INRIA

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team maestro

Models for Performance Analysis and Control of Networks

Sophia Antipolis

THEME COM

Table of contents

1. Team

Head of Maestro
Philippe Nain [DR, INRIA]

Vice-head of Maestro
Eitan Altman [DR, INRIA]

Administrative assistant
Ephie Deriche [TR, part-time, jointly with MASCOTTE]

Inria staff
Sara Alouf [CR]
Konstantin Avrachenkov [CR]
Alain Jean-Marie [DR]

University staff
Anne-Elisabeth Baert [Teaching Assistant U. Montpellier II]

Post-doctoral fellows
Urtzi Ayesta [EURONGI fellowship, 10/01/05–02/28/06]
Laura Cottatellucci [EURONGI fellowship, 10/01/05–12/31/05]
Dieter Fiems [FWO fellowship, 05/01/05–09/30/05]
Robin Groenevelt [ATER at UNSA, 04/08/05–09/30/05]
Arzad Alam Kherani [CEFIPRA fellowship, 08/01/03–07/15/05]
Giannis Koukoutsidis [INRIA fellowship for 1 year, until 08/01/05]

PhD students
Ahmad Al Hanbali [MENRT fellowship, 2rd year. Advisors: E. Altman and P. Nain]
Nicolas Bonneau [X Telecom, 2nd year. Advisors: E. Altman and M. Debbah]
Florence Clévenot-Perronnin [MENRT fellowship, 3rd year, until 09/30/05. Advisor: P. Nain]
Olivier Gandouet [MENRT fellowship, 2nd year. Advisor: A. Jean-Marie]
Robin Groenevelt [ATER at UNSA, 01/01/05–04/07/05. Advisor: P. Nain]
Mouhamad Ibrahim [MENRT fellowship, 1st year. Advisor: S. Alouf]
Dinesh Kumar [INRIA INTER fellowship, 1st year. Advisor: E. Altman]
Grigoriy Miller [“Cotutelle” scholarship, 3rd year. Advisor: K. Avrachenkov]
Balakrishna Prabhu [INRIA INTER fellowship, 3rd year, until 10/30/05. Advisors: E. Altman and K. Avrachenkov]

Visiting scientists
Urtzi Ayesta [CWI, Amsterdam, The Netherlands, 05/23/05–/06/05/05]
Vladimir Dobrynin [St. Petersburg State University, Russia, 07/10/05–07/18/05]
Vladimir Ejov [University of South Australia, Adelaïde, Australia, 06/24/05–07/06/05]
Jersy Filar [University of South Australia, Adelaïde, Australia, 03/21/05–04/03/05]
Luke Finlay [University of South Australia, Adelaïde, Australia, 06/27/05–06/28/05]
Vladimir Gaitsgory [University of South Australia, Adelaïde, 06/23/05–06/28/05]
Bezalel Gavish [Southern Methodist University, Dallas, USA, 05/01/05–05/06/05]
Moshe Haviv [The Hebrew University of Jerusalem, Israël, 01/16/05–01/29/05]
Hisao Kameda [University of Tsukuba, Japan, 03/23/05–03/30/05]
Harold Kushner [Brown University, Providence, USA, 09/12/05–09/16/05]
Richard Márquez [University of Los Andes, Venezuela, 07/01/05–07/31/05]
Evsey Morozov [Petrozavodsk University, Russia, 09/15/05–09/19/05]
Rudesindo Núñez Queija [CWI, Amsterdam, The Netherlands, 12/14/05–12/16/05]
Leon Petrosjian [St. Petersburg State University, Russia, 07/15/05–07/28/05]
Keith W. Ross [Polytehnic University, Brooklyn, NY, USA, 10/01/05–10/08/05]

Sergey Savchenko [Russian Academy of Science, Moscow, Russia, 04/03/05–04/17/05]
Vinod Sharma [IISC Bangalore, India, 10/10/05–01/10/06]
R. Srikant [University of Illinois at Urbana-Champaign, IL, USA, 10/02/05–10/05/05]
Don Towsley [University of Massachusetts, USA, 10/01/05–10/09/05]
Jorma Virtamo [Helsinki University of Technology, Finland, 10/01/05–10/06/05]
Uri Yechiali [University of Tel Aviv, Israel, 10/09/05–10/21/05]

Graduate students (internship)

Dhiman Barman [Boston University, USA, 05/15/05–08/05/05]
Anders Gjendemsjo [NTNU, Olso, Norway, 08/29/05–11/30/05]
Vegard Hassel [NTNU, Olso, Norway, 08/29/05–11/30/05]
Mouhamad Ibrahim [Master RSD, UNSA, 03/01/05–07/31/05]
Dinesh Kumar [IIT Delhi, India, 02/01/05–03/31/05]
Venkatesh Ramaiyan [IISC Bangalore, India, 10/02/05–10/23/05]
Srinivas Shakkottai [University of Illinois, Urbana–Champaign, USA, 05/16/05–08/07/05]

Undergraduate students (internship)

Danil Nemirovsky [St. Petersburg State University, Russia, 04/07/05–06/07/05]
Le Minh Ngo [Asian Institute of Technology, Bangkok, Thailand, 03/16/05–04/14/05]
Natalia Ossipova [St. Petersburg State University, Russia, 04/07/05–06/07/05]

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 2005 have focused on the following issues:

- performance evaluation of wireless, mobile, ad hoc and sensor networks, in particular within a research 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 programme
- dynamic aspects of the coverage of a mobile sensor movement with the support of the NSF ITR project “QoS in the Future Internet”
- 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: TCP, high speed congestion control, voice over IP, service differentiation, quality of service, multicast applications, content distribution systems, peer-to-peer systems, overlay networks, multimedia traffic generation
- Wireless (cellular, ad hoc, sensor) networks: power control, medium access control, transmission rate control, redundancy in source coding, mobility models, coverage
- Satellite communications: IP over satellite links, planning and resource allocation.

5. Software

5.1. Software

MAESTRO has developed two softwares, ALLEGRO, a multimedia traffic generator (see 2004 MAESTRO activity report for a brief description of ALLEGRO functionalities) and ERS, a set of tools for the analysis of discrete-event systems. These softwares can be downloaded from http://www-sop.inria.fr/maestro/soft/allegro.html and http://www-sop.inria.fr/mistral/soft/ers.html, respectively.

6. New Results

6.1. Quantitative analysis of protocols

Keywords: *FEC*, *MIMD algorithm*, *TCP*, *estimation of traffic characteristics*, *fairness*, *high-speed/scalable TCP*.

Participants: Ahmad Al Hanbali, Sara Alouf, Eitan Altman, Konstantin Avrachenkov, Dhiman Barman, Olivier Gandouet, Alain Jean-Marie, Arzad Alam Kherani, Grigoriy Miller, Daniele Miorandi, Philippe Nain, Balakrishna Prabhu.

6.1.1. High-speed congestion control

Participants: Eitan Altman, Konstantin Avrachenkov, Arzad Alam Kherani, Balakrishna Prabhu.

Due to the rapid increase of the bandwidth in networks (with links up to 10Gbps), the mechanisms of most of the existing versions of TCP that adapt to the available bandwidth turn out to be too slow, and need sometimes hours until they manage to grab the available bandwidth. Recently, new versions of TCP have been proposed which implement more aggressive mechanisms for adapting to the available throughput. High Speed TCP (proposed by S. Floyd) and Scalable TCP (proposed by T. Kelly) are two such mechanims.

In [16], E. Altman, K. Avrachenkov, A. A. Kherani and B. Prahbu in collaboration with C. Barakat (INRIA project-team PLANETE), study Scalable TCP, which uses a Multiplicative Increase Multiplicative Decrease (MIMD) algorithm for the window size evolution. The authors present a mathematical analysis of the MIMD congestion control algorithm in the presence of random losses. Random losses are typical to wireless networks but can also be used to model losses in wireline networks with a high bandwidth-delay product. The approach is based on showing that the logarithm of the window size evolution has the same behavior as the workload process in a standard G/G/1 queue. The Laplace-Stieltjes transform of the equivalent queue is then shown to directly provide the throughput of the congestion control algorithm and the higher moments of the window size.

In [18], E. Altman, K. Avrachenkov and B. Prahbu analyze fairness among sessions sharing a common bottleneck link, in the case when at least one session uses the MIMD algorithm. Both synchronous as well as asynchronous losses are considered. In the asynchronous case, only one session suffers a loss at a loss instant. Two models are then considered to determine which source looses a packet: a rate dependent model in which the packet loss probability of a session is proportional to its rate at the congestion instant, and the independent loss rate model. The authors first study how two MIMD sessions share the capacity in the presence of general combinations of synchronous and asynchronous losses. They show that, in the presence of rate dependent losses, the capacity is fairly shared whereas rate independent losses provide high unfairness. They also study inter-protocol fairness: how the capacity is shared in the presence of synchronous losses among sessions some of which use Additive Increase Multiplicative Decrease (AIMD) protocols whereas the others use MIMD protocols.

In [25], E. Altman, K. Avrachenkov, A. A. Kherani and B. Prahbu study an Adaptive Window Protocol (AWP) with general increase and decrease profiles in the presence of window dependent random losses. The authors derive a steady-state Kolmogorov equation, and then obtain its solution in analytic form for particular TCP versions proposed for high-speed networks, such as Scalable TCP and HighSpeed TCP. They also relate the window evolution process under an AWP to the workload process in queueing systems. This observation provides a way to compare various AWP protocols.

In [31], the same authors present an approximate expression for the throughput of a long-lived Scalable TCP session when the losses are i.i.d. and due to window dependent errors. In the second part of the paper, they analyze the case when losses are due to Markovian window independent errors.

6.1.2. Analysis of TCP at different granularities

Participants: Eitan Altman, Konstantin Avrachenkov.

