Activity Report 2015

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

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2. Overall Objectives

2.1. Presentation of MAESTRO

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

3. Research Program

3.1. Research Directions

MAESTRO's research directions belong to five main themes motivated by direct applications: network science, wireless networks, network engineering games, green networking and smart grids, content-oriented systems. These directions are very connected: network engineering games find applications in many networking fields, from wireless protocols to applications such as social networks. Green IT studies are often concerned with wireless networks, etc. The study of these applications often raises questions of methodological nature, less close to direct applications; these advances are reported in a separate section.

3.1.1. Network Science

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

3.1.2. Wireless Networks

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

3.1.3. Network Engineering Games

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

3.1.4. Green Networking and Smart Grids

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

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

3.1.5. Content-Oriented Systems

We generally study problems related with the placement and the retrieval of data in communication networks.

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

We also study other aspects related to replication and placement of data: how much to replicate it and on which servers to place it? Finally, we study optimal ways of retrieving the data through prefetching.

3.1.6. Advances in Methodological Tools

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

3.2. Scientific Foundations

The main mathematical tools and formalisms used in MAESTRO include:

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

4. Application Domains

4.1. Main Application Domains

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

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

5. Highlights of the Year

5.1. Highlights of the Year

- Project P11 "Data Communication Network Performance" with ALSTOM Transport (see §8.1.3) that was originally planned until May 2015 was extended for one additional year.
- The demonstration "Quantum random walk in networks" made at Bell Labs Future X days (Openday), Paris, France , on 10-11 June 2015 was the subject of an article in the journal *Industries & Technologies* titled "Une méthode quantique pour prédire l'évolution des réseaux". (Link for subscribers only: http://www.industrie-techno.com/une-methode-quantique-pour-predire-l-evolution-des-reseaux.38856.)
- Giovanni Neglia was invited to give a 20-hour PhD course on Complex Networks at the Univ. of Pisa, Italy, on 23-27 March 2015.
- 2015 is the 7th year of official collaboration with Indian institutions (IISc and IIT Mumbai).

6. New Software and Platforms

6.1. marmoteCore

Markov Modeling Tools and Environments - the Core
KEYWORDS: Modeling - Stochastic models - Markov model
FUNCTIONAL DESCRIPTION

marmoteCore is a C++ environment for modeling with Markov chains. It consists in a reduced set of high-level abstractions for constructing state spaces, transition structures and Markov chains (discrete-time and continuous-time). It provides the ability of constructing hierarchies of Markov models, from the most general to the particular, and equip each level with specifically optimized solution methods.

This software is developed within the ANR MARMOTE project: ANR-12-MONU-00019.

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- URL: http://marmotecore.gforge.inria.fr/

6.2. ns-3

KEYWORDS: Simulation - Communication networks
FUNCTIONAL DESCRIPTION

ns-3 is a discrete-event network simulator for Internet systems, targeted primarily for research and educational use.

In the framework of the research project with ALSTOM Transport (see §8.1.3), we have extensively validated several modules of ns-3, related to the PHY and the MAC layers. We have implemented a directional antenna using 3-dimensional data for the radiation diagram. Modules related to the Automatic Train Protection function used in train systems have been implemented and validated. Last, we have developped objects that allow to generate easily simulation scenarios.

- Participants: Sara Alouf, Abdulhalim Dandoush, Giovanni Neglia and Alina Tuholukova

7. New Results

7.1. Network Science

Participants: Eitan Altman, Konstantin Avrachenkov, Arun Kadavankandy, Jithin Kazhuthuveettil Sreedharan, Hlib Mykhailenko, Philippe Nain, Giovanni Neglia, Yonathan Portilla, Alexandre Reiffers-Masson.

7.1.1. Posting behavior in Social Networks and Content Active Filtering

In [57], Alexandre Reiffers-Masson and Eitan Altman in collaboration with Yezekael Hayel (UAPV), model the posting behavior in Social Networks in topics which have negative externalities, and propose content active filtering in order to increase content diversity. By negative externalities, it is meant that when the quantity of posted contents about some topic increases the popularity of posted contents decreases. They introduce a dynamical model to describe the posting behavior of users taking into account these externalities. Their model is based on stochastic approximations and sufficient conditions are provided to ensure its convergence to a unique rest point. They provide a closed form expression for this rest point. Content Active Filtering (CAF) are actions taken by the administrator of the Social Network in order to promote some objectives related to the quantity of contents posted in various topics. As objective of the CAF they consider maximizing the diversity of posted contents.

7.1.2. Network centrality measures

Recent papers studied the control of spectral centrality measures of a network by manipulating the topology of the network. In [56], Alexandre Reiffers-Masson, Eitan Altman and Yezekael Hayel (UAPV) extend these works by focusing on a specific spectral centrality measure, the Katz-Bonacich centrality. The optimization of the Katz-Bonacich centrality using a topological control is called the Katz-Bonacich optimization problem. The authors first prove that this problem is equivalent to a linear optimization problem. Thus, in the context of large graphs, one can use state-of-the-art algorithms. The authors provide a specific applications of the Katz-Bonacich centrality minimization problem based on the minimization of gossip propagation and make some experiments on real networks which validate the model assumptions.

Betweenness centrality is one of the basic concepts in the analysis of social networks. The initial definition for the betweenness of a node in a graph is based on the fraction of the number of geodesics (shortest paths) between any two nodes that this given node lies on, to the total number of the shortest paths connecting these nodes. This method has quadratic complexity and does not take into account indirect paths. In [45] K. Avrachenkov in collaboration with V. Mazalov (Korelian Institute of Applied Mathematical Research, Russia) and B. Tsynguev (Transbaikal State Univ., Russia) propose a new concept of betweenness centrality for weighted networks, called beta current flow centrality, based on Kirchhoff's law for electric circuits. In comparison with the original current flow centrality and alpha current flow centrality, this new measure can be computed for larger networks. The results of numerical experiments for some examples of networks, in particular, for the popular social network VKontakte as well as the comparison with PageRank method are presented.

PageRank has numerous applications in information retrieval, reputation systems, machine learning, and graph partitioning. In [44], K. Avrachenkov and A. Kadavankandy in collaboration with L.O. Prokhorenkova and A. Raigorodskii (both from Yandex Research) study PageRank in undirected random graphs with expansion property. The Chung-Lu random graph represents an example of such graphs. The authors show that in the limit, as the size of the graph goes to infinity, PageRank can be represented by a mixture of the restart distribution and the vertex degree distribution.

7.1.3. Mining social networks

Social Networks became a major actor in information propagation. Using the Twitter popular platform, mobile users post or relay messages from different locations. The tweet content, meaning and location show how an event-such as the bursty one "JeSuisCharlie" happened in France in January 2015 is comprehended in different countries. In [75], [76] researchers from UAPV and Inria (Mohamed Morchid, Yonathan Portilla,

Didier Josselin, Richard Dufour, Eitan Altman, Marc El-Beze, Jean-Valère Cossu, Georges Linarès, Alexandre Reiffers-Masson), studied clustering of the tweets according to the co-occurrence of their terms, including the country, and forecasting the probable country of a non located tweet, knowing its content. First, they present the process of collecting a large quantity of data from the Twitter website. The dataset consists of 2.189 located tweets about "Charlie", from the 7th to the 14th of January. The authors then describe an original method adapted from the Author-Topic (AT) model based on the Latent Dirichlet Allocation method (LDA). They define a homogeneous space containing both lexical content (words) and spatial information (country). During a training process on a part of the sample, the authors provide a set of clusters (topics) based on statistical relations between lexical and spatial terms. During a clustering task, they evaluate the method effectiveness on the rest of the sample that reaches up to 95% of good assignments. It shows that the model is pertinent to foresee tweet location after a learning process.

7.1.4. Analysis of Internet Memes

Memes have been defined by R. Dawkins as cultural phenomena that propagate through non genetic ways. In [42], Eitan Altman and Yonathan Portilla examine three very popular Internet Memes and study their impact on the society in mediterranean countries. the authors use existing software tools (such as Google Trends) as well as tools that they develop in order to quantify the impact of the Memes on the mediterranean societies. The authors obtain quite different results with the different tools they use, which they explain based on some propagation characteristic of each one of the Memes. The analysis shows the extent to which these Memes cross borders and thus contribute to the creation of a globalized culture. The authors finally identify some of the impacts of the globalization of culture.

7.1.5. Trend detection in social networks using Hawkes processes

In [52], Julio Cesar Louzada Pinto and Tijani Chahed (Telecom SudParis) in collaboration with Eitan Altman propose a new trend detection algorithm, designed to find trendy topics being disseminated in a social network. The authors assume that the broadcasts of messages in the social network is governed by a self-exciting point process, namely a Hawkes process, which takes into consideration the real broadcasting times of messages and the interaction between users and topics. The authors formally define trendiness and derive trend indices for each topic being disseminated in the social network. These indices take into consideration the time between the detection and the message broadcasts, the distance between the real broadcast intensity and the maximum expected broadcast intensity, and the social network topology. The proposed trend detection algorithm is simple and uses stochastic control techniques in order to calculate the trend indices. It is also fast and aggregates all the information of the broadcasts into a simple one-dimensional process, thus reducing its complexity and the quantity of data necessary to the detection.

