Activity Report 2019

Project-Team NEO

Network Engineering and Operations

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Networks and Telecommunications

Table of contents

Project-Team NEO

Creation of the Team: 2017 January 01, updated into Project-Team: 2017 December 01

Keywords:

Computer Science and Digital Science:

A1.5. - Complex systems
A1.5.1. - Systems of systems
A1.5.2. - Communicating systems
A3.3.3. - Big data analysis
A3.4. - Machine learning and statistics
A3.5. - Social networks
A3.5.2. - Recommendation systems
A6.1.1. - Continuous Modeling (PDE, ODE)
A6.1.2. - Stochastic Modeling
A6.2.2. - Numerical probability
A6.2.3. - Probabilistic methods
A6.2.6. - Optimization
A6.4.1. - Deterministic control
A6.4.2. - Stochastic control
A6.4.6. - Optimal control
A7.1. - Algorithms
A7.1.1. - Distributed algorithms
A7.1.2. - Parallel algorithms
A8.1. - Discrete mathematics, combinatorics
A8.2.1. - Operations research
A8.8. - Network science
A8.9. - Performance evaluation
A8.11. - Game Theory
A9.2. - Machine learning
A9.6. - Decision support
A9.9. - Distributed AI, Multi-agent

Other Research Topics and Application Domains:

B2.5.1. - Sensorimotor disabilities
B3.1. - Sustainable development
B3.1.1. - Resource management
B4.3.4. - Solar Energy
B4.4. - Energy delivery
B4.4.1. - Smart grids
B4.5.1. - Green computing
B6.2.1. - Wired technologies
B6.2.2. - Radio technology
B6.3.3. - Network Management

B6.3.4. - Social Networks
B8.1. - Smart building/home
B9.2.1. - Music, sound
B9.5.1. - Computer science
B9.5.2. - Mathematics
B9.6.3. - Economy, Finance
B9.6.4. - Management science
B9.6.5. - Sociology

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, until Aug 2019]
Andrei Bobu [Inria, from May 2019]
Swapnil Dhamal [Inria, until Feb 2019]
Kishor Yashavant Patil [Inria, from Oct 2019]
Chuan Xu [Inria, from Oct 2018]

PhD Students
Zaid Allybokus [Huawei, until Jun 2019]
Abhishek Bose [Inria, until Sep 2019]
Mandar Datar [Inria]
Maximilien Dreveton [Inria]
Guilherme Iecker Ricardo [Institut Telecom ex GET Groupe des Ecoles des Télécommunications]
Mikhail Kamalov [Inria, from Jun 2019]
Marie Masson [Orange]
Dimitra Politaki [Univ Côte d'Azur - Sophia Antipolis, until Mar 2019]
Tareq Si Salem [Univ Côte d'Azur, from Oct 2019]

Technical staff
Omar Mohamed [Inria, Engineer, from Jun 2019 until Sep 2019]
Cedric Richier [Inria, Engineer, from Mar 2019 until May 2019]

Administrative Assistant
Laurie Vermeersch [Inria]

Visiting Scientists
Vladimir Gaitsgory [Macquarie University, Australia, from Sep 2019 until Oct 2019]
Witold Szczechla [Warsaw University, Poland, from Oct 2019 until Dec 2019]

External Collaborator
Patrick Brown [Inria, Nov 2019]

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

Maximilien Dreveton, PhD student in NEO, has co-authored a book: *Leçons pour l'agrégation de mathématiques* [61].

The members of NEO have edited three collections: [64], [65], [66]. One collection is a result of the very successful EU Project CONGAS: Multilevel Strategic Interaction Game Models for Complex Networks.

Sara Alouf has been elected member of the Board of Directors of the ACM SIGMETRICS.

A workshop in the honor of Eitan Altman, at the occasion of his 60th birthday, took place at the University of Avignon on June, 3rd, 2019. Recordings of the presentations are available, see https://www.canal-u.tv/producteurs/universite_d_avignon_et_des_pays_de_vaucluse/colloque/wiopt_2019.

