Activity Report 2018

Project-Team Neo

Network Engineering and Operations

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Networks and Telecommunications

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1. Team, Visitors, External Collaborators

Research Scientists

Alain Jean-Marie [Team leader, Inria, Senior Researcher]
Sara Alouf [Inria, Researcher, HDR]
Eitan Altman [Inria, Senior Researcher, HDR]
Konstantin Avrachenkov [Inria, Senior Researcher, HDR]
Giovanni Neglia [Inria, Researcher, HDR]

Post-Doctoral Fellows

Nicolas Allegra [Inria, from Sep 2018]
Swapnil Dhamal [Inria]
Albert Sunny [Inria, until Apr 2018]
Chuan Xu [Inria, from Nov 2018]

PhD Students

Zaid Allybokus [Huawei]
Abhishek Bose [Inria, from Jun 2018]
Said Boularouk [Univ. d'Avignon et des pays du Vaucluse]
Mandar Datar [Inria, from May 2018]
Maximilien Dreveton [Inria, from Oct 2018]
Guilherme Iecker Ricardo [Institut Telecom, from Sep 2018]
Marie Masson [Orange]
Dimitra Politaki [Univ. de Nice - Sophia Antipolis]

Technical staff

Gagan Deep Singh Chhabra [Inria, until Oct 2018]

Administrative Assistant

Laurie Vermeersch [Inria]

2. Overall Objectives

2.1. Overall Objectives

NEO is an Inria project-team whose members are located in Sophia Antipolis (S. Alouf, K. Avrachenkov, G. Neglia), in Avignon (E. Altman) at LIA (Lab. of Informatics of Avignon) and in Montpellier (A. Jean-Marie) at LIRMM (Lab. Informatics, Robotics and Microelectronics of Montpellier). The team is positioned at the intersection of Operations Research and Network Science. By using the tools of Stochastic Operations Research, we model situations arising in several application domains, involving networking in one way or the other. The aim is to understand the rules and the effects in order to influence and control them so as to engineer the creation and the evolution of complex networks.

3. Research Program

3.1. Stochastic Operations Research

Stochastic Operations Research is a collection of modeling, optimization and numerical computation techniques, aimed at assessing the behavior of man-made systems driven by random phenomena, and at helping to make decisions in such a context.

The discipline is based on applied probability and focuses on effective computations and algorithms. Its core theory is that of Markov chains over discrete state spaces. This family of stochastic processes has, at the same time, a very large modeling capability and the potential of efficient solutions. By "solution" is meant the calculation of some *performance metric*, usually the distribution of some random variable of interest, or its average, variance, etc. This solution is obtained either through exact "analytic" formulas, or numerically through linear algebra methods. Even when not analytically or numerically tractable, Markovian models are always amenable to "Monte-Carlo" simulations with which the metrics can be statistically measured.

An example of this is the success of classical Queueing Theory, with its numerous analytical formulas. Another important derived theory is that of the Markov Decision Processes, which allows to formalize *optimal* decision problems in a random environment. This theory allows to characterize the optimal decisions, and provides algorithms for calculating them.

Strong trends of Operations Research are: a) an increasing importance of multi-criteria multi-agent optimization, and the correlated introduction of Game Theory in the standard methodology; b) an increasing concern of (deterministic) Operations Research with randomness and risk, and the consequent introduction of topics like Chance Constrained Programming and Stochastic Optimization. Data analysis is also more and more present in Operations Research: techniques from statistics, like filtering and estimation, or Artificial Intelligence like clustering, are coupled with modeling in Machine Learning techniques like Q-Learning.

4. Application Domains

4.1. Network Science

Network Science is a multidisciplinary body of knowledge, principally concerned with the emergence of global properties in a network of individual agents, from the "local" properties of this network, namely, the way agents interact with each other. The central model of "networks" is the graph (of Graph Theory/Operations Research), with nodes representing the different entities managing information and taking decisions, and the links representing the fact that entities interact, or not. Links are usually equipped with a "weight" that measures the intensity of interaction. Adding evolution rules to this quite elementary representation leads to dynamic network models, the properties of which Network Science tries to analyze.

A classical example of properties sought in networks is the famous "six degrees of separation" (or "small world") property: how and why does it happen so frequently? Another ubiquitous property of real-life networks is the Zipf or "scale-free" distribution for degrees. Some of these properties, when properly exploited, lead to successful business opportunities: just consider the PageRank algorithm of Google, which miraculously connects the relevance of some Web information with the relevance of the other information that points to it.

4.2. Network Engineering

In its primary acceptation, Network Science involves little or no engineering: phenomena are assumed to be "natural" and emerge without intervention. However, the idea comes fast to intervene in order to modify the outcome of the phenomenon. This is where NEO is positioned. Beyond the mostly descriptive approach of Network Science, we aim at using the techniques of Operations Research so as to engineer complex networks.

To quote just two examples: controlling the spread of diseases through a “network” of people is of primarily interest for mankind. Similarly, controlling the spread of information or reputation through a social network is of great interest in the Internet. Precisely: given the impact of web visibility on business income, it is tempting (and quite common) to manipulate the graph of the web by adding links so as to drive the PageRank algorithm to a desired outcome.

Another interesting example is the engineering of community structures. Recently, thousands of papers have been written on the topic of community *detection* problem. In most of the works, the researchers propose methods, most of the time, heuristics, for detecting communities or dense subgraphs inside a large network. Much less effort has been put in the understanding of community formation process and even much less effort has been dedicated to the question of how one can influence the process of community formation, e.g. in order to increase overlap among communities and reverse the fragmentation of the society.

Our ambition for the medium term is to reach an understanding of the behavior of complex networks that will make us capable of influencing or producing a certain property in said network. For this purpose, we will develop families of models to capture the essential structure, dynamics, and uncertainty of complex networks. The “solution” of these models will provide the correspondence between metrics of interest and model parameters, thus opening the way to the synthesis of effective control techniques.

In the process of tackling real, very large size networks, we increasingly deal with large graph data analysis and the development of decision techniques with low algorithmic complexity, apt at providing answers from large datasets in reasonable time.

5. Highlights of the Year

5.1. Highlights of the Year

NEO started a collaboration with QWANT within the joint QWANT-Inria laboratory, with two research projects. One is a direct collaboration, the other one is within the PIA ANSWER project. See Sections 8.1.2 and 9.2.1.

The book “Constrained Markov Decision Processes” by Eitan Altman is cited over 1000 times in Google Scholar.

Giovanni Neglia has been nominated IEEE Infocom 2018 Distinguished TPC member (Jan. 2018).

5.1.1. Awards

BEST PAPERS AWARDS:

[36]
E. HARGREAVES, D. S. MENASCHÉ, G. NEGLIA, C. AGOSTI. *Visibilidade no Facebook: Modelos, Medições e Implicações*, in "Brazilian Workshop on Social Network Analysis and Mining (BraSNAM)", Natal, Brazil, July 2018, https://hal.inria.fr/hal-01956316

[33]
K. VEERARUNA, S. MEMON, M. K. HANAWAL, E. ALTMAN, R. DEVANAND. *User Response Based Recommendations: A Local Angle Approach*, in "COMSNETS 2018 - 10th International Conference on COMmunication Systems & NETworkS", Bangalore, India, January 2018, pp. 1-8, https://hal.inria.fr/hal-01702355

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.

- Participants: Alain Jean-Marie, Hlib Mykhailenko, Benjamin Briot, Franck Quessette, Issam Rabhi, Jean-Marc Vincent and Jean-Michel Fourneau
- Partner: UVSQ
- Contact: Alain Jean-Marie
- Publications: marmoteCore: a Markov Modeling Platform - marmoteCore: a software platform for Markov modeling
- URL: http://marmotecore.gforge.inria.fr/

7. New Results

7.1. Stochastic Modeling

Participants: Eitan Altman, Konstantin Avrachenkov, Mandar Datar, Swapnil Dhamal, Alain Jean-Marie, Albert Sunny.