TCP is frequently modeled as a fluid whose amount increases smoothly until a loss occurs, in which case the fluid drops instantaneously to a lower level. This is the well-known saw-tooth model of the TCP sending rate evolution. An instance of this model can be found in [19], where E. Altman and K. Avrachenkov, in collaboration with C. Barakat (INRIA project-team PLANETE), have revisited their Sigcomm 2000 paper with more detailed discussions on ergodicity conditions for the TCP sending rate evolution, the derivation of the second moment of the TCP sending rate, and the numerical experiments.

Yet other fluid models have been used (in particular by F. P. Kelly) in which the increase and decrease parts of the TCP dynamics are replaced by their average value, so that TCP dynamics are described using a differential equation (referred below to as the smooth fluid model). In [26], E. Altman, in collaboration with R. Márquez and S. Sole-Alvarez (both from the University of Los Andes, Merida, Venezuela), has shown that the smooth fluid model provides a good approximation of the saw-tooth model.

6.1.3. Optimal dynamics of TCP/IP networks

Participants: Konstantin Avrachenkov, Urtzi Ayesta, Grigoriy Miller.

6.1.3.1. Optimal evolution of TCP sending rate

In [50], K. Avrachenkov and G. Miller, in collaboration with B. Miller and K. Stepanyan (both from Institute for Transmission Problems, Moscow, Russia), consider a nonlinear optimal stochastic control problem. The state of the link is described by a controlled hidden Markov process while the arrival of congestion notifications is described by a counting process with the intensity depending on the current transmission rate (control) and unobserved link state. The aim of the control is to achieve the maximum of some utility function taking into account the losses of transmitted information. A necessary optimality condition is derived in the form of stochastic maximum principle which allows the authors to obtain explicit analytic expressions for the optimal control in some particular cases. It is shown that for a Markovian path the optimal sending rate evolution is indeed piecewise deterministic as it is the case in the current TCP implementation. However, it is also shown that the optimal increase is not linear and the optimal multiplicative decrease is not proportional to the instantaneous sending rate. The optimal control takes advantage from a priori information about the path characteristics. In particular, this allows congestion control to achieve much smaller variance of the sending rate evolution, and at the same time to gain in the average throughput.

6.1.3.2. Optimal buffer size for Internet routers

In [34], K. Avrachenkov, in collaboration with U. Ayesta (CWI, The Netherlands) and A. Piunovskiy (University of Liverpool, UK), studies the optimal choice of the buffer size in Internet routers. The objective is to determine the minimum value of the buffer size required in order to fully utilize the link capacity. There are some empirical rules for the choice of the buffer size. The most known rule of thumb states that the buffer length should be set to the bandwidth delay product of the network. Several recent works suggest that, as a consequence of the traffic aggregation, the buffer size should be set to smaller values. The analytical results in [34] provide further evidence that indeed the buffer size should be reduced in the presence of traffic aggregation. Furthermore, their result states that the minimum required buffer is smaller than what previous studies suggested.

6.1.4. Loss policies for parallel TCP sessions

Participants: Eitan Altman, Dhiman Barman.

Consider permanent TCP sessions that share an intelligent bottleneck router. When the sum of the TCP rates reach the throughput capacity then a loss (or a congestion notification) occurs. It is assumed that the router decides which of the sessions will receive a notification (or will suffer a loss). Examples of such policies include (i) independent marking, (ii) choosing the flow with the largest throughput for marking, (iii) choosing the flow with the smallest throughput, (iv) choosing the flow for marking with a probability that is proportional to its rate. Surprisingly it has been shown that no matter what policy is used, the sum of TCP throughputs will be the same. However, the second moments do depend on the used marking policy. The above results have been obtained for two connections [62] by E. Altman, in collaboration with R. El Azouzi (University of Avignon, France), D. Ros and B. Tuffin (both from INRIA project-team ARMOR), and extended to any number of connections [59] by E. Altman and D. Barman, in collaboration with B. Tuffin and M. Vojnovic (Microsoft Research, Cambridge, UK).

6.1.5. TCP in wireless networks

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

TCP was designed to provide reliable end-to-end delivery of data over unreliable networks. In practice, most TCP deployments have been carefully optimized in the context of wired networks. Ignoring the characteristics of wireless Mobile Ad Hoc Networks (MANETs), such as high bit error rates, path asymmetry, network partitions, route failures, power constraints, etc. lead to TCP implementations with poor performance. In [13], A. Al Hanbali, E. Altman and P. Nain review proposals recently made to improve the performance of TCP in MANET environment.

In [40], E. Altman, in a collaborative work with A. Chockalingam, J. V. K. Murthy and R.Kumar (all from IISc, Bangalore, India), proposes a cross-layer design for TCP over a wireless channel. As resources are scarce and more expensive in radio communications, it becomes advantageous to invest in a cross-layer network design. The authors study how to jointly optimize the modulation scheme, the retransmission policy, the amount of forward error correction, etc., so as to optimize data transfer goodput using TCP. This is done by using the well-known TCP throughput formula to express the dependence of the throughput with respect to loss probabilities and of the round trip delay, and then express the loss rates and delays as a function of the physical, link and network layer parameters.

6.1.6. FEC (Forward Error Correction)

Participant: Alain Jean-Marie.

A. Jean-Marie, T. Alemu and Y. Calas have pursued the investigation of the interaction of FEC and the queue management algorithms, specifically, RED (Random Early Detection) and the standard Drop Tail (DT). The problem was to derive quantitative rules enabling to decide when one situation is better than the other. The critical object here is the process of losses. Several models, including a batch-Poisson process, have been analyzed. This last one allows the authors to derive asymptotic laws, involving moments of the *loss run length*, which explains the presence of a cross-over phenomenon when the packet loss rate increases. Simulations of networking situations illustrate the qualitative validity of the predictions [27], [28], [45].

6.1.7. Estimation of traffic characteristics

Participants: Alain Jean-Marie, Olivier Gandouet.

In the framework of the FLUX project (funded by the ACI Masses of Data), A. Jean-Marie and O. Gandouet have focused on the problem of recognizing long-lived and short-lived data flows (elephants and mice) using algorithms with a (very) small memory. The modeling of the problem reduces it to the estimation of some characteristics of multi-sets, like moments of frequencies, or the number of elements with specific properties. Algorithms based on probabilistic counting seem to offer this possibility. From there, they have explored two directions.

On one side, they have studied the intrinsic algorithmic difficulty of the question. Using results from the theory of "communication complexity", they have proved that no online algorithm could solve the problem in general with substantially less memory than an exact algorithm. This result holds whether the algorithm is exact or probabilistic.

On the other side, an algorithm allowing the estimation of the number of elephants in a flow of packets (an elephant being defined as having more than k times as much packets than a mouse) has been constructed, on the basis of the LogLog algorithm of Durand and Flajolet. For multi-sets in a specific (yet practical) family, this algorithm indeed uses much less memory than an exact algorithm.

6.1.8. Multicast

Participants: Sara Alouf, Alain Jean-Marie, Philippe Nain.

6.1.8.1. Secure multicast

In secure multicast communications (etc. TV over IP, confidential videoconferences) a hierarchical organization of encryption keys is often adopted to minimize the costs of updating the data encryption key at all members. However, volatile members still induce a high number of updates needed to ensure data confidentiality. It has been proposed to isolate these members to improve the quality of service rendered to long-lived members. In [58], S. Alouf, A. Jean-Marie and P. Nain develop a stochastic model of the system, the objective being to optimally tune its parameters. In particular, the joint distribution of disjoint populations in a M/G/∞ system is derived yielding the joint distribution of the populations at hand (ongoing work).

6.1.8.2. Reliable multicast protocol for unidirectional satellite (RMUS)

A. Jean-Marie and L. M. Ngo have analyzed one aspect of the RMUS protocol, which has been proposed for flow control in the satellite-based AI3 system (Asian Internet Interconnection Initiatives Project). This study

led to the conclusion that the acknowledgment implosion problem may impede the scalability of the protocol. The results will appear in [70].

6.2. Wireless networks

Keywords: *IEEE 802.11, UMTS, Wireless LAN, ad hoc network, association problem, connectivity, coverage, random matrix theory, rate control, sensor network.*

Participants: Sara Alouf, Eitan Altman, Konstantin Avrachenkov, Mouhamad Ibrahim, Arzad Alam Kherani, Giannis Koukoutsidis, Dinesh Kumar, Philippe Nain, Balakrishna Prabhu, Venkatesh Ramaiyan, Srinivas Shakkottai.

6.2.1. WLAN access

Participants: Sara Alouf, Mouhamad Ibrahim, Eitan Altman, Venkatesh Ramaiyan, Dinesh Kumar, Srinivas Shakkottai.

6.2.1.1. Analysis of IEEE 802.11

IEEE 802.11 represents the de facto standard for wireless local area networks. One of the well-known drawbacks of IEEE 802.11 is the low performance of its MAC protocol in terms of throughput in congested networks.

During his master internship, supervised by S. Alouf, M. Ibrahim has proposed an adaptive back-off mechanism whose contention window is set to an optimal size after a successful transmission. The proposed algorithm, called “Adaptive BEB”, relies on on-line counts of error-free frames received at a given station. The optimality achieved by Adaptive BEB refers to a maximum overall system throughput. Simulation results show that Adaptive BEB substantially improves the IEEE 802.11 standard and that its performance is steady under a variety of network conditions and configurations [57].

In [69] the same authors propose an alternative formulation of Adaptive BEB as well as an extension that enhances its performance over noisy channel. The extended algorithm, called Adaptive BEB++, makes use of an exponentially weighted moving average filter to estimate the packet error rate observed at a given station.