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

7.1.1. Network growth models

Network growth models that embody principles such as preferential attachment and local attachment rules have received much attention over the last decade. Among various approaches, random walks have been leveraged to capture such principles. In the framework of joint team with Brazil (Thanes), G. Neglia, together with G. Iacobelli and D. Figueiredo (both from UFRJ, Brazil), has studied a simple model where network growth and a random walker are coupled [23]. In particular, they consider the No Restart Random Walk model where a walker builds its graph (tree) while moving around. The walker takes s steps (a parameter) on the current graph. A new node with degree one is added to the graph and connected to the node currently occupied by the walker. The walker then resumes, taking another s steps, and the process repeats. They have analyzed this process from the perspective of the walker and the network, showing a fundamental dichotomy between transience and recurrence for the walker as well as power law and exponential degree distribution for the network.

7.1.2. Controlled Markov chains

E. Altman in collaboration with D. Josselin and S. Boularouk (CERI/LIA, Univ Avignon) study in [26] a multiobjective dynamic program where all the criteria are in the form of total expected sum of costs till absorption in some set of states. They assume that instantaneous costs are strictly positive and make no assumption on the ergodic structure of the Markov Decision Process. Their main result is to extend the linear program solution approach that was previously derived for transient Constrained Markov Decision Processes to the general ergodic structure. Several (additive) cost metrics are defined and (possibly randomized) routing policies are sought which minimize one of the costs subject to constraints over the other objectives.

7.1.3. Escape probability estimation in large graphs

Consider large graphs as the object of study and specifically the problem of escape probability estimation. Generally, this characteristic cannot be calculated analytically nor even numerically due to the complexity and large size of the investigation object. In [32], K. Avrachenkov and A. Borodina (Karelian Institute of Applied Mathematical Research, Russia) have presented an effective method for estimating the probability that the random walk on graph first enters a node b before returning into the starting node a. Regenerative properties of the random walk allow the use of an accelerated method for the simulation of cycles based on the splitting technique. The results of numerical experiments confirm the advantages of the proposed method.

7.1.4. Random surfers and prefetching

Prefetching is a basic technique used to reduce the latency of diverse computer services. Deciding what to prefetch amounts to make a compromise between latency and the waste of resources (network bandwidth, storage, energy) if contents is mistakenly prefetched. Modeling the problem in case of web/video/gaming navigation, is done by identifying a graph of "documents" connected by links representing the possible chaining. A surfer, either random or strategic, browses this graph. The prefetching controller must make it sure that the documents browsed are always available locally. In the case where the surfer is random and/or the graph is not completely known in advance, the question is largely unexplored. Q. Petitjean, under the supervision of S. Alouf and A. Jean-Marie, has determined through extensive simulations that when the graph is a tree, neither the greedy strategy, nor the one optimal when the tree is completely known, are optimal when the tree is discovered progressively.

7.1.5. The marmoteCore platform

The development of marmoteCore (see Section 6.1) has been pursued. Its numerical features for computing stationary distributions, average hitting times and absorption probabilities have been used in a joint work with F. Cazals, D. Mazauric and G. Santa Cruz (ABS team) and J. Roux (Univ Cote d'Azur) [52]. The software has been presented to young researchers in networking at the ResCom 2019 summer school.

7.2. Random Graph and Matrix Models

Participants: Konstantin Avrachenkov, Andrei Bobu.

7.2.1. Random geometric graphs

Random geometric graphs are good examples of random graphs with a tendency to demonstrate community structure. Vertices of such a graph are represented by points in Euclid space R^d, and edge appearance depends on the distance between the points. Random geometric graphs were extensively explored and many of their basic properties are revealed. However, in the case of growing dimension $d \to \infty$ practically nothing is known; this regime corresponds to the case of data with many features, a case commonly appearing in practice. In [30], K. Avrachenkov and A. Bobu focus on the cliques of these graphs in the situation when average vertex degree grows significantly slower than the number of vertices n with $n \to \infty$ and $d \to \infty$. They show that under these conditions random geometric graphs do not contain cliques of size 4 a.s. As for the size 3, they present new bounds on the expected number of triangles in the case $\log^2(n) \ll d \ll \log^3(n)$ that improve previously known results.