7.1.6. Study of the Youtube recommendation system

The Youtube recommendation system is one the most important view source of a video. In [54], Yonathan Portilla, Alexandre Reiffers-Masson, Eitan Altman in collaboration with Rachid El-Azouzi (UAPV) study the role of recommendation systems in boosting the popularity of videos. The authors first construct a graph that captures the recommendation system in Youtube and study empirically the relationship between the number of views of a video and the average number of views of the videos in its recommendation list. The authors then consider a random walker on the recommendation graph, i.e. a random user that browses through videos such that the video it chooses to watch is selected randomly among the videos in the recommendation list of the previous video it watched. The authors study the stability properties of this random process and show that the trajectory obtained does not contain cycles if the number of videos in the recommendation list is small (which is the case if the computer's screen is small).

7.1.7. Average consensus protocols

In [22] M. El Chamie (Univ. of Washington, USA), G. Neglia and K. Avrachenkov study the weight optimization problem for average consensus protocols by reformulating it as a Schatten norm minimization with parameter p. They show that as p approaches infinity, the optimal solution of the Schatten norm induced problem recovers the optimal solution of the original problem. Moreover, by tuning the parameter p in the

proposed minimization, it is possible to 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). They then propose a distributed algorithm to solve the Schatten norm minimization and show that it outperforms the other distributed weight selection methods.

7.1.8. Estimation techniques

The estimation of a large population's size by means of sampling procedures is a key issue in many networking scenarios. Their application domains span from RFID systems to peer-to-peer networks; from traffic analysis to wireless sensor networks; from multicast networks to WLANs. In [14], N. Accettura (Univ. of California Berkeley, USA), G. Neglia and L. A. Grieco (Politecnico di Bari, Italy) illustrate and classify in a coherent framework the main approaches proposed so far in the computer networks literature to deal with such a problem. In particular, starting from the methodologies proposed in ecological studies since the last century, they survey their counterparts in the computer network domain, finding that many lessons can be gained from this insightful investigation. Capture-Recapture techniques are deeply analyzed to allow the reader to exactly understand their pros, cons, and applicability bounds. Finally, they discuss some open issues that deserve further investigations and could be relevant to afford estimation problems in next generation Internet.

Online social networks (OSN) contain extensive amount of information about the underlying society that is yet to be explored. One of the most feasible technique to fetch information from OSN, crawling through Application Programming Interface (API) requests, poses serious concerns over the the guarantees of the estimates. In [70] J. Sreedharan and K. Avrachenkov in collaboration with B. Ribeiro (Purdue University, USA) focus on making reliable statistical inference with limited API crawls. Based on regenerative properties of the random walks, they propose an unbiased estimator for the aggregated sum of functions over edges and proved the connection between variance of the estimator and spectral gap. In order to facilitate Bayesian inference on the true value of the estimator, they derive the approximate posterior distribution of the estimate. Later the proposed ideas are validated with numerical experiments on inference problems in real-world networks.

7.1.9. Percolation in multilayer networks

In [79], P. Nain and his co-authors (S. Guha and P. Basu from Raytheon BB Technologies, D. Towsley from the Univ. of Massachusetts, C. Capar from Ericsson Research, A. Swami from the US Army Research Lab.) consider multiple networks formed by a common set of users connected via M different means of connectivity, where each user (node) is active, independently, in any given network with probability q. They show that when q exceeds a threshold $q_c(M)$, a giant connected component appears in the M-layer network—thereby enabling faraway users to connect using 'bridge' nodes that are active in multiple network layers, even though the individual layers may only have small disconnected islands of connectivity. They show that $q_c(M) \leq \sqrt{\log(1-p_c)}/\sqrt{M}$, where p_c is the bond percolation threshold of the underlying connectivity graph G, and $q_c(1) \equiv q_c$ is its site percolation threshold. The threshold $q_c(M)$ is found explicitly when G is a large random network with an arbitrary node-degree distribution and numerically for various regular lattices. Finally, an intriguingly close connection between this multilayer percolation model and the well-studied problem of site-bond percolation is revealed, in the sense that both models provide a smooth transition between the traditional site and bond percolation models. This connection is used to translate analytical approximations of the site-bond critical region developed in the 1990s, which are functions only of p_c and q_c of the respective lattice, to excellent general approximations of $q_c(M)$.

7.1.10. Extreme Value Theory for Complex Networks

In [20] J. Sreedharan and K. Avrachenkov in collaboration with N. Markovich (Institute of Control Sciences, Moscow) explore the dependence structure in the sampled sequence of complex networks. They consider randomized algorithms to sample the nodes and study extremal properties in any associated stationary sequence of characteristics of interest like node degrees, number of followers, or income of the nodes in online social networks, which satisfy two mixing conditions. Several useful extremes of the sampled sequence like the kth largest value, clusters of exceedances over a threshold, and first hitting time of a large value are

investigated. The dependence and the statistics of extremes is abstracted into a single parameter that appears in extreme value theory, called the Extremal Index. The authors derive this parameter analytically and also estimate it empirically. They propose the use of the Extremal Index as a parameter to compare different sampling procedures. As a specific example, degree correlations between neighboring nodes are studied in detail with three prominent random walks as sampling techniques.

7.1.11. Random Matrix Theory for Complex Networks

In [68] A. Kadavankandy and K. Avrachenkov in collaboration with L. Cottatellucci (Eurecom) consider an extension of Erdős-Rényi graph known in the literature as the Stochastic Block Model (SBM). They analyze the limiting empirical distribution of the eigenvalues of the adjacency matrix of a SBM. They derive a fixed point equation for the Stieltjes transform of the limiting eigenvalue empirical distribution function (e.d.f.), concentration results on both the support of the limiting e.d.f. and the extremal eigenvalues outside the support of the limiting e.d.f. Additionally, they derive analogous results for the normalized Laplacian matrix and discuss potential applications of the general results in epidemics and random walks.

In [40], the same authors continue with the analysis of eigenvectors of a Stochastic Block Model. The eigenvalue spectrum of the adjacency matrix of a SBM consists of two parts: a finite discrete set of dominant eigenvalues and a continuous bulk of eigenvalues. They characterize analytically the eigenvectors corresponding to the continuous part: the bulk eigenvectors. For symmetric SBM adjacency matrices, the eigenvectors are shown to satisfy two key properties. A modified spectral function of the eigenvalues, depending on the eigenvectors, converges to the eigenvalue spectrum. Its fluctuations around this limit converge to a Gaussian process different from a Brownian bridge. This latter fact disproves that the bulk eigenvectors are Haar distributed.

7.2. Wireless Networks

Participants: Eitan Altman, Abdulhalim Dandoush.

7.2.1. A General SDN-based IoT Framework with NVF Implementation

The emerging technologies of IoT (Internet of Things), SDN (Software Defined Networking), and NFV (Network Function Virtualization) have a great potential for the information service innovation in the Cloud and big data era. In [26], Jie Li (Tsukuba Univ.) in cooperation with Eitan Altman and with Corinne Touati (Inria Grenoble-Rhône-Alpes) have studied architecture issues in Internet of Things based on SDN with NFV implementation. The contribution of the paper is in providing a view point for integrating these technologies based on their existing standards.

7.2.2. Self-Organizing Network (SON)

Self-Organizing Network (SON) technology aims at autonomously deploying, optimizing and repairing the Radio Access Networks. In [31], Abdoulaye Tall, Zwi Altman (Orange, Issy les Moulineaux) and Eitan Altman showed that in certain cases, it is essential to take into account the impact of the backhaul state in the design of the SON algorithm. They revisit the Base Station load definition taking into account the backhaul state. They provide an analytical formula for the load along with a simple estimator for both elastic and guaranteed bit-rate traffic. They incorporate the proposed load estimator in a self-optimized Load Balancing algorithm. Simulation results for a backhaul constrained heterogeneous network illustrate how the correct load definition can guarantee a proper operation of the SON algorithm.

SON is further studied by these authors in [58], [59] where the Vertical Sectorization (VS) is adapted. VS consists in creating vertically separated sectors in the original cell using an Active Antenna Systems (AAS) supporting two distinct beams with different downtilts. The total transmit power is split between the two sectors, while the frequency bandwidth can be reused by each sector, creating additional interference between the two sectors. For low traffic demand, VS may lead to performance degradation, while for high traffic demand in both sectors, VS is likely to bring about important capacity gains. Hence intelligent activation policy of VS is needed to fully benefit from this feature. The authors propose an approach taking advantage of the more

focused downtilted beam. A dynamic alpha fair bandwidth sharing is proposed for low and medium load. It is autonomously replaced by full bandwidth reuse for high load scenarios using a threshold-based controller. A flow-level dynamic simulator is used to numerically validate the proposed mechanisms.

7.2.3. Automated Dynamic Offset for Network Selection in Heterogeneous Networks

Complementing traditional cellular networks with the option of integrated small cells and WiFi access points can be used to further boost the overall traffic capacity and service level. Small cells along with WiFi access points are projected to carry over 60% of all the global data traffic by 2015. With the integration of small cells on the radio access network levels, there is a focus on providing operators with more control over small cell selection while reducing the feedback burden. Altogether, these issues motivate the need for innovative distributed and autonomous association policies that operate on each user under the network operator's control, utilizing only partial information, yet achieving near-optimal solutions for the network. In [25], Majed Haddad (UAPV), Piotr Wiecek (Institute of Mathematics and Computer Science, Wroclaw), Saidi Habib (Inria project-team DYOGENE) and Eitan Altman propose a load-aware network selection approach applied to automated dynamic offset in heterogeneous networks. In particular, they investigate the properties of a hierarchical (Stackelberg) Bayesian game framework, in which the macro cell dynamically chooses the offset about the state of the channel in order to guide users to perform intelligent network selection decisions between macro cell and small cell networks. The authors effectively address the problem of how to intelligently configure a dynamic offset which optimizes network's global utility while users maximize their individual utilities.