In [48], E. Altman and D. Miorandi, in collaboration with A. Kumar and M. Goyal (both from IISc Bangalore, India), study the homogeneous case with saturated mobiles, in which all mobiles use the same back-off parameters (like in IEEE 802.11b). They obtain the throughput through a single fixed-point scalar equation. They also provide a computing procedure to compute the throughput of TCP over IEEE 802.11b.

In [53], E. Altman jointly with V. Ramayan and A. Kumar (both from from IISc Bangalore, India), derives throughput expressions for the non-homogeneous case, which allows them to model service differentiation among several classes. Such differentiation exists in the "e" version of IEEE 802.11. They provide a vector valued fixed-point equation, and give conditions for the uniqueness of its solution. They also give examples of non-uniqueness. In case of uniqueness, they show that the solution of the fixed-point equation provides good approximations for the throughputs.

6.2.1.2. Rate selection in 802.11

In [32], E. Altman and D. Kumar and V. Ramaiyan, in collaboration with A. Kumar (IISc Bangalore, India) derive closed-form expressions for the optimal PHY (physical) rate selection that achieves maximum throughput levels for the network at minimum power consumption. In the cooperative approach they seek to obtain the optimal PHY rates under two different scenarios – *max-min fair* rate (in which the objective is to obtain the highest value of a common rate to all users that satisfies the system’s constraints) as well as a *global multi-rate* allocation. In the non-cooperative approach a competitive *multi-rate* allocation is studied. Single node throughputs corresponding to the optimal PHY rates are numerically computed.

6.2.1.3. The association problem for 802.11 WiFi networks

In [71], S. Shakkottai and E. Altman, in collaboration with A. Kumar (IISc Bangalore, India), investigate the so-called association problem: when a mobile has connectivity with several WiFi networks, to which network should it connect to? Since mobiles can frequently make such choices, and since they are in general

not aware of each other, and are thus non-cooperative, the solution concept that these authors have developed uses a Nash equilibrium, which they explicitly compute.

6.2.2. Optimizing cellular networks using random matrix theory

Participants: Eitan Altman, Nicolas Bonneau, Laura Cottatellucci.

The work concerns applications of random matrix theory and unitary random matrix theory to cellular networks. In most cases of interest, explicit formulas depending only on a few meaningful system parameters can be derived.

In [36], N. Bonneau and E. Altman, in collaboration with M. Debbah and G. Caire (both from INSTITUT EURECOM, Sophia Antipolis), analyze base station deployment of CDMA cells along the line. Mobiles and base stations use spreading codes to simultaneously transmit their information, so that the receiving end can discriminate between the interfering users. Results are derived for three types of receiver structures: matched filter, Wiener filter and optimum filter. There is a uniformly distributed density d of users per meter as well as certain characteristics of the fading channel. The asymptotic regime of very dense networks are considered, where the spreading length N tends to infinity, d tends to infinity but the ratio $\frac{d}{N} \to \alpha$ is constant. Using random matrix theory, simple expressions for the performance measures, such as SINR and spectral efficiency in the large system limit, are derived.

Standard studies of uplink CDMA schemes assume a multiple access communication scheme, where each user modulates his signal with a pseudo-random i.i.d. sequence. In [37], N. Bonneau and E. Altman, in collaboration with M. Debbah and G. Caire (INSTITUT EURECOM), investigate the possible gain of using orthogonal spreading codes in the uplink CDMA. The problem is analyzed in the asymptotic regime. The results are based on random unitary matrix theory.

Orthogonal Frequency Division Multiplexing Access (OFDMA) is a technique allowing multiple users to simultaneously transmit to a base station. The bandwidth is divided into carriers on which users send their information. However, efficient algorithms to schedule transmission tend to consume too many resources, because of the feedback requirements. Using the reciprocity of the channel on each carrier, N. Bonneau and E. Altman, in collaboration with M. Debbah (INSTITUT EURECOM and A. Hjørungnes (UniK, Norway) show in [38] how to optimize the use of OFDMA carriers in a decentralized context in which the choice of carriers is done at the transmitters rather than at the base station. This can be most relevant to 802.16 (WiMax) where FDMA is used.

In [65], L. Cottatellucci, in collaboration with M. Debbah (INSTITUT EURECOM) and R. R. Müeller (University of Trondheim, Norway), analyzes the performance of large asynchronous CDMA systems with linear multi-user detectors (e.g. minimum mean square error detector, multistage Wiener filter, multistage detectors) in the uplink channel. While the performance of synchronous systems with square-root Nyquist chip waveforms is independent of the chip bandwidth, the performance of asynchronous systems depends on the pulse shape and the bandwidth. It increases as the bandwidth increases beyond half on the chip rate and, in such a case, asynchronous systems outperform the synchronous ones. The analysis, based on the self-averaging properties of random matrices, provides also a terse description of asynchronous CDMA systems in terms of a few macroscopic system parameters, (noise variance, the system load, the fading distribution of the channel, the power distribution and some coefficients able to describe the effects of the pulse shape and the bandwidth on the system) that facilitates cross-layer design.

In [64], L. Cottatellucci, in collaboration with M. Debbah (INSTITUT EURECOM) and R. R. Müeller (University of Trondheim, Norway), provides a low complexity linear multistage detector for multiuser multiple-input multiple-output CDMA systems with correlated spatial diversity. The low complexity detector is based on the properties of random matrices and achieves near-linear minimum mean square error (LMMSE) performance with the same complexity order per bit of a conventional single user matched filter detector. The multistage detector performance is also investigated.

6.2.3. Ad hoc and sensor networks

Participants: Ahmad Al Hanbali, Eitan Altman, Robin Groenevelt, Arzad Alam Kherani, Dinesh Kumar, Philippe Nain.

6.2.3.1. Route lifetime in vehicular ad hoc networks

The work of D. Kumar, A. A. Kherani and E. Altman in [56] aims to better understand the route lifetime dynamics in inter-vehicular mobile ad hoc networks (iv-MANETs or VANETs), that are a special class of MANETs, but exhibit very different behavior from them. These authors solve the problem of finding an optimal multi-hop route between two vehicular nodes on a highway. Under a Markovian assumption on the process of the speed of nodes, they shown that the optimal choice of speeds of relay nodes in a route attempts to equalize the lifetimes of adjacent links in a route. A monotone variation property of the speed of the relay nodes under the optimal policy is proved. The heuristics and structures developed can serve in designing a new set of efficient *interactive* routing protocols specifically tailored for high mobility ad hoc networks and iv-MANETs in particular.

6.2.3.2. Relaying performance in mobile ad hoc networks

In MANETs (Mobile Ad Hoc Networks) a route between two nodes often experiences failure when the mobility of nodes increases. This explains the poor performance of traditional ad hoc routing protocols. A well-known solution proposed, and analyzed by Tse and Grossglauser, is to use intermediary nodes as relay nodes. A relay node stores in its buffer packets for other nodes, and then transmit a packet when it is sufficiently close to the destination. In [54], A. Al Hanbali, A. A. Kherani, R. Grenovelt, P. Nain, and E. Altman study the contribution of a relay node in relaying data between a source and a destination, called *relay throughput*. When all nodes move according to the same mobility model, a uniform steady-state node position distribution achieves the lowest relay throughput. Explicit and closed form expressions for the relay throughput are provided for the Random Waypoint and The Random Direction mobility models, in both one and two dimensions. In addition, for the Random Walk mobility the mean waiting time of the packet in the relaying buffer of a relay node is derived for the high load case.

R. Groenevelt and P. Nain (in collaboration with G. Koole from the Vrije Universiteit of Amsterdam, The Netherlands) have introduced in [44] a generic stochastic model that accurately predicts the message delay in a mobile ad hoc network when nodes can relay messages. The model has only two input parameters: the number of nodes and the intensity of a finite number of homogeneous and independent Poisson processes modeling instances when any pair of nodes come within transmission range of one another. Explicit expressions are obtained for the Laplace-Stieltjes transform of the message delay, from which the expected message delay is derived in closed-form. These calculations are carried out for two relay protocols: the two-hop relay and the unrestricted relay protocols. Despite its simplicity, the model is able to accurately predict the performance of both relay protocols for a number of mobility models (Random Waypoint, Random Direction and Random Walker Mobility Models), as shown by simulations.

In [67] nodes move according to independent Brownian motions on a line and R. Groenevelt, E. Altman and P. Nain compute the expected time before a message reaches its destination when node relaying is used.

6.2.3.3. Coverage and connectivity

One important issue in ad hoc wireless networks is the characterization of the limiting performance, in terms of both connectivity and coverage. After studying in 2004 one-dimensional networks using a queueing theory approach, E. Altman, in collaboration with D. Miorandi (CREATE-NET, Italy), has studied in [51] the two-dimensional problem under various assumptions on the channel gains.

In [49], P. Nain, in collaboration with B. Liu (University of Massachusetts-Lowell, USA), P. Brass, O. Dousse (both from EPFL, Switzerland) and D. Towsley (University of Massachusetts, USA), has studied dynamic aspects of the coverage of a mobile sensor movement, and showed that sensor mobility can be exploited to compensate for the lack of sensors and improve the network coverage. This work has been further extended to the case of non-zero sensing duration (an intruder entering the detection area of a sensor cannot be detected before a minimum amount of time).

6.2.4. Analysis of UMTS networks

Participants: Eitan Altman, Giannis Koukoutsidis.

In [47], G. Koukoutsidis analyzes a Wideband Code Division Multiple Access (WCDMA) multiservice system. This system is composed of real-time traffic having dedicated channel access, admission control and limited rate control, and non real-time traffic with limited resource reservation and processor sharing rate control. A non-homogeneous quasi-birth-death process is used to model the system and evaluate its performance.