Network geometries are typically characterized by having a finite spectral dimension (SD), that characterizes the return time distribution of a random walk on a graph. The main purpose of this work is to determine the SD of random geometric graphs (RGGs) in the thermodynamic regime, in which the average vertex degree is constant. The spectral dimension depends on the eigenvalue density (ED) of the RGG normalized Laplacian in the neighborhood of the minimum eigenvalues. In fact, the behavior of the ED in such a neighborhood characterizes the random walk. Therefore, in [33] K. Avrachenkov together with L. Cottatellucci (FAU, Germany and Eurecom) and M. Hamidouche (Eurecom) first provide an analytical approximation for the eigenvalues of the regularized normalized Laplacian matrix of RGGs in the thermodynamic regime. Then, we show that the smallest non zero eigenvalue converges to zero in the large graph limit. Based on the analytical expression of the eigenvalues, they show that the eigenvalue distribution in a neighborhood of the minimum value follows a power-law tail. Using this result, they find that the SD of RGGs is approximated by the space dimension d in the thermodynamic regime.

In [42] K. Avrachenkov together with L. Cottatellucci (FAU, Germany and Eurecom) and M. Hamidouche (Eurecom) have analyzed the limiting eigenvalue distribution (LED) of random geometric graphs. In particular, they study the LED of the adjacency matrix of RGGs in the connectivity regime, in which the average vertex degree scales as $\log(n)$ or faster. In the connectivity regime and under some conditions on the radius r, they show that the LED of the adjacency matrix of RGGs converges to the LED of the adjacency matrix of a deterministic geometric graph (DGG) with nodes in a grid as the size of the graph n goes to infinity. Then, for

n finite, they use the structure of the DGG to approximate the eigenvalues of the adjacency matrix of the RGG and provide an upper bound for the approximation error.

7.3. Data Analysis and Learning

Participants: Konstantin Avrachenkov, Maximilien Dreveton, Giovanni Neglia, Chuan Xu.

7.3.1. Almost exact recovery in label spreading

In semi-supervised graph clustering setting, an expert provides cluster membership of few nodes. This little amount of information allows one to achieve high accuracy clustering using efficient computational procedures. Our main goal is to provide a theoretical justification why the graph-based semi-supervised learning works very well. Specifically, for the Stochastic Block Model in the moderately sparse regime, in [34] K. Avrachenkov and M. Dreveton have proved that popular semi-supervised clustering methods like Label Spreading achieve asymptotically almost exact recovery as long as the fraction of labeled nodes does not go to zero and the average degree goes to infinity.

7.3.2. Similarities, kernels and proximity measures on graphs

In [13], K. Avrachenkov together with P. Chebotarev (RAS Trapeznikov Institute of Control Sciences, Russia) and D. Rubanov (Google) have analytically studied proximity and distance properties of various kernels and similarity measures on graphs. This helps to understand the mathematical nature of such measures and can potentially be useful for recommending the adoption of specific similarity measures in data analysis.

7.3.3. The effect of communication topology on learning speed

Many learning problems are formulated as minimization of some loss function on a training set of examples. Distributed gradient methods on a cluster are often used for this purpose. In [47], G. Neglia, together with G. Calbi (Univ Côte d'Azur), D. Towsley, and G. Vardoyan (UMass at Amherst, USA), has studied how the variability of task execution times at cluster nodes affects the system throughput. In particular, a simple but accurate model allows them to quantify how the time to solve the minimization problem depends on the network of information exchanges among the nodes. Interestingly, they show that, even when communication overhead may be neglected, the clique is not necessarily the most effective topology, as commonly assumed in previous works.

In [48] G. Neglia and C. Xu, together with D. Towsley (UMass at Amherst, USA) and G. Calbi (Univ Côte d'Azur) have investigated why the effect of the communication topology on the number of epochs needed for machine learning training to converge appears experimentally much smaller than what predicted by theory.