7.2.4. Localization in ad-hoc wireless sensors networks

Range-based localization algorithms in wireless sensor networks are more accurate but also more computationally complex than the range-free algorithms. The work on this topic by M. S. Elgamel (Arab Academy for Science, Technology & Maritime Transport, Egypt) and A. Dandoush, previously reported, has been published in [23].

7.3. Network Engineering Games

Participants: Eitan Altman, Konstantin Avrachenkov, Giovanni Neglia.

7.3.1. Matching games and the association problem

In [33], Mikaël Touati, Jean-Marc Kélif (Orange Labs), Rachid El-Azouzi (UAPV), Marceau Coupechoux (Telecom ParisTech) and Eitan Altman propose two new algorithms for finding stable structures in ordinal coalition potential games. The first one is enumerative and it performs on a graph. The second one is a modified Deferred Acceptance Algorithm using counter-proposals. It finds a many-to-one matching. The authors illustrate with the example of video caching from a content creator's servers to a service provider's servers.

This is applied to the association of mobiles to IEEE 802.11-based WLANs in populated areas where many mobile terminals are covered by several Access Points (APs) [32]. These mobiles have the possibility to associate to the AP with the strongest signal (best-RSSI association scheme). This can lead to poor performances and overloaded APs. Moreover, the well-known anomaly in the protocol at the MAC layer may also lead to very unpredictable performances and affect the system throughput due to the presence of heterogeneous data rate nodes and the shared nature of the 802.11 medium. In [61], the same authors solve the joint resource allocation and mobile user association after modeling it as a matching game with complementarities, peer effects and selfish players.

7.3.2. Normalized Nash Equilibria for power control with correlated constraints

When correlated constraints are introduced to a game (i.e. the set of actions of a player depends on the policies of other players) there may exist infinitely many Nash equilibria. Assume one wishes to select a particular one u. According to the Karush Kuhn Tucker theorem, there exist Lagrange mutipliers such that the best response when all players use their equilibrium policy is the same as that obtained by optimizing the corresponding Lagrangian of that player. The Lagrange multipliers can be interpreted as marginal costs such that if they are

imposed on the player as some tax to pay then this induces the player to use Nash equilibrium. The following question arises: does there exist an equilibrium u for which the corresponding Lagrange multipliers are player independent. If the answer is positive then this would make in many cases the billing scalable and simple to implement. An equilibrium u for which the corresponding Lagrange multipliers are player independent is called a normalized Nash equilibrium (NNE). In [39], [50] and [24], Arnob Ghosh (Univ. of Pennsylvania), Laura Cottatellucci (Eurecom) and Eitan Altman provide new conditions for existence and uniqueness of NNE and apply this for power control games arising in cognitive radio [24] and in heterogeneous networks [39], [50].

7.3.3. Admission control to an infinite server queue

In [36], Eitan Altman studies in collaboration with Piotr Wiecek (Wrocław Univ. of Technology) and Arnob Ghosh (Univ. of Pennsylvania) a mean field approximation of the M/M/∞ queueing system. The problem they consider is quite different from standard games of congestion as they consider the case in which higher congestion results in smaller costs per user. This is motivated by a situation in which some TV show is broadcast so that the same cost is needed no matter how many users follow the show. Using a mean-field approximation, they show that this results in multiple equilibria of threshold type which is explicitly computed. The authors further derive the social optimal policy and compute the price of anarchy, and show that the mean-field approximation becomes tight as the workload increases, thus the results obtained for the mean-field model well approximate the discrete one.

7.3.4. Posting Time of Content over a Temporally-Ordered Shared Medium

In [17], Eitan Altman in collaboration with Nahum Shimkin (Technion) consider a game of timing between a random number of content creators, who compete for position and exposure time over a shared medium such as an on-line classified list. Contents (such as ads, messages, multimedia items or comments) are ordered according to their submission times, with more recent submissions displayed at the top (and better) positions. The instantaneous effectiveness of each ad depends on its current display position, as well as on a time-dependent exposure function common to all. Each content creator may choose the submission time of her content within a finite time interval, with the goal of maximizing the total exposure of this content. The authors formulate the problem as a non-cooperative game, analyze its symmetric equilibrium, characterize it in terms of a differential boundary value problem and devise a numerical scheme for its computation.

7.3.5. Routing Games

A central question in routing games has been to establish conditions for the uniqueness of the equilibrium, either in terms of network topology or in terms of costs. This question is well understood in two classes of routing games. The first is the non-atomic routing introduced by Wardrop on 1952 in the context of road traffic in which each player (car) is infinitesimally small; a single car has a negligible impact on the congestion. Each car wishes to minimize its expected delay. Under arbitrary topology, such games are known to have a convex potential and thus a unique equilibrium. The second framework is splitable atomic games: there are finitely many players, each controlling the route of a population of individuals (let them be cars in road traffic or packets in the communication networks). In [64], Eitan Altman and Corinne Touati (Inria Grenoble-Rhône-Alpes) study two other frameworks of routing games in which each of several players has an integer number of connections (which are population of packets) to route and where there is a constraint that a connection cannot be split. Through a particular game with a simple three link topology, they identify various novel and surprising properties of games within these frameworks. The authors show in particular that equilibria are non unique even in the potential game setting of Rosenthal with strictly convex link costs. They further show that non-symmetric equilibria arise in symmetric networks.

7.3.6. Resilience of Routing in Parallel Link Networks

Aniruddha Singhal, Corinne Touati (both from Inria Grenoble-Rhône-Alpes) in collaboration with Eitan Altman and Jie Li (Univ. of Tsukuba) revisit in [63], the resilience problem of routing traffic in a parallel link network model with a malicious player using a game theoretic framework. Consider that there are two players in the network: the first player wishes to split its traffic so as to minimize its average delay, which the

second player, i.e., the malicious player, tries to maximize. The first player has a demand constraint on the total traffic it routes. The second player controls the link capacities: it can decrease by some amount the capacity of each link under a constraint on the sum of capacity degradation. The authors first show that the average delay function is convex both in traffic and in capacity degradation over the parallel links and thus does not have a saddle point. They identify best responses strategies of each player and compute both the max-min and the min-max values of the game. One is especially interested in the min-max strategy as it guarantees the best performance under worst possible link capacity degradation. It thus allows to obtain routing strategies that are resilient and robust. The authors compare the results of the min-max to those obtained under the max-min strategies. They provide stable algorithms for computing both max-min and min-max strategies as well as for best responses.

7.3.7. The Social Medium Selection Game

In [72], Fabrice Lebeau (ENS Lyon) Corinne Touati and Nof Abuzainab (Inria Grenoble-Rhône-Alpes) in collaboration with Eitan Altman, consider competition of content creators in routing their content through various media. The routing decisions may correspond to the selection of a social network (e.g. twitter versus facebook or linkedin) or of a group within a given social network. The utility for a player to send its content to some medium is given as the difference between the dissemination utility at this medium and some transmission cost. The authors model this game as a congestion game and compute the pure potential of the game. In contrast to the continuous case, they show that there may be various equilibria. The authors show that the potential is M-concave which allows them to characterize the equilibria and to propose an algorithm for computing it. They then give a learning mechanism which leads to an efficient algorithm to determine an equilibrium. The authors finally determine the asymptotic form of the equilibrium and discuss the implications on the social medium selection problem.

7.3.8. Activation Games in Online Dating Platforms

In [41], Eitan Altman in collaboration with Francesco De Pellegrini (CREATE-NET, Trento) and Huijuan Wang (Delft Univ. of Technology) describe a model for the activation level of users in online dating platforms (ODPs). Such popular systems are conceived in order to match individuals from two groups of potential mates. The business of such platforms pivots around the customers' expectancy to get in contact with their future dates: upon the payment of a fee to the platform owner, ODPs provide specific tools to improve reach and visibility. However, ODPs require a critical number of active users in order to sustain their operations (and their business). Customers of the platform trade off on the price for being more visible and attract mates' contacts. A user becomes inactive if he or she is not contacted by others for some time: being contacted by potential mates acts as an activation signal. The aim of the analysis is to propose a game theoretical framework to capture such a complex activation problem in strategic form. The authors unveil the structure of Nash equilibria and further derive a Stackelberg formulation. The latter is a hierarchical game where the platform owner aims at maximizing profits while preserving the ODP activity level above a critical epidemic threshold.

7.3.9. Epidemics in Networks

Stojan Trajanovski, Huijuan Wang, Piet Van Mieghem (all from Delft Univ. of Technology), in collaboration with Yezekael Hayel (UAPV) and Eitan Altman have pursued their work in the Congas European project concerning malware attacks modeled as SIS (for Susceptible-Infected-Susceptible) epidemics in networks. In [34], the authors consider decentralized optimal protection strategies when a virus is propagating over a network. they assume that each node in the network can fully protect itself from infection at a constant cost, or the node can use recovery software, once it is infected. They model the system using a game theoretic framework and find pure, mixed equilibria, and the Price of Anarchy (PoA) in several network topologies. Further, they propose both a decentralized algorithm and an iterative procedure to compute a pure equilibrium in the general case of a multiple communities network. Finally, the authors evaluate the algorithms and give numerical illustrations of all results.