In [46], G. Koukoutsidis and E. Altman, in collaboration with J.-M. Kelif (FRANCE TELECOM R&D, Issy-les-Moulineaux), describe a modeling approach for studying fair rate sharing in a CDMA link with simultaneous transmissions with Poisson and Engset flow arrivals. The approach revisits and extends the Generalized Processor Sharing (GPS) scheme introduced, and analyzed, by J. M. Cohen in 1979, and it allows the authors to derive various performance metrics (expected transfer time, blocking probabilities, etc.).

6.2.5. Optimization and control of mobile networks

Participants: Eitan Altman, Konstantin Avrachenkov, Arzad Alam Kherani, Grigoriy Miller, Balakrishna Prabhu.

In [39], A. A. Kherani and B. Prabhu, in collaboration with V. S. Borkar (TATA Institute, Mombai, India), study the structure of the optimal policy in a decision problem faced by a wireless device. The device wants to transmit packets with minimal delay but it also wants to minimize the energy consumed by each transmission. The optimal policy for such a decision problem is shown to be of threshold type, where the threshold depends on the number of packets in the queue and the remaining energy in the battery.

E. Altman, K. Avrachenkov and G. Miller, along with R. Márquez (University of Los Andes, Merida, Venezuela), have worked on the problem of decentralized dynamic control of power and transmission rate in cellular networks. It is assumed that each mobile knows only the state of its own channel, and takes decisions on the power levels based on that information. For each mobile, its SINR (which is the ratio between the power received at a base station from the mobile and the sum of the powers corresponding to interferences from other mobiles and of noize) determines the transmission rate that the mobile can achieve. In [17] the authors consider the case of two mobiles, where the first mobile seeks for a power control strategy so as to maximize its transmission rate, whereas the other mobile, assumed to be malicious, tries to minimize the rate of the first mobile by the intereference that it causes. Both mobiles have constraints on their average power consumption. This problem is formulated as a stochastic zero-sum game, with a non-standard information structure. Foundations for solving such problems are laid in [17], and then implemented to derive structural properties of the optimal policies for each of the mobiles.

6.3. Content distribution networks and WWW

Keywords: *BitTorrent*, *Google*, *P2P*, *PageRank*, *fluid model*.

Participants: Konstantin Avrachenkov, Florence Clévenot-Perronnin, Danil Nemirovsky, Philippe Nain, Natalia Ossipova.

6.3.1. Document ranking in WWW

Participants: Konstantin Avrachenkov, Danil Nemirovsky, Natalia Ossipova.

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. Google computes the PageRank using the power iteration method which requires about one week of intensive computations. In [55] K. Avrachenkov, D. Nemirovsky and N. Osipova, in collaboration with N. Litvak (University of Twente, The Netherlands), propose and analyze Monte Carlo type methods for the PageRank computation. There are 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 for continuous updates of the PageRank as the structure of the Web changes.

6.3.2. Peer-to-peer systems

Participants: Florence Clévenot-Perronnin, Philippe Nain.

F. Clévenot-Perronnin and P. Nain, in collaboration with K. W. Ross (Polytechnic University, New York, USA), have investigated service differentiation and bandwidth diversity issues for BitTorrent like P2P networks. In [41] they introduce resource allocation strategies that are based on a single parameter. With the help of multiclass fluid models they show how this parameter could be tuned so as to achieve a target quality of service ratio.

In [22], F. Clévenot-Perronnin and P. Nain propose a new model of Squirrel, a P2P cooperative web cache. This work extends the analysis in [63] to an arbitrary number of nodes and to documents with different popularities.

6.4. Game theory applied to networking

Keywords: *Noncooperative games, pricing.*

Participants: Eitan Altman, Dhiman Barman, Nicolas Bonneau.

6.4.1. Priority level in a diffserv environment

In [60], E. Altman and D. Barman, in collaboration with R. El Azouzi (University of Avignon, France), D. Ros and B. Tuffin (both for INRIA project-team ARMOR), investigate the sharing of a multi-RED buffer by TCP and UDP traffic. They consider throughput, delay, and loss probability as performance measures. The relative quality of service of a connection depends on the choice of its priority level. They model the choice of the priority levels as a non-cooperative game, and study the properties of the equilibria. They also study the optimal pricing of the priority levels by the service provider so as to maximize its own benefits.

6.4.2. Non-cooperative multiple access techniques

Within the framework of non-cooperative game theory. N. Bonneau and E. Altman, in collaboration with M. Debbah (INSTITUT EURECOM), have introduced evolutionary games in the context of unslotted ALOHA in [35]. The evolutionary game framework is used for large populations that have many local interactions, each involving a small number of users. The equilibrium notion introduced by Smith in 1972 in biological context is called an Evolutionarily Stable Strategy (ESS). A strategy for various behaviors within one or more types of populations is an ESS if it is immune against mutations. The authors have identified conditions for the existence of non trivial ESS and have computed them explicitly for the ALOHA scheme.

6.4.3. Surveys on networking games

In [61], E. Altman, jointly with T. Boulogne (University of Paris 6), T. Jimenez and R. El Azouzi (both from University of Avignon, France) and L. Wynter (IBM T. J. Watson Research Center, New York, USA), surveys the applications of games to networks. The emphasis is on non-cooperative games but they cover in part cooperative ones. In [15], E. Altman only focuses on applications of game theory to queueing systems, and presents various queueing problems such as where and when to queue, how much to queue etc.

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

Keywords: *Nash equilibrium, evolutionarily stable strategy, service discipline, stability.*

Participants: Eitan Altman, Konstantin Avrachenkov, Dieter Fiems, Robin Groenevelt, Alain Jean-Marie, Philippe Nain.

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 static games, the structure of a conjecture is rather simple and well understood. When the game is dynamic in discrete-time, several structures are possible In a joint paper with M. Tidball (INRA, Montpellier), A. Jean-Marie establishes the relationships that exist between these dynamic conjectural equilibria and the classical Nash-feedback equilibria [24].

6.5.2. Stochastic recursive sequences

Participants: Eitan Altman, Robin Groenevelt.

E. Altman has pursued his work on a class of discrete-time stochastic recursive sequences of the form $X_{n+1} = A_n(X_n)+B_n$, where X_n and B_n are column vectors taking nonnegative values, and where A_n is some non-negative random field. It is assumed that $\{B_n\}$ is a stationary and ergodic process (allowing, in particular, for arbitrary time-correlations) and that $\{A_n\}$ is a renewal sequence. In [30] stability conditions of the sequence $\{X_n\}$ have been established, and $E[X_n]$ and $E[X_nX_{n+k}]$ have been computed in steady-state for any $k \geq 0$. These results have been applied to the study of the infinite server queue in discrete-time in the presence of time-correlated arrivals.

In [23], [43], R. Groenevelt and E. Altman use this formalism to compute the expected waiting time in two-queue polling systems with correlated vacations.

6.5.3. Advances in queueing theory

Participants: Konstantin Avrachenkov, Urtzi Ayesta, Dieter Fiems, Philippe Nain.

6.5.3.1. Scheduling

In [20], K. Avrachenkov, in collaboration with U. Ayesta (CWI, Amsterdam) and P. Brown (FRANCE TELECOM R&D, Sophia Antipolis), analyzes a Processor-Sharing (PS) queue with batch arrivals. The analysis is based on the integral equation derived by Kleinrock, Muntz and Rodemich. Using the contraction mapping principle, the authors demonstrate the existence and uniqueness of a solution to the integral equation. Then, the authors provide an asymptotic analysis as well as tight bounds for the expected response time conditioned on the service time. Finally, it is shown how these results can be applied to the Multi-Level Processor-Sharing scheduling.

As a natural multi-class generalization of the well-known (egalitarian) PS service discipline, Discriminatory Processor Sharing (DPS) is of great interest in many application areas, including telecommunications. Under DPS, the mean response time conditional on the service requirement is only available in closed-form when all classes have exponential service requirement distributions. For generally distributed service requirements, Fayolle et al. showed that the expected conditional response times satisfy a system of integrodifferential equations. In [33], K. Avrachenkov, in collaboration with U. Ayesta (CWI, Amsterdam) and P. Brown (FRANCE TELECOM R&D, Sophia Antipolis) and S. Nũnez Queija (CWI, Amsterdam), uses that result to prove that, for each class, the expected unconditional response time is finite and that the expected conditional response time has an asymptote, when the system is stable.

The asymptotic bias of each class is found in closed-form. The latter involves the mean service requirements of all classes and the second moments of all classes but the one under consideration. The authors also study DPS as a tool to achieve size-based scheduling, and provide guidelines as to how the weights of DPS must be chosen such that DPS outperforms PS.

6.5.3.2. Preemptive priority queues

In collaboration with Ger Koole (Vrije University, Amsterdam, The Netherlands), Dieter Fiems and Philippe Nain investigate in [66] discrete-time preemptive repeat identical queueing systems. The high- and low-priority interarrival times are assumed to be geometrically distributed and deterministic, respectively whereas the

service times are assumed to be deterministic for both classes. As an application, the queueing model is used to assess waiting times of scheduled patients in the presence of emergency arrivals.

6.5.4. Evolutionarily stable strategy (ESS)

Participant: Philippe Nain.

In [68], P. Nain, in collaboration with P. Bernhard, F. Hammelin (both from I3S, University of Nice Sophia Antipolis, France) and E. Wajnberg (INRA, Sophia Antipolis, France), finds the ESS driving the behavior of foreagers competing for a common patchily distributed resource. The innovation of this work lies on the fact that an unlimited number of foreagers reach the patch at random arrival times, wheras previous studies considered that a fixed number of foreagers reach the patch at the same time. In this setting, the authors find the optimal leaving rule, namely when foreagers should leave a path not yet exhausted in order to find a richer one, in spite of an uncertain travel time.

7. Contracts and Grants with Industry

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

Participants: Eitan Altman, Dhiman Barman.

