If this ratio is smaller than one then TCP Westwood+ takes more bandwidth, otherwise this is TCP New Reno which gets the larger part of the bandwidth. Inspired by these results, they propose a simple modification to the window decrease algorithm in TCP Westwood+ that solves the unfairness problem for large buffer sizes. For small buffers, the unfairness problem is still open.

6.1.3. Size-based scheduling

Participants: Konstantin Avrachenkov, Natalia Osipova.

In [79] K. Avrachenkov and N. Osipova, jointly with P. Brown (France Telecom R&D) have analyzed the Two-Level Processor Sharing (TLPS) scheduling discipline in a single server queue with Poisson arrivals and hyper-exponentially distributed job sizes. In the case of the hyper-exponential job size distribution with two phases, they have discovered a closed-form expression for the expected sojourn time as well as an approximation for the optimal value of the threshold that minimizes the expected sojourn time. In the case of the hyper-exponential job size distribution with more than two phases, they have derived a tight upper bound for the expected sojourn time conditioned on the job size. They have shown that when the variance of the job size distribution increases, the gain in system performance increases and the sensitivity to the choice of the threshold near its optimal value decreases. Thus the TLPS system yields better and more robust performance as the variance of the job size distribution increases.

This work was supported by FRANCE TELECOM R&D grant on "Modélisation et Gestion du Trafic dans le Réseau Internet" (see Section 7.2).

6.2. Wireless communications

Keywords: *IEEE 802.11, IEEE 802.16e, MANETs, VANETs, WIMAX, Wireless LAN, connectivity, coverage, delay-tolerant network, sensor networks.*

Participants: Sara Alouf, Eitan Altman, Konstantin Avrachenkov, Amar Azad, Nicolas Bonneau, Dinesh Kumar, Alvaro Fialho, Philippe Nain, Giovanni Neglia, Giuseppe Reina.

6.2.1. Analysis of wireless access protocols

Participants: Sara Alouf, Eitan Altman, Amar Azad.

6.2.1.1. WIMAX

Power save/sleep mode operation is the key point for energy-efficient usage of mobile devices driven by limited battery lifetime. In [77], S. Alouf, E. Altman and A. Azad establish a general approach for analyzing queueing models with repeated inhomogeneous vacations and apply it for the study of the power save mode defined in the IEEE 802.16e WIMAX standard. They derive the sojourn time in a $M/G/1$ queue with repeated vacations and the energy consumption when the power saving is activated as function of the protocol parameter. A constrained optimization problem is formulated and solved for the optimal values of the protocol parameters.

This research is carried out within ANR grant WINEM (see Section 7.4).

6.2.1.2. IEEE 802.11

Building on [83] E. Altman, in collaboration with D. Miorandi (CREATE-NET, Trento, Italy), A. Kumar and M. Goyal (IISC, Bangalore, INDIA), has developed an important generalization of the pioneering paper by G. Bianchi (over 1530 citations) on the performance evaluation of the IEEE 802.11 protocol. Their work, which considerably simplifies the solution method of G. Bianchi, and at the same time relaxes the memoryless assumption on the back-off durations, has now appeared in [19].

6.2.2. *Biologically inspired networks and services*

Participants: Sara Alouf, Eitan Altman, Alvaro Fialho, Giovanni Neglia, Giuseppe Reina.

The research in this topic has been partially funded by the IST FET grant BIONETS (see Section 8.1.2).

6.2.2.1. *Evolutionary epidemic routing*

S. Alouf, A. Fialho and G. Neglia, together with I. Carreras and D. Miorandi (CREATE-NET, Trento, Italy), have developed a framework to let forwarding schemes for Delay Tolerant Networks evolve in order to adapt to changing and a priori unknown environments. The framework is inspired by genetic algorithms: at each node a genotype describes the forwarding scheme used, a selection process fosters the diffusion of the fittest genotypes in the system and new genotypes are created by combining existing ones or by applying random changes. A case study implementation is presented in [57] and in [22]. Simulation results indicate that the proposed case-study implementation is able to track changes in the system conditions (e.g., number of nodes in the considered scenario), and achieves similar if not better performance than solutions statically optimized for a given operating point. A systematic analysis of the following issues is under study: parameters setting for the genetic operators used to generate new genotypes, evaluation of the convergence of the evolutionary mechanism, fitness definition. Preliminary results are reported in [68].

6.2.2.2. *Sensors coordination*

The possibility to employ reaction-diffusion models to build spatial patterns in sensor networks has already been advocated. However it has not been investigated how do these biologically-inspired solutions perform in comparison to more traditional ones, taking into account specificities of sensor networks like severe energy constraints. In [47], G. Neglia and G. Reina have presented some preliminary results on the comparison between a biologically inspired coordination mechanism based on activator-inhibitor interaction and a simple mechanism, where nodes do not communicate but activate their sensing circuitry according to some probability. It appears that the activator-inhibitor mechanism is able to spare energy for sensing purpose, activating a smaller number of sensors. At the same time, a high number of messages is needed in order to establish the pattern starting from a clean slate status.

This work received the **Best Paper Award** of the **Bionetics 2007 conference**.

6.2.2.3. *Evolutionary Games*

Evolutionary games are used for large populations; the corresponding solution concept (ESS - Evolutionary Stable Strategies) is defined as a distribution of strategies among the populations such that no mutation can intrude the existing populations; in other words, it is robust against a deviation of not only a single player (as is the case with the Nash equilibrium in the standard non-cooperative game theory) but even against deviations of a whole fraction of the population. Evolutionary games also focus on the evolution of strategies of players and on conditions for their convergence or non-convergence to an equilibrium.

In [39], [40], [41] E. Altman, in collaboration with R. El-Azouzi, T. Hamidou and Y. Hayel (Univ. of Avignon, France), has developed the theoretical foundations of the theory of evolutionary games, studying stability conditions. They have extended the mathematical model to a new class of **stochastic evolutionary games**. They have applied this formalism to study various networking problems including (i) competitive routing [30] (in collaboration with H. Kameda – Univ. of Tsukuba, Japan), (ii) the association problem in wireless access [20] (in collaboration with S. Shattokkai (Univ. of Illinois at Urbana-Champaign, USA) and A. Kumar (IISc, Bangalore, India)) and (iii) the evolution of TCP protocols in the Internet [61].