7.1.1. Markov chains with restart/jumps

In [7], K. Avrachenkov together with A. Piunovskiy and Y. Zhang (Univ. of Liverpool, UK) consider a discrete-time Markov process with restart. At each step the process either with a positive probability restarts from a given distribution, or with the complementary probability continues according to a Markov transition kernel. The main contribution of this work is an explicit expression for the expectation of the hitting time (to a given target set) of the process with restart. The formula is convenient when considering the problem of optimization of the expected hitting time with respect to the restart probability. The results with are illustrated with two examples in uncountable and countable state spaces and with an application to network centrality.

Then, in [19], K. Avrachenkov and I. Bogdanov (HSE, Russia) study the relaxation time in the random walk with jumps. The random walk with jumps combines random walk based sampling with uniform node sampling and improves the performance of network analysis and learning tasks. They derive various conditions under which the relaxation time decreases with the introduction of jumps.

7.1.2. Markov modeling of Lasers

A. Jean-Marie has continued the investigation of Markov models of Lasers at several levels of physical accuracy, in conjunction with F. Philippe, L. Chusseau and A. Vallet (Univ. Montpellier and CNRS). In [17], a Markov model of relatively low complexity, the “Canonical Markov Model” (CMM), is built on the basis of a time-scale decomposition of physical phenomena. This simplified model is validated by comparison with a “microscopic Markov model” previously existing. Thanks to its smaller state space, simulations with the CMM are orders of magnitude faster, and numerical investigation of stationary and transient features become possible. As an example, the focus is put in [17], [39] on the Laser “threshold”, a phenomenon related to sojourn of the CMM in states where no light is emitted. Simulations and numerical solutions reveal the existence of a bi-modal distribution for the particles for a certain range of parameters, thereby predicting a certain instability of the Laser for these values. Investigations continue with a quantification of the intensity of “flashes” through the computation of hitting times in the CMM.

7.1.3. The marmoteCore platform

The development of `marmoteCore` (see Section 6.1) has been pursued by A. Jean-Marie. The software library is now being used in NEO's research projects such as [17] or queuing models supporting the analysis of Green Data Centers. `marmoteCore` provides the classes necessary to represent the state space of Markov models, from the elementary bricks that are interval or rectangular domains, simplices, or binary sequences. From there, the user easily programs the construction of probability transition matrices or infinitesimal generators. Structural analysis methods allow to identify recurrent and transient classes, and to compute the period of the model. Numerous methods allow the Monte Carlo simulation of the chain, the computation of transient and stationary distributions, as well as hitting times. In conjunction with E. Hyon (Univ. Paris-Nanterre), extensions of the core of the software are being programmed for Markov Decision Processes and Stochastic Games.

7.1.4. Blockchain mining

S. Dhamal, T. Chahed (Telecom SudParis), W. Ben-Ameur (Telecom SudParis), E. Altman, A. Sunny, and S. Poojary (UAPV, the Univ. of Avignon) have studied a stochastic game framework for distributed computing settings such as blockchain mining in [42]. A continuous-time Markov chain model, where players arrive and depart according to a stochastic process, is proposed, and their investment strategies are determined based on the state of the system. Two scenarios are analyzed, based on whether the rate of problem getting solved is dependent on or independent of the computational power invested by the players. The equilibrium strategies are shown to follow a threshold policy when this rate is proportional to the total invested power, while the players are shown to invest proportionally to the reward-cost ratio when this rate is independent of the invested power. The effects of arrival and departure rates on the players' utilities are quantified using simulations.

The paper extends the game theoretic modeling and analysis of the static case (fixed number of miners) done in [18] by E. Altman in collaboration with A. Reiffers-Masson (IISc, India), D. Sadoc Menasché (UFRJ), M. Datar and S. Dhamal, and C. Touati (Inria Grenoble Rhône-Alpes).

7.2. Queueing Theory

Participants: Sara Alouf, Konstantin Avrachenkov, Alain Jean-Marie, Dimitra Politaki.

7.2.1. Multiclass processor sharing and random order scheduling policies

In [2], K. Avrachenkov and T. Bodas (LAAS-CNRS) consider a single server system serving a multiclass population. Some popular scheduling policies for such system are the discriminatory processor sharing (DPS), discriminatory random order service (DROS), generalized processor sharing (GPS) and weighted fair queueing (WFQ). In this work, the authors propose two classes of policies, namely MPS (Multi-class Processor Sharing) and MROS (Multi-class Random Order Service), that generalize the four policies mentioned above. For the special case when the multi-class population arrive according to Poisson processes and have independent and exponential service requirement with parameter μ, they show that the tail of the sojourn time distribution for a class i customer in a system with the MPS policy is a constant multiple of the tail of the waiting time distribution of a class i customer in a system with the MROS policy. This result implies that for a class i customer, the tail of the sojourn time distribution in a system with the DPS (GPS) scheduling policy is a constant multiple of the tail of the waiting time distribution in a system with the DROS (respectively WFQ) policy.

7.2.2. The marmoteCore-Q tool

Using the `marmoteCore` platform, a tool called `marmoteCore-Q` has been developed by D. Politaki under the supervision of S. Alouf and A. Jean-Marie for the simulation of a family of queueing models based on the general BMAP/PH/c queue with impatience and resubmissions. There exist many special cases of this queue for which analytical results are known. Examples are: the M/M/1 queue and its finite capacity version, the M/M/c/K queue, the M/PH/1 and M/PH/∞ queues, the M^X/M/1 and M^X/M/∞ queues. Such examples are used to validate the implementation of the `marmoteCore-Q` tool.

7.3. Random Graph and Matrix Models

Participants: Konstantin Avrachenkov, Maximilien Dreveton.

In [5], K. Avrachenkov, together with A. Kadavankandy (CentraleSupélec) and N. Litvak (Univ. of Twente, The Netherlands), analyse a mean-field model of Personalized PageRank on the Erdös-Rényi random graph containing a denser planted Erdös-Rényi subgraph. They investigate the regimes where the values of Personalized PageRank concentrate around the mean-field value. They also study the optimization of the damping factor, the only parameter in Personalized PageRank. Their theoretical results help to understand the applicability of Personalized PageRank and its limitations for local graph clustering.

7.4. Data Analysis and Learning

Participant: Konstantin Avrachenkov.

7.4.1. Unsupervised learning

In [6], K. Avrachenkov, together with A. Kondratev, V. Mazalov (Petrozavodsk State Univ., Russia) and D. Rubanov (Amadeus), applied game-theoretic methods for community detection in networks. The traditional methods for detecting community structure are based on selecting dense subgraphs inside the network. Here the authors propose to use the methods of cooperative game theory that highlight not only the link density but also the mechanisms of cluster formation. Specifically, they suggest two approaches from cooperative game theory: the first approach is based on the Myerson value, whereas the second approach is based on hedonic games. Both approaches allow to detect clusters with various resolutions. However, the tuning of the resolution parameter in the hedonic games approach is particularly intuitive. Furthermore, the modularity-based approach and its generalizations as well as ratio cut and normalized cut methods can be viewed as particular cases of the hedonic games. Finally, for approaches based on potential hedonic games a very efficient computational scheme using Gibbs sampling is suggested.

