INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team MAESTRO

Models for Performance Analysis and Control of Networks

Sophia Antipolis

THEME COM

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2. Overall Objectives

2.1. Overall Objectives

MAESTRO is a joint project-team of INRIA, CNRS and the University of Montpellier II (through the LIRMM laboratory), based in Sophia Antipolis and in Montpellier. It 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 2006 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);
- development of online statistical estimators of data flow characteristics with small memory consumptions, supported by the ACI grant FLUX;
- performance evaluation of peer-to-peer protocols using stochastic fluid models, with the support of FRANCE TELECOM R&D and Network of Excellence EURO-NGI;
- analysis of processor-sharing scheduling disciplines, with the support of FRANCE TELECOM R&D and Network of Excellence EURO-NGI;
- probabilistic and graph theoretical methods for the Web search engines in the framework of EGIDE ECO-NET program;
- 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

Participants: Konstantin Avrachenkov, Danil Nemirovsky, Natalia Osipova.

In 2006, K. Avrachenkov, D. Nemirovsky and N. Osipova have continued to develop a new software "Web Graph Analyzer" for the investigation of Web Graph properties. In particular, this software has a crawler with a user-friendly interface, and can efficiently compute the PageRank vector.

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, Konstantin Avrachenkov, Olivier Gandouet, Dinesh Kumar, Alain Jean-Marie, Philippe Nain.

6.1.1. Analysis of AIADD transport protocols

Participants: Eitan Altman, Konstantin Avrachenkov, Philippe Nain.

Recently, to overcome AIMD (Additive-Increase Multiplicative-Decrease) performance limitations, WESTWOOD TCP and its WESTWOOD+ variant have been proposed. Both of them are based on the new Additive Increase ADaptive Decrease (AIADD) paradigm, which leaves unchanged the probing phase of NEW RENO TCP and includes an adaptive shrinking phase. In particular, the adaptive decrease used by WESTWOOD TCP sets the congestion window according to the bandwidth left behind TCP at time of congestion, which is the end-to-end network available bandwidth. In [32], [39] E. Altman and his co-authors, including C. Barakat from INRIA project-team PLANETE, have analyzed AIADD protocols using a two-dimensional recursive equations to obtain the throughput of such protocols. They have first studied the case of i.i.d. RTTs, and then extended their results to the case where RTTs exhibit a Markovian pattern. This research is partly supported by a grant from FRANCE TELECOM R&D on Internet Traffic (Section 7.2).

6.1.2. Optimal dynamics of TCP/IP networks

Participant: Konstantin Avrachenkov.

In [37], K. Avrachenkov, in collaboration with L. Finlay and V. Gaitsgory both from the U. of South Australia, has applied the framework of periodic control optimization to study the AQM–TCP interaction. In particular, for a given TCP version, the optimal strategy for the AQM router is defined as the solution of a non-linear periodic optimization problem. This solution is obtained via a linear programming approach. It is also shown that depending on the choice of the utility function for the sending rate, the optimal control is either periodic or stationary. A particular attention is paid to a problem with a sigmoidal utility function, in which the evolution of the optimal sending rate exhibits the "saw-tooth" behavior of the "instantaneous" TCP sending rate. The sigmoidal utility function corresponds well to audio and video streaming applications. One of the main conclusions of the work in [37] is that an AQM scheme implementing only two thresholds might be enough. This work is supported by the French-Australian grant LINKAGE INTERNATIONAL (Section 8.1.3).

6.1.3. Size-based scheduling

Participants: Konstantin Avrachenkov, Natalia Osipova.

In [36], K. Avrachenkov and N. Osipova, jointly with P. Brown (FRANCE TELECOM R&D), have derived the conditional expected response time of the two-level processor sharing system when jobs have an hyper-exponential size distribution. This work is a follow-up of [9], where K. Avrachenkov and his co-authors showed that if the job size distribution has a decreasing hazard rate (which is the case of the hyper-exponential distribution), then the two-level processor sharing scheme outperforms the egalitarian processor sharing scheme. In [9], it was pointed out that a research topic is the choice of the threshold value, which controls the classification into small and large jobs. In that respect, asymptotic results obtained in [36] will help choosing a value of the threshold that minimizes the total expected response time. This work is carried out within the grant from FRANCE TELECOM R&D on Internet traffic (Section 7.2).

6.1.4. Estimation of traffic characteristics

Participants: Alain Jean-Marie, Olivier Gandouet.

In the framework of the FLUX project (supported by the ACI "Masses of pursued the analysis of the problem of recognizing long-lived and short-lived data flows (elephants and mice) using algorithms requiring a (very) limited memory capacity. A statistical estimator for the number of elephants in a data flow has been proposed, and its moments have been analyzed in detail [40]. This estimator has then been extended to more than two flows, and to flows with arbitrary distributions.

Recent advances focus on the application of *uniform sampling* techniques to this same problem, with the objective to reduce the dependence of the estimator on the detailed stochastic characteristics of the flow. Further research concerns the improvement of the hashing principle (which is at the heart of the algorithm) towards a better precision with little added memory consumption. Finally, work has begun on the application of probabilistic counting and sampling techniques to the approximate determination of local characteristics in graphs (such as degrees, girth and clustering coefficients).

6.2. Wireless communications

Keywords: *IEEE 802.11*, *IEEE 802.16e*, *WIMAX*, *Wireless LAN*, *delay-tolerant network*.

Participants: Sara Alouf, Eitan Altman, Mouhamad Ibrahim, Philippe Nain, Giovanni Neglia, Thanh Tung Vu.

6.2.1. Analysis of wireless access protocols

Participants: Sara Alouf, Eitan Altman, Mouhamad Ibrahim, Philippe Nain, Thanh Tung Vu.