6.2.3. *Mobile ad hoc networks*

Participants: Eitan Altman, Ahmad Al-Hanbali, Philippe Nain, Alonso Silva.

The research on “Mobile ad hoc networks” has been partially supported by by the IST FET grant BIONETS (see Section 8.1.2).

6.2.3.1. Massively dense ad-hoc networks

In collaboration with P. Bernhard (UNSA) and M. Debbah (INSTITUT EURECOM), E. Altman and A. Silva have investigated massively dense ad hoc networks. They have studied their continuum limits as the node density increases and as the graph providing the available routes becomes a continuous area with location and congestion dependent costs. Using techniques from vector calculus they have derived simple structural results on optimal routing when the cost does not depend on the congestion. They have also studied the congestion-dependent case under various formulations: global optimization, individual optimization and Nash equilibrium among several competing operators [29], [61].

Jointly with A. Kumar and V. Ramaiyan (IISc Bangalore, INDIA) and V. Ramaiyan, E. Altman has addressed joint power control and routing in massively dense single cell ad hoc networks. The transmission power determines the range and therefore the number of hops between a source and a destination. The number of hops together with the range determine the energy consumption. In [51] the energy consumption is optimized by identifying the best range and transmission power.

6.2.3.2. Sparse mobile ad-hoc networks

In [42] M. Ibrahim, A. Al Hanbali and P. Nain have considered a sparse mobile ad hoc network in the presence of throwboxes. Throwboxes are stationary wireless devices that act as fixed relays. They are deployed in the evolving area of the mobile nodes so as to increase contact opportunities between these nodes. Building up on earlier works (see 2005 and 2006 Maestro activity reports), consecutive meeting times between any mobile and any throwbox are modeled by a Poisson process, an assumption that is validated under a number of mobility models. The authors derive closed-form expressions for the distributions of the delivery delay and the total number of copies generated under two routing protocols, namely the multicopy two-hop routing protocol and the epidemic routing protocol, for the cases where throwboxes are fully disconnected or mesh connected. One of the main conclusions of this work is that by allowing certain degree of connectivity among throwboxes, the performance of such networks can be greatly increased.

In [12], P. Nain and E. Altman, jointly with A. Al Hanbali (Univ. of Twente, The Netherlands), R. Groenevelt (former MAESTRO PhD student, now researcher at Accenture, Sophia Antipolis) and A. Kherani (IIT, New Delhi, INDIA) have focused on the performance of the relay node in a two-hop relay protocol. Explicit and closed-form expressions for the relay throughput and the expected message waiting time at the relay buffer are provided. This work extends [75] to a limited number of copies.

In [76], M. Ibrahim, in collaboration with A. Al Hanbali (Univ. of Twente, The Netherlands), V. Simon and E. Varga (Budapest Univ. of Technology and Economics, Hungary), has characterized and reviewed various packet dissemination techniques in dense and sparse mobile ad-hoc networks. Using an application-based classification, two classes have been identified. The first class contains applications requiring high reliability in data delivery and where broadcasting is the major technique used for efficient packet dissemination. The second class contains delay tolerant applications where broadcasting techniques range from single copy to multi-copy epidemic spreading.

6.2.4. Cellular networks

Participants: Eitan Altman, Konstantin Avrachenkov, Dinesh Kumar.

6.2.4.1. Uplink power control with a finite number of power levels

In [28] E. Altman and K. Avrachenkov consider an uplink power control problem, where each mobile wishes to maximize its throughput (which depends on the transmission powers of all mobiles) but has a constraint on the average power consumption. A finite number of power levels are available to each mobile. The decision of a mobile to select a particular power level may depend on its channel state. Two settings are considered depending on the information of the channels of other mobiles: (i) the case of full state information and (ii) the case of local state information. In each setting both cooperative and non-cooperative power control are studied. The authors manage to characterize the structure of equilibria policies and, more generally, of the best response policies in the non-cooperative case. They present an algorithm to compute equilibria policies in the case of two noncooperative players. Finally, they study the situation where a malicious mobile, which also has

average power constraints, tries to jam the communication of the other mobile. The results are illustrated and validated through various numerical examples.

This is a joint work with B. Miller (Moscow Aviation Institute, Russia) and B. Prabhu (CWI, Amsterdam, The Netherlands).

6.2.4.2. Uplink power control with non-discrete power levels

In collaboration with A. Garnaev (St Petersburg State Univ., Russia), E. Altman and K. Avrachenkov have applied game theory to the well-known water-filling problem [62], [27], [26]. Within this setting, the zero sum-game formulation has been used to solve the jamming problem (in which a malicious user tries to minimize the throughput of packets corresponding to a power controlled channel). Other non zero-sum game formulations of this problem have also been proposed and an important contribution was to obtain explicitly the equilibrium strategies along with their structure and corresponding value.

6.2.4.3. Scheduling

Much work has been devoted to the scheduling of transmission of packets at a base station as a function of the channel state between the station and the mobiles. In [52] E. Altman, in collaboration with V. Sharma and D. Prasad (IISC, Bangalore, INDIA), uses Markov decision processes to compute an optimal schedule, and then compares its performance to those obtained by other frequently used methods.

In collaboration with J. M. Kelif (FRANCE TELECOM R&D), E. Altman focuses in [43] on a particular subclass of scheduling policies: the class of priority rules, where the priority is a function of the distance of a mobile to the base station. This results in a continuous priority set. In this work the authors compute the expected sojourn time under various priority rules and identify some hybrid priority rules that provide good performance.

6.2.5. UMTS networks

Participant: Eitan Altman.

6.2.5.1. Admission and GoS control in a multiservice WCDMA system

In [18] E. Altman studies the integration of real-time and data transfers in a WCDMA system. Since real time traffic requires some minimum bandwidth guarantees, call admission control is implemented for this traffic class. Downlink and uplink are analyzed separately. Mechanisms are also proposed for controlling the rate of real-time calls as a function of the load.

