Activity Report 2012

Project-Team MAESTRO

Models for the performance analysis and the control of networks

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Networks and Telecommunications

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Project-Team MAESTRO

Keywords: Discrete Event Systems, Markovian Model, Game Theory, Wireless Networks, Wireline Network, Control Theory, Delay Tolerant Networks, Cellular Networks, Peer-to-peer, Sensor Networks

In collaboration with LIA, Univ. of Avignon (UAPV). MAESTRO *is member of the joint laboratory between* INRIA *and* ALCATEL-LUCENT BELL LABS.

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

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2. Overall Objectives

2.1. Presentation of MAESTRO

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

2.2. Highlights of the Year

- Eitan Altman has received the France Telecom Prize awarded by the French Academy of Sciences.

BEST PAPERS AWARDS :

[47] **Classification of Content and Users in BitTorrent by Semi-supervised Learning Methods in 8th International Wireless Communications and Mobile Computing Conference (IWCMC)**. K. AVRACHENKOV, P. GONÇALVES, A. LEGOUT, M. SOKOL.

[53] **Analysis of TTL-based Cache Networks in 6th International Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS)**. N. CHOUNGMO FOFACK, P. NAIN, G. NEGLIA, D. TOWSLEY.

[58] **Satisfaire un internaute impatient est difficile in 14èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications (AlgoTel)**. F. V. FOMIN, F. GIROIRE, A. JEAN-MARIE, D. MAZAURIC, N. NISSE.

3. Scientific Foundations

3.1. Scientific Foundations

The main mathematical tools and formalisms used in MAESTRO include:

- theory of stochastic processes: Markov process, renewal process, point process, Palm measure, large deviations, branching process, mean-field approximation;
- theory of dynamical discrete-event systems: queues, fluid approximation;
- 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

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

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

5. New Results

5.1. Network Science

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

5.1.1. Epidemic models of propagation of content

E. Altman and P. Nain have studied in [96] in collaboration with A. Shwartz (Technion, Israel) and Y. Xu (Univ. Avignon/LIA) the efficiency of the existing methods for reducing availability of non-authorized copyrighted content for free download on the Internet. To model the propagation of the content, they used both branching processes as well as several epidemic models. One of the important finding is that the greatest impact of measures against unauthorized download is obtained whenever some parameter that describes the virality of the content is close to some critical value (which is computed in this work).

5.1.2. Control and game models for malware attack

In collaboration with M. H. R. Khouzani (Ohio State Univ., USA) and S. Sarkar (Univ. of Pennsylvania, USA), E. Altman has used in [31],[33], [32], optimal control theory to study malware attack in networks. The structure of optimal policies is obtained by using the Pontryagin maximum principle. In the first two references, optimal defense policies are studies in the goal of protecting the network. In the third work, the worst case behavior of the attack is identified using control theory. The authors then study in [34] the combined problem of identifying the defensive control that achieves the best performance under the worst possible malware attack. This is done through a zero-sum game context.

5.1.3. Time random walks on time varying graphs

In collaboration with D. Figueiredo (Federal Univ. of Rio de Janeiro, Brazil), B. Ribeiro and D. Towsley (both from the Univ. of Massachusetts at Amherst, USA), P. Nain has studied the behavior of a continuous time random walk (CTRW) on a stationary and ergodic time varying dynamic graph [57]. Conditions have been established under which the CTRW is a stationary and ergodic process. In general, the stationary distribution of the walker depends on the walker rate and is difficult to characterize. However, the stationary distribution has been characterized in the following cases: i) the walker rate is significantly larger or smaller than the rate in which the graph changes (time-scale separation), ii) the walker rate is proportional to the degree of the node that it resides on (coupled dynamics), and iii) the degrees of nodes belonging to the same connected component are identical (structural constraints). Examples are provided that illustrate these theoretical findings.

5.1.4. Quick detection of central nodes

In [50] K. Avrachenkov and M. Sokol, together with N. Litvak (Twente Univ., The Netherlands) and D. Towsley (Univ. of Massachusetts at Amherst, USA) propose a random walk based method to quickly find top k lists of nodes with the largest degrees in large complex networks. The authors show theoretically and by numerical experiments that for large networks the random walk method finds good quality top lists of nodes with high probability and with computational savings of orders of magnitude. They also propose stopping criteria for the random walk method which requires very little knowledge about the structure of the network.

5.1.5. Graph-based semi-supervised learning

In [48] K. Avrachenkov and M. Sokol, together with P. Gonçalves (INRIA project-team RESO) and A. Mishenin (St. Petersburg State Univ., Russia) develop a generalized optimization framework for graph-based semi-supervised learning. The framework gives as particular cases the Standard Laplacian, Normalized Laplacian and PageRank based semi-supervised learning methods. The authors provide new probabilistic interpretation based on random walks and characterize the limiting behaviour of the methods. The random walk based interpretation allows one to explain differences between the performances of methods with different smoothing kernels. It appears that the PageRank based method is robust with respect to the choice of the regularization

parameter and the labelled data. The theoretical results are illustrated with two realistic datasets, characterizing different challenges: “Les Misérables” characters social network and Wikipedia hyper-link graph. It appears that the PageRank based method can classify the Wikipedia articles with very good precision and perfect recall employing only the information about the hyper-text links.

In [47] K. Avrachenkov and M. Sokol, together with P. Gonçalves (INRIA project-team RESO) and A. Legout (INRIA project-team PLANETE) apply the theoretical results of [48] to classification of content and users in BitTorrent. The general intuition behind the application of the graph based semi-supervised learning methods is that the users with similar interests download similar contents. PageRank based semi-supervised learning method was chosen as it scales well with very large volumes of data. The authors provide recommendations for the choice of parameters in the PageRank based semi-supervised learning method, and show, in particular, that it is advantageous to choose labelled points with large PageRank score.

5.1.6. Optimal weight selection in average consensus protocols

In average consensus protocols, nodes in a network perform an iterative weighted average of their estimates and those of their neighbors. The protocol converges to the average of initial estimates of all nodes found in the network. The speed of convergence of average consensus protocols depends on the weights selected on links (to neighbors). In [92] K. Avrachenkov, M. El Chamie and G. Neglia address how to select the weights in a given network in order to have a fast speed of convergence for these protocols. They approximate the problem of optimal weight selection by the minimization of the Schatten p-norm of a matrix with some constraints related to the connectivity of the underlying network. They then provide a totally distributed gradient method to solve the Schatten norm optimization problem. By tuning the parameter p in the proposed minimization, it is possible to simply trade-off the quality of the solution (i.e. the speed of convergence) for communication/computation requirements (in terms of number of messages exchanged and volume of data processed). Simulation results on random graphs and on real networks show that this approach provides very good performance already for values of p that only needs limited information exchange. The weight optimization iterative procedure can also run in parallel with the consensus protocol and form a joint consensus–optimization procedure.

5.1.7. Reducing communication overhead of average consensus protocols

The average consensus protocol converges only asymptotically to consensus and implementing a termination algorithm is challenging when nodes are not aware of some global information (e.g. the diameter of the network or the total number of nodes). In [93] K. Avrachenkov, M. El Chamie and G. Neglia propose a totally distributed algorithm for average consensus where nodes send more messages when they have large differences in their estimates, and reduce their message sending rate when the consensus is almost reached. The convergence of the system is guaranteed to be within a predefined margin from the true average and the algorithm gives a trade-off between the precision of consensus and the number of messages send in the network. The proposed algorithm is robust against nodes changing their estimates and can also be applied in dynamic networks with faulty links.

5.2. Wireless Networks

Participants: Eitan Altman, Philippe Nain, Giovanni Neglia.

5.2.1. Estimation of population sizes in sensor networks

We have been working on several problems related to the estimation of population sizes. In collaboration with D. Kumar (IBM Research Center, Hawthorne, USA) and T. Başar (Univ. of Illinois at Urbana-Champaign, USA), E. Altman develops in [73] a Wiener filter that allows to estimate the number of sensors that cover the space at some selected points. The authors take advantage of spatial correlations between the number of sensors covering different points in order to derive the filter. We note that causality is not an issue in space, in contrast to filtering at different points in time.