MAESTRO has pursued its collaboration with FRANCE TELECOM R&D at Issy les Moulineaux within a new two-year research grant (Contrat de Recherche Externaliseé, CRE). In 2005 new policies for scheduling TCP connections between dedicated and shared channels in UMTS have been proposed, and a patent containing these results is being filled. Coordinators of this CRE are E. Altman for MAESTRO and J. M. Kelif for FRANCE TELECOM R&D.

7.2. Grant with France Telecom R&D on Internet Traffic

Participants: Eitan Altman, Konstantin Avrachenkov, Philippe Nain.

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." Several joint working seminars between MAESTRO and the group at FRANCE TELECOM R&D have been organized in 2005. Recent advances in congestion control for high speed networks and size-based scheduling have been reviewed. Key problems have been identified and their analysis will be pursued during the year 2006. Coordinators of this CRE are P. Brown for FRANCE TELECOM R&D and P. Nain for MAESTRO.

7.3. Collaboration with Esa on Scheduling

Participant: Alain Jean-Marie.

The topic of this collaboration was the design of efficient online scheduling policies for payloads. The specificities of the problem include various temporal and feasibility constraints, and a stochastic environment. A mathematical modeling of the problem was proposed, and several dynamic scheduling policies studied with the help of a specially-designed simulator. This contract was executed jointly with Ph. Chrétienne and E. Hyon from LIP6, Paris.

8. Other Grants and Activities

8.1. International initiatives

8.1.1. Network of Excellence: Euro-Ngi

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

In 2005 MAESTRO has been involved in two one-year EURO-NGI Specific Joint Research Projects: JRA.S.07: CELLULAR and JRA.S.11: FAIRNESS.

CELLULAR (project coordinator: T. Chahed from GET) focuses on Cross-layer Protocol Design for Wireless Networks. Within this project two postdoctoral students visited MAESTRO: L. Cottatellucci (three months) and U. Ayesta (one month with MAESTRO and three months with other teams of CELLULAR).

FAIRNESS (project coordinator: P. Nain) is devoted to Fair and Efficient Scheduling in Wired and Wireless Networks. R. Núñez Queija, U. Yechiali and U. Ayesta visited MAESTRO within this project.

8.1.2. Collaboration with Australia: Linkage International

MAESTRO together 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."

8.1.3. Collaboration with India: Cefipra

Since April 2003 MAESTRO has been involved in a three-year research grant with Prof. A. Kumar and Prof. A. Chockalingam, both from IISC (Bangalore), and with Prof V. S. Borkar from TATA Institute of Fundamental Research (Mumbai). The coordinators of this project are Prof. Kumar and E. Altman for the Indian and French institutions, 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. Within this program, D. Kumar visited the Indian Institute of Technology, Delhi, India (August 1-5, 2005) and the Indian Institute of Science, Bangalore, India (August 8-26, 2005). Moreover, R. Vennkatesh, a Ph.D. of Prof. Kumar from IISC visited MAESTRO for three weeks in October 2005. We have extended our cooperation with IISC through the visit of Prof. V. Sharma to MAESTRO.

8.1.4. 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 is to propose advanced optimization tools to design broadband wireless communication systems (OFDM, CDMA, MIMO, and ad hoc networks).

8.1.5. Collaboration with Russia and Belarus: Pai Eco-Net

MAESTRO together with N. Litvak and W. Scheinhardt from the University of Twente, The Netherlands, is involved in the PAI ECO-NET in partnership with V. Dobrynin, L. Petrosyan, D. Nemirovsky and N. Osipova from St. Petersburg State University, Russia, and A. Dudin and V. Klimenok from Belarussian State University, Belarus. The collaboration, started in 2005, bears on "Probabilistic and Graph Theoretical Methods in Search Engines." The collaboration has been extended for a second year (2006).

8.1.6. Collaboration with the USA: Nsf Itr project

Members of MAESTRO and the University of Massachusetts (UMASS) at Amherst (Prof. D. Towsley) have a long lasting collaboration in the area of performance evaluation and control of networks. Since 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 2005 P. Nain visited UMASS in this framework.

8.1.7. 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

Venezuelian partners are R. Márquez, L. Leon and J. Aguilar from ULA (Merida). Within this project MAESTRO hosted R. Márquez for three weeks in 2005.

8.2. National initiative

8.2.1. Incitative coordinated actions (Aci)

Members of MAESTRO are involved in two ACI (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 Urtzi Ayesta (CWI, Amsterdam, The Netherlands, 05/23/05–/06/05/05), Vladimir Dobrynin (St. Petersburg State University, Russia, 07/10/05–07/18/05), Evsey Morozov (Petrozavodsk State University, 09/16/06–09/18/05), Rudesindo Núñez Queija (CWI, Amsterdam, The Netherlands, 12/14/05–12/16/05), Leon Petrosjian (St. Petersburg State University, Russia, 07/15/05–07/28/05), Sergey Savchenko (Russian Academy of Science, Moscow, 04/03/05–04/17/05), Jorma Virtamo (Helsinki University of Technology, Finland, 10/01/05–10/06/05).

America Bezalel Gavish (Southern Methodist Univ., Dallas, TX, USA, 05/01/05–05/06/05), Harold Kushner (Brown University, Providence, CI, USA, 09/12/05–09/16/05), Keith W. Ross (Polytehnic University, Brooklyn, NY, USA, 10/01/05–10/08/05), R. Srikant (University of Illinois at Urbana-Champaign, IL, USA, 10/02/05–10/05/05), Don Towsley (University of Massachusetts, MA, USA, 10/01/05–10/09/05).

Maghreb and Middle-East Moshe Haviv (The Hebrew University of Jerusalem, Israël, 01/16/05–01/29/05), Uri Yechiali (University of Tel Aviv, Israel, 10/09/05–10/21/05).

Asia Hisao Kameda (University of Tsukuba, Japan, 03/23/05–03/30/05), Vinod Sharma (IISC Bangalore, India, 10/10/05–01/10/06).

Oceania Vladimir Ejov (Univ. of South Australia, Adelaïde, Australia, 06/24/05–07/06/05), Jersy Filar (University of South Australia, Adelaïde, Australia, 03/21/05–04/03/05), Luke Finlay (University of South Australia, Adelaïde, Australia, 06/27/05–06/28/05), Vladimir Gaitsgory (Univ. of South Australia, Adelaïde, Australia, 06/23/05–06/28/05).

8.4. Visits of Maestro staff to other research institutions

E. Altman visited FRANCE TELECOM R&D, Issy-les-Moulineaux, on February 15–16, 2005 and on June 21, 2005 within the framework of a two years contract with FRANCE TELECOM R&D which started in February 2005. On July 22-23, 2005 he visited INT (Institut National des Télécommunications) in Evry, France, for a collaboration with T. Chahed (as part of the CELLULAR Specific Joint Research Project of the Network of Excellence EURONGI). E. Altman also participated in a meeting at ENS in Paris, with other members of the CELLULAR EURONGI project May 26–27, 2005, and he participed in a meeting in Milano, Italy, on February 8, 2005, for preparation of the IST European BIONETS Integrated Project.

K. Avrachenkov CWI, Amsterdam (April 21–27, 2005), St. Petersburg State University, Russia (May 1–15, 2005), Belarussian State University, Belarus (December 23–31, 2005), and University of South Australia (November 1–30, 2005).

A.-E. Baert visited the Computer Science Laboratory of the ENS Lyon (November, 24–25).

L. Cottatellucci visited the Massachusetts Institute of Technology (MIT), Boston, USA, (October 14–15, 2005) on a travel grant from MIT, INT in Evry, France (November 14–17, 2005), and École Normale Supérieure (ENS) in Paris (November, 18 2005).

A. A. Kherani visited T. Basar and R. Srikant at University of Illinois, Urbana Champaign (May 2005), and R. Núñez Queija at CWI, Amsterdam, The Netherlands (June 2005).

D. Kumar visited IIT Delhi and IISC Bangalore, India (July 30 – August 27, 2005) and FRANCE TELECOM R&D, Issy les Moulineaux, France (June 21 and December 5–6, 2005). On June 21 he gave a presentation on "Novel Channel Switching Policies for Packet Data Transmission in UMTS" at FRANCE TELECOM R&D, Issy les Moulineaux, France.

A. Jean-Marie visited the GERAD, University of Montreal, Canada (May 9–May 28, 2005), and the Department of Applied Economics of the University of Valladolid (November 28–December 2, 2005).

P. Nain visited the University of Massachussets at Amherst, USA for two weeks in June 2005, in the framework of the NSF ITR project on "QoS in the future Internet".

B. Prabhu visited the University of St. Petersburg, Russia (August 19–31, 2005) in the framework of the PAI ECO-NET project.

9. Dissemination

9.1. Leadership within scientific community

9.1.1. Editorial activities

E. Altman is an Associate Editor of the following journals: *Journal of Economics, Dynamics and Control* (JEDC), *Stochastic Models*, *ACM/Kluwer Wireless Networks* (WINET), *Communication Networks* (COMNET), *SIAM Journal on Control and Optimization* (SICON), and *Journal of Discrete Event Dynamic Systems* (JDEDS) (starting January 2006). In 2005 E. Altman was Guest Editor of the following journals:

- *IEEE Journal on Selected Areas in Communications* (JSAC): "Wireless Ad Hoc Networks – Part I," Eds: J. E. Wieselthier, E. Altman, A. Ephremides, J. P. Macker, H. B. Russell, M. Steenstrup, and S. B. Wicker, Vol. 23, Number 1, January 2005.
- *IEEE Journal on Selected Areas in Communications* (JSAC): "Wireless Ad Hoc Networks – Part II," Eds: J. E. Wieselthier, E. Altman, A. Ephremides, J. P. Macker, H. B. Russell, M. Steenstrup, and S. B. Wicker, Vol. 23, Number 3, March 2005.
- *Telecommunication Systems*, Special Issue on "High Speed Transport Protocols," Editors: S. Molnar and E. Altman, Volume 30, Issue 4, December 2005.