6.2.1.1. Enhancement of IEEE 802.11

In [41], M. Ibrahim and S. Alouf propose an adaptive backoff algorithm for the contention-based distributed coordination function of the IEEE 802.11 standard. Relying on on-line measurements of the number of sources, the algorithm, called ADAPTIVE BEB, judiciously sets the size of the minimal contention window to adapt to the congestion level in the shared medium. An extension to ADAPTIVE BEB for enhancing its performance over noisy channels is further proposed. In this extension, M. Ibrahim and S. Alouf use a simple exponentially weighted moving average filter to derive a packet error rate estimator. The proposed algorithms have been thoroughly tested through simulations. These show that ADAPTIVE BEB exhibits a steady performance in terms of both the throughput and the packet delay, along with a high reactiveness to changes in the network load, whereas its extension reveals to be highly robust to errors on the channel.

During a three-month internship, supervised by S. Alouf and P. Nain, T. Vu has worked on the modeling of the IEEE 802.11 medium access control which is based on the CSMA/CA protocol [56].

6.2.1.2. Analysis of WIMAX networks

WIMAX is a family of standards for wireless metropolitan area networks. IEEE 802.16e is one WIMAX standard providing mobility for users. In [58], S. Alouf and E. Altman investigate the power save mode defined in the IEEE 802.16e standard. To evaluate the transfer delay incurred by the power save mode, and the amount of power it can save, they model the input buffer of a mobile as a single server queue with repeated vacations, in which both idle and busy periods depend on the customers arrival pattern. Current efforts focus on solving the model when packets arrive according to a Lévy input process. This research will be further developed withing the RNRT grant WINEM (Section 7.5).

6.2.2. Towards biologically inspired networks and services

Participants: Sara Alouf, Eitan Altman, Konstantin Avrachenkov, Alain Jean-Marie, Philippe Nain, Giovanni Neglia.

This work is carried out within the framework of the BIONETS project (Section 8.1.2). The motivation for BIONETS comes from (see http://www.bionets.eu/) "emerging trends towards pervasive computing and communication environments, where myriads of networked devices with very different features will enhance our five senses, our communication and tool manipulation capabilities. The complexity of such environments will not be far from that of biological organisms, ecosystems, and socioeconomic communities. Traditional communication approaches are ineffective in this context, since they fail to address several new features: a huge number of nodes including low-cost sensing/identifying devices, a wide heterogeneity in node capabilities, high node mobility, the management complexity, the possibility of exploiting spare node resources. BIONETS aims at a novel approach able to address these challenges. Nature and society exhibit many instances of systems in which large populations are able to reach efficient equilibrium states and to develop effective collaboration and survival strategies, able to work in the absence of central control and to exploit local interactions. We seek inspiration from these systems to provide a fully integrated network and service environment that scales to large amounts of heterogeneous devices, and that is able to adapt and evolve in an autonomic way."

As a first step towards "bio-inspired networks", S. Alouf and G. Neglia are investigating the possibility to use an evolutionary approach for epidemic routing in Delay Tolerant Networks. To route packets over such networks, one may use epidemic routing or one of its variants like probabilistic forwarding, K-hop schemes, or spray-and-wait. These protocols can be captured in a single framework which allows forwarding schemes to evolve so as to adapt to a changing, and a priori, unknown environment. As mentioned in [68], the fundamental components of this framework are: (i) the possibility to share with other nodes a description of the specific forwarding mechanism deployed at each node (this description is called the *forwarding genotype*), (ii) the possibility for each node to modify its forwarding scheme by applying random changes to it (genotype *mutations*) or by introducing some characteristics of other nodes genotypes (*crossover*), and (iii) a selection process which fosters the diffusion of the fittest forwarding genotypes, i.e., of those forwarding schemes achieving the best performance in the specific environment as regards the performance metric chosen (end-to-end delay, power consumption, etc.).

6.2.3. Routing in mobile ad hoc networks

Participants: Ahmad Al Hanbali, Eitan Altman, Philippe Nain.

In [44], E Altman, in collaboration with R. El-Azouzi (U. Avignon) and A. A. Kherani (Indian Institute of Technology, New Delhi), investigates the throughput of multi-hop routes, and the stability of forwarding queues in a wireless ad hoc network with random access channel. The main results are the characterization of the stability conditions, and the calculation of the end-to-end throughput by using balance arguments. The authors also investigate the impact of routing on the end-to-end throughput, and the stability of intermediate nodes. The findings are that (i) as long as the intermediate queues in the network are stable, the end-to-end throughput of a connection does not depend on the load at the intermediate nodes, (ii) if the weight of a link originating from a node is set to the number of neighbors of this node, then shortest path routing maximizes the minimum probability of end-to-end packet delivery in a network of weighted fair queues with coupled servers. This paper has received the Best Paper Award at the *IFIP Networking 2006* conference (440 submissions).

Mobile ad hoc networks (MANETs) often experience route failures and network disconnectivity, especially when the nodes are moving frequently and the network is sparse. M. Grossglauser and D. Tse have shown (*Infocom 2001*) that one can take advantage of node mobility in MANETs to increase the network throughput. This can be done by using the so-called "two-hop relay" protocol. However, this increase in the throughout is obtained at the expense of long delays. In order to reduce the (packet) delivery delay A. Al Hanbali, P. Nain, and E. Altman in a series of papers ([30], [31], [50]) consider a MANET that implements the Multicopy Two-hop Relay (MTR) protocol, in which the source is allowed to generate multiple copies of the same packet, unlike in the two-hop relay scheme where the source is allowed to generate at most one copy. Copies at relay nodes are assumed to have a limited lifetime (time-to-live TTL) in the network. Closed-form expressions and asymptotic results when the number of nodes is large are provided for the probability distribution of the packet delivery delay and for the energy needed to transmit a packet from the source to its destination. Node mobility is captured through the Markovian model developed in [64]. The results are validated through simulations for two mobility models, the random waypoint and the random direction mobility models. The performance of the MTR protocol are also compared to that of the epidemic routing protocol, in which both the source and the relay nodes are allowed to generate copies of a packet.

In [57], A. Al Hanbali and P. Nain, in collaboration with A. A. Kherani (Indian Institute of Technology, New Delhi), have extended the model and the analysis in [30] to allow for a limited number of copies. This extension is used to identify the number of copies that minimizes the expected delivery delay subject to a constraint on the energy consumption. In this work, they also develop a new model which relaxes the assumption that the inter-meeting times are exponentially distributed. This allows them to evaluate the impact of the exponential assumption on the performance; in particular, they observe that hyper-exponential inter-meeting times yield stochastically larger delivery delays.