7.4.2. Semi-supervised learning

Graph Semi-supervised learning (gSSL) aims to classify data exploiting two initial inputs: firstly, the data are structured in a network whose edges convey information on the proximity, in a wide sense, of two data points (e.g. correlation or spatial proximity) and, second, there is a partial information on some nodes, which have previously been labelled. Thus, the classification problem is usually a balance between two terms: one diffusing the information from the labelled points to the unlabelled ones through the network and another one that constrains the solution to be similar, on the labelled nodes, to the given labels. In practice, popular SSL methods as Standard Laplacian (SL), Normalized Laplacian (NL) or PageRank (PR), exploit those operators defined on graphs to spread the labels and, from a random walk perspective, the classification of a given point is given the maximum of the expected number of visits from one class. Anomalous diffusion can alter the way a graph is “explored” and, therefore, it can alter classification performance. In a nushell, Lévy flights/walks are a way to create superdiffusive regimes: the customary rule for their ignition is to allow the walkers to perform non-local jumps, whose length is distributed according to a fat-tailed probability density function with diverging second moment. Mathematically speaking, there have been several attempts to convert the Lévy flight phenomenon on networks and, in the context of gSSL, K. Avrachenkov in conjunction with S. De Nigris, E. Bautista, P. Abry and P. Gonçalves, settled in [38] for the use of fractional operators. In this SSL context, the authors cast those operators in the SSL problem in each different incarnation (SL, PR and NL) and investigated the beneficial effect of such a procedure for classification.

In [13], K. Avrachenkov, together with A. Kadavankandy (CentraleSupélec), L. Cottatellucci (EURECOM) and R. Sundaresan (IISc, India), tackle the problem of hidden community detection. We consider Belief Propagation (BP) applied to the problem of detecting a hidden Erdös-Rényi (ER) graph embedded in a larger and sparser ER graph, in the presence of side-information. We derive two related algorithms based on BP to perform subgraph detection in the presence of two kinds of side-information. The first variant of side-information consists of a set of nodes, called cues, known to be from the subgraph. The second variant of side-information consists of a set of nodes that are cues with a given probability. It was shown in past works that BP without side-information fails to detect the subgraph correctly when a so-called effective signal-to-noise ratio (SNR) parameter falls below a threshold. In contrast, in the presence of non-trivial side-information, we show that the BP algorithm achieves asymptotically zero error for any value of a suitably defined phase-transition parameter. We validate our results on synthetic datasets and a few real world networks.

7.4.3. Supervised learning

Graphlets are defined as k-node connected induced subgraph patterns. For instance, for an undirected graph, 3-node graphlets include closed triangles and open triangles. The number of each graphlet, called graphlet count, is a signature which characterizes the local network structure of a given graph. Graphlet count plays a prominent role in network analysis of many fields, most notably bioinformatics and social science. However, computing exact graphlet count is inherently difficult and computational expensive because the number of graphlets grows exponentially large as the graph size and/or graphlet size grow. To deal with this difficulty, many sampling methods were proposed to estimate graphlet count with bounded error. Nevertheless, these methods require large number of samples to be statistically reliable, which is still computationally demanding. Intuitively, learning from historic graphs can make estimation more accurate and avoid many repetitive counting to reduce computational cost. Based on this idea, in [29] K. Avrachenkov, together with X. Liu, J. Chen and J. Lui (CUHK, Hong Kong), propose a convolutional neural network (CNN) framework and two preprocessing techniques to estimate graphlet count. Extensive experiments on two types of random graphs and real world biochemistry graphs show that their framework can offer substantial speedup on estimating graphlet count of new graphs with high accuracy.

7.5. Game Theory

Participants: Eitan Altman, Swapnil Dhamal.

7.5.1. Resource allocation polytope games

S. Dhamal, W. Ben-Ameur, T. Chahed (both from Telecom SudParis), and E. Altman have studied two-player resource allocation polytope games in [24]. The strategy of a player is considered to be restricted by the strategy of the other player, with common coupled constraints. In the context of such games, novel notions of independent optimal strategy profile and common contiguous set are introduced. Necessary and sufficient conditions are derived for the game to have a unique pure strategy Nash equilibrium. Given an instance of the game, an efficient algorithm is presented to compute the price of anarchy. Under reasonable conditions, the price of stability is shown to be 1. A paradox is shown that higher budgets may lead to worse outcomes.

7.6. Applications in Telecommunications

Participants: Zaid Allybokus, Sara Alouf, Eitan Altman, Konstantin Avrachenkov, Swapnil Dhamal, Alain Jean-Marie, Giovanni Neglia, Dimitra Politaki.

7.6.1. Caching

A fundamental brick of the information-centric architectures proposed for Internet evolution is in-network caching, i.e. the possibility for the routers to store locally the contents and directly serve future requests. This has raised a new interest in the performance of networks of caches. Since 2012, there has been a significant research activity in NEO on this topic. Our work raised the attention of researchers at Akamai Technologies (the world leader in Content Delivery Networks). In real caching systems the hit rate is often limited by the speed at which contents can be retrieved by the Hard-Disk Drive (HDD) (this is the so-called *spurious misses*' problem). Akamai researchers asked us to design an algorithm to solve this problem. In [43] G. Neglia and D. Tsigkari, together with D. Carra (Univ. of Verona, Italy), M. Feng, V. Janardhan (Akamai Technologies, USA), and P. Michiardi (EURECOM) have proposed a simple randomized caching policy that makes optimal use of the RAM to minimize the load on the HDD and then the number of spurious misses. Moreover, experiments in Akamai CDN have shown that our policy reduces the HDD load by an additional 10% in comparison to the (highly optimized) baseline policy currently employed by Akamai. In [15] a subset of the same authors (G. Neglia, D. Carra, P. Michardi) have shown that the same approach can be adapted to minimize any miss cost function as far as the cost is additive over the misses.

More recently, we moved to consider the problem of caches' coordination in a dense cellular network scenario, where caches are deployed at base stations (BSs) and a user can potentially retrieve the content from multiple BSs. In this setting, the optimal content placement problem is NP-hard even when the goal is simply to maximize the hit ratio. Most of the existing literature has proposed heuristics assuming that content popularities are static and known, but in reality their estimation can be very difficult at the scale of the geographical area covered by a BS. In [14] E. Leonardi (Politecnico di Torino, Italy) and G. Neglia have introduced a class of simple and fully distributed caching policies, which require neither direct communication among BSs, nor a priori knowledge of content popularity (strongly deviating from the assumptions of existing literature). They have shown that optimal coordination can be achieved by applying minor changes to existing policies and piggybacking an additional information bit to each content request. How to achieve coordination for more complex performance metrics (e.g. the retrieval time or fairness) is still an open research problem that is now the PhD subject of G. Iecker, co-supervised by G. Neglia and T. Spyropoulos (EURECOM).

7.6.2. Modeling and workload characterization of data center clusters

There are many challenges faced when modeling computing clusters. In such systems, jobs to be executed are submitted by users. These jobs may generate a large number of tasks. Some tasks may be executed more than once while other may abandon before execution. D. Politaki, S. Alouf, F. Hermenier (Nutanix), and A. Jean-Marie have developed a multi-server queueing system with abandonments and resubmissions to model computing clusters. To capture the correlations observed in real workload submissions, a Batch Markov Arrival Process is considered. The service time is assumed to have a phase-type distribution. This model has not been analyzed in the literature. The distributions of the interarrivals and the service times found in the Google Cluster Data have been characterized and compared with fitted distributions. The authors findings support the model assumptions. Ongoing work investigates the approaches that can be adopted to overcome the technical challenges found in the performance evaluation of the computing clusters. In particular, the developed tool `marmoteCore-Q` (see §7.2.2) will be used.

To understand the essential characteristics of a computing cluster for modelling purposes, the same authors have looked into two datasets consisting of job scheduler logs. The first dataset comes from a Google cluster and is publicly available (https://github.com/google/cluster-data). The second dataset has been collected from the internal computing cluster of Inria Sophia-Antipolis Méditerrannée. After a preliminary analysis and sanitizing of each dataset, a numerical analysis is performed to characterize the different stochastic processes taking place in the computing cluster. In particular, the authors characterize the impatience process, the resubmission process, the arrival process (batch sizes and correlations) and the service time, considering the impact of the scheduling class and of the execution type.