In collaboration with A. Ali, T. Chahed and M. K. Panda (Telecom SudParis, France), D. Fiems (Gent Univ., Belgium), and L. Sassatelli (I3S, Univ. Nice Sophia Antipolis - CNRS, France), E. Altman has used in [37] Kalman filtering theory in order to estimate the number of mobiles in a delay tolerant ad-hoc network which have a copy of a broadcasted message.

5.2.2. Cellular networks: Small cells

Analysing performance measures of cellular systems combines tools from queueing theory and stochastic processes, on one hand, and geometric considerations on the other hand. In [72], V. Kavitha (Mymo Wireless, Bangalore, India), S. Ramanath (Lekha Wireless Solutions, Bangalore, India), and E. Altman compute the time it takes to transmit a file taking into account the channel conditions which vary due to mobility of terminals. Mobility considerations play a key role in small cells since handover may occur way before the transmission of the file ends.

5.2.3. Multi scale fairness concepts for resource allocation in wireless networks

In many applications that require resources, one needs these resources within some given deadline. These impose constraints when attempting to allocate resources fairly. In [14], E. Altman, K. Avratchenkov and S. Ramanath have extended the α fairness concept by Mo and Walrand so as to include time constraints. They study the question of how to compute such constrained fair allocation, and derive some asymptotic properties of constrained fair assignment.

5.2.4. Self organization in cellular communications

Self organization is an approach to design networks so as to allow them to configure in an automatic way. This allows to reduce the complexity in systems containing thousands of mobiles and a huge number of small cells. In cellular networks, self organization can be used for deciding on time or frequency reuse according to the interference in these time and frequency slots from other cells. The impact of self organization on communications are derived in [55] and [21] by R. Combes, and Z. Altman (Orange Labs, Issy les Moulineaux), in collaboration with E. Altman.

5.2.5. Streaming over wireless

In [75], E. Altman and M. Haddad study in collaboration with T. Jiménez and R. El-Azouzi (Univ. Avignon/LIA) and S.-E. Elayoubi (Orange Labs, Issy les Moulineaux) streaming service over cellular networks. The purpose is to obtain the exact distribution of the number of buffer starvations within a sequence of N consecutive packet arrivals. This is then applied to optimize the quality of experience (QoE) of media streaming service over cellular networks by exploiting the tradeoff between the start-up delay and the starvation.

5.2.6. Wireless network security

The operation of a wireless network relies extensively on exchanging messages over a universally known channel, referred to as the control channel. The network performance can be severely degraded if a jammer launches a denial-of-service (DoS) attack on such a channel.

In [94], P. Nain, M. Krunz, H. Rahbari and M. J. Abdel Rahman (all three from Univ. of Arizona, USA) design frequency hopping (FH) algorithms that mitigate DoS attacks on the control channel of an asynchronous ad hoc network. More specifically, three FH algorithms (called NUDoS, KMDoS, and NCMDoS) are developed for establishing unicast (NUDoS) and multicast (KMDoS and NCMDoS) communications in the presence of multiple jammers. KMDoS and NCMDoS provide different tradeoffs between speed and robustness to node compromise. These algorithms are fully distributed, do not incur any additional message exchange overhead, and can work in the absence of node synchronization. Furthermore, KMDoS and NCMDoS have the attractive feature of maintaining the multicast group consistency. NUDoS exploits the grid quorum system, whereas KMDoS and NCMDoS use the uniform k-arbiter and the Chinese remainder theorem (CRT) quorum systems, respectively. Extensive simulations are used to evaluate these algorithms.

5.3. Network engineering games

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

5.3.1. Fairness

Anti-trust laws have been introduced by many countries in the last century. This is due to the perception that free competition is better for society. This motivated H. Kameda (Univ. Tsukuba, Japan), C. Touati and A. Legrand (MESCAL, INRIA - CNRS) in cooperation with E. Altman, to define in [28] a fairness concept related to the outcome of competition, which is the Nash equilibrium concept.

5.3.2. Association problem

In [70], E. Altman and M. Haddad study in collaboration with C. Hasan and J.-M. Gorce (SOCRATE, INRIA - INSA) games related to the association problem of mobiles to an access point. It consists of deciding to which access point to connect. Here the choice is between two access points or more, where the access decisions may depend on the number of mobiles connected to each one of the access points. New results were obtained using elementary tools in congestion and crowding games.

5.3.3. Association and placement

The location of a base station has an impact on the throughuput of arriving mobiles that decide to connect to it. Given a cooperative behavior among base stations, E. Altman derives in [54] in collaboration with A. Coluccia (Univ. Salento, Italy) the equilibrium association policy and maximizes its performance by a suitable cooperative positioning of the base stations. The non-cooperative related model was studied in [16] by E. Altman, in collaboration with A. Kumar, C. Singh and R. Sundaresan (all three from IISc, Bangalore, India).

5.3.4. Power control with energy state

In [42] and [64], E. Altman, M. Haddad, J. Gaillard study with D. Fiems (Gent Univ., Belgium) a power control game over a collision channel. Each player has an energy state. When choosing a higher transmission power, the chance of a successful transmission (in the presence of other interference) increases at the cost of a larger decrease in the energy state of the battery. This dynamic game is studied when restricting to simple non-dynamic strategies that consist of choosing a given power level that is maintained during the lifetime of the battery. Surprising paradoxes were identified in the proposed Hawk and Dove game.

5.3.5. Routing games

In [65], M. Haddad, E. Altman and J. Galliard study in collaboration with D. Fiems (Gent Univ., Belgium) a sequential dynamic routing game on a line, where the decision of a user is spatio-temporal control. Each user ships its demand over time on a shared resource. Explicit expressions of the equilibrium of such systems are presented and compared to the global optimum case. The basic idea is taken from a previous paper on this subject by M. K. Hanawal (also with Univ. Avignon/LIA) and E. Altman, in collaboration with R. El-Azouzi (Univ. Avignon/LIA) and B. Prabhu (CNRS - LAAS), who show in [67] that one may transform the time dimension into a spatial component and thus obtain an equivalent standard routing game (where time plays no role) with infinitely many nodes.

5.3.6. Bayesian games in networking

We have considered several problems in networks in which decision makers have asymmetrical information. One of these is how one agent may benefit from revealing part of his information? We considered two types of hierarchical scenarios. In the first, we assume that an agent signals some information to another agent who then chooses an action based on that signal. This action determines the utility of both agents. In the second scenario, a player takes an action (such as pricing) and then the second player reacts to it. Both players' utilities depend on the actions of the two players. The action of the first player may reveal to the second player some of his private information. We use the framework of signalling game to solve the first type of problem and that of Bayesian game to solve the second. Other problems include pricing access to the Internet with partial

information [52] (by I. Brunetti (Univ. Bologna, Italy), M. Haddad (Univ. Avignon/LIA) and E. Altman). In [45], M. Haddad and E. Altman, in collaboration with P. Wiecek (Wroclaw Univ. of Technology, Poland), apply Bayesian games for the association problem in which users have to decide to which access point to connect.

5.3.7. Jamming

We have been working on various models that capture different aspects of jamming (on purpose noise generation). Jamming with partial information is studied in [51] using Bayesian games, by M. Haddad (Univ. Avignon/LIA), E. Altman and S. Azad, as well as [62] and [63] by E. Altman in collaboration with A. Garnaev (St. Petersburg State Univ., Russia) and Y. Hayel (Univ. Avignon/LIA). With K. Avrachenkov, they further consider a dynamic jamming problem in [61]. In all these models the jammer creates interference to the data packets. In [29] V. Kavitha and R. El-Azouzi (Univ. Avignon/LIA), R. Sundaresan (IISc, Bangalore, India), and E. Altman study a different type of jamming game. The jammer attacks the signalling channel and not the data itself. A Bayesian game is formulated and solved there.

5.3.8. Network neutrality and collusions

Network neutrality is a key issue in the future Internet. It is related to the question of whether the access to Internet will remain a universal service or whether it would be regulated by market forces according to economic interests of those that control the Internet access. One form of network non-neutrality is when an ISP gives preferential treatment to one content provider over others. We call this "collusion" or "vertical monopoly". In collaboration with T. Jimenez and Y. Hayel (Univ. Avignon/LIA), E. Altman studies this in [71] along with "horizontal monopolies" that may occur when several ISPs merge. They introduce a new concept of "price of collusion" and identify in [44] cases in which not only consumers loose from collusions but also the colliding agents, as also seen in a different model for network non-neutrality given in [69] by M. K. Hanawal (also with Univ. Avignon/LIA) and E. Altman in collaboration with R. Sundaresan (IISc, Bangalore, India). This is related to a special kind of Braess type paradox.