This is a joint work with J.-M. Kelif (FRANCE TELECOM R&D) and I. Koukoutsidis (FORTH-ICS, Greece).

6.2.5.2. Admission control in multiservice CDMA/HSDPA systems

The standard approach to compute the capacity of UMTS cellular networks has been to identify which of the uplink and downlink directions seems to be the bottleneck, and then to compute the capacity in that direction assuming that there is no bandwidth limitation on the opposite direction. If one does not know a-priori which of the direction is the bottleneck then one would compute the uplink capacity ignoring the downlink limitation, compute the downlink capacity ignoring the uplink limitations and then take the minimum. This approach turns out to over estimate the real joint uplink and downlink capacity, that E. Altman computes in [36] in collaboration with T. Chahed (GET/INT, Evry, France) and S. E. Elayoubi (FRANCE TELECOM R&D).

6.2.6. CDMA networks

Participants: Eitan Altman, Nicolas Bonneau.

The theory of random matrix theory is used for approximating performance measures that depend on eigenvalues of matrices whose entries are random, when the size of the matrix is large. E. Altman and N. Bonneau have used this theory in conjunction with yet another approximation that is valid asymptotically as the number of mobiles grows. In the case of non-cooperative games, one may approximate the Nash equilibrium as the number of mobiles grows by the Wardrop equilibrium, which is often much easier to compute. In collaboration with M. Debbah (INSTITUT EURECOM) and A. Hjørungnes (UniK, Oslo, Norway), they have combined both approximations in [35] to solve non-cooperative power control problems in CDMA.

In collaboration with A. Suarez, M. Debbah and L. Cottatellucci (INSTITUT EURECOM), E. Altman has also applied random matrix theory to solve the optimal decoding order under target rate constraints [53].

Other applications of random matrices to networking problems can be found in the PhD thesis of N. Bonneau [11].

6.2.7. *Sensor networks*

Participant: Eitan Altman.

An important issue in wireless sensor networks is the characterization of the limiting performance, in terms of both connectivity and coverage. In [85], E. Altman has studied connectivity issues in static sensor networks using a queueing theoretic setting in collaboration with D. Miorandi and G. Alfano (CREATE-NET, Trento, Italy). The approach consists in identifying an equivalence between busy periods in infinite server queues and connectivity ranges in sensor networks.

We have then pursued this work in collaboration with S. Yousefi, R. El-Azouzi and M. Fathy. We studied in [56], [55] the connectivity of vehicular mobile ad hoc networks and have analyzed the performance gains obtained by adding mobile base stations. In [84] we design optimal routing so as to maximize the life time of a connected path between a given source and a destination.

6.2.8. *Multihoming in WLANs*

Participants: Eitan Altman, Dinesh Kumar.

This problem arises when a mobile has the possibility to connect to several access points, possibly of different technologies. E. Altman, in collaboration with J.-M. Kelif (FRANCE TELECOM R&D), A. Kumar (IISC, Bangalore, India) and S. Shakkottai (Univ. of Illinois at Urbana-Champaign, USA), has investigated both the centralized framework in [44] and the decentralized approach in which the mobiles themselves take the association decisions [20], [45].

6.3. Information systems

Keywords: *Google, P2P storage system, PageRank, Steiner system, distributed VoD systems.*

Participants: Sara Alouf, Konstantin Avrachenkov, Anne-Elisabeth Baert, Abdulhalim Dandoush, Alain Jean-Marie, Philippe Nain, Danil Nemirovsky, Natalia Osipova, Kim-Son Pham.

6.3.1. *Document ranking on the Web*

Participants: Konstantin Avrachenkov, Danil Nemirovsky, Natalia Osipova, Kim-Son Pham.

PageRank is one of the principle criteria according to which Google ranks Web pages. PageRank can be interpreted as a frequency of visiting a Web page by a random surfer and thus it reflects the popularity of a Web page. Google computes the PageRank using the power iteration method which requires about one week of intensive computations. In [15] K. Avrachenkov, N. Litvak, D. Nemirovsky, and N. Osipova propose and analyze Monte Carlo type methods for the PageRank computation. The authors have discovered several advantages of the probabilistic Monte Carlo methods over the deterministic power iteration method: Monte Carlo methods provide good estimation of the PageRank for relatively important pages already after one iteration; Monte Carlo methods have natural parallel implementation; and finally, Monte Carlo methods allow continuous update of the PageRank as the structure of the Web changes.

In [33] K. Avrachenkov, N. Litvak and K.S. Pham study the PageRank mass of principal components in a bow-tie Web Graph, as a function of the damping factor c . Using a singular perturbation approach, they show that the PageRank share of IN components and Strongly Connected components remains high even for very large values of the damping factor, in spite of the fact that it drops to zero when $c \rightarrow 1$. However, a detailed study of the OUT component reveals the presence of “dead-ends” (small groups of pages linking only to each other) that receive an unfairly high ranking when c is close to one. The authors then argue that this problem can be mitigated by choosing c as small as $1/2$.

6.3.2. Graph based reputation systems

Participants: Konstantin Avrachenkov, Natalia Osipova, Kim-Son Pham.

Reputation systems are indispensable for the operation of Internet mediated services, electronic markets, document ranking systems, P2P networks and ad hoc networks. In [34] K. Avrachenkov, D. Nemirovsky, and K. S. Pham survey available distributed approaches to the graph based reputation measures. Graph based reputation measures can be viewed as random walks on directed weighted graphs whose edges represent interactions among peers. In [34] the distributed approaches to graph based reputation measures are classified into three categories. The first category is based on asynchronous methods. The second category is based on the aggregation/decomposition methods. And the third category is based on the personalization methods which use the information available locally.

6.3.3. Distributed video-on-demand systems

Participants: Anne-Elisabeth Baert, Alain Jean-Marie.

6.3.3.1. Multi-source distribution of content

As part of the VOODOO project A.-E. Baert and A. Jean-Marie have worked (jointly with V. Boudet, LIRMM, CNRS/University of Montpellier 2) on the dimensioning of the contents distribution platform of the startup society VODNET. The objective of this project is the development of an innovative visualization interface for video contents, based on a safe, reliable and optimized storage and transport infrastructure. The effectiveness of the infrastructure depends on the way data are distributed in the network of information servers, and on the way data sources are selected for a given downloading request. The problem is thus to develop placement and scheduling algorithms which are adapted one to the other.