7.6.3. Software Defined Networks (SDN)

The performance of computer networks relies on how bandwidth is shared among different flows. Fair resource allocation is a challenging problem particularly when the flows evolve over time. To address this issue, bandwidth sharing techniques that quickly react to the traffic fluctuations are of interest, especially in large scale settings with hundreds of nodes and thousands of flows. In this context, K. Avrachenkov and Z. Allybokus, together with J. Leguay (Huawei Research) and L. Maggi (Nokia Bell Labs), in [1] propose a distributed algorithm based on the Alternating Direction Method of Multipliers (ADMM) that tackles the multi-path fair resource allocation problem in a distributed SDN control architecture. Their ADMM-based algorithm continuously generates a sequence of resource allocation solutions converging to the fair allocation while always remaining feasible, a property that standard primal-dual decomposition methods often lack. Thanks to the distribution of all computer intensive operations, they demonstrate that large instances can be handled at scale.

7.6.4. Impulsive control of G-AIMD dynamics

Motivated by various applications from Internet congestion control to power control in smart grids and electric vehicle charging, in [20] K. Avrachenkov together with A. Piunovskiy and Y. Zhang (Univ. of Liverpool, UK) study Generalized Additive Increase Multiplicative Decrease (G-AIMD) dynamics under impulsive control in continuous time with the time average alpha-fairness criterion. They first show that the control under relaxed constraints can be described by a threshold. Then, they propose a Whittle-type index heuristic for the hard constraint problem. They prove that in the homogeneous case the index policy is asymptotically optimal when the number of users is large.

7.6.5. Application of Machine Learning to optimal resource allocation in cellular networks

In [9], E. Altman in collaboration with A. Chattopadhyay and B. Błaszczyszyn (from Inria DYOGENE team) consider location-dependent opportunistic bandwidth sharing between static and mobile downlink users in a cellular network. In order to provide higher data rate to mobile users, the authors propose to provide higher bandwidth to the mobile users at favourable times and locations, and provide higher bandwidth to the static users in other times. They formulate the problem as Markov decision process (MDP) where the per-step reward is a linear combination of instantaneous data volumes received by static and mobile users. The transition structure of this MDP is not known in general. They thus propose a learning algorithms based on stochastic approximation with one and with two time scales. The results are extended to address the issue of fair bandwidth sharing between the two classes of users.

To optimize routing of flows in datacenters, SDN controllers receive a packet-in message whenever a new flow appears in the network. Unfortunately, flow arrival rates can peak to millions per second, impairing the ability of controllers to treat them on time. Flow scheduling copes with this by segmenting the traffic between elephant and mice flows and by treating elephant flows in priority, as they disrupt short lived TCP flows and create bottlenecks. In [21], E. Altman in collaboration with F. De Pellegrini (UAPV), L. Maggi (Huawei), A. Massaro (FBK Trento), D. Saucez (Inria DIANA team) and J. Leguay (Huawei Research) propose a stochastic approximation based learning algorithm called SOFIA and able to perform optimal online flow segmentation. Extensive numerical experiments characterize the performance of SOFIA.

7.6.6. Forecast Scheduling

With the age of big data and with geo-localisation measurements available, the precision in predicting the mobility of users increases, and hence also that of the prediction of channel conditions. In [35], E. Altman in collaboration with H. Zaaraoui, S. Jema, Z. Altman (Orange Labs) and T. Jimenez (UAPV) propose a convex optimization approach to Forecast Scheduling which makes use of current and future predicted channel conditions to obtain an optimal alpha fair schedule. They further extend the model in [34] to take into account different types of random events such as arrival and departure of users and uncertainties in the mobile trajectories. Simulation results illustrate the significant performance gain achieved by the Forecast Scheduling algorithms in the presence of random events.

7.6.7. Fairness in allocation to users with different time constraints

E. Altman and S. Ramanath (IIT Bombay, India) study in [31] how to allocate resources fairly when different users have different time constraints for using the resources. They formulate this as a Markov Decision Process (MDP) for a two user case and provide a Dynamic Program (DP) solution. Simulation results in an LTE framework are provided to support the theoretical claims.

7.7. Applications in Social Networks

Participants: Eitan Altman, Konstantin Avrachenkov, Swapnil Dhamal, Giovanni Neglia.

7.7.1. Fairness in Online Social Network Timelines

Facebook News Feed personalization algorithm has a significant impact, on a daily basis, on the lifestyle, mood and opinion of millions of Internet users. Nonetheless, the behavior of such algorithm lacks transparency, motivating measurements, modeling and analysis in order to understand and improve its properties. E. Altman and G. Neglia, together with other researchers from THANES team (E. Hargreaves and D. Menasché from UFRJ, A. Reiffers-Masson from IIsc, and E. Altman) and with the journalist C. Agosti (Univ. of Amsterdam), have proposed a reproducible methodology encompassing measurements, an analytical model and a fairness-based News Feed design. The model leverages the versatility and analytical tractability of time-to-live (TTL) counters to capture the visibility and occupancy of publishers over a News Feed. Measurements from 2018 Italian political election are used to parameterize and to validate the expressive power of the proposed model. Then, we have conducted a what-if analysis to assess the visibility and occupancy bias incurred by users against a baseline derived from the model. Our results indicate that a significant bias exists and it is more prominent at the top position of the News Feed. In addition, we have found that the bias is non-negligible even for users that are deliberately set as neutral with respect to their political views, motivating the proposal of a novel and more transparent fairness-based News Feed design. This is a very recent research direction, but it has already led to 4 publications [36], [27], [28], [12] with a *best paper award* for [36].

7.7.2. Sampling online social networks

In the framework of network sampling, random walk (RW) based estimation techniques provide many pragmatic solutions while uncovering the unknown network as little as possible. Despite several theoretical advances in this area, RW based sampling techniques usually make a strong assumption that the samples are in stationary regime, and hence are impelled to leave out the samples collected during the burn-in period. In [4] K. Avrachenkov, together with V.S. Borkar (IIT Bomaby, India), A. Kadavankandy (CentraleSupélec) and J.K. Sreedharan (Purdue Univ., USA), propose two sampling schemes without burn-in time constraint to estimate the average of an arbitrary function defined on the network nodes, for example, the average age of users in a social network. The central idea of the algorithms lies in exploiting regeneration of RWs at revisits to an aggregated super-node or to a set of nodes, and in strategies to enhance the frequency of such regenerations either by contracting the graph or by making the hitting set larger. Our first algorithm, which is based on reinforcement learning (RL), uses stochastic approximation to derive an estimator. This method can be seen as intermediate between purely stochastic Markov chain Monte Carlo iterations and deterministic relative value iterations. The second algorithm, which we call the Ratio with Tours (RT)-estimator, is a modified form of respondent-driven sampling (RDS) that accommodates the idea of regeneration. We study the methods via simulations on real networks. We observe that the trajectories of RL-estimator are much more stable than those of standard random walk based estimation procedures, and its error performance is comparable to that of respondent-driven sampling (RDS) which has a smaller asymptotic variance than many other estimators. Simulation studies also show that the mean squared error of RT-estimator decays much faster than that of RDS with time. The newly developed RW based estimators (RL- and RT-estimators) allow to avoid burn-in period, provide better control of stability along the sample path, and overall reduce the estimation time.

7.7.3. Crawling ephemeral content

In [3], K. Avrachenkov and V.S. Borkar (IIT Bombay, 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 a 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 authors derive the Whittle index for a simple deterministic model and provide its theoretical justification. They also outline an extension to a fully stochastic model.

7.7.4. Posting behavior

In [32], E. Altman in collaboration with A. Reiffers-Masson (IISc, India), Y. Hayel and G. Marrel (UAPV) consider a “generalized” fractional program in order to solve a popularity optimization problem in which a source of contents controls the topics of her contents and the rate with which posts are sent to a time line. The objective of the source is to maximize its overall popularity in an Online Social Network (OSN). The authors propose an efficient algorithm that converges to the optimal solution of the Popularity maximization problem.