5.3.9. Competition over popularity in social networks

We focus on competition of video contents for popularity. We analyze the impact of sharing, embedding, advertisement and other actions by the users for increasing the popularity and visibility. This then allowed E. Altman in [80], [38] and [95] to propose stochastic game models and to fully determine the equilibrium policy. He further proposes a dynamic game for the study of partial information and obtain the equilibrium policies and equilibrium performance. In [39], [79] the results are further extended for the wireless context.

5.3.10. Stochastic geometry methods for wireless design issues

Stochastic geometry seems to be the adequate tool in order to model correctly randomness in the location of networks elements such as the mobile terminals and the fixed base stations. Modeling the locations of both as independent spatial processes, In [66] and [25], M. K. Hanawal and E. Altman study in collaboration with F. Baccelli (TREC, INRIA - ENS) properties of Nash equilibria obtained in a multiple access game. They also derive the saddle point obtained in jamming games [68].

5.3.11. In which content to specialize

E. Altman considers in [40] the question of how should a content provider decide in which content to specialize. He shows that the problem is equivalent to the so called "Crowding" games, which allows him to prove the existence of a pure equilibrium. The conclusion is then that there is no gain by diversifying in several contents.

5.3.12. Cognitive radio

In collaboration with J. Elias (Univ. Paris Descartes-Sorbonne) and F. Martignon (LRI-Univ. Paris-Sud), E. Altman study in [56] the question of which priority level to use in a cognitive radio network: higher priority (primary user) or lower one (secondary user). The utilities are function of both the price and the quality of service. After deriving an equilibrium in this game problem, the authors study the question of how to choose prices so as to induce efficient equilibria.

5.3.13. Constrained games

In collaboration with A. Galindo-Serrano and L. Guipponi (CTTC, Spain), E. Altman studies in [60] a game theoretical problem of power control in several base stations with a coupled constraint: the interference at a given point in space should be upper bounded by some constant. The authors establish the existence of a continuum of constrained equilibria to this type of games and show that there is a unique one with some desirable scaling properties (i.e. that consitutes a normalized Nash equilibrium).

5.3.14. Dynamic coalition games

In collaboration with M. K. Panda and T. Chahed (Telecom SudParis, France), E. Altman considers the question of whether to join a multicast session or not. In contrast to many queueing problems, the congestion here is a desirable property, since the cost per user decreases as the number of users connected to the multicast session increases. In [74] the equilibrium policies are derived; these exhibit a surprising structure.

5.3.15. Evolutionary games

The relatively young theory of Evolutionary games considers a large number of interactions between pairs of randomly selected players. It is thus based on a relatively narrow scope in which the one that interacts is the player. In collaboration with Y. Hayel (Univ. Avignon/LIA) and E. V. Belmega (ETIS/ENSEA - Univ. Cergy-Pontoise - CNRS), E. Altman has been developing in [26] an alternative theory of evolutionary game in which a player consists of a group of interacting agents. This is in line with today's understanding of evolution of species (e.g. Dawkins' book "The Selfish Gene" in which the player is the gene of the species). We plan to apply this to energy dependent power control in wireless systems. We also plan to apply these in other areas such as the evolution of languages over social networks, in which some preliminary results (over Twitter) were already obtained in [81] by E. Altman and Y. Portilla (Univ. Avignon/LIA).

5.4. Green networking

Participants: Sara Alouf, Nicaise Choungmo Fofack, Delia Ciullo, Alain Jean-Marie.

5.4.1. Analysis of power saving in cellular networks with continuous connectivity

We have pursued our effort in the analysis of the continuous connectivity mode used in 4G cellular networks. Assuming Poisson traffic at each user, S. Alouf and V. Mancuso (Institute IMDEA Networks, Madrid, Spain) analyze the impact of 3GPP-defined power saving mechanisms on the performance of users with continuous connectivity. Each downlink mobile user's traffic is seen as $M/G/1$ queue, and the base station's downlink traffic as an $M/G/1\,PS$ queue with multiple classes and inhomogeneous vacations. The model is validated through packet-level simulations in [35]; its results show that consistent power saving can be achieved in the wireless access network.

The case of web traffic is investigated in [13] where the same authors, with the participation of N. Choungmo Fofack, perform in addition a sensitivity analysis to assess the impact of model parameters on the performance and cost metrics. It is found that significant power save can be achieved while users are guaranteed to experience high performance. Important outcomes of this work include the need to limit the number of active users in a cell (to less than 350 users – reasonable for 3GPP LTE, 802.16 and HSPA networks) in order to limit the web page download time, and the need to limit the web page size as large pages can dramatically decrease the energy saving. A *green attitude* would be to design web sites with short pages having few embedded objects, enabling cellular operators to use reasonable power save parameters and yet achieve a dramatic cost economy at both base station and mobile user sides, without any quality degradation.

5.4.2. Analysis of base station sleep modes in cellular networks

D. Ciullo, L. Chiaraviglio (INRIA project-team MASCOTTE), M. Ajmone Marsan (Politecnico di Torino, Italy and Institute IMDEA Networks, Spain), M. Mellia and M. Meo (Politecnico di Torino, Italy) study in [78] base station sleep modes. Putting into sleep mode some base stations in periods of low traffic improves the energy efficiency of cellular access networks. Two schemes are considered whether the sleep mode is activated

once per day or multiple times per day having progressively fewer active base stations. For both schemes, the optimal base station sleep times are identified according to the traffic. Considering real traffic traces, the study reveals that significant energy saving can be achieved, the actual value strongly depending on the traffic pattern. An important result is that most of the potential savings can be attained with a single daily sleep mode, avoiding the increased complexity coming from the use of multiple sleep modes per day.

5.4.3. Analysis of sleep modes in backbone networks

The case of backbone networks is considered in [86] where L. Chiaraviglio (INRIA project-team MASCOTTE)), D. Ciullo, M. Mellia and M. Meo (Politecnico di Torino, Italy) formulate a theoretical model based on random graph theory. This model allows to estimate the potential gains achievable by adopting sleep modes in fixed networks where some devices consume energy proportionally to the handled traffic. Putting a given fraction of devices in sleep mode reduces the energy these consume but increases the energy consumed by the devices still active due to the additional load these have to handle. The model of [86] allows to predict how much energy can be saved in different scenarios. The results show that sleep modes can be successfully combined with load proportional solutions. However, if the static power consumption component is one order of magnitude less than the load proportional component, then sleep modes are no longer convenient. Thanks to random graph theory, this model gauges the impact of different properties of the network topology.

5.5. Content-oriented systems

Participants: Konstantin Avrachenkov, Nicaise Choungmo Fofack, Delia Ciullo, Philippe Nain, Giovanni Neglia, Marina Sokol.

5.5.1. Performance analysis of peer-assisted Video-on-Demand (VoD) systems

In [88] and [97], D. Ciullo, V. Martina and E. Leonardi (Politecnico di Torino, Italy), M. Garetto (Università di Torino, Italy), and G. L. Torrisi (CNR, Italy) consider peer-assisted Video-on-Demand systems. Some of the essential aspects of such systems are peer churn, bandwidth heterogeneity, and Zipf-like video popularity. The authors propose an analytical framework to tightly characterize the scaling laws for the additional bandwidth that servers must supply to guarantee perfect service, taking into account these essential aspects.

The results in [88] and [97] reveal that the catalog size and the content popularity distribution have a huge effect on the system performance. Also, users' cooperation can effectively reduce the servers' burden for a wide range of system parameters, confirming it as an attractive solution to limit the costs incurred by content providers as the system scales to large populations of users. Moreover, in [89] the same authors provide important hints for the design of efficient peer-assisted VoD systems under server capacity constraints.