This research is carried out within the framework of the IST project BIONETS (Section 8.1.2).

6.2.4. Optimization and control of mobile networks

Participants: Eitan Altman, Konstantin Avrachenkov, Nicolas Bonneau, Dinesh Kumar, Gregory Miller, Alberto Suarez-Real, Daniel Menasche, Corinne Touati.

6.2.4.1. Fair power and rate control in cellular networks

In [35], E. Altman and C. Touati, in collaboration with J. Galtier (INRIA project-team MASCOTTE and FRANCE TELECOM R&D), propose combined power and rate control for cellular networks, both for the uplink and for the downlink. In particular, they study the case of macro-diversity, where several base stations transmit simultaneously to some mobiles located at the cells edges. The proposed control yields both optimality (in the Pareto sense) and fairness. The publication of this work, carried out within a past research grant from FRANCE TELECOM R&D, had been delayed during the process of patenting.

6.2.4.2. Optimizing cellular networks using random matrix theory

The work concerns some applications of random matrix theory and unitary random matrix theory to cellular networks. Explicit formulas for performance metrics, depending only on a few meaningful parameters, can be derived in many cases of interest.

In [20], N. Bonneau, M. Debbah (INSTITUT EURECOM) and E. Altman have derived asymptotic results for the performance of a downlink CDMA system with orthogonal spreading and multi-cell interference when considering an infinite network. The objective is to determine, for a dense and infinite multi-cell network, the optimal distance between base stations. Each user is equipped with a linear matched filter. The problem is analyzed in the asymptotic regime: very dense networks are considered where the spreading length N tends to infinity, the number of users per meter d tends to infinity but the load per meter $\frac{d}{N} = \alpha$ is constant. The theoretical results were shown to be very accurate predictions of the system's behavior in the finite size case. (A shorter version of this work was reported in the 2005 MAESTRO Activity Report.) This work is carried out within the IST project BIONETS (Section 8.1.2).

6.2.4.3. Structural property of solutions to path optimization problems

The inherent nature of the physical setup and transmission mechanism in wireless ad hoc networks with random channel access, results in correlations between the link metrics of adjacent links, when considering path optimization problems. In [45], D. Kumar and E. Altman, along with A. A. Kherani (Indian Institute of Technology, New Delhi), identify a special structure inherent to the solution of Dynamic Programming problems arising in such an optimization over paths. According to this structure, the optimal policy tries to equalize the link metrics of adjacent links in a multi-hop route. The authors have validated this structural property with simulations.

6.2.4.4. Optimal hop distance in a mobile ad hoc network

In [47], D. Kumar and E. Altman study, in partnership with A. Kumar and V. Ramaiyan (IISC Bangalore), a dense ad hoc network. In a dense multi-hop network of mobile nodes capable of applying adaptive power control, they consider the problem of finding the optimal hop distance that maximizes a certain throughput measure in bit–meters/sec, subject to average network power constraints. The mobility of nodes is restricted to a circular periphery area centered at the nominal location of nodes. Using numerical analysis the authors discover that choosing the nearest node as next hop is *not always* optimal. Optimal throughput performance is also attained at non-trivial hop distances depending on the available average network power. This work was carried out within the CEFIPRA project with India (Section 8.1.4).

6.2.4.5. Discrete uplink power control

In [61], E. Altman, K. Avrachenkov, B. Miller (IITR, Moscow) and B. Prabhu (CWI, Amsterdam) study 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 (full or local information). Both cooperative and non-cooperative power control are considered. The authors characterize the structure of equilibria policies and, more generally, of best-response policies in the non-cooperative case. They present an algorithm to compute equilibria policies in the case of two non-cooperative players. Finally, they study the case where a malicious mobile, which also has average power constraints, tries to jam the communication of another mobile. The results are illustrated and validated through various numerical examples.

In the above problems, the controls depend on (local) states but they do not influence the state. The control problem can be seen as a repeated game with a random environment. E. Altman, K. Avrachenkov, N. Bonneau, D. S. Menasche, in collaboration with B. Prabhu (CWI, Amsterdam) and M. Debbah (INSTITUT EURECOM), have further studied the more complex case in which the states of the mobiles are controlled as well. These states may represent queue sizes at the mobiles, which may determine quality of service parameters such as delay or loss probabilities [60], [59].

6.2.4.6. Uplink power control with non-discrete power levels

During his master internship, supervised by E. Altman and M. Debbah (INSTITUT EURECOM), A. Suarez-Real has studied uplink power control problems for a continuous power spectrum. Both non-cooperative and adversary situations are considered [55]. This work is supported by ARC IFANY (Section 8.2.1).

6.2.4.7. Analysis of UMTS networks

E. Altman and N. Hegde (FRANCE TELECOM R&D) in [23] use QBD (Quasi Birth Death) processes to model and to analyze the performance of uplink CDMA systems that carry both real-time (voice) as well as elastic (data) traffic. The bandwidth not used by the real-time traffic is shared among the elastic traffic sessions. The system under study decreases the transmission rate of real-time calls in case of congestion, thus decreasing the quality of service. The expected sojourn time of elastic calls is computed, and the expected quality of real-time calls as a function of admission control policies is also derived.

6.2.4.8. Opportunistic scheduling

The most popular approach for downlink opportunistic scheduling in cellular networks is the proportional fairness approach. To compute its performance, one usually makes the assumption that the normalized gain between the base station and any mobile is a random variable that does not depend on the location of the mobile (normalized gain refers to the gain at a given point divided by its average value at that point). In [43] K. Khawam and D. Kofman (ENST Paris), in collaboration with E. Altman, propose a more accurate model that defines three zones: (i) zone 0 is the region the closest to the base station – the gain there is assumed to be constant so that the mobiles in this region receive the maximum power; (ii) zone 2 is the farthest from the base station – the maximum power is almost never received there; (iii) zone 1 lies between zones 0 and 2. In [43] various scheduling mechanisms are proposed, in which the relative priority of these zones may vary. For each mechanism, the average throughput in each zone is computed as a function of the control parameters.