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

P. Nain is an Associate Editor of *Performance Evaluation*, *Operations Research Letters* and *IEEE/ACM Transactions on Networking* (starting January 2006).

9.1.2. Participation in technical program committees

E. Altman was a program committee member of *IEEE Infocom 2005* (Miami, FL, USA, March 13–17, 2005), *Networking 2005* (Waterloo, Canada, May 2–6, 2005), *11th European Wireless Conference* (Nicosia, Cyprus, April 10–13, 2005), *WONS 2005 – The Second Annual Conference on Wireless On Demand Network Systems and Services* (St. Moritz, Switzerland, January 19–21, 2005), *Int. Workshop on Protocols for Fast Long-Distance Networks* (PFLDNET – Lyon, France, February 3–4, 2005), *Ad hoc Now'05 - 4th International Conference on AD-HOC Networks and Wireless* (Cancun, Mexico, October 6–9,2005), *WiOpt'05 – Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks* (Riva del Garda, Trentino, Italy, April 3–7, 2005), *IWQoS 2005 – 13th IEEE Int. Workshop on Quality of Service* (Pasau, Germany, June 21–23, 2005), *WICON 2005 - First Int. Wireless Internet Conference* (Budapest, Hungary, July 10-14, 2005).

A. Jean-Marie was a program committee member of the following conferences: *Performance 2005* (Juan-les-Pins, France, October 3–7, 2005), *MAMA 2005* (held in conjunction with Sigmetrics 2005), *MASCOTS 2005* (Atlanta, GA, USA, September 27–29, 2005), *Asian Internet Engineering Conference 2005* (AINTEC 2005 – Bangkok, Thailand, December 13-15), *2nd European Performance Evaluation Workshop 2005* (EPEW 2005 – Versailles, France, September 1–3, 2005).

P. Nain was a program committee member of *ACM Sigmetrics 2005* (Banff, Canada, June 6-10, 2005) and *MAMA 2005* (held in conjunction with Sigmetrics 2005).

9.1.3. Conferences, meetings and tutorial organization

S. Alouf was Publicity Chair and Webmaster of *Performance 2005* (Juan-Les-Pins, October 3–7, 2005 – http://www-sop.inria.fr/maestro/performance2005/).

E. Altman was the General Chair of *WiOpt'05* (Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks – Riva del Garda, Trentino, Italy, April 3-7, 2005), steering committee member of the conferences *WiOpt'05* and *ValueTools 2006* (Conf. on Performance Evaluation Methodologies and Tools – Pisa, Italy, October 2006), and Tutorial Co-Chair (with Z. Liu, IBM T.J. Watson) of*Performance 2005* ((Juan-Les-Pins, October 3–7, 2005).

K. Avrachenkov organized and chaired the invited session on "Searching and Ranking in Information Networks" at *INFORMS Applied Probability Conference* (Ottawa, Canada, July 6–8, 2005). He also organised and chaired the "Work-in-Progress" session at *Performance 2005* (Juan-Les-Pins, October 3–7, 2005).

E. Deriche was Publicity Chair of *WiOpt'05* (Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks – Riva del Garda, Trentino, Italy, April 3-7, 2005). She was also Arrangement Co-Chair (with D. Sergeant from INRIA) of *Performance 2005* (Juan-Les-Pins, October 3–7, 2005), *ICGT'05* (7th International Colloquium on Graph Theory, Hyères, France, September 12-16, 2005), and of the workshop "JCB 60" organized in Sophia Antipolis on December 8-9, 2005, to celebrate the 60th birthday of J.-C. Bermond.

A. Jean-Marie co-organized and co-chaired (with J.-M. Fourneau, University of Versailles, France) the IFIP WG7.3 workshop on October 8, 2005 in Juan-les-Pins, France.

P. Nain was the General Chair of the IFIP WG7.3 24th International Symposium on Computer Performance, Modeling, Measurements and Evaluation (*Performance 2005*), Juan-les-Pins, October 3-7, 2005.

9.1.4. Participation in thesis committees

K. Avrachenkov participated as co-thesis advisor in the PhD thesis committee of Balakrishna Prabhu (UNSA, 10/04/05).

E. Altman participated as a reviewer in the HDR thesis committee of Tijani Chahed (University of Paris 6, 07/12/05) and in the PhD thesis committees of Patrick Maille (ENST BRETAGNE, 07/11/05), Yezekael Hayel (University of Rennes 1, France, 12/9/05), Matthieu Jonckheere (Ecole Polytechnique, Palaiseau, France, 12/9/05). He participed as a co-advisor in the PhD thesis committee of Balakrishna Prabhu (UNSA, France, 10/04/05).

A. Jean-Marie participated as a reviewer in the PhD thesis committees of J. Orozco (University of Rennes 1, France, 04/04/05) and Martín Varela Rico (University of Rennes 1, France, 11/10/05).

P. Nain participated as the thesis advisor in the PhD thesis committees of Patrick Brown (UNSA, France, 12/15/05), Florence Clévenotrronin (UNSA, France, 10/3/05), Robin Groenevelt (UNSA, France, 04/07/05), and as a reviewer in the PhD thesis committee of Charles Bockstal (University Paul Sabatier, Toulouse, France, 11/04/05).

9.1.5. PhD theses defended in 2005

The following PhD theses were defended in 2005:

R. Groenevelt (advisor: P. Nain) on April 7, 2005 [11] (committee members: R. Mazumdar and M. Mandjes, reviewers; J.-C. Bermond, G. Koole, I. Litovsky, P. Nain).

F. Clévenot-Perronnin (advisor: P. Nain) on October 3, 2005 [10] (committee members: R. Srikant and D. Towsley, reviewers; E. Biersack, P. Nain, K. W. Ross, J.-M. Vincent).

B. Prabhu (advisors: E. Altman and K. Avrachenkov) on October 4, 2005 [12] (committee members: G. Koole and J. Virtamo, reviewers; E. Altman, K. Avrachenkov, T. Bonald, R. Srikant).

9.1.6. Research administration

A. Jean-Marie

- is head of the APR (Algorithms and Performance of Networks) Project of the LIRMM Laboratory of the University of Montpellier II.
- is co-chair of the Department of Informatics of the LIRMM Laboratory, Montpellier.
- coordinated the curriculum of the Master Program in Computer Science, specialization in Research, at the University of Montpellier II, until September 2005.
- is a member of the Specialists Committee (Commission de Spécialistes) in Computer Science at the University of Montpellier II.
- acted as an expert for the DGA (Direction Générale de l'Armement).
- acted as an expert for the LAAS (Laboratoire d'Analyse et d'Architecture des Systèmes) of Toulouse.

P. Nain

- is vice-chair of the Projects Committee of the INRIA Unit Research of Sophia Antipolis (since September 1, 2005).
- is a member of the Scientific Committee of CNRT (Centre Nationaux de Recherche Technologiques) TELIUS (Telecom, Internet and Usage).
- is in charge of the Master program on "Networking and Distributed Systems" at the University of Nice Sophia Antipolis (since the academic year 2000-2001).
- is a member of the Advisory Board (and treasurer) of IFIP WG7.3 (elected in 2002).

9.1.7. Miscellaneous

E. Altman, A Jean-Marie and P. Nain are (elected) members of IFIP WG7.3 on "Computer System Modeling".

9.2. Teaching

A.-E. Baert participated in the course on "Communication and Networks" of the Master in Computer Science of the University of Montpellier II (12H). She taught courses on the "Quality of Service in Networks" in the Master of the University of Montpellier II (14H), and a course on "Random Models" (21H).

R. Groenevelt taught courses at the University of Nice-Sophia Antipolis on Discrete Mathematics (48H), SAS Programming and Data Mining (24H), Game Theory (18H), and participed to the course on Numerical Programming at ESSI (6H).

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, 9H). He taught a course on Random Discrete Structures in the Master in Informatics of the University of Montpellier II (27H).

A. A. Kherani taught a course on NS-2 Network Simulator in the Master Program on "Networks and Distributed Systems" at the University of Nice Sophia Antipolis (15H).

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 (21H).

9.3. Conference and workshop committes, invited conferences

E. Altman was a Keynote speaker at the *MSO 2005 – Fifth IASTED International Conference on Modelling, Simulation and Optimization* (Oranjestad, Aruba, August 29–31, 2005).

S. Alouf attended (as an author of a paper) *IEEE Infocom 2005* (Miami, FL, USA, March 13–16).

K. Avrachenkov gave presentations at *IEEE Infocom 2005* (Miami, FL, USA, March 13–17, 2005), *INFORMS Applied Probability Conference* (Ottawa, Canada, July 6–8, 2005), Worshop on "Optimal Stopping and Stochastic Control" (Petrozavodsk, Russia, August 22–26, 2005), Workshop on Congestion Control at the Hamilton Institute (Ireland, September 27–28, 2005 – invited lecture), *IEEE CDC/ECC 2005* (Seville, Spain, December 12–15, 2005).

N. Bonneau gave presentations at *ICASSP 2005 – IEEE International Conference on Acoustics, Speech and Signal Processing* (Philadelphia, PA, USA, March 18–23, 2005), *ITC'19 – 19th International Teletraffic Congress* (Beijing, China, August 29–September 2, 2005), *2005 IEEE International Symposium on Information Theory* (Adelaide, Australia, September 4–9, 2005), *ISWCS 2005 – 2nd International Symposium on Wireless Communication Systems* (Siena, Italy, September 5–7, 2005).