5.5.2. Analysis of TTL-based cache networks

N. Choungmo Fofack, P. Nain and G. Neglia, together with D. Towsley (Univ. of Massachusetts at Amherst, USA) introduced in [87] a novel Time-To-Live (TTL) replacement policy to manage a set of documents buffering routers in information-centric networks. The TTL policy assigns a timer to each content stored in the cache and redraws the timer at each content request. In [53] they have showed that this TTL policy is more general than other policies like least frequently used (LRU), first-in-first-out (FIFO) or random (RND) as it mimics their behavior under an appropriate choice of its parameters. While exact formulas for the performance metrics of interest (hit/miss processes) are derived for a linear network and a tree network with one root cache and N leaf caches, for more general networks, an approximate solution is found with relative errors smaller than 10^{-3} and 10^{-2} for exponentially distributed and constant TTLs respectively. It is demonstrated in [53] that the TTL model can be implemented and used to optimize a multi-content cache network under realistic constraints such as the cache size limitation.

5.5.3. CCN interest routing as multi-armed bandit problem

In [49] K. Avrachenkov and P. Jacko (BCAM, Spain) consider Content Centric Network (CCN) interest forwarding problem as a Multi-Armed Bandit (MAB) problem with delays. The authors investigate the transient behaviour of the ϵ-greedy, tuned ϵ-greedy and Upper Confidence Bound (UCB) interest forwarding policies. Surprisingly, for all the three policies very short initial exploratory phase is needed. It is demonstrated that the tuned ϵ-greedy algorithm is nearly as good as the UCB algorithm, commonly reported as the best currently available algorithm. The uniform logarithmic bound for the tuned ϵ-greedy algorithm in the presence of delays is proved. In addition to its immediate application to CCN interest forwarding, the new theoretical results for MAB problem with delays represent significant theoretical advances in machine learning discipline.

In [46] K. Avrachenkov together with L. Cottatellucci and L. Maggi (both from Eurecom, France) consider the choice of CCN Access Points (APs) when CCN APs are wireless base stations. It is assumed that the slow fading channel attenuations follow an autoregressive model. In the single user case, the authors formulate this selection problem as a restless multi-armed bandit problem and propose two strategies to dynamically select a band at each time slot. The objective is to maximize the SNR in the long run. Each of these strategies is close to the optimal strategy in different regimes. In the general case with several users, the authors formulate the problem as a stochastic game with uncountable state space, where the objective is the SINR. Then the authors propose two strategies to approximate the best response policy for one user when the other users' strategy is fixed.

5.6. Advances in methodological tools

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

5.6.1. Perturbation analysis

In [17] K. Avrachenkov, together with R. Burachik, J. Filar V. Gaitsgory (Univ. of South Australia, Australia), study a linear programming problem with a linear perturbation introduced through a parameter $\epsilon > 0$. The authors identify and analyze an unusual asymptotic phenomenon in such a linear program. Namely, discontinuous limiting behavior of the optimal objective function value of such a linear program may occur even when the rank of the coefficient matrix of the constraints is unchanged by the perturbation. The authors show that, under mild conditions, this phenomenon is a result of the classical Slater constraint qualification being violated at the limit and propose an iterative, constraint augmentation approach for resolving this problem.

5.6.2. Zero-sum games

In [18] K. Avrachenkov, together with L. Cottatellucci and L. Maggi (both from Eurecom, France), study zero-sum two-player stochastic games with perfect information. The authors propose two algorithms to find the uniform optimal strategies and one method to compute the optimality range of discount factors. The convergence in finite time for one algorithm is proved. In particular, the uniform optimal strategies are also optimal for the long run average criterion and, in transient games, for the undiscounted criterion as well.

5.6.3. Approximations in semi-Markov zero-sum games

In conjunction with E. Della Vecchia and S. Di Marco (both from National Univ. Rosario, Argentina), A. Jean-Marie has pursued the studies on the Rolling Horizon procedure and other approximations in stochastic control problems. Their first study on convergence conditions for average-cost MDPs has been published in [23].

They have then turned to the case of discounted semi-Markov zero-sum games. Generalizing previous contributions of the literature, they have established existence conditions and geometric convergence results when action spaces are compact and rewards possibly unbounded. The bounds they obtain hold for the Rolling Horizon procedure as well as for variants called Approximate Rolling Horizon [91]. In the same semi-Markovian context, they have also performed a sensitivity analysis of the model with respect to its parameters: cost function, discount factor, transition probabilities and state space [90].

5.6.4. Retrial queues

In [84] K. Avrachenkov and P. Nain, in collaboration with U. Yechiali (Tel Aviv Univ.), consider a retrial system with two input streams and two orbit queues. More specifically, there are two independent Poisson streams of jobs feeding a single-server service system having a limited common buffer that can hold at most one job. If a type-i job (i=1,2) finds the server busy, it is blocked and routed to a separate type-i retrial (orbit) queue that attempts to re-dispatch its jobs at its specific Poisson rate. This creates a system with three dependent queues. Such a queueing system serves as a model for two competing job streams in a carrier sensing multiple access system. The authors study the queueing system using multi-dimensional probability generating functions, and derive its necessary and sufficient stability conditions while solving a boundary value problem. Various performance measures are calculated and numerical results are presented.

5.6.5. Branching processes

In collaboration with D. Fiems (Gent Univ., Belgium), E. Altman introduces in [41] non-standard new branching processes and applies them to evaluate queueing processes. The processes are characterized by replacing the standard Algebra involved in the definition of branching processes by the max-plus algebra. Among the applications introduced are (i) polling systems with infinite server, and (2) new Cruz type bounds for systems with feedback.

Standard branching have been used in the past to study polling systems. In [30] V. Kavitha (LIA/Univ. Avignon) and E. Altman have revisited this method and applied it to spatial sensors, that receive or send data via a mobile relay or base stations. They derive conservation laws for this continuous state space polling system which allows them to compute optimal polling strategies.

D. Fiems (Gent Univ., Belgium) and E. Altman have further used in [24] semi-linear processes, which extend branching processes, to compute expected waiting times in polling systems with generally distributed walking times (the standard i.i.d. assumption is replaced with the assumption that the walking times are stationary ergodic).

In [22], the problem of parallel TCP connections is studied by O. Czerniak and U. Yechiali (Tel Aviv Univ., Israel), in collaboration with E. Altman, for a model in which, when the sum of throughputs reaches some value, there is a loss. It is assumed that the connection to suffer the loss is chosen according to a round robin policy. The expected throughputs of the connections are computed using an approach based on multitype branching processes.

6. Bilateral Contracts and Grants with Industry

6.1. Bilateral Contracts with Industry

MAESTRO members are involved in the INRIA ALCATEL-LUCENT BELL LABS joint laboratory and participate in several ADRs (Action de Recherche/Research Action). The joint laboratory consists of three ADRs in its first phase (2008–2012) and six ADRs in its second phase (starting October 2012).

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

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

Coordinators are Isabelle Guérin Lassous (INRIA project-team RESO) for INRIA and Ludovic Noirie for ALTCATEL-LUCENT.

The new paradigm of "semantic networking" for the networks of the future brings together "flow-based networking", "traffic-awareness" and "self-management" concepts to get "plug-and-play" networks. The natural traffic granularity is the flow. MAESTRO's task is to elaborate on the scheduling of flows in routers having in mind the fairness among flows with different round-trip times. Three joint INRIA ACATEL-LUCENT patents have been filed already, one in 2009 (inventors for INRIA: S. Alouf, K. Avrachenkov, D. Carra, P. Nain) and two in 2010 (inventors for INRIA: S. Alouf, K. Avrachenkov, A. Blanc).

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

Participants: Eitan Altman, Majed Haddad, Manjesh Kumar Hanawal.

Coordinators are Bruno Gaujal (head of INRIA project-team MESCAL) for INRIA and Laurent Roullet for ALTCATEL-LUCENT.

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

Many key features in mobile access networks rely on user velocity information in order to reinforce the perception of performance stability during mobility. Based on the analytical framework elaborated during the first phase that show the need for an efficient method of user speed estimation, the first objective of the research activity (strongly supported by the Wireless Business Unit) is to devise a procedure for user speed estimation or classification.