6.2.4.9. A fluid model for computing interference

In order to compute the capacity of cellular networks, an important parameter is the amount of interference from other cells on any given cell C. This is usually hard to obtain. Often, this amount is approximated to be a constant times the interference generated by cell C. J.-M. Kelif (FRANCE TELECOM R&D) and E. Altman propose in [42] an alternative approximation based on replacing the discrete base stations of other cells by a continuous "fluid" of base stations. Compared to the discrete cellular network, the approximation is shown to be very accurate. Based on that approximation method, J.-M. Kelif and E. Altman have been able to compute the performance of some scheduling policies that give a priority level to a mobile as a function of its distance from the base station (article in preparation). This work is supported by a grant from FRANCE TELECOM R&D on Third Generation Mobiles (Section 7.1).

6.2.5. Coverage and connectivity

Participant: Eitan Altman.

One important issue in ad hoc wireless networks is the characterization of the limiting performance, in terms of both connectivity and coverage. In [26], E. Altman and D. Miorandi (CREATE-NET, Italy) address this issue in a queueing theoretic setting. By using properties of the GI/D/∞ queueing model, they derive exact results, in the one-dimensional case, for the coverage probability, the node isolation and the connectivity distance for various node placement statistics, in the case of a deterministic channel model. The case of a random channel is investigated with the help of the more general GI/G/∞ framework. In particular, explicit results are obtained when nodes are distributed according to a Poisson distribution operating in a fading/shadowing environment The approach consists in identifying an equivalence between busy periods in infinite server queues and connectivity ranges in sensor networks. The paper is an extended version of a conference paper reported in the 2004 MAESTRO Activity Report. This research was supported by the EURONGI Specific Joint Research Project "Cellular2" (Section 8.1.1).

6.3. Internet applications

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.

6.3.1. Document ranking on the Web

Participants: Konstantin Avrachenkov, Danil Nemirovsky, Natalia Osipova.

Surfers on the Internet frequently use search engines to find pages satisfying their queries. However, there are typically hundreds or thousands of relevant pages available on the Web. Thus, listing them in a proper order is a crucial and non-trivial task. PageRank is one of the main 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. In [19], K. Avrachenkov and N. Litvak (U. of Twente) have studied to what extent a page can control its PageRank. Using an asymptotic analysis their provide simple conditions that show whether or not new links result in an increased PageRank for a Web page and its neighbors. Furthermore, they show that there exists an optimal (although impractical) linking strategy. Their main findings are that (1) a Web page benefits from links inside its Web community, and (2) irrelevant links penalize the Web pages and their Web communities.

In [38] K. Avrachenkov, D. Nemirovsky and N. Osipova have presented the software tool "Web Graph Analyzer". This tool is designed to perform a comprehensive analysis of the Web Graph structure. A Web Graph is a graph whose vertices are Web pages and whose edges are hyperlinks. With the help of the Web Graph analyzer, one can study local graph characteristics, such as numbers and sets of incoming/outgoing links to/from a given page, the page level relative to a given root page, and the global graph characteristics such as PageRank, Giant Strongly Connected Component, the number of dangling nodes. The Web Graph Analyzer has a user friendly GUI that allows an easy collection of a part of WWW and its thorough investigation. The Web Graph Analyzer is based on the ORACLE DBMS, which scales well with large data volumes.

This research was done in the framework of the PAI ECO-NET grant (Section 8.1.6).

6.3.2. Distributed video-on-demand systems

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

6.3.2.1. Multi-source distribution of contents

As part of a research convention with the startup society VODDNET, A.-E. Baert and A. Jean-Marie have conducted (jointly with V. Boudet, LIRMM, CNRS/U. of Montpellier II) the realization of a simulation program aimed at optimizing the dimensioning of their contents distribution platform. The program has been realized in collaboration of L. Lacressonière and M. Paniez, from the Master program in Computer Science of the Univ. Montpellier II [66].

6.3.2.2. Data replication and distribution problems in a video-on-demand distributed system

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

In a first work, A.-E. Baert, A. Jean-Marie and their co-authors [62] have proposed a probabilistic model based on the *popularity* distribution of documents. In this setting, minimizing the average download time 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.

In a second step, realized with the help of X. Roche (PhD candidate, LIRMM, CNRS/U. of Montpellier II), the authors have studied the optimal data distribution which minimizes the *variance* of the download time of documents, assuming they have identical popularity. This problem, called "MINVAR", can be reduced to a Steiner System Problem (generalizing Steiner Triple Systems). The authors find an optimality condition for the MINVAR problem. Under appropriate assumptions on documents and the number of hosts, the problem has been solved exactly. Heuristics and approximation algorithms have been proposed and evaluated [63].

6.3.3. Peer-to-peer storage systems

Participants: Sara Alouf, Abdulhalim Dandoush, Philippe Nain.

During his master internship, supervised by S. Alouf and P. Nain, A. Dandoush has evaluated and compared the performance of two schemes for recovering lost data in a peer-to-peer storage system. The first approach is centralized and relies on a server that recovers multiple losses at once, whereas the second approach is distributed. Through a Markovian analysis and mean fluid approximation, the performance of each scheme has been calculated, in terms of the delivered data lifetime and data availability [54].

In [51], S. Alouf, A. Dandoush and P. Nain have extended the model of [54] to account for more elaborate data recovery processes. Numerical computations are provided which assess the impact of each system parameter on the performance of the storage system.

6.4. Game theory applied to networking

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

Participants: Eitan Altman, Nicolas Bonneau, Giovanni Neglia, Corinne Touati.

6.4.1. A game-theoretic approach to fairness

Participants: Eitan Altman, Corinne Touati.

The proportional fairness concept is perhaps the mostly used fairness concept in networking and is widely used. This concept turns out to be a special case of the Nash Bargaining concept from game theory. In [28], C. Touati, E. Altman and J. Galtier (INRIA project-team MASCOTTE and FRANCE TELECOM R&D) study properties of this fairness concept as well as ways to compute it efficiency.