7.4. Game Theory

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

7.4.1. Resource allocation: Kelly mechanism and Tullock game

The price-anticipating Kelly mechanism (PAKM) is one of the most extensively used strategies to allocate divisible resources for strategic users in communication networks and computing systems. It is known in other communities as the Tullock game. The users are deemed as selfish and also benign, each of which maximizes his individual utility of the allocated resources minus his payment to the network operator. E. Altman, A. Reiffers-Masson (IISc Bangalore, India), D. Sadoc-Menasche (UFJR, Brazil), M. Datar, S. Dhamal, C. Touati (Inria Grenoble-Rhone-Alpes) and R. El-Azouzi (CERI/LIA, Univ Avignon) have first applied this type of games to competition in crypto-currency protocols between miners in blockchain [11]. Blockchain is a distributed synchronized secure database containing validated blocks of transactions. A block is validated by special nodes called miners and the validation of each new block is done via the solution of a computationally difficult problem, which is called the proof-of-work puzzle. The miners compete against each other and the first to solve the problem announces it, the block is then verified by the majority of miners in this network, trying to reach consensus. After the propagated block reaches the consensus, it is successfully added to the distributed database. The miner who found the solution receives a reward either in the form of crypto-currencies or in the form of a transaction reward. The authors show that the discrete version of the game is equivalent to a congestion game and thus has an equilibrium in pure strategies.

E. Altman, M. Datar, C. Touati (Inria Grenoble-Rhone-Alpes) and G. Burnside (Nokia Bell Labs) then introduce further constraints on the total amount of resources used and study pricing issues in this constrained game. They show that a normalized equilibrium (in the sense of Rosen) exists which implies that pricing can be done in a scalable way, i.e; prices can be chosen to be independent of the player. A possible way to prove this structure is to show that the utilities are strict diagonal concave (which is an extension to game setting of concavity) which they did in [27].

In [25], Y. Xu, Z. Xiao, T. Ni, X. Wang (all from Fudan Univ, China), J. H. Wang (Tsinghua Univ, China) and E. Altman formulate a non-cooperative Tullock game consisting of a finite amount of benign users and one misbehaving user. The maliciousness of this misbehaving user is captured by his willingness to pay to trade for unit degradation in the utilities of benign users. The network operator allocates resources to all the users via the price-anticipating Kelly mechanism. They present six important performance metrics with regard to the total utility and the total net utility of benign users, and the revenue of network operator under three different scenarios: with and without the misbehaving user, and the maximum. We quantify the robustness of PAKM against the misbehaving actions by deriving the upper and lower bounds of these metrics.

7.4.2. A stochastic game with non-classical information structure

In [44], V. Kavitha, M. Maheshwari (both from IIT Bombay, India) and E. Altman introduce a stochastic game with partial, asymmetric and non-classical information. They obtain relevant equilibrium policies using a new approach which allows managing the belief updates in a structured manner. Agents have access only to partial information updates, and their approach is to consider optimal open loop control until the information update. The agents continuously control the rates of their Poisson search clocks to acquire the locks, the agent to get all the locks before others would get reward one. However, the agents have no information about the acquisition status of others and will incur a cost proportional to their rate process. The authors solved the problem for the case with two agents and two locks and conjectured the results for a general number of agents. They showed that a pair of (partial) state-dependent time-threshold policies form a Nash equilibrium.

7.4.3. Zero-Sum stochastic games over the field of real algebraic numbers

In [14], K. Avrachenkov together with V. Ejov (Flinders Univ, Australia), J. Filar and A. Moghaddam (both from Univ of Queensland, Australia) have considered a finite state, finite action, zero-sum stochastic games with data defining the game lying in the ordered field of real algebraic numbers. In both the discounted and the limiting average versions of these games, they prove that the value vector also lies in the same field of real algebraic numbers. Their method supplies finite construction of univariate polynomials whose roots contain these value vectors. In the case where the data of the game are rational, the method also provides a way of checking whether the entries of the value vectors are also rational.

7.4.4. Evolutionary Markov games

I. Brunetti (CIRED), Y. Hayel (CERI/LIA, Univ Avignon) and E. Altman extend in [59] evolutionary game theory by introducing the concept of individual state. They analyze a particular simple case, in which they associate a state to each player, and suppose that this state determines the set of available actions. They consider deterministic stationary policies and suppose that the choice of a policy determines the fitness of the player and it impacts the evolution of the state. They define the interdependent dynamics of states and policies and introduce the State Policy coupled Dynamics in order to study the evolution of the population profile. They prove the relation between the rest points of the system and the equilibria of the game. Then they assume that the processes of states and policies move with different velocities: this assumption allows them to solve the system and then find the equilibria of the game with two different methods: the singular perturbation method and a matrix approach.