6.2. Bilateral Grants with Industry

6.2.1. CRE "Content-Centric Networking" (October 2010 – December 2012)

Participants: Sara Alouf, Konstantin Avrachenkov, Nicaise Choungmo Fofack, Philippe Nain, Giovanni Neglia.

Contractor: Orange Labs (http://www.orange.com/en/innovation)

Participants: Bruno Kauffmann, Luca Muscariello, Alain Simonian.

The objective of this grant (CRE) is to develop mathematical models for the analysis of Content-Centric Networks (CCN). This research focuses on routing and caching policies.

P. Nain is responsible for INRIA. This work is done in collaboration with C. Barakat (PLANETE, INRIA).

6.2.2. CRE "Self Optimization in Networks" (October 2009 – September 2012)

Participants: Eitan Altman, Richard Combes.

Contractors are

- Orange Labs (http://www.orange.com/en/innovation). Participant: Zwi Altman,
- Univ. Pierre and Marie Curie (UPMC, http://www.upmc.fr). Participant: Sylvain Sorin.

This grant (CRE) from Orange Labs is related to a Cifre thesis allocated to R. Combes, whose advisors are E. Altman, S. Sorin (UPMC) and Z. Altman (Orange Labs).

7. Partnerships and Cooperations

7.1. National Initiatives

7.1.1. ANR Verso ECOSCELLS (11/2009–10/2012)

Participants: Eitan Altman, Konstantin Avrachenkov, Philippe Nain.

ANR VERSO ECOSCELLS (Efficient Cooperating Small Cells) aims at developing algorithms and solutions which will be required for the deployment of small cell networks. The theoretical studies will define and solve the models needed to understand the behavior of radio channels, and will design the algorithms which will allow the exploitation of the diversity (user, spatial, interference, etc.) in these networks. The consortium gathers two main industrial groups in the telecommunication domain (ALCATEL-LUCENT BELL LABS (leader) and Orange Labs), together with three leading SMEs (3ROAM, SEQUANS and SIRADEL) and six academic partners (Univ. of Avignon, INRIA through its project-teams MAESTRO, MASCOTTE and SWING, INSTITUT EURECOM, LAAS-CNRS and Laboratoire des Signaux et Systèmes/SUPELEC).

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

7.1.2. Inria Cooperative Research Initiative (ARC) OCOQS (2011-2012)

Participant: Alain Jean-Marie.

The finishing ARC OCOQS (Optimal threshold policies in COntrolled Queuing Systems) was devoted to the structural analysis of Markov Decision Processes, with the objective to improve the set of formal techniques available to prove that optimal control policies have a particular structure (typically, threshold-type). One of the benchmarks for this project was the extension of the model solved in [27]. This project also involved A. Busic (INRIA project-team TREC), E. Hyon (LIP6 and Univ. Paris 10) and I. Vliegen (Univ. Twente).

http://www.di.ens.fr/~busic/OCOQS/

7.2. European Initiatives

7.2.1. FP7 Projects

7.2.1.1. CONGAS

Participants: Eitan Altman, Konstantin Avrachenkov, Alexandre Reiffers.

Title: Dynamics and coevolution in multi level strategic interaction games

Type: Collaborative project

Subprogramme Area: FET Proactive: Dynamics of Multi-Level Complex Systems

Instrument: Specific Targeted Research Project (STREP)

Duration: October 1, 2012 – September 30, 2015

Coordinator: Center for Research and Telecommunication Experimentation for Network Communities (CREATE-NET) (Italy)

Other partners:

- Université D'Avignon et des Pays de Vaucluse (UAPV) (France)
- Technische Universiteit Delft (TUDelft) (The Netherlands)
- Imperial College of Science, Technology and Medicine (IMPERIAL) (United Kingdom)
- Universityá di Pisa (UNIPI) (Italy)
- Technion - Israel Institute of Techonology (TECH) (Israel)

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

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

K. Avrachenkov is the coordinator for INRIA. E. Altman is a scientific coordinator of the project.

7.2.1.2. TREND

Participants: Sara Alouf, Delia Ciullo.

Title: Towards Real Energy-efficient Network Design

Subprogramme Area: ICT-2009.1.1 The Network of the Future

Instrument: Network of Excellence (NoE)

Duration: September 1, 2010 – August 31, 2013

Coordinator: Politecnico di Torino (PoliTO) (Italy)

Other partners:

- Alcatel-Lucent Bell Labs (France)
- Huawei Technologies Dusseldorf GmbH (HWDU) (Germany)
- Telefonica Investigacion y Desarrollo (TID) (Spain)
- France Telecom - Orange (FT) (France)
- Fastweb (FW) (Italy)
- Universidad Carlos III (UC3M) (Spain)
- iMinds (Belgium)
- Technical University of Berlin (TUB) (Germany)
- Ecole Polytechnique Fédérale de Lausanne (EPFL) (Switzerland)
- Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT) (Italy)
- Panepistimio Thessalias - University of Thessaly (UTH) (Greece)

Collaborating institutions:

- Fondazione Ugo Bordoni (Italy)
- Technische Universitat Dresden (Germany)
- Deutsche Telekom Laboratories (Germany)
- Institute IMDEA Networks (Spain)
- CNR Institute for High Performance Computing and Networking (ICAR-CNR) (Italy)
- International Hellenic University (Greece)
- Institut National de Recherche en Informatique et en Automatique (Inria) (France)
- Boston University (United States)

See also: http://www.fp7-trend.eu/

Abstract: TREND aims at integrating the activities of major European players in networking, including manufacturers, operators, research centers, to quantitatively assess the energy demand of current and future telecom infrastructures, and to design energy-efficient, scalable and sustainable future networks.

MAESTRO's task is to propose and analyze energy-aware network cellular network design and management, in collaboration with the other partners.

7.3. International Initiatives

7.3.1. Inria Associate Teams

7.3.1.1. GANESH

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

Inria principal investigator: Eitan Altman

International Partners (Institution - Laboratory - Researcher):

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

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

IIT Madras (India) - Electrical Engineering - Venkatesh Ramaiyan

Duration: 2012 - 2014

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

This project aims at producing outstanding contributionis to the foundations of the theory of networks, in game theory, team theory, optimization and analysis. Three areas in networkiing will be used to apply these: (i) economy of networks and network neutrality, (2) schedulling in wireless networks, and (3) distributed optimization issues in ad-hoc networks.

7.3.2. Inria International Partners

7.3.2.1. St. Petersburg State Univ.

Participant: Konstantin Avrachenkov.

MAESTRO has a continuing collaboration with St. Petersburg State Univ.. St. Petersburg State Univ. is a partner in INRIA Internship International programme. In particular, MAESTRO hosts every year several intern students from St. Petersburg State Univ.. The collaboration with L. Petrosyan and A. Garnaev is on the application of game theory to resource allocation in networks. The collaboration with V. Dobrynin is on data clustering.

7.3.3. Participation In International Programs

7.3.3.1. STIC Tunisie

Participants: Eitan Altman, Majed Haddad.

E. Altman and M. Haddad have been collaborating with I. Mabrouki (Institut Supérieur d'Informatique et des Techniques de Communication, Tunisia) on intelligent jamming in wireless networks, i.e. jamming in which the jammer is aware of the protocol used by the network.

7.3.3.2. Indo-French Centre for the Promotion of Advanced Research (IFCPAR)

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

Within project 4000-IT on "Emerging Strategies for Wireless Communication Networks," K. Avrachenkov, E. Altman and M. K. Hanawal (also with Univ. Avignon/LIA) have been collaborating with V. Borkar and V. Kavitha (IIT Mumbai, India), A. Kumar, R. Sundaresan and C. Singh (Indian Institute of Science, India) on evaluating and optimization issues in wireless networks. They also worked on network neutrality issues.