7.7.5. Recommendation system for OSNs

When a user interested in a service/item, visits an online web-portal, it provides description of its interest through initial search keywords. The system recommends items based on these keywords. The user is satisfied if it finds the item of its choice and the system benefits, otherwise the user explores an item from the list. In [33], E. Altman in collaboration with K. Veeraruna, S. Memon, M. Hanawal and R. Devanand (IEOR IIT Bombay, India), develop algorithms that efficiently utilize user responses to recommended items and find the item of user's interest quickly. The authors first derive optimal policies in the continuous Euclidean space and adapt the same to the space of discrete items.

7.7.6. Opinion dynamics

S. Dhamal, W. Ben-Ameur, T. Chahed (both from Telecom SudParis), and E. Altman have studied the problem of optimally investing in nodes of a social network, wherein two camps attempt to maximize adoption of their respective opinions by the population. In [11], several settings are analyzed, namely, when the influence of a camp on a node is a concave function of its investment on that node, when one of the camps has uncertain information regarding the values of the network parameters, when a camp aims at maximizing competitor's investment required to drive the overall opinion of the population in its favor, and when there exist common coupled constraints concerning the combined investment of the two camps on each node. In [23], the possibility of campaigning in multiple phases is explored, where the final opinion of a node in a phase acts as its initial bias for the next phase. A further intricate setting where a camp's influence on a node also depends on the node's initial bias, is analyzed in [22]. Extensive simulations are conducted on real-world social networks for all the considered settings.

7.7.7. Information diffusion under practical models

S. Dhamal has studied the effectiveness of adaptive seeding in multiple phases under the independent cascade model of information diffusion, in [25]. The effect on the mean and standard deviation of the extent of diffusion is observed, with an explanation of how adaptive seeding reduces uncertainty in diffusion. The other aspects studied are: how the number of phases impacts the effectiveness of diffusion, how the diffusion progresses phase-by-phase, and how to optimally split the total seeding budget across phases. Another study [26] generalizes the linear threshold model to account for multiple product features, and presents an integrated framework for product marketing using multiple channels: mass media advertisement, recommendations using social advertisement, and viral marketing using social networks. An approach for allocating budget among these channels is proposed.

7.8. Applications to Energy

Participant: Giovanni Neglia.

7.8.1. Smart grids

Balancing energy demand and production is becoming a more and more challenging task for energy utilities because of the larger penetration of renewable energies, more difficult to predict and control. While the traditional solution is to dynamically adapt energy production to follow the time-varying demand, a new trend is to drive the demand itself. We have first considered the direct control of inelastic home appliances, whose energy consumption cannot be shaped, but simply deferred. Our solution does not suppose any particular intelligence at the appliances, the actuators are rather smart plugs, simple devices with communication capabilities that can be inserted between appliances' plugs and power sockets and are able to interrupt/reactivate power flow. During previous years we have considered both closed-loop and open-loop control of such devices in order to satisfy a probabilistic bound on the aggregated power consumption. Recently, G. Neglia, together with L. Giarré (Univ. di Modena e Reggio Emilia, Italy), I. Tinnirello and G. Di Bella (Univ. di Palermo, Italy) have considered a mixed approach [16]. They have been able to quantify the trade-off between the amount of controlled power and delays experienced by the users to evaluate to which scale this solution should be deployed.

We have also looked at Demand-Response (DR) programs, whereby users of an electricity network are encouraged by economic incentives to re-arrange their consumption in order to reduce production costs. Several recent works proposed DR mechanisms relying on a macroscopic description of the population that does not model individual choices of users. In [8], G. Neglia, together with A. Benegiamo (EURECOM/Inria) and P. Loiseau (EURECOM) has shown that these macroscopic models hide important assumptions that can jeopardize the mechanisms' implementation (such as the ability to make personalized offers and to perfectly estimate the demand that is moved from a timeslot to another). Then, starting from a microscopic description that explicitly models each user's decision, they have introduced new DR mechanisms with various assumptions on the provider's capabilities. Contrarily to previous studies, they have found that 1) the resulting optimization problems are complex and can be solved numerically only through heuristics, 2) the savings from DR mechanisms are significantly lower than those suggested by previous studies.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

NEO members are involved in the

- Inria-Nokia Bell Labs joint laboratory: the joint laboratory consists of five ADRs (Action de Recherche/Research Action) in its third phase (starting October 2017). NEO members participate in one ADR "Distributed Learning and Control for Network Analysis" (see §8.1.1).
- Inria-QWANT joint laboratory "Smart search is privacy" (see §8.1.2);
- Inria-Orange Labs joint laboratory (see §8.1.3).

8.1.1. ADR Nokia on the topic "Distributed Learning and Control for Network Analysis" (October 2017 – September 2021)

Participants: Eitan Altman, Konstantin Avrachenkov, Mandar Datar, Maximilien Dreveton, Alain Jean-Marie.

- Contractor: Nokia Bell Labs (http://www.bell-labs.com)
- Collaborator: Gérard Burnside

Over the last few years, research in computer science has shifted focus to machine learning methods for the analysis of increasingly large amounts of user data. As the research community has sought to optimize the methods for sparse data and high-dimensional data, more recently new problems have emerged, particularly from a networking perspective that had remained in the periphery.

The technical program of this ADR consists of three parts: Distributed machine learning, Multiobjective optimisation as a lexicographic problem, and Use cases / Applications. We address the challenges related to the first part by developing distributed optimization tools that reduce communication overhead, improve the rate of convergence and are scalable. Graph-theoretic tools including spectral analysis, graph partitioning and clustering will be developed. Further, stochastic approximation methods and D-iterations or their combinations will be applied in designing fast online unsupervised, supervised and semi-supervised learning methods.

8.1.2. Qwant contract on "Asynchronous on-line computation of centrality measures" (15 December 2017 – 14 May 2020)

Participants: Nicolas Allegra, Konstantin Avrachenkov.

- Contractor: Qwant
- Collaborator: Sylvain Peyronnet

We shall study asynchronously distributed methods for network centrality computation. The asynchronous distributed methods are very useful because they allow efficient and flexible use of computational resources on the one hand (e.g., using a cluster or a cloud) and on the other hand they allow quick local update of centrality measures without the need to recompute them from scratch.

8.1.3. Orange CIFRE on the topic "Self-organizing features in the virtual 5G radio access network" (November 2017 – October 2020)

Participants: Eitan Altman, Marie Masson.

- Contractor: Orange Labs (https://orange.jobs/site/en-innovation-rd/)
- Collaborator: Zwi Altman

The considerable extent of the complexity of 5G networks and their operation is in contrast with the increasing demands in terms of simplicity and efficiency. This antagonism highlights the critical importance of network management. Self-Organizing Networks (SON), which cover self-configuration, self-optimization and self-repair, play a central role for 5G Radio Access Network (RAN).

This CIFRE thesis aims at innovating in the field of managing 5G RAN, with a special focus on the features of the SON-5G. Three objectives are identified: a) develop self-organizing features (SON in 5G-RAN), b) develop cognitive managing mechanisms for the SON-5G features developed, and c) demonstrate how do the self-organizing mechanisms fit in the virtual RAN (vRAN).

8.1.4. Huawei CIFRE on the topic "Scalable Online Algorithms for SDN controllers" (June 2016 – May 2019)

Participants: Zaid Allybokus, Konstantin Avrachenkov.

- Contractor: Huawei Technologies (http://www.huawei.com/en/about-huawei/research-development)
- Collaborators: Jérémie Leguay

Software-Defined Networking (SDN) technologies have radically transformed network architectures. They provide programmable data planes that can be configured from a remote controller platform.

The objective of this CIFRE thesis is to provide fundamental answers on how powerful SDN controller platforms could solve large online flow problems to optimize networks in real-time and in a distributed or semi-distributed fashion. We use methods from both optimization and dynamic programming.