6.3.3.2. Data replication and distribution problems in a distributed VoD System

A.-E. Baert and A. Jean-Marie jointly with V. Boudet (LIRMM, CNRS/University of Montpellier 2, France) have worked on the problem of data replication and distribution in a particular infrastructure for distributed Video on Demand (VOD). The problem was to minimize the average download time of a document under various assumptions. This particular quality of service metric is not commonly encountered in the literature.

The authors examine the data replication problem in this particular Grid Delivery Network (GDN). In this system, the data are divided into fixed size blocks which must be replicated on hosts to decrease the total download time. The authors have proposed a probabilistic model to optimize the average download time of requests based on the hosts availability and the document size distribution. The objective function induced by this model is a discrete non-linear problem. They showed that this problem can be solved in real values by Lagrangian optimization. In addition, in a particular case, this problem can be reduced to a knapsack problem. Based on these observations, the authors propose approximation algorithms validated by simulations [80].

6.3.4. Peer-to-peer storage systems

Participants: Sara Alouf, Abdulhalim Dandoush, Philippe Nain.

Distributed systems using a network of peers has become an alternative solution for storing data. In [23], S. Alouf, A. Dandoush and P. Nain propose simple analytical models to evaluate the performance of peer-to-peer storage systems, assuming that peers lifetime is exponentially distributed. This assumption has been relaxed in [67] and [81] to account for hyperexponential lifetimes with n phases.

6.4. Game theory applied to networking

Keywords: *Nash bargaining, cooperative/non-cooperative games, network formation game.*

Participants: Eitan Altman, Konstantin Avrachenkov, Giovanni Neglia.

6.4.1. Survey

Participants: Eitan Altman, Konstantin Avrachenkov.

E. Altman is co-editing a monograph survey on paradigms from biology, physics and social sciences for wireless networking. A preliminary version has already appeared as a deliverable in [61].

Another survey on game theory applied to networks, written in collaboration with R. El-Azouzi (Univ. Avignon, France), appeared in [14].

6.4.2. Pricing differential services

Participant: Eitan Altman.

Pricing could serve as an additional tool in congestion control and in network management as it can regulate demands for different classes of quality of services. In [32], E. Altman designs a pricing mechanism for purchasing priorities in a differentiated service architecture. The approach is based on computing the equilibrium achieved by the users for a given pricing function, and then on optimizing the network utility over all possible pricing choices.

This is a joint work with R. El-Azouzi (Univ. Avignon, France), R. Márquez (Univ. Los Andes, Mérida, Venezuela), D. Ros and B. Tuffin (INRIA team DYONISOS).

6.4.3. Network formation games

Participant: Giovanni Neglia.

G. Neglia, in collaboration with G. Lo Presti (CERN, Switzerland), H. Zhang (Suffolk Univ., USA) and D. Towsley (Univ. of Massachusetts, Amherst, USA) has employed the framework of network formation games [82] to characterize the robustness of the Tit-for-Tat strategy implemented in BitTorrent. In particular, they have characterized in [48] the set of *pairwise stable networks* peers and how peers can dynamically reach such configurations. They have also evaluated the loss of efficiency peers experience because of their lack of coordination and shown that the loss of efficiency is in general unbounded despite the utilization of the Tit-for-Tat strategy.

6.5. Stochastic processes, queueing, control theory and game theory

Keywords: *Conjectural equilibria, discriminatory processor sharing queue, queue with impatient customers.*

Participants: Eitan Altman, Konstantin Avrachenkov, Nicolas Bonneau, Alain Jean-Marie.

6.5.1. Advances in game theory

Participants: Eitan Altman, Konstantin Avrachenkov, Nicolas Bonneau, Alain Jean-Marie.

Fundamental results in stochastic games with constraints and with a distributed information structure have been obtained in [78] by E. Altman, K. Avrachenkov and N. Bonneau, in collaboration with R. El-Azouzi (Univ. Avignon, France), M. Debbah (INSTITUT EURECOM) and S. D. Menasche (Univ. Massachusetts, Amherst, USA). In these games, each player controls another Markov chain. A player only knows its own state but the state of other players influences also its cost. The authors have established the existence of equilibria among the stationary policies.

An application of this theory to wireless networks [25], [28] has received the **Best Paper Award** of the *IEEE Globecom 2007 conference*.

E. Altman has pursued other fundamental research on games with constraints in collaboration with S. Sarkar (Univ of Pennsylvania, USA) and E. Solan (Tel Aviv Univ., Israel). In [31] the authors obtain a solution based on a linear program to compute stationary saddle-point policies in a zero-sum game with constraints stochastic games in which the transition probabilities are controlled by only one player.

6.5.1.1. Fluid limits for Processor Sharing Queues

In a joint work with A. Bentahar (Post-doctoral fellow of CNRS in the LIRMM laboratory), A. Jean-Marie has extended to the multi-class case the results existing for the single-class case. They have proved the convergence of the stochastic model to the fluid limit, and solved the fluid differential equations with the help of multidimensional renewal theory. The results apply as well to some flavors of “discriminatory” processor sharing.

6.5.2. *Branching processes with queueing applications*

Participant: Eitan Altman.

In collaboration with D. Fiems (Univ. Ghent, Belgium), E. Altman has contributed in [13] to the development of the theory of branching processes with migration in two directions: (i) multi-type continuous state-space and (ii) non-Markov migration process (for both discrete state-space and continuous state-space). They have illustrated the theory by applying it to study the expected waiting times in symmetric polling systems with correlated vacations.

6.5.3. *Advances in queueing theory*

Participants: Konstantin Avrachenkov, Natalia Osipova.