7.4. International Research Visitors

7.4.1. Visits of International Scientists

7.4.1.1. Professors / Researchers

Abdelfettah Belghith (from October 15, 2012 until October 20, 2012)
Institution: ENSI, Univ. of Manouba (Tunisia)

Amel Ben Slimane (from October 15, 2012 until October 20, 2012)
Institution: ENSI, Univ. of Manouba (Tunisia)

Vivek Borkar (from June 3, 2012 until June 23, 2012)
Institution: Indian Institute of Technology Bombay (India)

Ananthanarayanan Chockalingam (from June 11, 2012 until June 22, 2012)
Institution: Indian Institute of Science (India)

Jerzy Filar (from June 21 2012 until July 7 2012)
Institution: Flinders Univ. (Australia)

David Hay (from June 25, 2012 until June 26, 2012)
Institution: Hebrew Univ. of Jerusalem (Israel)

Nelly Litvak (from November 4, 2012 until November 8, 2012)
Institution: Univ. of Twente (Netherlands)

Issam Mabrouki (from October 15, 2012 until October 20, 2012)
Institution: Univ. of Manouba (Tunisia)

Evsey Morozov (from September 18, 2012 until September 23, 2012)
Institution: Petrozavodsk State Univ. (Russian Federation)

Balakrishna Prabhu (from November 21, 2012 until November 23, 2012)
Institution: LAAS-CNRS (France)

Rajesh Sundaresan (from May 24 until June 14, 2012)
Institution: Indian Institute of Science (India)

Uri Yechiali (from April 10, 2012 until April 25, 2012)
Institution: Tel Aviv Univ. (Israel)

7.4.1.2. Post-doctoral fellows

Andrey Lukyanenko (from November 16, 2012 until December 15, 2012)
Institution: Aalto Univ. (Finland)

Ali Jahromi (from June 24, 2012 until June 30, 2012)
Institution: Univ. of Adelaide (Australia)

Bruno Ribeiro (from February 4, 2012 until March 7, 2012)
Institution: BBN Technologies (USA)

7.4.1.3. Ph.D. students

Mohammad Abdel Rahman (from June 27, 2012 until August 14, 2012)
Subject: Elaborating new mobility models for ad hoc networks
Institution: Univ. of Arizona (USA)

Nicolas Accettura (from February 2012 until August 2012)
Subject: Population size estimation
Institution: Politecnico di Bari (Italy)

Rodrigo Vaca Ramirez (from November 23, 2012 until February 20, 2013)

Subject: Vertical handover framework towards energy efficiency

Institution: Univ. of Edinburgh

7.4.1.4. Graduate students

Imen Mahjri (from October 1, 2012 until December 31, 2012)

Subject: Road Traffic Mobility Models in Complex Systems

Institution: ENSI, Univ. of Manouba (Tunisia)

Yonathan Portilla (From April 23, 2012 until July 6, 2012)

Subject: Analyzing the evolution of written language in Twitter

Institution: Univ. of Avignon

7.4.1.5. Internships

Sushma Hanawal (from August 2012 until February 2013)

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

Institution: SJCE Mysore (India)

Vasily Medyanikov (from June 20, 2012 until September 29, 2012)

Subject: Monte Carlo Methods for Centrality Measures in Online Social Networks

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

7.4.2. Visits to International Teams

MAESTRO members have visited (the)

- Basque Center for Applied Mathematics (BCAM), Bilbao, Spain in the period June 19–20, 2012 (**S. Alouf**);
- BBN Technologies, Cambridge, MA, USA in the periods November 12–13 and 15–16, 2012 (**G. Neglia**);
- École polytechnique fédérale de Lausanne (EPFL), Switzerland in the period November 5–9, 2012 (**D. Ciullo**);
- Fordham Univ. at Rose Hill campus, Bronx, NY, USA in the period November 19–21, 2012 (**G. Neglia**);
- GERAD, Univ. Montreal, Canada in the period April 16–May 11, 2012 (**A. Jean-Marie**);
- Indian Institute of Science (IISc), Bangalore, India in the periods January 10–20, 2012 and July 12–19, 2012 (**E. Altman**);
- Politecnico di Torino, Italy in the period July 23–27, 2012 (**D. Ciullo**);
- Univ. of Liverpool, UK in the period May 14–18 (**K. Avrachenkov**);
- Univ. of Massachusetts at Amherst, USA in the periods February 13–15 and November 20–28, 2012 (**P. Nain**) and on November 14, 2012 (**G. Neglia**);
- Univ. of Palermo, Italy in the period December 17–21, 2012 (**G. Neglia**);
- Univ. of Twente, Enschede, The Netherlands in the period March 26–30 (**K. Avrachenkov**).

8. Dissemination

8.1. Scientific Animation

8.1.1. Editorial activities

MAESTRO members are

Editor-in-Chief of

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

Associate Editors of (in alphabetical order)

- *Computer Communications* (COMCOM) (**E. Altman** since 2010);
- *Dynamic Games and Applications* (DGAA) (**E. Altman** since 2011);
- *Journal of Economic Dynamics and Control* (JEDC) (**E. Altman** since 2001);
- *Performance Evaluation* (PEVA) (**K. Avrachenkov** since 2008);

Guest editor of Special Issues of

- *IEEE Journal of Selected Areas in Communications* (JSAC) on "The economics of communication networks and systems" [77] (**E. Altman**).

8.1.2. Conferences, meetings and tutorial organization

MAESTRO members were

in the Steering Committee of

- 10th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2012, Paderborn, Germany) (**E. Altman** as chair);
- 6th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS, Cargèse, France) (**E. Altman** as co-chair);
- 6th Intl. Conference on Network Games, Control and Optimization (NETGCOOP 2012, Avignon, France) (**E. Altman**);
- Workshop on Telecom Economics, Engineering and Policy (co-located with ITC 2012, Kraków, Poland) (**E. Altman**);

TPC co-chair of

- 6th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2012, Cargèse, France) (**A. Jean-Marie**);
- Workshop "Networking games & resource allocation" (Petrozavodsk, Russia) (**E. Altman**).

8.1.3. Participation in technical program committees (TPC)

MAESTRO members were in the TPC of

1. ACM 3rd Intl. Workshop on Mobile Opportunistic Networks (MobiOpp 2012, Zurich, Switzerland) (**G. Neglia**);
2. ACM SIGMETRICS/Performance 2012 (London, UK) (**A. Jean-Marie**);
3. 8th Advanced International Conference on Telecommunications (AICT 2012, Stuttgart, Germany) (**K. Avrachenkov**);
4. IADIS Multi Conference on Computer Science and Information Systems (MCCSIS 2012, Lisbon, Portugal) (**M. Haddad**);
5. 32nd IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2013, Turin, Italy) (**G. Neglia**);

6. IEEE 77th Vehicular Technology Conference (VTC2013-Spring, Dresden, Germany) (**S. Alouf**, **D. Ciullo**);
7. 3rd Intl. Conference on Access Networks (ACCESS 2012, Venice, Italy) (**K. Avrachenkov**);
8. 19th Intl. Conference on Analytical and Stochastic Modelling Techniques and Applications (ASMTA 2012, Grenoble, France) (**K. Avrachenkov**);
9. Intl. Conference on Computer Communication Networks (ICCCN 2012, Munich, Germany) Network Science and Social Networks Track (**G. Neglia**);
10. 6th Intl. Conference on Game Theory and Management (GTM 2012, St. Petersburg, Russia) (**E. Altman**);
11. 3rd Intl. Conference on Game Theory for Networks (Gamenets 2012, Vancouver, Canada) (**E. Altman**);
12. 6th Intl. Conference on Network Games, Control and Optimization (NETGCOOP 2012, Avignon, France) (**K. Avrachenkov**);
13. 11th Intl. Conference on Next Generation Wired/Wireless Networking (NEW2AN 2012, St. Petersburg, Russia) (**K. Avrachenkov**);
14. 6th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2012, Cargèse, France) (**S. Alouf**, **K. Avrachenkov**, **A. Jean-Marie**, **P. Nain**, **G. Neglia**);
15. 2nd Intl. Conference on Smart Grids and Green IT Systems (SMARTGREENS 2013, Aachen, Germany) (**D. Ciullo**);
16. 3rd Intl. Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (Energy 2013, Lisbon, Portugal) (**D. Ciullo**);
17. 27th Intl. Symposium on Computer and Information Sciences (ISCIS 2012, Paris, France) (**A. Jean-Marie**);
18. 14th Intl. Symposium on Dynamic Games and Applications (ISDGA 2012, Byšice, Czech Republic) (**E. Altman**);
19. 10th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2012, Paderborn, Germany) (**S. Alouf**);
20. 24th Intl. Teletraffic Conference (ITC 2012, Kraków, Poland) (**S. Alouf**);
21. 5th Intl. Workshop on Multiple Access Communications (MACOM 2012, Dublin, Ireland) (**K. Avrachenkov**);
22. Intl. Workshop "Networking Games and Management" (Petrozavodsk, Russia) (**K. Avrachenkov**);
23. 14èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications (AlgoTel 2012, La Grande Motte, France) (**A. Jean-Marie**);
24. 8th Spain, Italy and Netherlands Meeting on Game Theory (SING 8, Budapest, Hungary) (**E. Altman**);
25. 9th Workshop on Algorithms and Models for the Web Graph (WAW 2012, Halifax, Nova Scotia, Canada) (**K. Avrachenkov**);
26. 14th Workshop on Mathematical Performance Modeling and Analysis (MAMA 2011, London, UK) (**A. Jean-Marie**, **P. Nain**);
27. First Workshop on Pricing and Incentives in Networks (W-PIN 2012, London, UK) (**E. Altman**).