9. Partnerships and Cooperations

9.1. Regional Initiatives

MYDATA (Sept. 2018 - Nov. 2020) This is a research project in cooperation with two other labs (LJAD and GREDEG) from Univ. Côte d'Azur to study how to achieve privacy through obfuscation. The project is funded by IDEX UCA$^{\text{JEDI}}$ Academy 1 on "Networks, Information and Digital society."

9.2. National Initiatives

9.2.1. PIA ANSWER

Participants: Konstantin Avrachenkov, Abhishek Bose.

Project Acronym: ANSWER

Project Title: Advanced aNd Secured Web Experience and seaRch

Coordinator: QWANT

Duration: 15 November 2017 – 31 December 2020

Others Partners: Inria Project-Teams WIMMICS, INDES, COFFEE

Abstract: ANSWER is a joint project between QWANT and Inria, funded by the French Government's initiative PIA "Programme d'Investissement d'Avenir".

The aim of the ANSWER project is to develop the new version of the search engine http://www.qwant.com by introducing radical innovations in terms of search criteria as well as indexed content and security. This initiative is a part of the Big Data Big Digital Challenges field, since a Web search engine deals with large volumes of heterogeneous and dynamic data.

Of the five characteristics of big data, the ANSWER project will focus more particularly on the aspects of Velocity in terms of near real-time processing of results, and Variety for the integration of new indicators (emotions, sociality, etc.) and meta-data. The Volume, Value and Veracity aspects will necessarily be addressed jointly with these first ones and will also be the subject of locks, especially on the topics of crawling and indexing.

This registration of the search engine in the Big Data domain will only be reinforced by developments in the Web such as the Web of data, and generally by the current trend to integrate the Web of increasingly diverse, rich and complex resources.

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

Participant: Konstantin Avrachenkov.

Program: EU COST

Project acronym: COSTNET

Project title: European Cooperation for Statistics of Network Data Science

Duration: May 2016 - April 2020

Coordinator: Ernst Wit (NL), Gesine Reinert (UK)

Other partners: see http://www.cost.eu/COST_Actions/ca/CA15109

Abstract: A major challenge in many modern economic, epidemiological, ecological and biological questions is to understand the randomness in the network structure of the entities they study: for example, the SARS epidemic showed how preventing epidemics relies on a keen understanding of random interactions in social networks, whereas progress in curing complex diseases is aided by a robust data-driven network approach to biology.

Although analysis of data on networks goes back to at least the 1930s, the importance of statistical network modelling for many areas of substantial science has only been recognized in the past decade. The USA is at the forefront of institutionalizing this field of science through various interdisciplinary projects and networks. Also in Europe there are excellent statistical network scientists, but until now cross-disciplinary collaboration has been slow.

This Action aims to facilitate interaction and collaboration between diverse groups of statistical network modellers, establishing a large and vibrant interconnected and inclusive community of network scientists. The aim of this interdisciplinary Action is two-fold. On the scientific level, the aim is to critically assess commonalities and opportunities for cross-fertilization of statistical network models in various applications, with a particular attention to scalability in the face of Big Data. On a meta-level, the aim is to create a broad community which includes researchers across the whole of Europe and at every stage in their scientific career and to facilitate contact with stakeholders.

9.4. International Initiatives

9.4.1. Inria Associate Teams Not Involved in an Inria International Labs

9.4.1.1. MALENA

Title: Machine Learning for Network Analytics

International Partner (Institution - Laboratory - Researcher):

Indian Institute of Technology Bombay (India) - Electrical Communication Engineering - Vivek Borkar

Start year: 2017

See also: http://www-sop.inria.fr/members/Konstantin.Avratchenkov/MALENA.html

In the past couple of decades network science has seen an explosive growth, enough to be identified as a discipline of its own, overlapping with engineering, physics, biology, economics and social sciences. Much effort has gone into modelling, performance measures, classification of emergent features and phenomena, etc, particularly in natural and social sciences. The algorithmic side, all important to engineers, has been recognised as a thrust area (e.g., two recent Nevanlinna Prize (J. Kleinberg 2006 and D. Spielman 2010) went to prominent researchers in the area of network analytics). Still, in our opinion the area is yet to mature and has a lot of uncharted territory. This is because networks provide a highly varied landscape, each flavour demanding different considerations (e.g., sparse vs dense graphs, Erdös-Rényi vs planted partition graphs, standard graphs vs hypergraphs, etc). Even adopting existing methodologies to these novel situations is often a nontrivial exercise, not to mention many problems that cry out for entirely new algorithmic paradigms. It is in this context that we propose this project of developing algorithmic tools, drawing not only upon established as well as novel methodologies in machine learning and big data analytics, but going well beyond, e.g., into statistical physics tools.

9.4.1.2. THANES

Title: THeory and Application of NEtwork Science

International Partner (Institution - Laboratory - Researcher):

Universidade Federal do Rio de Janeiro (Brazil) - Department of Computer and Systems Engineering (PESC/COPPE) - Daniel Ratton Figueiredo, Edmundo De Souza e Silva

Universidade Federal do Rio de Janeiro (Brazil) - Math institute - Giulio Iacobelli

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

Start year: 2017

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

We plan move beyond the study of a single network and focus on multiplex networks, i.e. multiple interacting networks. Multiplex networks have recently raised as "one of the newest and hottest themes in the statistical physics of complex networks." They originate from the observation that many complex systems, ranging from living organisms to critical infrastructures, operate through multiple layers of distinct interactions among their constituents. In particular we plan to work on the co-evolution of the different layers of a multiplex network and on how epidemics spread in such setting.

9.4.2. Inria International Partners

9.4.2.1. Informal International Partners

NEO has continued collaborations with researchers from GERAD, Univ. Montreal (Canada), Flinders Univ. (Australia), Univ. of South Australia (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), Saint Petersburg State Univ. (Russia), Petrozavodsk State Univ. (Russia) and Ghent Univ. (Belgium).

9.4.3. Participation in Other International Programs

9.4.3.1. Indo-French Center of Applied Mathematics (IFCAM)

NEO is involved in the IFCAM with the MALENA project. See §9.4.1.1.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

9.5.1.1. Professors/Researchers

Damiano Carra, Date: 23-27 April, Institution: Univ. of Verona (Italy)

Daniel Figueiredo, Date: 9-13 July, Institution: UFRJ (Brazil)

Giulio Iacobelli, Date: 9-13 July, Institution: UFRJ (Brazil)

Nikhil Karamchandani, Date: 11-15 June, Institution: IIT Bombay (India)

Nelly Litvak, Date: 2-14 July, Institution: Univ. of Twente (Netherlands)

Vladimir Mazalov, Date: 16-17 July, Institution: Petrozavodsk State Univ. (Russia)

Daniel Sadoc Menasché, Date: 31 August - 6 September, Date: 8-12 December, Institution: UFRJ (Brazil)

Bruno Ribeiro, Date: 9-18 July, Institution: Purdue Univ. (USA)

Vikas Vikram Singh, Date: 1-8 June, Institution: IIT Delhi (India)

Rajesh Sundaresan, Date: 15-26 January, Institution: IISc Bangalore (India)

9.5.1.2. Postdoc/PhD Students

Víctor Bucarey López, Date: 18-19 October, Institution: Université Libre de Bruxelles (Belgium)

Yuzhou Chen, Date: 7 June - 6 September, Institution: Southern Methodist Univ. (USA)

Eduardo Hargreaves, Date: 31 August - 6 September, Institution: UFRJ (Brazil)

Mayank Kakodkar, Date: 9-13 July, Institution: Purdue Univ. (USA)

Mikhail Kamalov, Date: 1 September - 30 November, Institution: Univ. St. Petersburg (Russia)

Maria Kleshnina, Date: 2-8 July, Institution: Queensland Univ. (Australia)

Suhail Mohmad Shah, Date: 18 June - 14 August, Institution: IIT Bombay (India)

9.5.2. Internships

Note: UNS is the Univ. Nice Sophia-Antipolis.