In [49], [86] N. Osipova has studied the Processor-Sharing queueing model with a hyper-exponential service time distribution and Poisson batch arrival process. In the case of the hyper-exponential service time distribution she has found an analytical expression for the expected conditional response time function and has obtained an alternative proof of its concavity with respect to the service time. N. Osipova has applied the obtained results to the Two Level Processor-Sharing (TLPS) model with the hyper-exponential service time distribution and has found the expected response time for the TLPS model. In contrast with the BPS queue, the expected conditional response time function is not a concave function in the TLPS model.

This work was supported by FRANCE TELECOM R&D grant on "Modélisation et Gestion du Traffic dans le Réseau Internet" (see Section 7.2).

7. Contracts and Grants with Industry

7.1. Grant from France Telecom R&D on 3rd Generation Mobiles (2005-2007)

Participants: Eitan Altman, Dinesh Kumar.

MAESTRO has pursued its collaboration with FRANCE TELECOM R&D at Issy les Moulineaux within a new two-year research grant (Contrat de Recherche Externalisée, CRE). In 2006 a patent has been filed concerning new policies for scheduling TCP connections between dedicated and shared channels in UMTS. In 2007 the participants have studied the association problem (which network should a user connect to at any time) within a heterogeneous network environment (WLAN on one hand, and UMTS cellular network on the other hand). Coordinators of this CRE are E. Altman for MAESTRO and J.-M. Kelif for FRANCE TELECOM R&D.

7.2. Grant from France Telecom R&D on Internet Traffic (2005-2007)

Participants: Eitan Altman, Konstantin Avrachenkov, Alberto Blanc, Philippe Nain, Natalia Osipova.

Since January 2005 MAESTRO has been involved in a three-year research grant (CRE) with FRANCE TELECOM R&D in Sophia Antipolis, on the theme "Internet Traffic Management and Modeling." This grant has two major research directions: application of size-based scheduling to IP networks, and analysis of new TCP versions for high-speed links. In 2007, the participants have derived an accurate bound on the expected sojourn time in a Two Level Processor Sharing queueing system with hyper-exponential service time distribution and infinite number of phases. This allowed us to study the Two Level Processor Sharing system in the case of a heavy-tailed service time distribution. Also, an explicit expression for the expected sojourn time for the Batch Processor Sharing system with the hyper-exponential service time distribution was obtained. This grant was concluded with a final MAESTRO-FRANCE TELECOM R&D seminar with the overview of the achieved results and the discussion on future research.

7.3. ANR RIAM Spi3-Pro (2006-2007)

Participants: Konstantin Avrachenkov, Elaine Isnard, Huyen Do, Danil Nemirovsky, Philippe Nain.

The aim of this two-year project (2006-2007) is to develop and to evaluate a software for the tracking of multimedia content published on the Web. This tool will be used by free-lance professional photographers to protect their rights against malicious behaviors. The industrial partner is CANON and the work was supervised by professional photographers.

Within this project, the task of MAESTRO is to develop a software module which will allow an autonomous and an automatic navigation in the Internet. This work builds on the expertise on Web crawlers developed over the years by MAESTRO.

7.4. ANR Télécommunications WINEM (2007-2009)

Participants: Sara Alouf, Eitan Altman, Amar Azad.

This project, called WINEM, for “WIMAX Network Engineering and Multihoming”, started on January 1st 2007 and will last for 3 years. It aims at engineering and evaluating solutions for the issues left open in the WIMAX standard, such as quality of service and service differentiations. Other issues are related to mobility management, resource allocation, multihoming, pricing, cross-layer optimization and performance tuning. The project partners are: FRANCE TELECOM R&D, GET (ENST Bretagne and INT), INRIA (INRIA teams DYONISOS and MAESTRO), INSTITUT EURECOM, LIA (Université d Avignon), and Motorola. S. Alouf is the coordinator for INRIA.

On September 21, A. Azad gave a presentation entitled “Power save mode analysis for IEEE 802.16e using M/G/1 queue with non homogeneous vacations” within a WINEM meeting organized in Paris.

7.5. VodDnet (2006-2007)

Participants: Anne-Elisabeth Baert, Alain Jean-Marie.

Members of MAESTRO were involved in a research contract with VODDNET, a company funded by Languedoc- Roussillon Incubation. The system under study was a multi-source content distribution infrastructure based on data segmentation and replication. The research convention involved the programming of a simulation software, the design of a mathematical model for the control and performance prediction of the system, and simulation experiments validating the model. A. Jean-Marie coordinated this project.

This industrial collaboration will be followed by a 3-year research grant from the National Research Agency (ANR RIAM VOODOO (2008-2010)).

7.6. MELAUDY (2006-2007)

Participants: Anne-Elisabeth Baert, Alain Jean-Marie.

Members of MAESTRO were involved in a research contract with MELAUDY, a company funded by Languedoc-Roussillon Incubation. The system under study is a high-fidelity audio streaming system over power lines. The research convention involves the quality of service characterization of different PLC devices at the packet level, and the design of protocols allowing the high-throughput, multi-canal, zero-loss transport of data over this communication medium. A. Jean-Marie was the coordinator of this project.

8. Other Grants and Activities

8.1. International initiatives

8.1.1. Network of Excellence: EuroFGI (2007-2008)

MAESTRO is a member of the Network of Excellence (NoE) EUROFGI which is a continuation of the EURONGI Network of Excellence on “Design and Engineering of the Next Generation Internet, Towards Convergent Multi-Service Networks” (see 2004-2006 MAESTRO activity reports).

Within this NoE MAESTRO further participates in one EUROFGI Specific Joint Research Project on Self Organizing Networks.

8.1.2. IST Grant BIONETS (2006-2009)

MAESTRO is a partner of the IST FET European Integrated Project BIONETS on “BIOlogically-inspired autonomic NETworks and Services”. E. Altman is the coordinator of the work package on paradigm collection and foundations.

BIONETS is a project belonging to the IST FET Proactive Initiative Program on “Situating and Autonomic Communication”. There are sixteen partners involved and MAESTRO, together with INRIA project-team OASIS and colleagues from INSTITUT EURECOM, is one of them. BIONETS is planned for four years and started on January 1st 2006.