7.4.5. Stochastic replicator dynamics

In [12], K. Avrachenkov and V.S. Borkar (IIT Bombay, India) have considered a novel model of stochastic replicator dynamics for potential games that converts to a Langevin equation on a sphere after a change of variables. This is distinct from the models of stochastic replicator dynamics studied earlier. In particular, it

is ill-posed due to non-uniqueness of solutions, but is amenable to the Kolmogorov selection principle that picks a unique solution. The model allows us to make specific statements regarding metastable states such as small noise asymptotics for mean exit times from their domain of attraction, and quasi-stationary measures. We illustrate the general results by specializing them to replicator dynamics on graphs and demonstrate that the numerical experiments support theoretical predictions.

7.4.6. Stochastic coalitional better-response dynamics for finite games with application to network formation games

In [57], K. Avrachenkov and V.V. Sing (IIT Delhi, India) have considered coalition formation among players in n-player finite strategic game over infinite horizon. At each time a randomly formed coalition makes a joint deviation from a current action profile such that at new action profile all the players from the coalition are strictly benefited. Such deviations define a coalitional better-response (CBR) dynamics that is in general stochastic. The CBR dynamics either converges to a $\mathcal{K}$-stable equilibrium or becomes stuck in a closed cycle. The authors also assume that at each time a selected coalition makes mistake in deviation with small probability that add mutations (perturbations) into CBR dynamics. They prove that all $\mathcal{K}$-stable equilibria and all action profiles from closed cycles, that have minimum stochastic potential, are stochastically stable. A similar statement holds for strict $\mathcal{K}$-stable equilibrium. They apply the CBR dynamics to study the dynamic formation of the networks in the presence of mutations. Under the CBR dynamics all strongly stable networks and closed cycles of networks are stochastically stable.

7.4.7. Strong Stackelberg equilibria in stochastic games

In a joint work with V. Bucarey López (Univ Libre de Bruxelles, Belgium and Inria team INOCS), E. Della Vecchia (Univ Nacional de Rosario, Argentina), and F. Ordóñez (Univ de Chile, Chile), A. Jean-Marie has considered Stackelberg equilibria for discounted stochastic games. The motivation originates in applications of Game Theory to security issues, but the question is of general theoretical and practical relevance. The solution concept of interest is that of Stationary Strong Stackelberg Equlibrium (SSSE) policies: both players apply state feedback policies; the leader announces her strategy and the follower plays a best response to it. Tie breaks are resolved in favor of the leader. The authors provide classes of games where the SSSE exists, and we prove via counterexamples that SSSE does not exist in the general case. They define suitable dynamic programming operators whose fixed points are referred to as Fixed Point Equilibrium (FPE). They show that the FPE and SSSE coincide for a class of games with Myopic Follower Strategy. Numerical examples shed light on the relationship between SSSE and FPE and the behavior of Value Iteration, Policy Iteration and Mathematical programming formulations for this problem. A security application illustrates the solution concepts and the efficiency of the algorithms introduced. The results are presented in [67], [50], [51].

7.4.8. Routing on a ring network

R. Burra, C. Singh and J. Kuri (IISc Bangalore, India), study in [60] with E. Altman routing on a ring network in which traffic originates from nodes on the ring and is destined to the center. The users can take direct paths from originating nodes to the center and also multihop paths via other nodes. The authors show that routing games with only one and two hop paths and linear costs are potential games. They give explicit expressions of Nash equilibrium flows for networks with any generic cost function and symmetric loads. They also consider a ring network with random number of users at nodes, all of them having same demand, and linear routing costs. They give explicit characterization of Nash equilibria for two cases: (i) General i.i.d. loads and one and two hop paths, (ii) Bernoulli distributed loads. They also analyze optimal routing in each of these cases.