They then considered the game-formation problem while balancing multiple, possibly conflicting objectives like cost, high performance, security and resiliency to viruses. In [60], Stojan Trajanovski, Fernando Antonio Kuiper and Piet Van Mieghem (all from Delft Univ. of Technology) in collaboration with Yezekael Hayel (UAPV) and Eitan Altman use a game-formation approach to network design where each player (node), aims to collectively minimize the cost of installing links, of protecting against viruses, and of assuring connectivity. In the game, minimizing virus risk as well as connectivity costs results in sparse graphs. They show that the Nash Equilibria are trees that, according to the Price of Anarchy (PoA), are close to the global optimum, while the worst-case Nash Equilibrium and the global optimum may significantly differ for small infection rate and link installation cost. Moreover, the types of trees, in both the Nash Equilibria and the optimal solution, depend on the virus infection rate, which provides new insights into how viruses spread: for a high infection rate, the path graph is the worst- and the star graph is the best-case Nash Equilibrium. However, for small and intermediate infection rates, trees different from the path and star graphs may be optimal.

7.3.10. Retrial games

In [46] K. Avrachenkov in collaboration with E. Morozov and R. Nekrasova (both from Petrozavodsk State Univ., Russia) consider a single-server retrial system with one and several classes of customers. In the case of several classes, each class has its own orbit for retrying customers. The retrials from the orbits are generated with constant retrial rates. In the single class case, the objective is finding an optimal retrial rate. Whereas in the multi-class case, a game theoretic framework is used and equilibrium retrial rates are found. The performance criteria balance the number of retrials per retrying customer with the number of unhappy customers.

7.3.11. Cooperative Network Design

The Network Design problem has received increasing attention in recent years. Previous works have addressed this problem considering almost exclusively networks designed by selfish users, which can be consistently suboptimal. In [18] K. Avrachenkov, J. Elias (Univ. Paris Descartes, France), F. Martignon (Univ. Paris Sud, France), G. Neglia and L. Petrosyan (St. Petersburg State Univ.) address the network design issue using cooperative game theory, which permits to study ways to enforce and sustain cooperation among users. Both the Nash bargaining solution and the Shapley value are widely applicable concepts for solving these games. However, the Shapley value presents several drawbacks in this context. For this reason, they solve the cooperative network design game using the Nash bargaining solution (NBS) concept. More specifically, they extend the NBS approach to the case of multiple players and give an explicit expression for users' cost allocations. They further provide a distributed algorithm for computing the Nash bargaining solution. Then, they compare the NBS to the Shapley value and the Nash equilibrium solution in several network scenarios, including real ISP topologies, showing its advantages and appealing properties in terms of cost allocation to users and computation time to obtain the solution.

Numerical results demonstrate that the proposed Nash bargaining solution approach permits to allocate costs fairly to users in a reasonable computation time, thus representing a very effective framework for the design of efficient and stable networks.

7.4. Green Networking and Smart Grids

Participants: Sara Alouf, Eitan Altman, Alberto Benegiamo, Alain Jean-Marie, Giovanni Neglia.

7.4.1. Energy efficiency and management in wireless networks

In [35], Rodrigo A. Vaca Ramirez and John S. Thompson (Univ. of New England), in collaboration with Eitan altman and Victor Ramos Ramos (UAM - Univ. Autonoma Metropolitana Unidad Iztapalapa) consider a low complexity virtual Multiple-input Multiple-output (MIMO) coalition formation algorithm. The goal is to obtain improvements in energy efficiency by forming multi-antenna virtual arrays for information transmission in the uplink. Virtual arrays are formed by finding a stable match between single antenna devices such as mobile station (MS) and relay stations (RS) by using a game theoretic approach derived from the concept of the college admissions problem. They focus on enhancing the MS performance by forming virtual coalitions with the RSs. Thus, power savings are obtained through multi-antenna arrays by implementing the

concepts of spatial diversity and spatial multiplexing for uplink transmission. They focus on optimizing the overall consumed power rather than the transmitted power of the network devices. Furthermore, it is shown analytically and by simulations that when overall consumed power is considered as an optimization metric, the energy efficiency of the single antennas devices is not always improved by forming a virtual MIMO array. Hence, single antenna devices may prefer to transmit on their own when channel conditions are favorable. In addition, the simulation results show that the proposed framework provides comparable energy savings and a lower implementation complexity when compared to a centralized exhaustive search approach that is coordinated from the Base Station.

Sara Alouf, Ioannis Dimitriou (now at Univ. Patras, Greece) and Alain Jean-Marie had worked on the modeling of wireless communication base stations with autonomous energy supply (solar, wind). They had proposed a versatile 5-dimensional Markov model of the device, and shown that the Quasi Birth-Death framework is adequate for solving the model. This work has been completed with a companion product-form model based on E. Gelenbe's modeling of energy networks with signals [48].

7.4.2. Stochastic Geometric Models for Green Networking

In [16], Eitan Altman in collaboration with Cengis Hasan, Manjesh Kumar Hanawal (IIT Mumbai), Shlomo Shamai (Technion), Jean-Marie Gorce (Inria project-team SOCRATE), Rachid El-Azouzi (UAPV) and Laurent Roullet (Alcatel Lucent Bell Labs) study both the uplink and downlink energy efficiency based on the assumption that base stations are distributed according to an independent stationary Poisson point process. This type of modeling allows to make use of the property that the spatial distribution of the base stations after thinning (switching-off) is still a Poisson process. This implies that the probability of the SINR can be kept unchanged when switching-off base stations provided that one scales up the transmission power of the remaining base stations. The authors then solve the problem of optimally selecting the switch-off probabilities so as to minimize the energy consumptions while keeping unchanged the SINR probability distribution. They then study the trade-off in the uplink performance involved in switching-off base stations. These include energy consumption, the coverage and capacity, and the impact on amount of radiation absorbed by the transmitting user.

7.4.3. Direct Load Control

Energy demand and production need to be constantly matched in the power grid. The traditional paradigm to continuously adapt the production to the demand is challenged by the increasing penetration of more variable and less predictable energy sources, like solar photovoltaics and wind power. An alternative approach is the so called direct control of some inherently flexible electric loads to shape the demand. Direct control of deferrable loads presents analogies with flow admission control in telecommunication networks: a request for network resources (bandwidth or energy) can be delayed on the basis of the current network status in order to guarantee some performance metrics. In [53] G. Neglia, in collaboration with G. Di Bella (Telecom Italia, Italy), L. Giarré and I. Tinnirello (Univ. of Palermo, Italy) go beyond such an analogy, showing that usual teletraffic tools can be effectively used to control energy loads. In particular they propose a family of control schemes which can be easily tuned to achieve the desired trade-off among resources usage, control overhead and privacy leakage.

7.4.4. Charge of Electric Vehicles

The massive introduction of Electric Vehicles (EVs) will make fleet managers spend a significant amount of money to buy electric energy. If energy price changes over time, accurate scheduling of recharging times may result in significant savings. In [29] C. Rottondi (IDSIA Dalle Molle Institute for Artificial Intelligence, Switzerland), G. Neglia and G. Verticale (Politecnico di Milano, Italy) evaluate the complexity of the optimal scheduling problem considering a scenario with a fleet manager having full knowledge of the customers' traveling needs at the beginning of the scheduling horizon. They prove that the problem has polynomial complexity and provide complexity lower and upper bounds. Moreover, they propose an online sub-optimal scheduling heuristic that schedules the EVs' recharge based on historical travelling data. They compare the performance of the optimal and sub-optimal methods to a benchmark online approach that does not rely on any

prior knowledge of the customers' requests, in order to evaluate whether the additional complexity required by the proposed strategies is worth the achieved economic advantages. Numerical results show up to of 35% cost savings with respect to the benchmark approach.

7.5. Content-Oriented Systems

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

7.5.1. Modeling modern DNS caches

Sara Alouf and Nicaise Choungmo Fofack (former PhD student at MAESTRO, currently at Ingima) have thoroughly revised their study of the modern behavior of DNS caches. In particular the closure properties of the class of distributions called *diagonal matrix-exponential* are fully derived, hence the analytic models presented in [78] to study tree of caches with general caching durations are extended to the case of polytrees [15].

7.5.2. Data placement and retrieval in distributed/peer-to-peer systems

In previous years, Alain Jean-Marie and collaborators from the Univ. Montpellier have defined a family of combinatorial designs that minimize the variance in the availability of replicated documents in unreliable infrastructures. Then with Jean-Claude Bermond (CNRS, with the Inria project-team COATI), Dorian Mazauric (now with Inria project-team ABS) and Joseph Yu (UFV Vancouver), it was shown that *well-balanced families* solve the problem, and such families were constructed for small numbers of replicas. This work is now published in [21]. During the internship of Mikhail Grigorev, several methods for generating at random good solutions have been investigated.