BIONETS specializes on the design of protocols that will allow evolution of services over a self-organizing wireless network that contains a huge amount of cheap sensors, as well as a limited number of intelligent terminals. The project proposes an inter-disciplinary strategy for designing such networks (called bionets) by using methods and tools from biology, physics, economics. MAESTRO’s task is to collect such tools and to adapt them to Bionets.

8.1.3. Collaboration with Australia: Linkage International (2005-2007)

MAESTRO, in partnership with CNRS (J.-B. Lasserre, H. Frankowska), University of Paris Dauphine (J.-P. Aubin), University of Utrecht (A. Gnedin) and University of South Australia (V. Ejov, J. Filar, L. Finlay, V. Gaitsgory, P. Howlett) participates in a three-year (2005-2007) international cooperation grant, LINKAGE INTERNATIONAL, of the Australian Research Council on the subject of “Singular Perturbations and Multiscale Models in Optimization and Control”.

8.1.4. Collaboration with Venezuela (2004-2007)

Since January 2004 MAESTRO and INRIA project-team OASIS have been partners in a four-year collaboration with the University of Los Andes (ULA), Merida, Venezuela, through a funding of the ECOS program. French partners are D. Ros (INRIA project-team ARMOR and ENST Bretagne), D. Caromel (INRIA project-team OASIS), H. Mounier (University of Paris 11, Orsay), and E. Altman (project coordinator). Our Venezuelan partners are R. Márquez, L. Leon and J. Aguilar from ULA. This year, visits of researchers and students did not include MAESTRO members.

8.2. National initiatives

8.2.1. INRIA Cooperative Research Initiative (ARC) IFANY (2006-2007)

Members of MAESTRO participate in the ARC (Cooperative Research Initiative, sponsored by INRIA) IFANY “InFormAtioN theorY: New challenges and new interdisciplinary tools” (2006-2007), whose coordinator is E. Altman. Other INRIA project-teams involved are TREC, HIPERCOM, ARMOR and TEMICS. Other groups participating are ENST Bretagne, University of Avignon, FRANCE TELECOM R&D, INSTITUT EURECOM, EPFL, University of Cyprus and University of Thessaly. The objective of ARC IFANY is to bring together methods and tools used in traditional information theory, together with new tools (stochastic geometry, game theory, percolation) so as to come up with new notions of capacity of wireless networks.

Website: <http://www-sop.inria.fr/maestro/ifany/>.

8.2.2. ARC COINC (2006-2007)

Members of MAESTRO participate in the ARC COINC (2006-2007), headed by B. Gaujal (INRIA project-team MESCAL), and aimed at developing computational tools and new applications for what is now known as the “network calculus” framework.

Website: <http://perso.bretagne.ens-cachan.fr/~bouillar/coinc/>.

8.2.3. COLOR Arigatoni on wheels (2007)

The COLOR (Coopération Locale de Recherche) “Arigatoni on wheels” is a one-year projet focusing on information exchange in Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) systems via an overlay network called Arigatoni, designed by L. Liquori (INRIA project-team MASCOTTE) who coordinated this project. P. Nain participated in this project for MAESTRO. Other participants are from Politechnico Torino and ETH Zurich.

Website: <http://www-sop.inria.fr/mascotte/Luigi.Liquori/ARIGATONI/Ariwheels.htm>.

8.3. Invited scientists

Europe: U. Ayesta (LAAS, Toulouse, 01/20/07–02/03/07 and 03/18/07–03/26/07); A. Dudin (Belarussian State University, Belarus, 10/09/07–10/19/07); A. Garnaev (St. Petersburg State University, Russia, 05/27/07–06/06/07 and 10/18/07–10/28/07); V. Klimenok (Belarussian State University, Belarus, 10/09/07–10/19/07); G. Koole (Vrije University, Amsterdam, The Netherlands, 04/23/07–05/05/07); G. Miller (MAI, Moscow, Russia, 04/01/07–05/12/07); L. Petrosyan (St. Petersburg State University, Russia, 07/21/07–08/04/07); A. Pionovsky (University of Liverpool, UK, 01/27/07–01/31/07); E. Winands (Eindhoven University of Technology, The Netherlands, 02/07/07–02/24/07); K. Zarifi (Darmstadt University of Technology, Germany, 07/09/07–08/09/07).

America: T. Başar (University of Illinois at Urbana–Champaign, USA, 03/18/07–03/23/07); S. Sarkar (University of Pennsylvania, USA, 1/10/07–6/15/07); W. Sandholm (University of Wisconsin, USA, 11/18/07–11/30/07).

Maghreb, Middle-East: U. Yechiali (Tel Aviv University, Israel, 03/26/07–03/04/07 and 04/04/07–04/11/07).

Oceania: V. Ejov (University of South Australia, Adelaide, Australia, 07/12/07–07/20/07); J. Filar (University of South Australia, Adelaide, Australia, 06/24/07–07/08/07); V. Gaitsgory (University of South Australia, Adelaide, Australia, 06/13/07–06/18/07).

8.4. Visits of Maestro staff to other research institutions

S. Alouf visited INRIA project-team MESCAL at INRIA Grenoble - Rhône-Alpes (February 15–16, 2007) gave a seminar within the “Performance Evaluation Seminar in Grenoble”.

E. Altman visited Tel-Aviv University (Statistics and OR Dept.) and the Technion (EE Dept.), Israel (April 19–29, 2007), and the University of Los Andes (as part of the ECOS program) Merida, Venezuela (July 27 – August 25, 2007).

He was one of four distinguished researchers to be invited by the EE Dept. of the University Autonoma Metropolitana-Iztapalapa of Mexico for the celebration of the 25th anniversary. During his visit (October 26 – November 5, 2007) he gave an invited talk as part of the event, and another invited talk at the *Centro de Investigación y Estudios Avanzados del I.P.N* (Cinvestav). He also gave an invited seminar on Constrained Games in the Seminar on Game Theory at HPC Paris (February 5, 2007) and was an invited speaker in the E-Quality workshop on “Performance Analysis of Mobile and Wireless Communications” at Eurandom, Eindhoven (November 15–16, 2007).

K. Avrachenkov visited Technical University of Tempere on 5–11 March 2007 University of Liverpool on 29 April – 9 May, 2007; St. Petersburg State University on May 17–26, 2007; LAAS CNRS, Toulouse on November 7–12, 2007 .