8.1.4. Leadership within the scientific community

- E. Altman was one of the two recipients of the France Telecom Prize delivered by the Académie des Sciences.
- E. Altman is a fellow member of IEEE (Class of 2010).
- E. Altman, A. Jean-Marie and P. Nain are (elected) members of IFIP WG7.3 on "Computer System Modeling".
- P. Nain is the vice-Chair of the IFIP WG7.3 working group on "Computer System Modeling" (since June 30, 2007).

8.1.5. Research administration

E. Altman is co-responsible of one of the five themes of the SFR (Structure Fédérative de Recherche) AGORANTIC (in which INRIA is a founding member) entitled "Digital Culture and Virtual Societies."

K. Avrachenkov (together with A. Legout and F. Gandon) is co-responsible of the multi-disciplinary research theme (Action Transversale) "Semantic and Complex Networks" at INRIA Sophia Antipolis - Méditerranée.

A. Jean-Marie

- is the scientific coordinator of INRIA activities in Montpellier (since 2008);
- is member of the managing sub-committee of the Project-Team Committee of the INRIA Sophia Antipolis - Méditerranée research center (since July 2010);
- is a member of the Steering Committee of the GDR RO, a national research initiative on Operations Research sponsored by the CNRS;
- was a member of the Recruiting Committee of INRIA engineers and technicians (IT) at Inria Sophia Antipolis - Méditerranée;
- was a member of the Selection Committee of the 2012 Robert Faure prize of the French Society for Operations Research and Decision Support (ROADEF).

P. Nain

- is Chairman of INRIA's Evaluation Committee since September 1st, 2012 (http://www.inria.fr/en/institute/organisation/committees/evaluation-committee);
- is Head of project-team MAESTRO;
- is a member of the INRIA steering group (13 people including 6 researchers) in charge of producing of the INRIA 2013-2017 strategic plan;
- has represented INRIA/ at the Scientific Council of the Univ. of Nice-Sophia Antipolis from July 2011 to June 2012.

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

- CC: General Information Commission (**N. Choungmo Fofack** as PhD Student Representative, since 2011);
- ComRes: Commission Restauration (**N. Choungmo Fofack** as PhD Student Representative, since 2011);
- CSD: Doctoral Committee (**S. Alouf**, since February 2006);
- MASTIC: a commission in charge of internal and regional scientific animation and popularization (**S. Alouf**, since November 2011);
- NICE: Invited Researchers Committee (**K. Avrachenkov**, since 2010);

and in charge of the following tasks

- Validation of Teams yearly activity reports (**K. Avrachenkov**, since 2010);
- Accounting for the monthly Project-Team Committee meetings (**S. Alouf**);
- Organizing MAESTRO internal meetings (**N. Choungmo Fofack**).

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

Licence : S. Alouf, “Probability and Statistics”, 36H ETD, 1st year Water Engineering degree (L3), Univ. of Nice Sophia Antipolis (UNS), France.

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

Licence : M. El Chamie, “Database”, 20H ETD, Computer Science Program (L2), Univ. of Nice Sophia Antipolis (UNS), France.

Master : S. Alouf, “Performance Evaluation of Networks”, 32.5H ETD, M2 IFI Ubinet, Univ. of Nice Sophia Antipolis (UNS), France.

Master : K. Avrachenkov, “Probability and Statistics”, 27H ETD, M1 EuroAquae, Univ. of Nice Sophia Antipolis (UNS), France.

Master : A. Jean-Marie, “Metrology and Quality of Service for Networks”, 18H ETD, M2, Univ. of Montpellier 2, France.

Master : G. Neglia, “Performance Evaluation of Networks”, 22.5H ETD, M2 IFI Ubinet, Univ. of Nice Sophia Antipolis (UNS), France.

Doctorat : E. Altman, “Competition for popularity in social networks”, 4H ETD, 2nd Intl. Summer School on Cognitive Wireless Communications (COST Action IC0902), France.

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

Doctorat : G. Neglia, “Complex Networks”, 4.5H ETD, Univ. of Palermo, Italy.

Doctorat : G. Neglia, “Perron Frobenius Theory”, 20H ETD, Univ. of Nice Sophia Antipolis (UNS), France.

8.2.2. Supervision

PhD: Lorenzo Maggi, “Markovian Competitive and Cooperative Games with applications to Communications,” Univ. of Nice Sophia Antipolis, October 9 2012, advisors: Konstantin Avrachenkov and Laura Cottatellucci (INSTITUT EURECOM).

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

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

PhD in progress: Richard Combes, “Self-organizing functionalities in radio networks,” October 1 2009, advisors: Eitan Altman and Zwi Altman (France Telecom) and Sylvain Sorin (Univ. Pierre and Marie Curie).

PhD in progress: Eugenio Della Vecchia, “Contribution to the solution of problems in stochastic control and games”, October 1 2008, advisors: Silvia Di Marco (National Univ. of Rosario, Argentina) and Alain Jean-Marie.

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

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

PhD in progress: Manjesh Kumar Hanawal, “Resource allocation and learning algorithms in small cells wireless networks,” January 1 2010, advisors: Eitan Altman and Rachid El-Azouzi (Univ. of Avignon).

PhD in progress: Cengis Hasan, "Optimization of resource allocation for small cells networks," January 1 2010, advisors: Eitan Altman and Jean-Marie Gorce (INRIA project-team SWING).

PhD in progress: Alexandre Reiffers, "Modelling competition and cooperation in telecommunication networks," October 15 2012, advisor: Eitan Altman.

PhD in progress: Marina Sokol, "Clustering and learning tecnhiques for traffic/user classification," October 1 2009, advisors: Paulo Gonçalves (INRIA project-team RESO) and Philippe Nain.

8.2.3. Juries

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

- Olivier Brun: February 6, 2012, LAAS-CNRS (**K. Avrachenkov** as jury member);

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

- Ali Arshad: November 12, 2012, Telecom SudParis (**K. Avrachenkov** as reviewer, **E. Altman** as jury member);
- Olivier Fercoq: September 17, 2012, Ecole Polytechnique (**K. Avrachenkov** as reviewer);
- Oussama Habachi: September 28, 2012, Univ. of Avignon (UAPV) (**E. Altman** as jury member);
- Lorenzo Maggi: October 9, 2012, INSTITUT EURECOM (**K. Avrachenkov** as co-advisor);
- Marco Rosa: March 6, 2012, Univ. of Milano, Italy (**K. Avrachenkov** as reviewer);
- Cristiano Tapparello: March 14, 2012, Univ. of Padua, Italy (**G. Neglia** as reviewer);
- Cheng Wan: September 26, 2012, Univ. Pierre et Marie Curie (Paris 6) (**E. Altman** as reviewer).