F. Clévenot-Perronnin gave lectures at *Performance 2005* (Juan-les-Pins, France, October 3–7, 2005), *IEEE 10th Int. Workshop on Web Content Caching and Distribution* (WCW 2005 – Sophia Antipolis, France, September 12–14 2005).

L. Cottatellucci gave invited lectures at Institut National des Télécommunications (INT) in Evry, France (November 17, 2005), École Normale Supérieure, Paris (November 18, 2005), INSTITUT EURECOM, Sophia Antipolis (8 December 2005), and FRANCE TELECOM R&D in the framework of "Cellular" specific research project of the EuroNGI Network of Excellence – December 6, 2005).

R. Groenevelt gave lectures at *IEEE Infocom 2005* (Miami, FL, USA, March 13–16) and at *Performance 2005* (Juan-les-Pins, France, October 3–7, 2005), and presented a poster at *ACM SIGMETRICS 2005* (Banff, Canada, June 6–10).

A. Jean-Marie was an invited speaker at the Lunteren Conference (30th Conference on the Mathematics of Operations Research), The Netherlands, January 18–20, 2005. He gave a presentation at the Colloque International du 25e anniversaire du GERAD, Montreal, Canada, May 11–13, 2005. The paper [24] was also presented at that workshop. The paper [42] was presented to the Optimization Days, Montreal, Canada, May 9–11, 2005. Together with Bruno Gaujal (INRIA project-team MESCAL), A. Jean-Marie taught course on Optimal Control and Balance Word at the EJC'O5: Ecole Jeunes Chercheurs en Algorithmique et Calcul Formel, Montpellier, April 2005.

A. A. Kherani gave lectures at *WiOpt 2005* (Trento, Italy, April 3–7, 2005), *IEEE Infocom 2005* (Miami, FL, USA, March 13–16) and *IFIP Networking 2005* (Waterloo, Canada, May 2–6, 2005).

G. Koukoutsidis presented a paper at the *19th International Teletraffic Congress* (ITC-19 –Beijing, China, August 29– September 2, 2005).

D. Kumar presented a paper at the *19th International Teletraffic Congress* (ITC-19 –Beijing, China, August 29– September 2, 2005).

B. Prabhu gave lectures at *IEEE Infocom 2005* (Miami, FL, USA, March 13–16), *Pfldnet 2005 – Third International Workshop on Protocols for Fast Long-Distance Networks* (Lyon, France, February 3–4, 2005), *Mathematics 2005* (Liverpool, UK, April 4–7, 2005), *Workshop on Optimal Stopping and Stochastic Control* (Petrozavodsk, Russia, August 22–26, 2005).

10. Bibliography

Major publications by the team in recent years

[1] R. AGRAWAL, A. M. MAKOWSKI, P. NAIN. *On a reduced load equivalence for fluid queues under subexponentiality*, in "QUESTA", Special Issue on <<Queues with Heavy-Tailed Distributions >>, Ed. K. Sigman, vol. 33, n° 1-3, 1999, p. 5-41.

[2] E. ALTMAN. *Constrained Markov Decision Processes*, Chapman and Hall/CRC, 1999.

[3] E. ALTMAN, K. AVRACHENKOV, C. BARAKAT. *A stochastic model of TCP/IP with stationary random losses*, in "Proceedings of ACM Sigcomm 2000 Conference, Computer Communication Review, Stockholm, Suède", vol. 30, n° 4, August 2000, p. 231-242.

[4] E. ALTMAN, A. FERREIRA, J. GALTIER. *Réseaux Satellitaires de Télécommunications*, Dunod, 1999.

[5] E. ALTMAN, B. GAUJAL, A. HORDIJK. *Discrete-Event Control of Stochastic Networks: Multimodularity and Regularity*, Lecture Notes in Mathematics, Springer-Verlag, Series: Lecture Notes in Mathematics, December 2003.

[6] O. A. HELLAL, E. ALTMAN, A. JEAN-MARIE, I. KURKOVA. *On loss probabilities in presence of redundant packets and several traffic sources*, in "Performance Evaluation", vol. 36-37, 1999, p. 486-518.

[7] A. JEAN-MARIE, Z. LIU, P. NAIN, D. TOWSLEY. *Computational aspects of the workload distribution in the MMPP/G/1 queue*, in "IEEE Transactions on Selected Areas in Communications", vol. 16, n° 5, 1998, p. 640-652.

[8] Z. LIU, P. NAIN, D. TOWSLEY. *Sample path methods in the control of queues*, in "QUESTA", Special Issue on <<Optimization of Queueing Systems >>, Ed. S. Stidham, vol. 21, 1995, p. 293-335.

[9] Z. LIU, P. NAIN, D. TOWSLEY. *Exponential bounds with applications to call admission*, in "Journal of the ACM", vol. 44, nº 3, May 1997, p. 366-394.

Doctoral dissertations and Habilitation theses

[10] F. CLÉVENOT-PERRONNIN. *Fluid Models for Content Distribution Systems*, Ph. D. Thesis, University of Nice Sophia Antipolis, France, October 2005.

[11] R. GROENEVELT. *Stochastic Models for Mobile Ad Hoc Networks*, Ph. D. Thesis, University of Nice Sophia Antipolis, France, April 2005.

[12] B. J. PRABHU. *Markov Chains and Decision Processes for Congestion Avoidance and Power Control*, Ph. D. Thesis, University of Nice Sophia Antipolis, France, October 2005.

Articles in refereed journals and book chapters

[13] A. AL-HANBALI, E. ALTMAN, P. NAIN. *A survey of TCP over mobile ad hoc networks*, in "3rd Issue of IEEE Communications Surveys & Tutorials", vol. 7, nº 3, August 2005.

[14] T. ALEMU, A. JEAN-MARIE. *Etude de la Configuration Dynamique des Paramètres de RED*, in "TSI : Technique et Science Informatiques", vol. 24, nº 2/3, 2005, p. 153–178.

[15] E. ALTMAN. *Applications of dynamic games in queues*, in "Advances in Dynamic Games", vol. 7, 2005, p. 309–342.

[16] E. ALTMAN, K. AVRACHENKOV, C. BARAKAT, A. KHERANI, B. PRABHU. *Analysis of MIMD congestion control algorithm for high speed networks*, in "Computer Networks", vol. 48, 2005, p. 972–989.

[17] E. ALTMAN, K. AVRACHENKOV, R. MÁRQUEZ, G. MILLER. *Zero-sum constrained stochastic games with independent state processes*, in "Mathematical Methods in Operations Research", vol. 62, 2005, p. 375-386.

[18] E. ALTMAN, K. AVRACHENKOV, B. PRABHU. *Fairness in MIMD congestion control algorithms*, in "Telecommunication Systems", vol. 30, nº 4, 2005, p. 387–415. A shorter version appeared in Proc. of IEEE Infocom 2005.

[19] E. ALTMAN, C. BARAKAT, V. M. RAMOS-RAMOS. *Analysis of AIMD protocols over paths with variable delay*, in "Computer Networks", vol. 48, nº 6, 2005, p. 972–989.

[20] K. AVRACHENKOV, U. AYESTA, P. BROWN. *Batch arrival processor-sharing with application to multi-level processor sharing scheduling*, in "Queueing Systems", vol. 50, nº 4, 2005, p. 459–480.

[21] Y. CALAS, A. JEAN-MARIE. *Qualité audio pour un schéma FEC simple*, in "TSI : Technique et Science Informatiques", vol. 24, nº 2/3, 2005, p. 203–228.

[22] F. CLÉVENOT-PERRONNIN, P. NAIN, K. W. ROSS. *Stochastic fluid model for cache clusters*, in "Performance Evaluation", vol. 59, nº 1, January 2005, p. 1–18.

[23] R. GROENEVELT, E. ALTMAN. *Analysis of alternating-priority queueing models with (cross) correlated switchover times*, in "Queueing Systems", Special Issue on Stochastic Networks, vol. 51, 2005, p. 199-237.

[24] A. JEAN-MARIE, M. TIDBALL. *Consistent conjectures, equilibria and dynamic games*, in "Dynamic Games: Theory and Applications", A. HAURIE, G. ZACCOUR (editors). , Mathematics of Decision Making, Springer Verlag, 2005.

[25] A. KHERANI, B. PRABHU, K. AVRACHENKOV, E. ALTMAN. *Comparative study of different adaptive window protocols*, in "Telecommunication Systems", vol. 30, nº 4, 2005, p. 321–350. A shorter version appeared in Proc. of IEEE Infocom 2005.

[26] R. MÁRQUEZ, E. ALTMAN, S. SOLE-ALVAREZ. *Time-averaging of high-speed data transfer protocols*, in "IEEE Transactions on Automatic Control", nº 12, December 2005, p. 2065–2069.

Publications in Conferences and Workshops

[27] T. ALEMU, Y. CALAS, A. JEAN-MARIE. *The interaction of forward error correction and active queue management*, in "Networking 2005, Waterloo, Ontario, Canada", May 2–6 2005, p. 1146–1155.

[28] T. ALEMU, A. JEAN-MARIE, Y. CALAS. *Interaction de FEC avec des mécanismes de gestion active des files d'attente*, in "Colloque Francophone sur l'Ingénierie des Protocoles (CFIP'05), Bordeaux", March 29–April 1 2005, p. 547–561.

[29] S. ALOUF, E. ALTMAN, J. GALTIER, J.-F. LALANDE, C. TOUATI. *Quasi-optimal bandwidth allocation for multi-spot MFTDMA satellites*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[30] E. ALTMAN. *On stochastic recursive equations and infinite server queues*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005, p. 1195–1202.

[31] E. ALTMAN, K. AVRACHENKOV, A. KHERANI, B. PRABHU. *Analysis of scalable TCP in the presence of Markovian losses*, in "Proc. of 3rd International Workshop on Protocols for Very Long-Distance Networks (PFLDnet'05), Lyon, France", February 3–4 2005.