During his visit in LAAS CNRS K. Avrachenkov gave an invited lecture at MOCOSY seminar series.

A. Jean-Marie visited the Universidad Técnica Federico Santa Maria, Valparaiso, Chile, September 11–30, 2007.

9. Dissemination

9.1. Leadership within scientific community

9.1.1. Editorial activities

E. Altman is an Associate Editor of the journals: *Journal of Economics, Dynamics and Control* (JEDC), *ACM/Kluwer Wireless Networks* (WINET), and *Journal of Discrete Event Dynamic Systems* (JDEDS).

A. Jean-Marie is an Associate Editor for *RAIRO Operations Research* and *Performance Evaluation*.

P. Nain is an Associate Editor of *IEEE/ACM Transactions on Networking*, *Performance Evaluation* and *Operations Research Letters*. As of December 17, 2007, P. Nain will become Editor-in-Chief of *Performance Evaluation*.

9.1.2. Participation in technical program committees

1. IEEE Infocom 2007 (Anchorage, USA) (**A. Jean-Marie, P. Nain**)
2. ACM Sigmetrics 2007 (San Diego, CA, USA) (**P. Nain**)
3. IEEE International Symposium on Information Theory (ISIT 2007 – Nice, France) (**E. Altman**)
4. 20th International Teletraffic Congress (ITC-20 – Ottawa, Canada) (**S. Alouf**)
5. 15th IEEE International Conference on Networks (ICON 2007 – Adelaide, South Australia) (**K. Avrachenkov**)
6. 2nd International Conference on Performance Evaluation Methodologies and Tools (ValueTools 2007 – Nantes, France) (**S. Alouf**)
7. 15th IEEE International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS 2007 – Istanbul) (**K. Avrachenkov**)
8. 7th International Conference on Next Generation Teletraffic and Wired/Wireless Advanced Networking (NEW2AN 2007 – St. Petersburg) (**K. Avrachenkov**)
9. IEEE Globecom 2007 Performance Modeling, QoS and Reliability Symposium (Globecom 2007 PMQRS – Washington, DC, USA) (**S. Alouf**)
10. 1st International Conference on Network Control and Optimization (NET-COOP 2007 – Avignon, France) (**K. Avrachenkov**)
11. International Conference on Game Theory and Management (GTM 2007 – St. Petersburg, Russia) (**E. Altman**)
12. Workshop on Mathematical performance Modeling and Analysis (MAMA 2007 – San Diego, CA, USA) (**A. Jean-Marie, P. Nain**)
13. 1st International Workshop on Game theory for Communication networks (Game-Comm 2007 – Nantes, France) (**E. Altman, K. Avrachenkov**)
14. 1st International Workshop on Network Simulation Tools (NSTools 2007 – Nantes, France) (**E. Altman**)
15. ACM Sigmetrics 2007 Student Workshop (San Diego, California, USA) (**S. Alouf**)
16. IEEE Wireless Communications and Networking Conference (WCNC 2007 – Hong-Kong, China) (**E. Altman**).

9.1.3. Conferences, meetings and tutorial organization

- S. Alouf was the Publication Chair of the *Second International Conference on Performance Evaluation Methodologies and Tools* (Valuetools 2007) and of its 4 workshops: GameComm 2007, Inter-Perf 2007, SMCTools 2007 and NSTools 2007 (Nantes, France, October 23–25, 2007). She has co-organized a seminar on Peer-to-Peer networking within the **Intech' Sophia club** that was held on December 17, 2007.
- E. Altman participated in the Steering Committee of the following conferences: WiOpt 2007 (*Workshop on Modeling in Mobile Ad Hoc and Wireless Networks*, Limassol, Cyprus, April 16–20, 2007), Valuetools 2007 (*2nd International Conference on Performance Evaluation Methodologies and Tools*, Nantes, France, October 23–25, 2007), and NetCoop 2007 (*International Conference on Network Control and Optimization*, Avignon, France, June 5–7, 2007).
- K. Avrachenkov was an invited session chair and organizer at *EURO XXII Conference 2007*.
- E. Deriche participated in the organization of the *Random Matrix Theory for Wireless Communications* 15 hours course, sponsored by ARC IFANY (April 13–15, 2007, Limassol, Cyprus) and the meeting for *IST FET European project BIONETS* partners. She was a member of the organizing committee of the *IEEE Information Theory Winter School* (La Colle-sur-Loup, March 12–16, 2007), and a member of the organizing committee of the conference NetCoop 2007 (Avignon, France, June 5–7, 2007).

9.1.4. Participation in thesis committees

- K. Avrachenkov was a reviewer of the PhD thesis of Rade Stanojevic (Hamilton Institute, National University of Ireland, Maynooth).
- A. Jean-Marie participated as a reviewer in the PhD thesis committees of A. Bušić (U. Versailles St Quentin, Jul. 16, 2007), of H. Charara (INP Toulouse, Nov. 6, 2007), and participated in the thesis committee of T.H. Dao Thi (U. Paris 7, Dec. 3, 2007). He is member of the Best Thesis Award Committee of SPECIF, the French Society for Education and Research in Computer Science.

9.1.5. PhD theses defended in 2007

The following PhD theses were defended in 2007:

- N. Bonneau on September 24, 2007 [11] (co-advisors: E. Altman and M. Debbah).

9.1.6. Research administration

S. Alouf is a member of the Doctoral Committee of INRIA Sophia Antipolis.

A. Jean-Marie

- is the scientific coordinator of INRIA activities in Montpellier.
- is co-head of the APR (Algorithms and Performance of Networks) project-team of the LIRMM Laboratory, a joint research unit of CNRS and the University of Montpellier II.
- has been co-chair of the Department of Computer Science of the LIRMM Laboratory, Montpellier (80 permanent staff) until June 2007.
- is a member of the Recruiting Committee (Commission de Spécialistes) in Computer Science at the University of Montpellier II.
- is a member of the Steering Committee of the GDR RO, a national research initiative on Operations Research sponsored by the CNRS.