7.5.3. Fairness in caching systems

Data offloading from the cellular network to lowcost WiFi has been the subject of several research works in the last years. In-network caching has also been studied as an efficient means to further reduce cellular network traffic. In [49] M. El Chamie (Univ. of Washington, USA), C. Barakat (Inria project-team DIANA) and G. Neglia consider a scenario where mobile users can download popular contents (e.g., maps of a city, shopping information, social media, etc.) from WiFi-enabled caches deployed in an urban area. They study the optimal distribution of contents among the caches (i.e., what contents to put in each cache) to minimize users' access cost in the whole network, and argue that this optimal distribution does not necessarily provide geographic fairness, i.e., users at different locations can experience highly variable performance. In order to mitigate this problem, they propose two different cache coordination algorithms based on gossiping. These algorithms achieve geographic fairness while preserving the minimum access cost for end users.

In [43] K. Avrachenkov in collaboration with V.S. Borkar (IIT Mumbai, India) consider the task of scheduling a crawler to retrieve from several sites their ephemeral content. This is content, such as news or posts at social network groups, for which a user typically loses interest after some days or hours. Thus development of a timely crawling policy for ephemeral information sources is very important. The authors first formulate this problem as an optimal control problem with average reward. The reward can be measured in terms of the number of clicks or relevant search requests. The problem in its exact formulation suffers from the curse of dimensionality and quickly becomes intractable even with moderate number of information sources. Fortunately, this problem admits a Whittle index, a celebrated heuristics which leads to problem decomposition and to a very simple and efficient crawling policy. The Whittle index is derived, together with its theoretical justification.

7.6. Advances in Methodological Tools

Participants: Eitan Altman, Konstantin Avrachenkov, Ilaria Brunetti.

7.6.1. Control theory

In [19] K. Avrachenkov in collaboration with O. Habachi (UAPV) and A. Piunovskiy and Y. Zhang (both from Univ. of Liverpool, UK) investigate infinite horizon deterministic optimal control problems with both gradual and impulsive controls, where any finitely many impulses are allowed simultaneously. Both discounted and long run time average criteria are considered. They establish very general and at the same time natural conditions, under which the dynamic programming approach results in an optimal feedback policy. The established theoretical results are applied to the Internet congestion control, and by solving analytically and nontrivially the underlying optimal control problems, they obtain a simple threshold-based active queue management scheme, which takes into account the main parameters of the transmission control protocols, and improves the fairness among the connections in a given network.

7.6.2. Game theory

7.6.2.1. Evolutionary games

Standard Evolutionary Game framework is a useful tool to study large interacting systems and to understand the strategic behavior of individuals in such complex systems. Adding an individual state to model a local feature of each player in this context, allows one to study a wider range of problems in various application areas as networking, biology, etc. In [47], Ilaria Brunetti and Eitan Altman in collaboration with Yezekael Hayel (UAPV) introduce such an extension of evolutionary game framework and particularly, focus on the dynamical aspects of this system. Precisely, the authors study the coupled dynamics of the strategies and the individual states inside a population of interacting individuals. They consider here a two-strategies evolutionary game. They first obtain a system of combined dynamics and they show that the rest-points of this system are equilibria of the evolutionary game with individual state. Second, by assuming two different time scales between states and strategy dynamics, one can compute explicitly the equilibria. Then, by transforming the evolutionary game with individual states into a standard evolutionary game, the authors obtains an equilibrium which is equivalent, in terms of occupation measure, to the previous one. Finally, they show a generalization of the model. All the results are illustrated with numerical results.

7.6.2.2. Stochastic Games

Motivated by uncertainty in the value of the interest rate, in [62] K. Avrachenkov in collaboration with A. Varava (KTH, Sweden) study discounted zero-sum stochastic games with and arbitrary discount factor. Their general goal is to obtain a power series expansion of the value of the game with respect to the discount factor around its nominal value. They consider a specific but important class of stochastic games – completely mixed stochastic games. As an illustrative example they take a tax evasion model.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

MAESTRO members are involved in the

- Inria Alcatel-Lucent Bell Labs joint laboratory: the joint laboratory consists of six ADRs (Action de Recherche/Research Action) in its second phase (starting October 2012). MAESTRO members participate in two ADRs (see §8.1.1 and §8.1.2).
- Inria ALSTOM joint laboratory: the joint laboratory consists of four projects. MAESTRO members participate in project P11 (see §8.1.3).

8.1.1. ADR "Self-Organized Networks in Wireless" (July 2008 – June 2016)

Participant: Eitan Altman.

- Contractor: Alcatel-Lucent Bell Labs (http://www.alcatel-lucent.com/bell-labs)
- Collaborators: Laurent Roullet (coordinator), Véronique Capdevielle.

Coordinator for Inria: Bruno Gaujal (team MESCAL).

During the investigations carried out within this ADR, in collaboration with Alcatel-Lucent Bell Labs and WIRELESS ENB teams (System Engineering and Modem), three technical solutions to the LTE Mobility State Estimation problem have been proposed. In particular,

- Three patents have been submitted and filed (two in 2013, and one in 2014);
- A white paper written by the joint team (Inria/Bell-Labs and Wireless SE) summarizing the theoretical baseline of the methods, their performances, as well as the implementation issues, is documented.

These solutions have been set up between Inria and Alcatel-Lucent Bell Labs iteratively after numerous meetings, in order to cope with the product requirements.

8.1.2. ADR "Network Science" (June 2013 – August 2016)

Participants: Konstantin Avrachenkov [coordinator], Jithin Kazhuthuveettil Sreedharan, Philippe Nain, Giovanni Neglia.

- Contractor: Alcatel-Lucent Bell Labs (http://www.alcatel-lucent.com/bell-labs)
- Collaborators: Philippe Jacquet (coordinator), Alonso Silva.

"Network Science" aims at understanding the structural properties and the dynamics of various kind of large scale, possibly dynamic, networks in telecommunication (e.g., the Internet, the web graph, peer-to-peer networks), social science (e.g., community of interest, advertisement, recommendation systems), bibliometrics (e.g., citations, co-authors), biology (e.g., spread of an epidemic, protein-protein interactions), and physics. The complex networks encountered in these areas share common properties such as power law degree distribution, small average distances, community structure, etc. Many general questions/applications (e.g., community detection, epidemic spreading, search, anomaly detection) are common in various disciplines and are being analyzed in this ADR "Network Science". In particular, in the framework of this ADR we are interested in efficient network sampling (see §7.1.2).

8.1.3. Project P11 "Data Communication Network Performance" (December 2013 – May 2016)

Participants: Sara Alouf [coordinator], Konstantin Avrachenkov, Abdulhalim Dandoush, Philippe Nain, Giovanni Neglia, Alina Tuholukova.

- Contractor: ALSTOM Transport (http://www.alstom.com/transport/)
- Collaborators: Pierre Cotelle, Pascal Derouet (coordinator from November 2015), Pierre Dersin, Sébastien Simoens (coordinator until October 2015).

The objective of this study is to build a simulation platform (see §6.2) and develop an evaluation methodology for predicting Quality of Service and availability of the various applications supported by the data communication system of train networks.

8.2. Bilateral Grants with Industry

8.2.1. "Multi-Objective Optimization for LTE-Advanced Networks" (December 2012 – November 2015)

Participant: Eitan Altman.

- Contractor: Orange Labs (http://www.orange.com/en/innovation)
- Collaborators: Zwi Altman, Abdoulaye Tall.

The objective of this Cifre thesis is threefold: (1) to develop solutions based on stochastic approximations and optimal control for the optimization and setting of LTE-Advanced Networks; (2) to develop queuing models to capture the dynamics of the traffic and the physical layer mechanisms (e.g. relay, MIMO, scheduling); and (3) to apply the developed methods to engineering problems such the interference management, load balancing, optimization of coverage and capacity, and mobility management.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR Marmote

Participants: Alain Jean-Marie, Issam Rabhi.

ANR Program: Modèles Numériques (MN) 2012, number ANR-12-MONU-0019

Project title: MARkovian MOdeling Tools and Environments

Duration: January 2013 - June 2017

Coordinator: Alain Jean Marie (Inria)

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

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

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

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. CONGAS

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

Title: Dynamics and COevolution in Multi-Level Strategic INteraction GAmeS

Programm: FP7

Duration: October 2012 - September 2015

Coordinator: Create-Net

Partners:

- iNSPIRE, Create-Net (center for Research and Telecommunication Experimentation for Networked Communities) (Italy)
- Mathematics department, Imperial College of Science, Technology and Medicine (United Kingdom)
- Electrical Engineering, Technion Israel Institute of Technology
- Telecommunications Department, Technische Univ. Delft (Netherlands)
- Computer Science Laboratory, Univ. d'Avignon et des Pays de Vaucluse (France)
- Department of Information Engineering, Univ. di Pisa (Italy)

Inria contact: Konstantin Avrachenkov

Many real world systems possess a rich multi-level structure and exhibit complex dynamics that are the result of a web of interwoven interactions among elements with autonomous decision-making capabilities. CONGAS will develop new mathematical models and tools, rooted in game theory, for the analysis, prediction and control of dynamical processes in such complex systems. It will provide a coherent theoretical framework for understanding the emergence of structure and patterns in such systems, accounting for interactions spanning various scales in time and space, and acting at different structural and aggregation levels. This framework will be built around game theoretical concepts, in particular evolutionary and multi-resolution games, and will include also techniques drawn from graph theory, statistical mechanics, control and optimization theory. Specific attention will be devoted to systems that are prone to intermittency and catastrophic events due to the effect of collective dynamics. The theory developed in the project will be validated by considering three use cases, one on the growth of the Internet, one on business ecosystems and one on viral marketing dynamics in Internet marketplaces. The CONGAS Consortium comprises seven universities and research institution and includes leading scientists in game theory, evolutionary games, complex systems science, network science and data-driven analysis of socio-technical systems.