6.4.2. Non-cooperative multiple access techniques

Participants: Eitan Altman, Nicolas Bonneau.

E. Altman, N. Bonneau and M. Debbah (Institut Eurécom) study a simplified version of the slotted ALOHA protocol in [34]. Both the cooperative and the non-cooperative approaches are considered. The framework is that of correlated games along with the notion of correlated equilibria. Not only this work applies the notion of correlated equilibria in the context of networking, but it extends it to the multi-criterion case, where each mobile (player) has several objectives. Explicit formulas characterizing the throughput are obtained, and the extent to which coordination could improve transmission in the cooperative and non-cooperative case is analyzed.

6.4.3. Network formation games

Participant: Giovanni Neglia.

G. Neglia has investigated the possibility to apply the framework of network formation games to model the interaction of nodes in sensors networks and in delay tolerant networks. This framework has been employed to study peer-to-peer networks in [69].

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, Alain Jean-Marie.

6.5.1. Advances in game theory

Participant: Alain Jean-Marie.

Conjectures have been introduced in game theory in an attempt to model anticipations formed by players in the absence of a complete information. Equilibria reached in a game with conjectures are called “conjectural equilibria”. In [24] (realized in conjunction with M. Tidball (INRA, Montpellier), A. Jean-Marie has shown that when the idea of conjectures is used in a dynamic learning process, the outcome of the process may enjoy Pareto-efficiency. This is in relation with the question of the stability of a Cartel in the field of Macroeconomics, raised by Osborne. This last problem is in turn related to the question of designing *incentives* (or threats) to regulate non-Nash interactions between economic agents. This issue has been studied in [67], where necessary conditions for the existence of *Credible Incentive Equilibria* have been obtained, both for static and dynamic games.

6.5.2. Advances in queueing theory

Participants: Eitan Altman, Konstantin Avrachenkov.

6.5.2.1. Impatience in Queues with Vacations

Impatience phenomena that cause customers to leave a queue before being served, have been much studied in the queueing literature. These models are useful, in particular, to understand reaction to congestion in call centers or in connecting to a computer network. Most existing models consider impatience due to large queues. In [18], E. Altman, in collaboration with U. Yechiali (Tel Aviv U.) another phenomenon of impatience: that of customers who find the server on vacation. They have computed performance measures such as the expected number of customers in the system, and the probability that a customer will leave before being served. This research was supported by the EuroNGI Specific Joint Research Project "Fairness2" (Section 8.1.1).

6.5.2.2. The discriminatory processor sharing queue

At the joint invitation of O. Boxma (Eurandom) and R. Núñez Queija (CWI and TNO), K. Avrachenkov and E. Altman, in collaboration with U. Ayesta (CWI), wrote a survey on the Discriminatory Processor Sharing (DPS) discipline [14]. DPS is a multi-class generalization of the egalitarian processor sharing model. In DPS, all jobs present in the system are served simultaneously at rates controlled by a vector of weights g_k: whenever there are N_k jobs of class $k = 1, ..., K$ present in the system, each class-k job is served at rate $g_k / \sum_{j=1}^{K} g_j N_j$. The authors hope that the survey will be useful for the networking community, as there are many evidences that the bandwidth sharing in bottleneck nodes in the Internet can be modeled using DPS queues. This research was supported by the EuroNGI Specific Joint Research Project "Fairness2" (Section 8.1.1).

7. Contracts and Grants with Industry

7.1. Grant from France Telecom R&D on 3rd Generation Mobiles

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 [53]. Furthermore, 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) [52]. 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

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

Since January 2005 MAESTRO has been involved in a two-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 the first direction, in 2006, the participants have derived a simple approximation of the optimal threshold value in Two Level Processor Sharing; in the second research direction, they have proposed the analysis of TCP-AQM interaction and carried out a comparison between TCP New Reno and TCP TCP Westwood+.

7.3. Collaboration with ESA on Scheduling

Participant: Alain Jean-Marie.

The topic of this collaboration wit the European Space Agency (ESA) was the design of efficient online scheduling policies for satellite payloads on launchers. The collaboration was initiated in 2005 and pursued in 2006. It is executed jointly with Ph. Chrétienne and E. Hyon from LIP6, Paris.

The specificity of the problem includes various temporal and feasibility constraints, and a stochastic environment. The collaboration in 2006 concentrated on the extension and test of a discrete-event simulator for the system in consideration [65].

The mathematical modeling of the problem has led to the OBP research proposal that is funded by the GDR RO (the French national research initiative on Operations Research), and involves researchers of MAESTRO and LIP6.

7.4. ANR RIAM SPI3-PRO

Participants: Konstanstin Avrachenkov, Philippe Nain, Natalia Osipova.

The aim of this project 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 will be supervised by professional photographers. The kick-off meeting of SPI3-PRO, a one-year project, took place on Dec. 6, 2006.

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 will build on the expertise on Web crawlers developed over the years by MAESTRO.

7.5. ANR Telecommunications WINEM

Participants: Sara Alouf, Eitan Altman, Philippe Nain.

This project, called WINEM, for WIMAX Network Engineering and Multihoming, is to be started imminently and will last for 3 years. The project partners are: FRANCE TELECOM R&D, GET (ENST Bretagne and INT), INRIA (project-teams ARMOR and MAESTRO), INSTITUT EURECOM, LIA (Université d Avignon), and Motorola. It is dedicated to the IEEE 802.16e standard for Broadband Wireless Metropolitan Access. S. Alouf is the coordinator for INRIA.

8. Other Grants and Activities

8.1. International initiatives

8.1.1. Network of Excellence: EuroNGI

MAESTRO is a member of the Network of Excellence (NoE) EuroNGI on "Design and Engineering of the Next Generation Internet, Towards Convergent Multi-Service Networks". E. Altman is the co-coordinator of the work package on "Control and optimization in telecommunication networks".