Nour Elhouda Ayari, Date: 4 April - 8 October, Institution: Tunis SUP'COM, Supervisors: E. Altman and M. Haddad (UAPV), Subject: Speed Estimation in Mobile Networks

Gianmarco Calbi, Date: 15 March - 31 August, Institution: Master RIF, UNS, Supervisor: G. Neglia, Subject: Asynchronous Approximate Distributed Computation for Machine Learning

Yu-Zhen Chen, Date: 1 June - 31 July, Institution: The Chinese Univ. of Hong Kong, Supervisor: K. Avrachenkov, Subject: Application of deep learning for graphlet statistics estimation

Kostantinos Dermentzis, Date: 20 November 2017 - 19 May 2018, Institution: National Technical Univ. of Athens (Greece), Supervisor: G. Neglia, Subject: Caching Policies with Partial Future Knowledge: the case of Spark

Vladyslav Fedchenko, Date: 1 March - 31 August, Institution: Master IFI Ubinet, UNS, Supervisor: G. Neglia, Subject: Estimating Content Popularity in Cache Networks

Pulkit Goel, Date: 15 May - 31 July, Institution: IIT New Delhi (India), Supervisor: K. Avrachenkov, Subject: Application of Deep Learning for Recovering Graph Motifs

Nisha Mishra, Date: 5 February - 20 July, Institution: ENSIMAG, Supervisor: E. Altman and C. Touati, Subject: Routing Games

Utsav Sen, Date: 15 May - 31 July, Institution: IIT New Delhi (India), Supervisor: K. Avrachenkov, Subject: Asynchronously distributed and randomized methods for computing network centralities

Adeel Siddiqui, Date: 1 October 2018 - 30 September 2019, Institution: Univ. Côte d'Azur, Supervisor: G. Neglia, Subject: Achieve Web Privacy by Obfuscation

Xing Yafei, Date: 1 March - 31 August, Institution: Master IFI Ubinet, UNS, Supervisor: K. Avrachenkov, Subject: Distributed Approaches for Graph-based Unsupervised Learning

Xiawen Zhu, Date: 1 March - 31 August, Institution: Master IFI Ubinet, UNS, Supervisor: K. Avrachenkov, Subject: Distributed Approaches for Graph-based Unsupervised Learning

9.5.3. Visits to International Teams

9.5.3.1. Research Stays Abroad

Eitan Altman

- Date: 1-8 March, Institution: Technion (Israel)
- Date: 12-23 April, Institution: Technion and Univ. Tel-Aviv (Israel)
- Date: 10-21 December, Institution: IIT Bombay (India)

Konstantin Avrachenkov

- Date: 29 January - 2 February, Institution: Univ. Liverpool (United Kingdom)
- Date: 21-22 May, Institution: Saint Petersburg State Univ. (Russia)
- Date: 17-18 September, Institution: Univ. Leiden (The Netherlands)
- Date: 19-23 September, Institution: Univ. Twente (The Netherlands)
- Date: 15-18 October, Institution: IIT Bombay (India)

Abhishek Bose

- Date: 19-23 November, Institution: IIT Bombay (India)

Swapnil Dhamal

- Date: 17-18 September, Institution: IISc Bangalore (India)
- Date: 19 September, Company: IBM Research Labs Bangalore (India)

Alain Jean-Marie

Date: 24 September - 14 October, Institution: Univ. of Montreal (Canada)

Date: 2-27 November, Institution: National Univ. of Rosario (Argentina)

Giovanni Neglia

- Date: 11-16 November, Institution: Purdue Univ. (USA)
- Date: 3-8 November, Institution: IIT Bombay (India)

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

- Eitan Altman was the general chair of the 6th Intl. Conf. on Wireless Networks and Mobile Communications (WINCOM'18), Marrakesh, Morocco, 16-19 October 2018;
- Eitan Altman is the general chair of the 12th EAI International Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2019), Palma de Mallorca, Spain, 13-15 March 2019;
- Eitan Altman is a steering committee member of the
  - 4th Intl. Symposium on Ubiquitous Networking (UNET 2018), Hammamet, Tunisia, 2-5 May 2018;
  - 9th EAI Intl. Conf. on Game Theory for Networks (GAMENETS 2019), Paris, France, 25-26 April 2019;
- Dimitra Politaki was the general chair of the workshop "Monde des mathematiques industrielles (MOMI)," Inria Sophia Antipolis Méditerranée, 26-27 February 2018.

10.1.1.2. Member of the Organizing Committees

- G. Neglia is publicity co-chair of the 20th Intl. Symposium on Mobile Ad Hoc Networking and Computing (ACM Mobihoc, Catania, Italy, 2019).

10.1.2. Scientific Events Selection

10.1.2.1. Chair of Conference Program Committees

- Eitan Altman was TPC co-chair of ITC 30 (Vienna, Austria, Sept. 2018);

10.1.2.2. Member of the Conference Program Committees

- ACM Sigmetrics / IFIP Performance 2019 (Phoenix, Arizona, USA) (S. Alouf, K. Avrachenkov)
- 19th Conf. of the Société Française de Recherche Opérationnelle et d'Aide à la Décision (ROADEF 2018, Lorient, France) (A. Jean-Marie)
- 9th EAI Intl. Conf. on Sensor Systems and Software (S-CUBE 2018, Chengdu, China) (E. Altman)
- 15th European Performance Engineering Workshop (EPEW 2018, Paris, France) (A. Jean-Marie)
- IEEE Intl. Conf. on Computer Communications (INFOCOM 2019, Paris, France) (G. Neglia)
- 26th IEEE Intl. Conf. on Network Protocols (ICNP 2018, Cambridge, UK) (K. Avrachenkov)
- 3rd Intl. Conf. on Pervasive and Embedded Computing (PEC 2018) (K. Avrachenkov)
- 6th Intl. Conf. on Wireless Networks and Mobile Communications (WINCOM'18, Marrakesh, Morocco) (E. Altman)
- European Conf. on Queueing Theory (ECQT 2018, Jerusalem, Israel) (K. Avrachenkov)
- 9th Intl. Conf. on Network Games, Control and Optimization (NETGCOOP 2018, New York, USA) (K. Avrachenkov)
- 18th Intl. Symposium on Dynamic Games and Applications (ISDG 2018, Grenoble, France) (E. Altman)
- 2018 Intl. Workshop on Resource Allocation, Cooperation and Competition in Wireless Networks (RAWNET, Shangai, China, 2018) (K. Avrachenkov, G. Neglia)
- Workshop on AI in Networks (WAIN, Toulouse, France, 2018) (G. Neglia)
- 15th Workshop on Algorithms and Models for the Web Graph (WAW 2018, Moscow, Russia) (K. Avrachenkov)
- 20th Workshop on MAthematical performance Modeling and Analysis (MAMA 2018, Irvine, USA) (A. Jean-Marie)
- 2018 Intl. Workshop on Content Caching and Delivery in Wireless Networks (CCDWN 2018, Shanghai, China) (K. Avrachenkov)
- Workshop Technologies for the Wireless Edge (EdgeTech 2018) (K. Avrachenkov)

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- *Elsevier Computer Communications (COMCOM)* (G. Neglia);
- *Elsevier International Journal of Performance Evaluation* (K. Avrachenkov);
- *ACM Transactions on Modeling and Performance Evaluation of Computing Systems (ACM ToMPECS)* (K. Avrachenkov);
- *Wiley Transactions on Emerging Telecommunications Technologies (ETT)* (S. Alouf);
- *IEEE JSAC* Special issue on Caching for Communication Systems and Networks (S. Alouf, G. Neglia);

10.1.3.2. Reviewer - Reviewing Activities

- *ACM Transactions on Modeling and Performance Evaluation of Computing Systems* (ACM ToMPECS) (G. Neglia)