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

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

9.2.2. Collaborations in European Programs, except FP7 & H2020

Participants: Konstantin Avrachenkov, Abdulhalim Dandoush.

Program: EU COST

Project acronym: ACROSS

Project title: Autonomous Control for a Reliable Internet of Services

Duration: November 2013 - November 2017

Coordinator: Rob Van Der Mei (CWI) and J.L. Van Den Berg (TNO), The Netherlands

Other partners: see http://www.cost-across.nl/

Abstract: Currently, we are witnessing a paradigm shift from the traditional information-oriented Internet into an Internet of Services (IoS). This transition opens up virtually unbounded possibilities for creating and deploying new services. Eventually, the ICT landscape will migrate into a global system where new services are essentially large-scale service chains, combining and integrating the functionality of (possibly huge) numbers of other services offered by third parties, including cloud services. At the same time, as our modern society is becoming more and more dependent on ICT, these developments raise the need for effective means to ensure quality and reliability of the services running in such a complex environment. Motivated by this, the aim of this Action is to create a European network of experts, from both academia and industry, aiming at the development of autonomous control methods and algorithms for a reliable and quality-aware IoS.

9.3. International Initiatives

9.3.1. Inria Associate Teams not involved in an Inria International Labs

9.3.1.1. THANES

Participants: Eitan Altman, Konstantin Avrachenkov, Jithin Kazhuthuveettil Sreedharan, Philippe Nain, Giovanni Neglia, Alexandre Reiffers-Masson.

Title: THeory and Application of NEtwork Science

International Partners (Institution - Laboratory - Researcher):

Purdue Univ. (USA) - Department of Computer Science - Bruno Ribeiro

UFRJ (Brazil) - Department of Computer and Systems Engineering - Edmundo de Souza e Silva, Daniel Ratton Figueiredo, Daniel Sadoc

Duration: 2014 – 2017

See also: https://team.inria.fr/thanes/

Our goal is to study how services in Online Social Networks (OSN) can be efficiently designed and managed. This research requires to answer 3 main questions: 1) How can the topology of an OSN be discovered? Many services need or can take advantage of some knowledge of the network structure that is usually not globally available and in any case changes continuously due to structural dynamics. 2) How does services' adoption spread across the OSN? On the one hand the popularity of a service is determined by word-of-mouth through the links of the OSN and, on the other end, the service may contribute to reshape the structure of the OSN (e.g. by creating new connections). 3) How do different services compete for the finite attention and money of OSN users? In particular our purpose is to provide analytical models (corroborated by simulations and experiments on real networks) to understand such complex interactions.

9.3.2. Inria International Partners

9.3.2.1. Informal International Partners

MAESTRO has continued collaborations with researchers from GERAD, Univ. Montreal (Canada), Flinders Univ. (Australia), National Univ. of Rosario (Argentina), Technion - Israel Institute of Technology (Israel), Univ. of Arizona (USA), Univ. of Illinois at Urbana-Champaign (USA), Univ. of Liverpool (UK), Univ. of Massachusetts at Amherst (USA), Univ. of Florence (Italy), Univ. of Palermo (Italy), Univ. of Twente (The Netherlands) and Petrozavodsk State Univ. (Russia); Ghent Univ. (Belgium); see Sections 9.4.1.1 and 9.4.2.

9.3.3. Participation In other International Programs

MAESTRO has continued collaborations with researchers from IIT Mumbai and IISc Bangalore. In 2015, these collaborations where partly supported by IFCAM and Cefipra.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

9.4.1.1. Professors / Researchers

Giuseppe Bianchi

Date: 9-10 December 2015

Institution: Univ. of Roma (Italy)

Vivek Borkar

Date: 10-18 October 2015

Institution: IIT Mumbai (India)

Jerzy Filar

Date: 6-10 July 2015

Institution: Flinders Univ. (Australia)

Vaishnav Janardhan

Date: 4 March 2015

Institution: Akamai Technologies (USA)

Moshe Haviv

Date: 28 September - 8 October 2015

Institution: Univ. of Jerusalem (Israel)

Jie Li

Date: 13 January - 15 April 2015
Institution: Univ. of Tsukuba (Japan)

Vladimir Mazalov
Date: 14-28 February and 18-24 November 2015
Institution: Russian Academy Of Sciences (Russia)

Leon Petrosjan
Date: 29 July 2015
Institution: St Petersburg Univ. (Russia)

Bruno Ribeiro
Date: 8-26 June 2015
Institution: Carnegie Mellon Univ. (USA)

Matteo Sereno
Date: October 2015 - March 2016
Institution: Univ. of Torino (Italy)

9.4.1.2. Post-doc / Ph.D. students

Tejas Bodas
Date: 15-30 March and 12 October - 11 December 2015
Institution: IIT Mumbai (India)

Rajib Ranjan Maiti
Date: 9-12 March 2015
Institution: CNR Pisa (Italy)

9.4.1.3. Internships

Andrea Cantore
Date: 1 March - 31 August 2015
Institution: Univ. Nice Sophia-Antipolis (France)
Supervisor: Giovanni Neglia

Amal Chaker
Date: 1 March - 31 August 2015
Institution: Univ. Nice Sophia-Antipolis (France)
Supervisor: Giovanni Neglia

Ashish Chandra
Date: 21 May - 20 July 2015
Institution: IIT Mumbai (India)
Supervisor: Konstantin Avrachenkov

Baptiste Goujaud
Date: 1 June - 31 August
Institution: ENS Cachan (France)
Supervisor: Eitan Altman

Mikhail Grigorev
Date: 15 September - 31 October 2015
Institution: MIPT (Russia)
Supervisor: Alain Jean-Marie

Lenar Iskhakov

Date: 15 September - 31 October 2015

Institution: MIPT (Russia)

Supervisor: Konstantin Avrachenkov

Wafa Khlif

Date: 1 March - 31 August 2015

Institution: Univ. Nice Sophia-Antipolis (France)

Supervisor: Sara Alouf

Maksim Mironov

Date: 15 September - 31 October 2015

Institution: MIPT (Russia)

Supervisor: Konstantin Avrachenkov

Dimitra Politaki

Date: 1 March - 31 August 2015

Institution: Univ. Nice Sophia-Antipolis (France)

Supervisor: Sara Alouf

Dimitra Tsigkari

Date: 15 October 2015 - 31 July 2016

Institution: Univ. of Thessaloniki (Greece)

Supervisor: Giovanni Neglia

Alina Tuholukova

Date: 1 March - 31 August 2015

Institution: Univ. Nice Sophia-Antipolis (France)

Supervisor: Konstantin Avrachenkov, Giovanni Neglia

9.4.2. Visits to International Teams

9.4.2.1. Sabbatical programme

Philippe Nain

Date: 1 March 2015 - 29 February 2016

Institution: MIT, Laboratory for Information & Decision Systems - LIDS (USA)

Activities: Besides conducting research with colleagues at MIT, Univ. of Massachusetts in Amherst, MA, and Raytheon BBN Technologies in Cambridge, MA, P. Nain has been asked by Inria to launch new scientific collaborations between Inria and universities of the East Coast and to strengthen existing ones. He attended the Inria-Industry Meeting (San Francisco, May 11, 2015) and the fifth BIS (Berkeley-Inria-Stanford) workshop (Berkeley May 12-14, 2015).

9.4.2.2. Research stays abroad

Eitan Altman

Date: 16-20 February, 21-31 October, 21-28 December 2015

Institution: Technion (Israel)

Date: 27 April - 8 May 2015

Institution: New York Univ. - Tandon School of Engineering (USA)

Date: 20-30 May 2015

Institution: IISc Bangalore and IIT Mumbai (India)

Konstantin Avrachenkov

Date: 2-10 March 2015

Institution: IIT Mumbai (India)

Date: 11-19 May 2015

Institution: Yandex Research (Russia)

Ilaria Brunetti

Date: 5 January - 15 April 2015

Institution: Macquaire Univ. (Australia)

Alain Jean-Marie

Date: 3-25 October 2015

Institution: Univ. of Montreal (Canada)

Date: 7-18 December 2015

Institution: Univ. of Rosario (Argentina)

Jithin Kazhuthuveettil Sreedharan

Date: 1-14 August 2015

Institution: Univ. Federal do Rio de Janeiro (Brazil)

Arun Kadavankandy

Date: 25-29 May 2015

Institution: IIT Mumbai (India)

Philippe Nain

Date: 10-15 May 2015

Institution: Univ. of California, Berkeley (USA)

Date: June 4-6, 14-20, July 13-17, September 20-26, November 15-21, December 6-11 2015

Institution: Univ. of Massachusetts at Amherst (USA)

Giovanni Neglia

Date: 19 and 26 January; 2, 9 and 23 February; 2 and 9 March; 4-7 and 29 May; 13-17 July; 11-14 and 21 September; 22-23 October; 12-17 November 2015

Institution: Univ. of Florence (Italy)

Date: August 1-19 2015

Institution: Univ. Federal do Rio de Janeiro (Brazil)

Alexandre Reiffers-Masson

Date: 1-15 August 2015

Institution: New York Univ. - Tandon School of Engineering (USA)

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

- A. Dandoush was co-chair of the International Workshop on Physics Inspired Paradigms in Wireless Communications and Networks (Physcomnet 2015, Mumbai, India).