Within this network, MAESTRO further participates in three EuroNGI Specific Joint Research Projects "JRA.S.07 Cellular2" and "JRA.S.11 Fairness2" (both projects were launched in 2005 and were granted a one-year extension in 2006) and "JRA.S.23 Delayed":

- Cellular2 (project coordinator: T. Chahed from GET, France) focuses on cross-layer protocol design for wireless networks.
- Fairness2 (project coordinator: P. Nain) is devoted to the performance evaluation of fair and efficient scheduling in wired and wireless networks.
- Delayed (project coordinator : R. Núñez Queija, CWI and TNO, The Netherlands) focuses on transfer control with delayed feedback signals.

Within Fairness2 project there have been collaborations between E. Altman and E. Solan (Tel Aviv University) on using game theoretical methods for resources sharing.

Cellular2 project has seen collaborations between T. Chahed (INT), E. Altman and D. Kumar (INRIA). On Oct. 9, D. Kumar gave a lecture entitled "Simulation study of a reliable open loop transport for fountain coded traffic in WLAN downlink" within a Cellular2 meeting organized in Pisa, Italy.

On Nov. 11, K. Avrachenkov participated in a one-day EuroNGI workshop organized within JRA.S.23 Delayed (Eindhoven, The Netherlands) and gave a lecture entitled "Delay-based congestion control modeled by state-dependent delay differential equations".

8.1.2. European Grant: BIONETS

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 "Situated 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

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 India: CEFIPRA

Since April 2003 MAESTRO has been involved in a three-year research grant with A. Kumar and A. Chockalingam (IISC Bangalore) and with V. Borkar (TATA Institute of Fundamental Research, Mumbai). The coordinators of this project are A. Kumar and E. Altman for the Indian and French sides, respectively. The theme of the cooperation is "New Strategies for Wireless Communication Networks." This cooperation financed the two-year postdoctoral position at INRIA of A. A. Kherani. The program has been extended in 2006 to six more months and has ended on Oct. 31, 2006. Within this program, E. Altman visited the IISC Bangalore (Oct. 22–31, 2006) and MAESTRO has hosted A. Kumar (June 17–July 1, 2006), A. Chockalingam (July 16–29, 2006) and V. Borkar (Oct. 1–21, 2006).

8.1.5. Collaboration with Norway: Aurora project

The AURORA project is a joint research program funded by the Research Council of Norway and the French Ministry of Foreign Affairs. The participants belong to the following institutions: INRIA Sophia Antipolis (project-team MAESTRO; N. Bonneau contributed to this project) and INSTITUT EURECOM, France, UniK - University Graduate Center and University of Oslo, Norway. The objective of this project is to propose advanced optimization tools to design broadband wireless communication systems (OFDM, CDMA, MIMO, and ad hoc networks). Within this program, N. Bonneau visited UniK (Oslo; April 12 – May 9, 2006). The complete project plan can be found at Aurora Project website: http://www.unik.no/~arehj/projects/aurora/aurora.html.

8.1.6. Collaboration with Russia and Belarus: PAI ECO-NET

MAESTRO, together with N. Litvak and W. Scheinhardt both from the University of Twente, The Netherlands, is involved in the PAI ECO-NET project in partnership with V. Dobrynin, A. Garnaev, L. Petrosyan, D. Nemirovsky and S.K. Pham from St. Petersburg State University, Russia, and A. Dudin and V. Klimenok from Belarussian State University, Belarus. ECO-NET is a two-year project (2005-2006) devoted to "Probabilistic and Graph Theoretical Methods in Search Engines."

8.1.7. Collaboration with the USA: NSF ITR project

Members of MAESTRO and the University of Massachusetts (UMASS) at Amherst (D. Towsley) have a long lasting collaboration in the area of performance evaluation and control of networks. Since Sep. 1, 2001, we have been associated with UMASS in a five-year NSF ITR project on "QoS in the future Internet". This project finances visits of members of MAESTRO to UMASS. In 2006, P. Nain visited UMASS within this framework. The program has ended on Aug. 31, 2006.

8.1.8. Collaboration with Venezuela

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 the MAESTRO project.

8.2. National initiative

8.2.1. Cooperative Research Initiative (ARC)

Members of MAESTRO participate in the ARC (Cooperative Research Initiative, sponsored by INRIA) IFANY "InFormAtioN theorY: New challenges and new interdisciplinary tools", 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. The website of ARC IFANY is http://www-sop.inria.fr/maestro/ifany/.

Members of MAESTRO also participate in the ARC COINC, 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. The website of ARC COINC is http://www-id.imag.fr/Laboratoire/Membres/Gaujal_Bruno/Coinc/coinc.html.

8.2.2. Incitative coordinated actions (ACI)

Members of MAESTRO are involved in two ACIs (Incitative Coordinated Actions) sponsored by the CNRS, INRIA, the Ministry of Education and Research and other institutions.

One is the FLUX project of the ACI "Masses of Data". Its main topic is the use of probabilistic counting to devise lightweight algorithms for flow classification in networks.

The second one is the SR2I (Security of Interdomain Routing in the Internet) of the ACI "Security in Informatics", the topic of which is the reliability and security of the BGP routing protocol.

8.3. Invited scientists

Europe U. Ayesta (LAAS, Toulouse, France, 04/12/06–04/176/06 and 09/09/06–09/16/06); A. Dudin and V. Klimenok (Belarussian State University, Belarus, 06/12/06-06/22/06); A. Garnaev (St. Petersburg State U., Russia, 06/29/06–07/01/06 and 11/30/06–12/09/06); G. Koole (Vrije University, Amsterdam, The Netherlands, 11/20/06); E. Morozov (Russian Academy of Sciences, Russia, 11/01/06–11/07/06); L. Petrosyan (St. Petersburg State University, Russia, 07/02/06–07/07/06); A. Piunovsky (University of Liverpool, UK, 04/08/06–04/16/06 and 09/10/06–09/17/06).

America T. Başar (University of Illinois at Urbana–Champaign, IL, USA, 07/01/06–07/31/06); L. Mason (McGill University, USA, 09/10/06–09/17/06).