7.4.9. Routing games applied to the network neutrality debate

The Network Neutrality issue has been at the center of debate worldwide lately. Some countries have established laws so that principles of network neutrality are respected. Among the questions that have been discussed in these debates there is whether to allow agreements between service and content providers, i.e. to allow some preferential treatment by an operator to traffic from some providers (identity-based discrimination). In [63], A. Reiffers-Masson (IISc Bangalore), Y. Hayel, T. Jimenez (CERI/LIA, Univ Avignon) and E. Altman, study this question using models from routing games.

7.4.10. Peering vs transit: A game theoretical model for autonomous systems connectivity

G. Accongiagioco (IMT, Italy), E. Altman, E. Gregori (Institute of Informatics and Telematics, Univ Pisa) and Luciano Lenzini (Dipartimento di Informatica, Univ Pisa) propose a model for network optimization in a non-cooperative game setting with specific reference to the Internet connectivity. The model describes the decisions taken by an Autonomous System when joining the Internet. They first define a realistic model for the interconnection costs incurred; then they use this cost model to perform a game theoretic analysis of the decisions related to link creation and traffic routing, keeping into account the peering/transit dichotomy. The proposed model does not fall into the standard category of routing games, hence they devise new tools to solve it by exploiting specific properties of the game. They prove analytically the existence of multiple equilibria.

7.4.11. Altruistic behavior and evolutionary games

Within some species like bees or ants, the one who interacts is not the one who reproduces. This implies that the Darwinian fitness is related to the entire swarm and not to a single individual and thus, standard Evolutionary Game models do not apply to these species. Furthermore, in many species, one finds altruistic behaviors, which favors the group to which the playing individual belongs, but which may hurt the single individual. In [58], [62], I. Brunetti (CIRED), R. El-Azouzi, M. Haddad, H. Gaiech, Y. Hayel (LIA/CERI, Univ Avignon) and E. Altman define evolutionary games between group of players and study the equilibrium behavior as well as convergence to equilibrium.

7.5. Applications in Telecommunications

Participants: Eitan Altman, Konstantin Avrachenkov, Giovanni Neglia.

7.5.1. Elastic cloud caching services

In [37], G. Neglia, together with D. Carra (Univ of Verona, Italy) and P. Michiardi (Eurecom), has considered in-memory key-value stores used as caches, and their elastic provisioning in the cloud. The cost associated to such caches not only includes the storage cost, but also the cost due to misses: in fact, the cache miss ratio has a direct impact on the performance perceived by end users, and this directly affects the overall revenues for content providers. The goal of their work is to adapt dynamically the number of caches based on the traffic pattern, to minimize the overall costs. They present a dynamic algorithm for TTL caches whose goal is to obtain close-to-minimal costs and propose a practical implementation with limited computational complexity: their scheme requires constant overhead per request independently from the cache size. Using real-world traces collected from the Akamai content delivery network, they show that their solution achieves significant cost savings specially in highly dynamic settings that are likely to require elastic cloud services.

7.5.2. Neural networks for caching

In [19] G. Neglia, together with V. Fedchenko (Univ Côte d'Azur) and B. Ribeiro (Purdue Univ, USA), has proposed a caching policy that uses a feedforward neural network (FNN) to predict content popularity. This scheme outperforms popular eviction policies like LRU or ARC, but also a new policy relying on the more complex recurrent neural networks. At the same time, replacing the FNN predictor with a naive linear estimator does not degrade caching performance significantly, questioning then the role of neural networks for these applications.

7.5.3. Similarity caching

In similarity caching systems, a user request for an object o that is not in the cache can be (partially) satisfied by a similar stored object o', at the cost of a loss of user utility. Similarity caching systems can be effectively employed in several application areas, like multimedia retrieval, recommender systems, genome study, and machine learning training/serving. However, despite their relevance, the behavior of such systems is far from being well understood. In [41], G. Neglia, together with M. Garetto (Univ of Turin, Italy) and E. Leonardi (Politechnic of Turin, Italy), provides a first comprehensive analysis of similarity caching in the offline, adversarial, and stochastic settings. They show that similarity caching raises significant new challenges, for which they propose the first dynamic policies with some optimality guarantees. They evaluate the performance of the proposed schemes under both synthetic and real request traces.