8.3. Popularization

Activities are presented in chronological order:

- M. El Chamie presented the topic "Belief propagation and classification in complex networks" at the *Salon du Numérique*, Inria stand, held in parallel with the World Wide Web 2012 (www2012) conference, April 16–20, 2012, Lyon, France.
- A. Reiffers delivered a conference titled "Competition over popularity in social networks" organized by the association "Les petits débrouillards" in Carpentras on October 16, 2012.
- S. Alouf delivered two conferences titled "Comment marche le Web ?" at the Henri Matisse High School of Vence (December 6, 2012), and at the Aix-Valabre High School at Gardanne (December 13, 2012).
- An article portraying N. Choungmo Fofack has appeared in *LISA* (December 7, 2012), available here: https://lisa.sophia.inria.fr/nicaise-choungmo-fofack-doctorant-dans-lequipe-maestro-797.html).
- E. Altman made a presentation on "Des points de rencontre entre la technologie de l'information et les sciences humaines et sociales" in the *Café-in* series of popular content at the INRIA Sophia Antipolis - Méditerrannée Center on December 17, 2012.
- An article titled "Internet" has appeared in *Savoirs Jeunes* (December 17, 2012) (interview of S. Alouf by E. Kuntzelmann, available here: http://juniors.savoirs.essonne.fr/questions-a).

8.4. Participation in scientific events

8.4.1. Keynotes, tutorials and invited talks

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

- *The mathematics of file dissemination*, at the 6th Young European Queueing Theorist (YEQT-VI) workshop on "Analytic Methods in Queueing Systems", November 1–3, 2012, Eindhoven, The Netherland (**P. Nain**);

the following tutorials (in alphabetical order):

- *Competition over popularity of content in social networks*, at the 6th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS), October 8, 2012, Cargèse, France (**E. Altman**);
- *Game theoretic modeling of competition over popularity in social networks*, at the 6th Intl. Conference on Network Games, Control and Optimization (NetGCoop), November 28, 2012, Avignon, France (**E. Altman**);
- *Socio-economic and legal Issues in the Internet: game theoretical models*, at the 6th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS), October 8, 2012, Cargèse, France (**E. Altman**, **M. K. Hanawal**);

and the following invited talks (in alphabetical order):

- *Analysis of power saving in cellular networks with continuous connectivity*, at the Basque Center for Applied Mathematics (BCAM), June 20, 2012, Bilbao, Spain (**S. Alouf**);
- *Competition over popularity in social networks*, at Imperial college, December 7, 2012, London, UK, and at the Institut Supérieur d'Informatique et des Techniques de Communication, December 15, 2012, Hammam Sousse, Tunisia, (**E. Altman**);
- *Distributed weight selection in consensus protocols by Schatten norm minimization*, at Fordham university, November 20, 2012, Rose Hill Campus Bronx, NY 10458 (**G. Neglia**);
- *Optimal control of carbon sequestration: the case of leaky reservoirs*, at the Univ. of Valladolid, Dept. Applied Maths, February 29, 2012, Valladolid, Spain (**A. Jean-Marie**);
- *Quick detection of large degree nodes in complex networks*, at the Univ. of Liverpool, May 17, 2012, Liverpool, UK (**K. Avrachenkov**).

8.4.2. Conferences and workshops

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

- 31st IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2012), March 25–30, Orlando, Florida, USA (**J. Gaillard**);
- 6th Intl. Conference on Network Games, Control and Optimization (NetGCoop 2012), November 28–30, 2012, Avignon, France (**E. Altman**, **K. Avrachenkov**);
- 6th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2012), October 9–12, Cargèse, France (**E. Altman**, **N. Choungmo Fofack**, **M. Haddad**);
- 10th Intl. Symposium on Modeling and Optimization in Mobile, Ad hoc and Wireless Networks (WiOpt), May 14–18, Padeborn, Germany (**E. Altman**);
- 3rd Intl. Workshop on Traffic Analysis and Classification (TRAC 2012), August 27–31, Limassol, Cyprus (**K. Avrachenkov**);
- Optimization Days 2012, May 7–9, Montreal, Canada (**A. Jean-Marie**);
- 12th Viennese Workshop on Optimal Control, Dynamic Games and Nonlinear Dynamics, May 30 - June 2, Vienna, Austria (**A. Jean-Marie**);
- Workshop on Network Science in Electrical Engineering and Computer Science, January 09–13, 2012, Bangalore, India (**E. Altman**);
- BiCi Workshop: Sinergic Investigations in Network Science (SINS), October 14–19, 2012, Bertinoro, Italy (**K. Avrachenkov**).

8.4.3. Technical program committee meetings

MAESTRO members have participated in the following TPC meetings:

- 32nd IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2013), November 10, 2012, Phoenix, Arizona, USA (**G. Neglia**);
- 24th Intl. Teletraffic Conference (ITC 2012), May 11, 2012, Paris, France (**S. Alouf**).

8.4.4. Schools and students workshops

MAESTRO members have attended the following courses:

- Course in "Scaling methods for stochastic networks" (10H) at the Basque Center for Applied Mathematics (BCAM), January 16–20, 2012, Bilbao, Spain (**N. Choungmo Fofack**);
- Euro-NF PhD Course in "Information Centric Networking" (30H) at Athens Univ. of Economics and Business (AUEB), May 14–18, 2012, Athens, Greece (**N. Choungmo Fofack**);
- Tutorials on "Performance Evaluation Methodologies and Tools" (20H) at VALUETOOLS 2012 Conference, October 9–12, 2012, Cargèse, France (**I. Brunetti**, **M. El Chamie**, **J. Gaillard**, **O. Habachi**, **A. Reiffers**).

9. Bibliography

Major publications by the team in recent years

[1] S. ALOUF, G. NEGLIA, I. CARRERAS, D. MIORANDI, Á. FIALHO. *Fitting genetic algorithms to distributed on-line evolution of network protocols*, in "Computer Networks", December 2010, vol. 54, n° 18, p. 3402-3420 [*DOI :* 10.1016/J.COMNET.2010.06.015], http://hal.inria.fr/hal-00640798/en/.

[2] E. ALTMAN, P. NAIN, J.-C. BERMOND. *Distributed Storage Management of Evolving Files in Delay Tolerant Ad Hoc Networks*, in "Proc. of IEEE INFOCOM 2009", Rio de Janeiro, Brazil, April 19-25, 2009, p. 1431–1439, http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5062059.

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

[4] E. ALTMAN, T. BAŞAR, F. DE PELLEGRINI. *Optimal Control in Two-Hop Relay Routing*, in "IEEE Transactions on Automatic Control", March 2011, vol. 56, n° 3, p. 670–675, http://dx.doi.org/10.1109/TAC.2010.2095930.

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

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[10] X. ZHANG, G. NEGLIA, J. KUROSE, D. TOWSLEY. *Performance Modeling of Epidemic Routing*, in "Elsevier Computer Networks", July 2007, vol. 51, n° 10, p. 2867–2891, http://dx.doi.org/10.1016/j.comnet.2006.11.028.

[11] H. ZHANG, G. NEGLIA, D. TOWSLEY, G. LO PRESTI. *Stability and Efficiency of Unstructured File Sharing Networks*, in "IEEE Journal on Selected Areas in Communications", September 2008, vol. 26, n° 7, p. 1284–1294.

Publications of the year

Articles in International Peer-Reviewed Journals

[12] U. G. ACER, P. GIACCONE, D. HAY, G. NEGLIA, S. TARAPIAH. *Timely Data Delivery in a Realistic Bus Network*, in "IEEE Transactions on Vehicular Technology", March 2012, vol. 61, n° 3, p. 1251–1265 [*DOI :* 10.1109/TVT.2011.2179072], http://hal.inria.fr/hal-00759357.

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

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[21] R. COMBES, Z. ALTMAN, E. ALTMAN. *Self-Organizing Relays: Dimensioning, Self-Optimization, and Learning*, in "IEEE Transactions on Network and Service Management", December 2012, vol. 9, n° 4, p. 487–500, http://dx.doi.org/10.1109/TNSM.2012.082512.120252.

[22] O. CZERNIAK, E. ALTMAN, U. YECHIALI. *Orchestrating parallel TCP connections: Cyclic and probabilistic polling policies*, in "Performance Evaluation", March-April 2012, vol. 69, n° 3-4, p. 150–163, Selected papers from ValueTools 2009, http://dx.doi.org/10.1016/j.peva.2011.04.003.

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Systems (BIONETICS 2011), York, UK, December 5-6, 2011, Revised Selected Papers", LNICST, 2012, vol. 103, p. 115–124, Work-in-Progress Paper, http://dx.doi.org/10.1007/978-3-642-32711-7_9.

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[47] *Best Paper*
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