Maghreb and Middle-East E. Solan (Tel Aviv University, Israel, 09/01/06–09/07/06).

Asia A. Chockalingam (IISC Bangalore, India, 07/16/06–07/29/06); H. Kameda (University of Tsukuba, Japan, 08/22/06–09/28/06); A. Kumar (IISC, India, 06/17/06–07/01/06); V. Borkar (TATA Institute of Fundamental Research, Mumbai, India, 10/01/06–10/21/06); J. Lui (Chinese University of Hong-Kong, China, 11/20/06 – 11/24/06).

Oceania J. Filar (University of South Australia, Adelaïde, Australia, 07/02/06–07/14/06), V. Gaitsgory (University of South Australia, Adelaïde, Australia, 06/26/06–07/08/06).

8.4. Visits of Maestro staff to other research institutions

E. Altman visited the Indian Institute of Science (IISCBangalore, India (Oct. 22–31, 2006) and Tel Aviv University, Israel (May 9–23, 2006).

K. Avrachenkov visited Tel Aviv University, Israel (May 15–20, 2006), St. Petersburg State University, Russia (June 5–10, 2006), University of Zielona Gora, Poland (Sep. 16–22, 2006), CWI, The Netherlands (Nov. 7–15, 2006), University of Twente, The Netherlands (Nov. 16-19, 2006).

N. Bonneau visited UniK, Oslo (April 12–May 09, 2006) in the frame of Aurora project.

P. Nain visited the University of Massachusetts, USA (May 15–19, 2006), Vrije University, Amsterdam, The Netherlands (Nov. 13, 2006).

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), *Communication Networks* (COMNET), *SIAM Journal on Control and Optimization* (SICON), 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*.

9.1.2. Participation in technical program committees

S. Alouf was a program committee member of the *First International Conference on Performance Evaluation Methodologies and Tools (Valuetools 2006)*, Oct. 11–13, 2006, Pisa, Italy.

E. Altman was a program committee member of the following conferences:

- *International Workshop on Protocols for Fast Long-Distance Networks (PFLDNET 2006)*, Nara, Japan, Feb. 2–3, 2006,

- *Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt 2006)*, Boston, MA, USA, April 3–7, 2006 (he was also a member of the steering committee),
- *IEEE International Workshop on Quality of Service (IWQoS 2006)* Yale University, New Haven, CT, USA, June 19-21, 2006,
- *European Wireless Conference (EW 2006)*, Athens, Greece, 2-5, April 2006,
- *Wireless On-demand Network Systems (WONS 2006)*, Les Menuires, France, Jan. 18–20th, 2006,
- *12th International Symposium on Dynamic Games and Applications*, Polytech, U. Nice Sophia Antipolis, July 2006, France,
- *International Conference on AD-HOC Networks and Wireless (AdHocNow)*, Ottawa, Canada, Aug. 17–19, 2006,
- *IEEE Infocom 2006*, Barcelona, Spain, April 23-27, 2006,
- *IFIP Networking 2006*, Coimbra, Portugal, May 15–9, 2006.

K. Avrachenkov was a program committee member of the following conferences:

- *The 6th International Conference on Next Generation Teletraffic and Wired/Wireless Advanced Networking (NEW2AN 2006)*, St. Petersburg, Russia, May 29 – June 2, 2006,
- *The 14th IEEE International Conference on Networks (ICON2006)* Singapore, Sep. 13–15, 2006,
- *IEEE Globecom 2006*, San Francisco, CA, USA, Nov. 27 – Dec. 1, 2006.

A. Jean-Marie was a program committee member of the following conferences:

- *MAMA 2006* (held in conjunction with Sigmetrics/Performance 2006), Saint-Malo, France, June 26–30, 2006,
- *3rd European Performance Evaluation Workshop 2005 (EPEW 2006)*, Budapest, Hungary, June 21–22, 2006,
- *3rd International Conference on the Quantitative Evaluation of SysTems (QEST 2006)*, Univ. of California at Riverside, CA, USA, Sep. 11–14, 2006,
- *Asian Internet Engineering Conference 2006 (AINTEC 2006)*, Bangkok, Thailand, Nov. 28–30, 2006,
- *21st International Symposium on Computer and Information Sciences (ISCIS 2006)*, Istanbul, Turkey, Nov. 1–3, 2006.

P. Nain was a program committee member of the following conferences:

- *IEEE Infocom 2006*, Barcelona, Spain, April 23–27, 2006,
- *21st International Symposium on Computer and Information Sciences (ISCIS 2006)*, Istanbul, Turkey, Nov. 1–3, 2006),
- *MAMA 2006* (held in conjunction with Sigmetrics/Performance 2006), Saint-Malo, France, June 26–30, 2006.

9.1.3. Conferences, meetings and tutorial organization

E. Altman organized and chaired the program committee of the *First International Conference on Performance Evaluation Methodologies and Tools (Valuetools 2006*), Oct. 11-13, 2006, Pisa, Italy.
He also co-organized (together with H. Levy and I. Eliazar) a three-day workshop in Shefayim, Israel, at the event of the retirement of U. Yechiali (Tel Aviv University).

E. Altman is now working on the preparation of a Special Issue of the journal *Probability In the Engineering Sciences* (PEIS) based on selected papers from the workshop.

E. Deriche was a member of the organizing committee of the *12th International Symposium on Dynamic Games and Applications* (July 3–6, 2006, Sophia Antipolis).
She organized the kick-off meeting of the ARC IFANY (March 29–30, 2006, ENST, Paris).

9.1.4. Participation in thesis committees

E. Altman participated as a reviewer in the PhD thesis committee of Kinda Khawam, ENST Paris (Nov. 14, 2006) and in the HdR thesis committee of Bruno Tuffin (April 10, 2006). He also participated as a thesis co-advisor in the PhD thesis committee of Ahmad Al Hanbali (U. of Nice Sophia Antipolis, Nov. 20, 2006).

K. Avrachenkov participated as thesis co-advisor in the PhD thesis committee of Gregory Miller (MAI, Moscow, Russia, Dec. 22, 2006).