P. Nain

- has been the Chair of the Project-team Committee of the Research Center of INRIA Sophia Antipolis - Méditerranée since September 1st, 2007.
- is Head of project-team MAESTRO.

- is a member of the management of the Research Center of INRIA Sophia Antipolis - Méditerranée.
- until August 31st, 2007 was the Vice-Chair of the Project-team Committee of the Research Center of INRIA Sophia Antipolis - Méditerranée.
- is a member of the Evaluation Committee of INRIA.
- until September 1st, 2007, was in charge of the Master program on “Networks and Distributed Systems” at the University of Nice Sophia Antipolis.
- is a member of the Steering Committee of the ANR (National Research Agency) research program in Télécommunications.
- is a member of the Scientific Committee of the Graduate School of Information and Communication Sciences (école doctorale STIC) of the University of Nice Sophia Antipolis.
- is treasurer of IFIP WG7.3 on “Computer System Modeling”.

9.1.7. Miscellaneous (nominations, awards, etc.)

- E. Altman, K. Avrachenkov and N. Bonneau, with M. Debbah, R. El-Azouzi and D. S. Menasche, have received the **Best Paper Award** of the *IEEE Globecom 2007 conference* (November 26-30, 2007, Washington DC, USA) [25].
- G. Neglia and G. Reina received the **Best Paper Award** of the *Bionetics 2007 conference* (December 10–13, 2007, Budapest, Hungary) [47].
- E. Altman and K. Avrachenkov, with A. Garnaev (St Petersburg State University, Russia), received the **Second Best Paper Award** of *EuroFGI NetCoop 2007* (June 5–7, 2007, Avignon, France) [26].
- P. Nain has been appointed Editor-in-Chief of *Performance Evaluation*. His term will start on December 17, 2007.
He has been elected for a two-year term (July 1, 2007–June 30, 2009) at the Board of Directors of ACM Sigmetrics.
- E. Altman, A Jean-Marie and P. Nain are (elected) members of IFIP WG7.3 on “Computer System Modeling”.

9.2. Teaching

- S. Alouf participated in the course on “Performance Evaluation of Networks” in the Master Program on “Networks and Distributed Systems” at the University of Nice Sophia Antipolis (6H), and in the course on “Probability and Statistics” in the Engineering Program at Polytech’ Nice-Sophia (48H).
- E. Altman gave a 4H course in the *IEEE Winter School on Information and Coding* (March 12–16, 2007, La Colle-sur-Loup, France).
- K. Avrachenkov taught a course on Dynamic Programming within the Mathematics Master Program at the University of Nice Sophia Antipolis (18H).
- A.-E. Baert taught courses in the Master in Informatics of the University of Montpellier II on Performance Evaluation (6H), “Quality of Service in Networks” (27H), Random Discrete Structures (27H) and Metrology and Quality of Services (68H). She participated in the course on “Communication and Networks” of the Master in Computer Science of the University of Montpellier II (30H).
- A. Dandoush participated as a “moniteur” in the course on “Networking and System Architecture” in the Bachelor Program on “Computer Science” at the IUT of Nice Sophia Antipolis (96H).
- A. Jean-Marie taught a course on “Random Discrete Structures” (12H), and one on “Metrology and Quality of Service for Networks” (12H), both in the Master in Computer Science of the University of Montpellier II. He was invited to give a short course on “Network Calculus” at the University of Valparaiso, Chile.

P. Nain taught a course on the Performance Evaluation of Networks in the Master Program on “Networks and Distributed Systems” at the University of Nice Sophia Antipolis (24H).

G. Neglia taught a course on Computer Networks within the Bachelor Program on “Telecommunication Engineering” at the University of Palermo, Italy (50H).

9.3. Participation in conferences and workshops

S. Alouf attended the *First EURO-FGI International Conference on Network Control and Optimization* (Avignon, France, June 5–7, 2007).

E. Altman gave presentations at WiOpt 2007 (*Workshop on Modeling in Mobile Ad Hoc and Wireless Networks*, April 16–20, 2007, Limassol, Cyprus) including SPASWIN 2007 and WNC3 2007 one day workshops, Valuetools 2007 (*2nd International Conference on Performance Evaluation Methodologies and Tools*, October 23–25, 2007, Nantes, France) including GameCom and SMCTools one day workshop, NetCoop 2007 (*International Conference on Network Control and Optimization*, June 5–7, 2007, Avignon, France), and *Stochastic Network Workshop* (July 4–6, 2007, Edinburg, UK).

K. Avrachenkov gave presentations at the EUROFGI *International Conference on Network Control and Optimization* (NetCoop 2007 – Avignon, France, June 5–7, 2007) and at the *22nd European Conference on Operations Research* (EURO XXII – Prague, Czech Republic, July 8–11, 2007).

A. Azad gave a presentation at the *8th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks* (WoWMoM 2007 – Helsinki, Finland, June 18–21, 2007).

A. Dandoush gave presentations at the *joint ED SFA and ED STIC Doctoral Colloquium* (Sophia Antipolis, May 10–11, 2007) and the *20th International Teletraffic Congress* (ITC 2007 – Ottawa, Canada, June 17–21, 2007). He also attended the *9th IEEE Information Theory Winter School* (La Colle sur Loup, France, March 12–16, 2007).

M. Ibrahim gave a presentation at the *Performance 2007 Conference* (Cologne, Germany, October 2–5, 2007).

G. Neglia gave presentations at EUROFGI *International Conference on Network Control and Optimization* (NetCoop 2007 – Avignon, France, June 5–7, 2007), at the *Workshop on Socially and Biologically Inspired Wired and Wireless Networks* (Bionetworks – Pisa, Italy, October 8, 2007), and at the *2nd International Conference on Bio-Inspired Models of Network, Information, and Computing Systems* (BIONETICS 2007 – Budapest, Hungary, December 10–13, 2007).

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- [12] A. AL-HANBALI, A. A. KHERANI, R. GROENEVELT, P. NAIN, E. ALTMAN. *Impact of Mobility on the Performance of Relaying in Ad hoc Networks: Extended Version*, in "Computer Networks", vol. 51, n^o 14, October 2007, p. 4112–4130.
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