- S. Alouf and A. Jean-Marie are the general chairs of the 13th SIGMETRICS/PERFORMANCE Joint International Conference on Measurement and Modeling of Computer Systems (ACM SIGMETRICS/IFIP PERFORMANCE 2016, Antibes Juan-les-Pins, France).

10.1.1.2. Member of the organizing committees

- E. Altman was in the steering committee and an advisor in the organizing committee of 13th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt 2015, Mumbai, India).

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

MAESTRO members were in the TPC of the following events (in alphabetical order):

- 10th ACM MobiCom Workshop on Challenged Networks (CHANTS 2015, Paris, France) (**G. Neglia**)
- 11th Advanced Intl. Conference on Telecommunications (AICT 2015, Brussels, Belgium) (**K. Avrachenkov**);
- IEEE ICC Workshop on Dynamic Social Networks (DySON 2015, London, UK), (**K. Avrachenkov**).
- 35th IEEE Intl. Conference on Computer Communications (IEEE INFOCOM 2016, San Francisco, USA) (**G. Neglia**)
- 7th IEEE Intl. Workshop on Network Science for Communication Networks (IEEE NetSciCom 2015, Hong Kong, PRC) (**K. Avrachenkov**, **G. Neglia**);
- 15th Intl. Conference on Next Generation Wired/Wireless Networking (NEW2AN 2015, St. Petersburg, Russia) (**K. Avrachenkov**);
- 9th Intl. Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2015, Berlin, Germany) (**K. Avrachenkov**, **G. Neglia**)
- 30th Intl. Symposium on Computer and Information Sciences (ISCIS 2015, London, UK) (**A. Jean-Marie**);
- 13th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks (WiOpt 2015, Mumbai, India), (**K. Avrachenkov**);
- 8th Intl. Workshop on Multiple Access Communications (MACOM 2015, Helsinki, Finland) (**K. Avrachenkov**);
- Intl. Workshop on Physics Inspired Paradigms in Wireless Communications and Networks (Physcomnet 2015, Mumbai, India) (**A. Jean-Marie**);
- Musimorphoses (Paris, France)) (**E. Altman**);
- 12th Workshop on Algorithms and Models for the Web Graph (WAW 2015, Eindhoven, The Netherlands) (**K. Avrachenkov**);
- 17th Workshop on Mathematical Performance Modeling and Analysis (MAMA 2015, Portland, Oregon, USA) (**A. Jean-Marie**, **P. Nain**).

10.1.2.2. Reviewer

The members of the team reviewed numerous papers for numerous international conferences.

10.1.3. Journal

10.1.3.1. Member of editorial boards (list in alphabetical order of journal name)

- *Performance Evaluation* (PEVA) (**P. Nain** Editor-in-Chief since 1 January 2008).
- *ACM Transactions on Modeling and Performance Evaluation of Computing Systems* (ToMPECS) (**K. Avrachenkov** since 2015).
- *Dynamic Games and Applications* (DGAA) (**E. Altman** since 2011);
- *Elsevier Computer Communications* (COMCOM) (**G. Neglia** since 2014);
- *IEEE Transactions on Control of Networks* (TCNS) (**E. Altman** since 2013);
- *IEEE/ACM Transactions on Networking* (ToN) (**E. Altman** since 2013);
- *Journal of Economic Dynamics and Control* (JEDC) (**E. Altman** since 2001);
- *Performance Evaluation* (PEVA) (**K. Avrachenkov** since 2008).

10.1.3.2. Reviewer - Reviewing activities (list in alphabetical order of journal name)

- *Computer Communications* (COMCOM) (**S. Alouf**);
- *Computers in Industrial Engineering* (**A. Jean-Marie**);
- *IEEE Trans. on Control of Network Systems* (TCNS) (**A. Reiffers-Masson**);
- *IEEE Trans. on Mobile Computing* (TMC) (**G. Neglia**);
- *Mathematical Problems in Engineering* (**A. Jean-Marie**);
- *Performance Evaluation* (PEVA) (**J. K. Sreedharan**);
- *Social Network Analysis and Mining* (SNAM) (**A. Reiffers-Masson**);

10.1.4. Invited talks

MAESTRO members gave the following invited talks (in alphabetical order):

- *A Markovian queueing system for modeling a smart green base station*, in the series "séminaire Fondation HEC", Gerad, Montréal, Canada, 13 October 2015, (**A. Jean-Marie**);
- *Extremes and Random Walks in Network Sampling Processes*, seminar at Yandex, Russia, 13 May 2015 (**K. Avrachenkov**);
- *Game models in epidemics in networks* seminar at Telecom SudParis on 22 October 2015 (**E. Altman**);
- *Game Theory and Online Social Network* seminar at NYU, New York, USA, August 2015 (**A. Reiffers-Masson**);
- *Graph-based Semi-supervised Learning Methods*, seminar at IIT Mumbai, India, 4 March 2015 (**K. Avrachenkov**);
- *Modeling with Markov chains: the MARMOTE software*, UCN@Sophia Labex seminar, 3 September 2015 (**A. Jean-Marie**);
- *On the convergence of the Rolling Horizon procedure*, 2nd 2015 Meeting of the COS working group of the GdR RO, Paris, 3 December 2015 (**A. Jean-Marie**).

10.1.5. Leadership within the scientific community

- E. Altman is a fellow member of IEEE (Class of 2010).
- E. Altman, A. Jean-Marie and P. Nain are (elected) members of IFIP WG7.3 on "Computer System Modeling".

10.1.6. 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."
- is Scientific coordinator of the European project CONGAS.

K. Avrachenkov

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

A. Jean-Marie

- is the scientific coordinator of Inria activities in Montpellier (since 2008); as part of this duty, he represents Inria at the Scientific Council of the Doctoral School "Sciences and Agrosciences" of the Univ. of Avignon, at the Regional Conference of Research Organisms (CODOR), at the Regional Consulting Committee for Research and Technological Development (ARAGO Committee);
- is a member of the Steering Committee of the GDR RO, a national research initiative on Operations Research sponsored by the CNRS;
- is Head of project-team MAESTRO since October 2014;
- was member of the recruitment committee for a *Maître de Conférences* position at Univ. Paris Est Créteil.

P. Nain

- has been Chairman of Inria's Evaluation Committee from 1 September 2012 to 31 August 2015 (http://www.inria.fr/en/institute/organisation/committees/evaluation-committee).

G. Neglia

- is the scientific delegate for European partnerships for Inria Sophia Antipolis – Méditerranée.

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

- CC (Comité de Centre): General Information Commission (**G. Neglia** since September 2013);
- CLFP: Training Committee (**S. Alouf**, since November 2014);
- CSD: Doctoral Committee (**S. Alouf**, since February 2006);
- MASTIC: a commission in charge of popularization and regional and internal scientific animation (**S. Alouf**, from November 2011 until December 2015);
- NICE: Invited Researchers Committee (**K. Avrachenkov**, since 2010).

MAESTRO members are in charge of the following tasks for the research center and the project-team:

- Supervision and validation of the project-teams' yearly activity reports (**K. Avrachenkov**, since 2010);
- Organizing MAESTRO internal meetings (**J. K. Sreedharan**, since November 2013).

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence:

S. Alouf, "Probability", 33H, 1st year Water Engineering degree (L3), Univ. of Nice Sophia Antipolis (UNS), France.

G. Neglia, "Probability", 18H, 1st year Water Engineering degree (L3), UNS, France.

A. Reiffers-Masson, "Introduction to telecommunications network engineering", 63H, Computer Science Program (L2), Univ. of Avignon (UAPV), France.

Master:

S. Alouf, "Performance Evaluation of Networks", 31.5H, M2 IFI Ubinet, UNS, France.

A. Jean-Marie, "Foundations of Network Modeling", 12H, MPRI, Univ. Paris Diderot/ENS Ulm/Univ. Paris Saclay, France.

G. Neglia, "Distributed Optimization and Games", 31.5H, M2 IFI Ubinet, UNS, France.

G. Neglia, responsible for the "Winter School on Complex Networks", 29H, M1 Computer Science, UNS, France.

K. Avrachenkov, "Random-walk based algorithms for complex network analysis" at "Winter School on Complex Networks", 2H, M1 Computer Science, UNS, France.

A. Reiffers-Masson, "Information theory", 7.5H, Computer Science Program (M1), UAPV, France.

A. Reiffers-Masson, "Radio Interface", 9H, Computer Science Program (M1), UAPV, France.

A. Reiffers-Masson, "Sentimental Analysis", 13.5H, Computer Science Program (M2), UAPV, France.

A. Reiffers-Masson, "Cryptography", 13.5H, Computer Science Program (M2), UAPV, France.

Doctorat:

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

G. Neglia, "PhD School on Network Science", 20H, Univ. of Pisa, Italy.

10.2.2. Supervision

PhD defended:

Ilaria Brunetti, "New approaches to Evolutionary Games and Decision Dynamics", UAPV, 8 December 2015, advisor: Eitan Altman.

Julio Cesar Louzada Pinto, " Dissemination of information in opinion dynamics in social networks", Telecom SudParis, 14 January 2016, advisors: Eitan Altman, Tijani Chahed and Jeremie Jakubowicz.