A. Jean-Marie participated as a reviewer in the PhD thesis committee of P. Chambreuil (Tech. U. Belfort-Montbéliard and U. Franche-Comté, Jun. 23, 2006), and in the PhD thesis committee of M. Bouklit (U. Montpellier II, July 5, 2006).
In 2006 he has been appointed member of the Best Thesis Award Committee of SPECIF, the French Society for Education and Research in Computer Science.

P. Nain participated as thesis co-advisor in the PhD thesis committee of Ahmad Al Hanbali (U. of Nice Sophia Antipolis, Nov. 20, 2006), and in the PhD thesis committee of Menno Dobber (Vrije University, Amsterdam, The Netherlands, May 13, 2006). P. Nain was a member of the Best Thesis Award Committee of Telecom Valley (Provence-Alpes–Côte d'Azur Region).

9.1.5. PhD theses defended in 2006

The following PhD theses were defended in 2006:

A. Al Hanbali (Advisors: E. Altman and P. Nain) on November 20, 2006 [11] (committee: G. Koole, J. Lui (reviewers), H. Afifi, E. Altman, E. Biersack, W. Dabbous, P. Nain).

G. Miller (Advisors: K. Avrachenkov and A. Pankov) on December 22, 2006 [12] (committee: E. Y. Rubinovich, E. A. Rudenko (reviewers), A. Pankov, K. Avrachenkov, A. Borisov). "These en co-tutelle" between the University of Nice Sophia Antipolis, France, and Moscow Aviation Institute, Russia.

9.1.6. Research administration

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

A. Jean-Marie

- is 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.
- is co-chair of the Department of Computer Science of the LIRMM Laboratory, Montpellier (80 permanent staff).
- 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

- is a member of the management of the Research Unit of INRIA Sophia Antipolis.
- is Head of project-team MAESTRO.
- is Vice-Head of the Project-Committee of the Research Unit of INRIA Sophia Antipolis.
- is a member of the Evaluation Committee of INRIA.

- is 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 Telecommunications.
- 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

- A. A. Kherani, R. El-Azouzi and E. Altman [44] were awarded the **Best Paper Award** of *IFIP Networking 2006* (May 2006, Coimbra, Portugal).
- A. Al-Hanbali [30] (joint paper with P. Nain and E. Altman) was **Finalist for Best Student Paper Award** at *Valuetools 2006* (October 2006, Pisa, Italy).
- 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 "Probability and Statistics" in the Engineering Program at Polytech' Nice-Sophia (52H).

E. Altman taught a course on the Network Simulator (ns-2) within the Master Program on "Networks and Distributed Systems" at the University of Nice Sophia Antipolis (24H).

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. Jean-Marie participated in the course on "Dynamics and Algorithmics of Networks" of the Master in Computer Science MPRI (Paris 6/ENS/École Polytechnique, 6H). He taught a course on Random Discrete Structures in the Master in Informatics of the University of Montpellier II (20H).

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).

9.3. Participation in conferences and workshops

A. Al Hanbali presented a paper at *Infocom 2006* (Barcelona, Spain, April 23–29) and at the *First International Conference on Performance Evaluation Methodologies and Tools (Valuetools 2006)* (Oct. 11–13, 2006, Pisa, Italy). He also gave a poster presentation at the *IEEE International Workshop on Quality of Service (IWQoS 2006)* (Yale University, New Haven, CT, USA, June 19-21, 2006).

S. Alouf attended (as an author of a paper) *IFIP Networking 2006* (Coimbra, Portugal, May 15–19, 2006). She also attended the EURO-NGI *workshop on Stochastic Performance Models for Resource Allocation in Communication Systems* (Amsterdam, Netherlands, Nov. 8–10, 2006).

E. Altman was an invited plenary speaker at the *12th International Symposium on Dynamic Games and Applications* (Sophia Antipolis, France, July 2006) and gave a presentation at *Infocom 2006* (Barcelona, Spain, April 23–29, 2006). He was also an invited speaker in the *Second Madrid Conference on Queueing Theory (MCQT)* (July 2006).

K. Avrachenkov was an invited plenary speaker at the *First International Conference for Young Researchers in Computer Science, Control, Electrical Engineering and Telecommunications (ICYR'06)* (Sep. 18-20, Zielona Gora, Poland). He has also given presentations at the *Workshop in honour of Uri Yechiali*, (Shefayim, Israel, May 17–19, 2006), the *6th International Conference on Next Generation Teletraffic and Wired/Wireless Advanced Networking (NEW2AN 2006)* (St.Petersburg, Russia, May 29 – June 2, 2006), and the EuroNGI workshop organized within JRA.S.23 Delayed (Eindhoven, The Netherlands, Nov. 11, 2006). He also attended the EURO-NGI *workshop on Stochastic Performance Models for Resource Allocation in Communication Systems* (Amsterdam, Netherlands, Nov. 8–10, 2006).

M. Ibrahim gave a presentation at *IFIP Networking 2006* (Coimbra, Portugal, May 15–19, 2006).

D. Kumar presented two papers at the *4th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2006*) (April 3–7, 2006, Boston, USA) and one paper at *IFIP Networking 2006* (May 15-19, 2006, Coimbra, Portugal). He also gave an invited talk at Euro-Ngi Cellular2 meeting (Oct. 9, 2006, Pisa, Italy).

P. Nain was an invited speaker at the *EuroNGI Workshop on Stochastic Performance Models for Resource Allocation in Communication Systems* (Amsterdam, The Netherlands, Nov. 8–10, 2006). He attended (as an author of a paper) *Infocom 2006* (Barcelona, Spain, April 23–29, 2006).

G. Neglia gave a presentation at *ACM SIGCOMM workshop on Challenged Networks* (Pisa, Italy, Sep. 15, 2006).

N. Osipova has given presentations at the *First International Conference on Performance Evaluation Methodologies and Tools (ValueTools'06)* (Pisa, Italy, Oct. 11–13, 2006), *EuroNGI Workshop on Stochastic Performance Models for Resource Allocation in Communication Systems* (Amsterdam, The Netherlands, Nov. 8–10, 2006).

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