[32] E. ALTMAN, A. KUMAR, D. KUMAR, R. VENKATESH. *Cooperative and non-cooperative control in IEEE 802.11 WLANs*, in "19th International Teletraffic Congress (ITC 19), Beijing, China", 2005.

[33] K. AVRACHENKOV, U. AYESTA, P. BROWN, R. N. QUEIJA. *Discriminatory processor sharing revisited*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[34] K. AVRACHENKOV, U. AYESTA, A. PIUNOVSKIY. *Optimal choice of the buffer size in the Internet routers*, in "Proc. of IEEE Conference on Decision and Control and European Control Conference ECC 2005 (CDC-ECC'05), Seville, Spain", december 12–15 2005.

[35] N. BONNEAU, E. ALTMAN, M. DEBBAH. *An evolutionary game perspective to ALOHA with power control*, in "19th International Teletraffic Congress (ITC 19), Beijing, China", August 29–September 2 2005.

[36] N. BONNEAU, E. ALTMAN, M. DEBBAH, G. CAIRE. *Spectral efficiency of CDMA uplink cellular networks*, in "Proc. of IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP 2005), Philadelphia, PA, USA", March 2005.

[37] N. BONNEAU, E. ALTMAN, M. DEBBAH, G. CAIRE. *When to synchronize in uplink "CDMA"*, in "Proc. of IEEE International Symposium on Information Theory (ISIT 05), Adelaide, Australia", September 4–9h 2005.

[38] N. BONNEAU, M. DEBBAH, A. HJØRUNGNES, E. ALTMAN. *Performance of channel inversion schemes for multi-user OFDMA*, in "2nd International Symposium on Wireless Communication Systems (ISWCS 2005), Siena, Italy", September 5–7 2005.

[39] V. S. BORKAR, A. A. KHERANI, B. J. PRABHU. *Closed and open loop optimal control of buffer and energy of a wireless device*, in "Proc. of Workshop on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOPT 2005, Trento, Italy", April 3–7 2005.

[40] A. CHOCKALINGAM, E. ALTMAN, J. V. K. MURTHY, R. KUMAR. *Cross-layer design for optimizing TCP performance*, in "Proc. of IEEE International Conference on Communications (ICC'2005), Seoul, Korea", May 16-20 2005.

[41] F. CLÉVENOT-PERRONNIN, P. NAIN, K. W. ROSS. *Multiclass P2P networks: Static resource allocation for service differentiation and bandwidth diversity*, in "Proc. of Performance 2005, October 5-7, Juan-les-Pins, France", Performance Evaluation, vol. 62, n° 1-4, October 2005, p. 32–49.

[42] K. ERDLENBRUCH, C. FIGUIÈRES, A. JEAN-MARIE, M. TIDBALL. *Forest taxation and cutting behaviour*, in "Optimization Days 2005, Montreal", May 2005.

[43] R. GROENEVELT, E. ALTMAN. *Analysis of alternating-priority queueing models with (cross) correlated switchover times*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[44] R. GROENEVELT, P. NAIN, G. KOOLE. *Message delay in mobile ad hoc networks*, in "Proc. of Performance 2005, October 5-7, Juan-les-Pins, France", Performance Evaluation, vol. 62, n° 1-4, October 2005, p. 210–228.

[45] A. JEAN-MARIE, Y. CALAS, T. ALEMU. *On the compromise between burstiness and frequency of events*, in "Proc. of Performance 2005, Juan-les-Pins, France", Performance Evaluation, vol. 62, n° 1–4, October 2005, p. 382–399.

[46] G. KOUKOUTSIDIS, E. ALTMAN, J. M. KELIF. *Fair rate sharing models in a CDMA link with multiple classes of elastic traffic*, in "Proc. of the 19th International Teletraffic Congress (ITC 19), Beijing, China", 29 August – 2 September 2005.

[47] G. KOUKOUTSIDIS. *A non-homogeneous QBD approach for the admission and GoS control in a multiservice WCDMA system*, in "IWQoS - 13th Intenrational Workshop on Quality of Service, Passau, Germany", LNCS, vol. 3552, June 21–23 2005, p. 327–340.

[48] A. KUMAR, E. ALTMAN, D. MIORANDI, M. GOYAL. *New insights from a fixed point analysis of single cell IEEE 802.11 WLANs"*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[49] B. LIU, P. BRASS, O. DOUSSE, P. NAIN, D. TOWSLEY. *Mobility improves coverage of sensor networks*, in "Proc. of IEEE MobiHoc 2005, Urbana-Champaign, IL, USA", May 25-28 2005.

[50] B. MILLER, K. AVRACHENKOV, K. STEPANYAN, G. MILLER. *Flow control as stochastic optimal control problem with incomplete information*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[51] D. MIORANDI, E. ALTMAN. *Coverage and connectivity of ad hoc networks in presence of channel randomness*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[52] P. NAIN, D. TOWSLEY, B. LIU, Z. LIU. *Properties of random direction models*, in "Proc. of IEEE Infocom 2005, Miami, FL, USA", March 13–17 2005.

[53] V. RAMAIYAN, A. KUMAR, E. ALTMAN. *Fixed point analysis of single cell IEEE 802.11e WLANs: Uniqueness, multistability and throughput differentiation*, in "Proc. of ACM Sigmetrics 2005", Performance Evaluation Review, vol. 33, n° 1, June 2005.

Internal Reports

[54] A. AL-HANBALI, A. A. KHERANI, R. GROENEVELT, P. NAIN, E. ALTMAN. *Impact of mobility on the performance of relaying in ad hoc networks*, To appear in the Proc. of IEEE Infocom 2006 conf., Technical report, n° RR-5480, INRIA, Sophia Antipolis, January 2005.

[55] K. AVRACHENKOV, N. LITVAK, D. NEMIROVSKY, N. OSIPOVA. *Monte Carlo methods in PageRank computation: When one iteration is sufficient*, Presented at the 5-th IMACS Seminar on Monte Carlo Methods, Technical report, n° 1754, University of Twente, The Netherlands, May 2005.

[56] D. KUMAR, A. A. KHERANI, E. ALTMAN. *Route lifetime based interactive routing in intervehicle mobile ad hoc networks*, Technical report, n° RR-5691, INRIA, Sophia Antipolis, September 2005.

Miscellaneous

[57] M. IBRAHIM. *Conception and analysis of an adaptive backoff algorithm for 802.11 wireless LANs*, Technical report, University of Nice Sophia Antipolis, June 2005.

Bibliography in notes

[58] S. ALOUF, A. JEAN-MARIE, P. NAIN. *Analysis and optimization of group rekeying schemes for secure multicast*, Work in progress.

[59] E. ALTMAN, D. BARMAN, B. TUFFIN, M. VOJNOVIC. *Parallel TCP sockets: Simple model, throughput and validation*, 2006, To appear in Proc. of IEEE Infocom Conference.

[60] E. ALTMAN, D. BARMAN, R. EL AZOUZI, D. ROS, B. TUFFIN. *Differentiated services: A game-theoretic approach*, 2006, To appear in Computer Networks.

[61] E. ALTMAN, T. BOULOGNE, R. EL AZOUZI, T. JIMENEZ, L. WYNTER. *A survey on networking games*, 2006, To appear in Computers and Operations Research, Volume 33, Issue 2, February 2006, p. 286-311.

[62] E. ALTMAN, R. EL AZOUZI, D. ROS, B. TUFFIN. *Loss strategies for competing AIMD flows*, Corrected proof available online since September 6, 2005, 2006, To appear in Computer Networks.

[63] F. CLÉVENOT-PERRONNIN, P. NAIN. *A Simple model for the analysis of the Squirrel peer-to-peer caching system*, in "Proc. of IEEE Infocom 2004, Hong Kong", March 7–11 2004.

[64] L. COTTATELLUCCI, M. DEBBAH, R. R. MÜLLER. *Low complexity detection for multiuser MIMO systems with correlated spatial diversity*, 2006, To appear in the Proc. of IEEE 2nd International Symposium on Communications, Control and Signal Processing (ISCCSP 2006).

[65] L. COTTATELLUCCI, M. DEBBAH, R. R. MÜLLER. *Linear multiuser detection for asynchronous CDMA systems: Chip pulse design and time delay distribution*, 2006, Submitted to IEEE Workshop on Information Theory (ITW'2006).

[66] D. FIEMS, G. KOOLE, P. NAIN. *Waiting times of scheduled patients in the presence of emergency requests*, November 2005, Submitted to Computers and Operations Research.

[67] R. GROENEVELT, E. ALTMAN, P. NAIN. *Relaying in mobile ad hoc networks: The Brownian motion mobility model*, 2006, To appear in Journal of Wireless Networks (WINET).

[68] F. HAMMELIN, P. BERNHARD, P. NAIN, E. WAJNBERG. *Foreaging under competition: Evolutionarily stable patch-leaving strategies with random arrival times. 1. Scramble competition*, 2006, To appear in Annals of Dynamic Games.

[69] M. IBRAHIM, S. ALOUF. *Design and analysis of an adaptive backoff algorithm for IEEE 802.11 DCF mechanism*, 2006, Submitted to Networking '06.

[70] L. M. NGO, A. JEAN-MARIE. *The impact of the implosion problem on the backoff time for a reliable multicast protocol*, 2006, To appear in the Proc. of 4th IEEE International Conference on Computer Science, Research Innovation and Vision for the Future, Ho Chi Minh City, Vietman, February 2006 .

[71] S. SHAKKOTTAI, E. ALTMAN, A. KUMAR. *The case of non-cooperative multihoming of users to access points in IEEE 802.11 WLANs*, 2006, To appear in Proc. of IEEE Infocom Conference.