Alexandre Reiffers-Masson, "Competition over visibility and popularity in on line social networks", UAPV, 12 January 2016, advisors: Eitan Altman and Yezekael Hayel.

Abdoulaye Tall, "Optimization and Self-Optimization for LTE networks", UAPV, 17 December 2015, advisors: Eitan Altman and Zwi Altman.

PhD in progress:

Alberto Benegiamo, "Mathematical tools for smart grids," 1 November 2013 interrupted in 31 August 2015, advisors: Patrick Loiseau (Eurecom) and Giovanni Neglia.

Arun Kadavankandy, "Random Matrix Theory and Complex Networks," 5 March 2014, advisors: Konstantin Avrachenkov and Laura Cottatellucci (Eurecom).

Jithin Kazhuthuveettil Sreedharan, "Diffusion processes in complex networks," 23 July 2013, advisor: Konstantin Avrachenkov.
Hlib Mykhailenko, "Probabilistic approaches for big data analysis," 1 May 2014, advisors: Fabrice Huet (SCALE team) and Philippe Nain.
Yonathan Portilla, "Analysis of social networks," 1 January 2012, advisor: Eitan Altman.

10.2.3. Juries

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

- Nidhi Hegde: "Resource Allocation in Wireless Data Networks", 16 January 2015, UPMC, (**E. Altman** as reviewer);
- Patrick Maillé: "Insights from economic studies of telecommunication networks", 7 October 2015, Univ. de Rennes, (**E. Altman** as reviewer);

and in the Ph.D. committees of (in alphabetical order):

- Ilaria Brunetti: "New approaches to Evolutionary Games and Decision Dynamics", UAPV, 8 Dec. 2015, (**E. Altman** as advisor);
- The Dang Huynh: "Extension de PageRank et application aux réseaux sociaux", Univ. Paris Diderot, 1 June 2015, (**K. Avrachenkov** as reviewer);
- Ovidiu-Constantin Iacoboaiea: "Coordination of self organizaion (SON) functionalities in future radio access networks", Telecom ParisTech, 2 Oct. 2015, (**E. Altman** as reviewer);
- Ane Izagirre: "Interpolation approximations for steady-state performance measures", INSA, Toulouse, 21 September 2015, (**K. Avrachenkov** as reviewer);
- Maialen Larrañaga: "Dynamic control of stochastic and fluid resource-sharing systems", Univ. of Toulouse, 23 September 2015, (**A. Jean-Marie** as reviewer);
- Julio Cesar Louzada Pinto: "Dissemination of information and opinion dynamics in social networks", Telecom SudParis, 14 January 2016, (**E. Altman** as advisor);
- Fatima Zahra Moataz, "Towards Efficient and Fault-Tolerant Optical Networks: Complexity and Algorithms", Univ. of Nice Sophia Antipolis, 30 Oct. 2015, (**A. Jean-Marie** as jury president);
- Alexandre Reiffers-Masson: "Competition over visibility and popularity in on line social networks", UAPV, 12 January 2016, (**E. Altman** as advisor);
- Abdoulaye Tall: "Optimization and Self-Optimization for LTE networks", UAPV, 17 Dec. 2015, (**E. Altman** as advisor).

10.3. Popularization

Activities are presented in chronological order:

- S. Alouf delivered a conference titled "Comment marche le Web ?" at Lycée General et Technologique du Rempart, Marseille, for two classes of high school students (20 March 2015).
- A. Reiffers-Masson participated to the "Fête de la science" at the UAPV, (8 October 2015). His presentation was about Online Social Networks.

S. Alouf is a member of MASTIC, a commission in charge of popularization and regional and internal scientific animation (from November 2011 until December 2015).

10.4. Participation in scientific events

10.4.1. Keynotes, tutorials and invited talks

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

- *Defense strategies against SIS epidemics in networks*, at 6th Conference on Decision and Game Theory for Security (GameSec), London, UK, 4 November 2015 (**E. Altman**);
- *Graph-based semi-supervised learning methods*, at 5th Intl. Conference on Network Analysis (NET), Nizhny Novgorod, Russia, 18 May 2015 (**K. Avrachenkov**);
- *Timelines Analysis and competition over popularity, influence and visibility in social networks*, at IEEE ICC Workshop on Dynamic SOcial Networks (DySON), London, UK, 8 June 2015 (**E. Altman**);

the following tutorials (in alphabetical order):

- *Complex Networks and their Analysis with Random Walks*, at 27th Intl. Teletraffic Congress (ITC 27), Gent, Belgium, 7 September 2015 (**K. Avrachenkov**);

and the following invited talks (in alphabetical order):

- *Competition in social networks*, at "Stochastic networks and stochastic geometry" a conference dedicated to François Baccelli on his 60th birthday, Institut Henri Poincaré, Paris, 12-14 January 2015 (**E. Altman**);
- *Exploration and exploitation in learning in multiobjective MDPs*, at NETLEARN/ORANGE workshop on Learning and Networks, Issy-les-Moulineaux, 9 October 2015 (**E. Altman**);
- *Extremes and Random Walks in Network Sampling Processes*, at EURANDOM workshop on Random Walks on Random Graphs and Applications, Eindhoven, Netherlands, 14-16 April 2015 (**K. Avrachenkov**);
- *Game models in social networks*, at NYU Workshop on Control and Optimization of Network Systems (CONES), New York, USA, 1 May 2015 (**E. Altman**);
- *Performance Evaluation... of a Laser*, at Imperial College, Seminar in the honor of Pr. E. Gelenbe/ ISCIS 2015, London, UK, 23 September 2015 (**A. Jean-Marie**);
- *Spectral Properties of Random Matrices for Stochastic Block Model*, at Intl. Workshop on Physics Inspired Paradigms in Wireless Communications and Networks (PHYSCOMNET), IIT Mumbai, India, 29 May 2015 (**A. Kadavankandy**);
- *Whittle index policy for crawling ephemeral content*, at Workshop on Modern trends in controlled stochastic processes, Univ. of Liverpool, UK, 29 June 2015 (**K. Avrachenkov**).

E. Altman was part of a one hour panel on network neutrality which took place as part of the WiOpt conference in IIT Mumbai, India, 25-29 May, 2015.

10.4.2. Conferences and workshops

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

- Bell Labs Future X days (Openday), Paris, France , 10-11 June 2015 (**J. K. Sreedharan**);
- 12th European Workshop on Performance Engineering (EPEW), Madrid, Spain, 31 August - 1 September 2015 (**A. Jean-Marie**);
- 54th IEEE Conference on Decision and Control (CDC 2015), Osaka, Japan, 15-18 December 2015 (**K. Avrachenkov**, **G. Neglia**);
- 14th IFIP International conference on networking (Networking 2015), Toulouse, France, 20-22 May 2015 (**G. Neglia**);
- 3rd Intl. workshop on Big Data and Social Networking Management and Security (BDSN), Limassol, Cyprus, 7 December 2015 (**A. Reiffers-Masson**);
- 12th Workshop on Algorithms and Models for the Web-graph (WAW), Eindhoven, Netherlands, 10-11 December 2015 (**A. Kadavankandy**);
- 6th Workshop on Dynamic Games in Management Science, Montreal, Canada, 22-23 October 2015, (**I. Brunetti**).

10.4.3. Schools and doctoral courses

MAESTRO members have attended the following events (list in alphabetical order):

- COST ACROSS Summer School on "NFV meets Big Data Architecture and Performance Evaluation" (30H), Würzburg, Germany, 8-15 April 2015 (**A. Dandoush**);
- 12th EDBT Summer School on "Graph Data Management" (26H), Palamós, Spain, 31 August - 4 September 2015 (**H. Mykhailenko**);
- WAW 2015 School on complex networks and graph models (16H), Eindhoven, Netherlands, 7-8 December 2015 (**A. Kadavankandy** and **J. K. Sreedharan**).

11. Bibliography

Major publications by the team in recent years

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

[9] N. CHOUNGMO FOFACK, P. NAIN, G. NEGLIA, D. TOWSLEY. *Performance evaluation of hierarchical TTL-based cache networks*, in "Computer Networks", June 2014, vol. 65, pp. 212-231 [*DOI :* 10.1016/J.COMNET.2014.03.006], https://hal.inria.fr/hal-01094694

[10] F. V. FOMIN, F. GIROIRE, A. JEAN-MARIE, D. MAZAURIC, N. NISSE. *To satisfy impatient Web surfers is hard*, in "Journal of Theoretical Computer Science (TCS)", March 2014, vol. 526, pp. 1-17 [*DOI :* 10.1016/J.TCS.2014.01.009], https://hal.inria.fr/hal-00966985

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Publications of the year

Doctoral Dissertations and Habilitation Theses

[12] I. BRUNETTI. *New approaches to evolutionary game theory and decision dynamics*, Université d'Avignon et des Pays de Vaucluse, December 2015, Ph.D. Thesis

[13] A. REIFFERS-MASSON. *Competition over visibility and popularity in Online Social Networks*, Université d'Avignon et des Pays de Vaucluse, January 2016, Ph.D. Thesis

Articles in International Peer-Reviewed Journals

[14] N. ACCETTURA, G. NEGLIA, L. A. GRIECO. *The Capture-Recapture approach for population estimation in computer networks*, in "Computer Networks (Elsevier)", October 2015, vol. 89, pp. 107-122 [*DOI :* 10.1016/J.COMNET.2015.07.013], https://hal.inria.fr/hal-01255730

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