- *European Journal of Operational Research* (A. Jean-Marie)
- *IEEE Networking Letters* (G. Neglia)
- *EURASIP Journal on Wireless Communications and Networking* (G. Neglia)
- *Journal of Economic Dynamics and Control* (A. Jean-Marie)
- *IEEE Transactions on Parallel and Distributed Systems* (G. Neglia)
- *IEEE Transactions on Signal and Information Processing over Networks* (G. Neglia)
- *IEEE/ACM Transactions on Networking* (G. Neglia)
- *Performance Evaluation* (PEVA) (S. Alouf)
- *Probability in the Engineering and Informational Sciences* (A. Jean-Marie)

10.1.4. Invited Talks

- E. Altman gave a keynote lecture on "Game Theoretic Models for Routing Over Wireless Links " at the 6th Intl. Conf. on Wireless Networks and Mobile Communications (WINCOM'18), October 16-19, Marrakesh, Morocco.
- K. Avrachenkov gave an invited talk on "Analysis of relaxation time in random walk with jumps" at the Intl. Conf. on Trends and Perspectives in Linear Statistical Inference (LinStat'2018, 19-25 August) in Bedlewo, Poland.
- K. Avrachenkov gave an invited talk on "Singularly perturbed linear programs and their application to MDP" at Univ. of Twente, September 20, Enschede, The Netherlands.
- G. Neglia gave an invited talk on "Implicit Coordination of Caches in Small Cell Networks under Unknown Popularity Profiles" at the workshop Technologies for the Wireless Edge (EdgeTech) EdgeTech of the 24th Annual Intl. Conf. on Mobile Computing and Networking (ACM MobiCom 2018), November 2, New Delhi, India.
- G. Neglia gave an invited talk on "Transient and Slim versus Recurrent and Fat: Random Walks and the Trees they Grow" at the UCA workshop on Social Interactions and Complex Dynamics, November 29-30, Nice, France.

10.1.5. Leadership within the Scientific Community

- E. Altman is a fellow member of IEEE (Class of 2010).
- E. Altman and A. Jean-Marie are (elected) members of IFIP WG 7.3 on "Computer System Modeling".
- E. Altman is member of WG 6.3 of IFIP on Performance of Communication Systems.

10.1.6. Research Administration

S. Alouf

- is member of the scientific committee of the joint laboratory Inria-Alstom since May 2014;
- is member of CLF, the training committee of Inria Sophia Antipolis Méditerranée, since November 2014;
- is vice-head of project-team NEO since January 2017.

K. Avrachenkov

- is responsible for the supervision and validation of the project-teams' yearly activity reports since 2010;
- is a member of NICE, the Invited Researchers Committee of Inria Sophia Antipolis Méditerranée, since 2010.
- is a member of scientific committee for Labex UCN@Sophia;
- is a member of scientific and pedagogical committee for the graduate school of UCA DS4H.

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);
- is member of the managing sub-committee of the Project-Team Committee of the Inria Sophia Antipolis – Méditerranée research center since December 2017;
- 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 NEO since January 2017.

G. Neglia

- is the scientific delegate for European partnerships for Inria Sophia Antipolis – Méditerranée since 2014;
- is member of the Inria COST GTRI (International Relations Working Group of Inria’s Scientific and Technological Orientation Council since 2016;
- is member of the scientific animation committee for the IDEX UCA$^{\mathrm{JEDI}}$ research program “Social Interactions and Complex Dynamics” since 2017.

D. Politaki was one of the organizers of the fortnightly PhD Seminars of Inria Sophia Antipolis Méditerranée until September 2018.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence :

G. Neglia, “Probability”, 60H, Undergraduate Water Engineering degree (L3), Univ. of Nice Sophia Antipolis (UNS), France.

Master :

A. Jean-Marie, “Performance Evaluation of Networks”, 15.75H, M2 IFI Ubinet, UNS, France.

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

G. Neglia, “Performance Evaluation of Networks”, 15.75H, M2 IFI Ubinet, UNS, France.

G. Neglia, responsible for the “Winter School on Complex Networks”, 22.5H, M1 Computer Science, UNS, France.

Doctorat:

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

10.2.2. Supervision

PhD defended:

Said Boularouk, “Helping space apprehension by visually impaired people”, UAPV, 5 Dec. 2018, advisors: Eitan Altman and Didier Josselin.

PhD in progress :

Zaid Allybokus, “Scalable Online Algorithms for SDN Controllers”, 1 July 2016, advisors: Konstantin Avrachenkov and Lorenzo Maggi (Huawei).

Abhishek Bose, “Adaptive crawling with machine learning techniques”, 1 June 2018, advisor: Konstantin Avrachenkov.

Mandar Datar, “Singular perturbation approach for machine learning in multiobjective optimisation”, 1 May 2018, advisor: Eitan Altman.

Maximilien Dreveton, “Statistical Physics Methods for Distributed Machine Learning”, 1 Oct. 2018, advisor: Konstantin Avrachenkov.

Guilherme Iecker Ricardo, “Caching for wireless networks”, 1 Sept. 2018, advisors: Giovanni Neglia and Pietro Elia (EURECOM).

Marie Masson, “Fonctionnalités auto-organisantes dans le réseau d’accès radio 5G virtuels”, 1 Dec. 2017, advisors: Eitan Altman and Zwi Altman (Orange).

Dimitra Politaki, “Greening data center”, 1 February 2016, advisors: Sara Alouf and Fabien Hermenier (UNS).

10.2.3. Juries

NEO members participated in the Ph.D. committees of (in alphabetical order):

- Hafiz Ali, “Random Matrix Theory and Large Dimensional graphs”, CentraleSupelec, 24 September (K. Avrachenkov as reviewer);
- Xinwei Bai, “Performance bounds for random walks in the positive orthant”, Univ. Twente, 20 September (K. Avrachenkov as reviewer);
- Yoann Couble, “Optimisation de la gestion des ressources de la voie retour”, Institut National Polytechnique de Toulouse, 3 September (S. Alouf as reviewer);
- Thibault Debatty, “Design and analysis of distributed k-nearest neighbors graph algorithms”, TELECOM ParisTech, 5 October (G. Neglia as reviewer);
- Philippe Ezran, “Topology Optimization of Wireless Networks”, Univ. Paris-Saclay, 23 January (E. Altman as reviewer);
- Dalia-Georgiana Popescu, “Les hyperfractales pour la modelisation des reseaux sans fil”, LINCS, 21 November (K. Avrachenkov as reviewer);
- Rémi Varloot, “Dynamic Network Formation”, Université de recherche Paris Sciences et Lettres, École normale supérieure, 1 June (G. Neglia as jury president).

10.3. Popularization

10.3.1. Internal or external Inria responsibilities

- D. Politaki is a member of MASTIC, a commission in charge of popularization and regional and internal scientific animation, since July 2016.

10.3.2. Interventions

On October 12th, in the framework of *La Fête de la Science*, M. Dreveton participated in a mediation activity at *Espace de l’Art Concret* in Mouans-Sartoux. It was a mix between art and sciences (maths and physics). The topic was randomness and the targeted public was primary school students, from two different classes (one in the morning and one in the afternoon). Activities involved loaded dices, Galton Board, double pendulum, and some online program (http://weavesilk.com/, pupils really liked this). Each game was presented and students would figure out where the randomness comes from, and play/experiment by themselves (30 min per group).

11. Bibliography

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Articles in International Peer-Reviewed Journals

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[2] K. AVRACHENKOV, T. BODAS. *On the equivalence between multiclass processor sharing and random order scheduling policies*, in "ACM SIGMETRICS Performance Evaluation Review", March 2018, vol. 45, n^o 4, pp. 2 - 6 [*DOI :* 10.1145/3273996.3273998], https://hal.inria.fr/hal-01935447

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