7.5.4. Performance evaluation and optimization of 5G wireless networks

In small cell networks, high mobility of users results in frequent handoff and thus severely restricts the data rate for mobile users. To alleviate this problem, one idea is to use heterogeneous, two-tier network structure where static users are served by both macro and micro base stations, whereas the mobile (i.e., moving) users are served only by macro base stations having larger cells; the idea is to prevent frequent data outage for mobile users due to handoff. In [16], A. Chattopadhyay and B. Błaszczyszyn (Inria DYOGENE team) in collaboration with E. Altman use the classical two-tier Poisson network model with different transmit powers, assume independent Poisson process of static users and doubly stochastic Poisson process of mobile users moving at a constant speed along infinite straight lines generated by a Poisson line process. Using stochastic geometry, they calculate the average downlink data rate of the typical static and mobile (i.e., moving) users, the latter accounted for handoff outage periods. They consider also the average throughput of these two types of users.

In [15], the same authors consider location-dependent opportunistic bandwidth sharing between static and mobile downlink users in a cellular network. Each cell has some fixed number of static users. Mobile users enter the cell, move inside the cell for some time and then leave the cell. 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 a long run average reward Markov decision process (MDP) where the per-step reward is a linear combination of instantaneous data volumes received by static and mobile users, and find the optimal policy. The transition structure of this MDP is not known in general. To alleviate this issue, they propose a learning algorithm based on single timescale stochastic approximation. Also, noting that the unconstrained MDP can be used to solve a constrained problem, they provide a learning algorithm based on multi-timescale stochastic approximation. The results are extended to address the issue of fair bandwidth sharing between the two classes of users. Numerical results demonstrate performance improvement by their scheme, and also the trade-off between performance gain and fairness.

7.5.5. The age of information

Two decades after the seminal paper on software aging and rejuvenation appeared in 1995, a new concept and metric referred to as the age of information (AoI) has been gaining attention from practitioners and the research community. In the vision paper [46], D.S. Menasche (UFRJ, Brazil), K. Trivedi (Duke Univ, USA) and E. Altman show the similarities and differences between software aging and information aging. In particular, modeling frameworks that have been applied to software aging, such as the semi Markov approach can be immediately applied in the realm of age of information. Conversely, they indicate that questions pertaining to sampling costs associated with the age of information can be useful to assess the optimal rejuvenation trigger interval for software systems.

The demand for Internet services that require frequent updates through small messages has tremendously grown in the past few years. Although the use of such applications by domestic users is usually free, their access from mobile devices is subject to fees and consumes energy from limited batteries. If a user activates his mobile device and is in the range of a publisher, an update is received at the expense of monetary and energy costs. Thus, users face a tradeoff between such costs and their messages aging. It is then natural to ask how to cope with such a tradeoff, by devising aging control policies. An aging control policy consists of deciding, based on the utility of the owned content, whether to activate the mobile device, and if so, which technology to use (WiFi or cellular). In [28] E. Altman, R. El-Azouzi (CERI/LIA, Univ Avignon), D.S. Menasche (UFRJ, Brazil) and Y. Xu (Fudan Univ, China) show the existence of an optimal strategy in the class of threshold strategies, wherein users activate their mobile devices if the age of their poadcasts surpasses a given threshold and remain inactive otherwise. The accuracy of their model is validated against traces from the UMass DieselNet bus network. The first version of this paper, among the first to introduce the age of information, appeared already in arXiv on 2010.

7.5.6. Wireless transmission vehicle routing

The Wireless Transmission Vehicle Routing Problem (WT-VRP) consists of searching for a route for a vehicle responsible for collecting information from stations. The new feature w.r.t. classical vehicle routing is the

possibility of picking up information via wireless transmission, without visiting physically the stations of the network. The WT-VRP has applications in underwater surveillance and environmental monitoring. In [53], L. Flores Luyo and E. Ocaña Anaya (IMCA, Brazil), A. Agra (Univ Aveiro, Brazil), R. Figueiredo (CERI/LIA, Univ Avignon) and E. Altman, study three criteria for measuring the efficiency of a solution and propose a mixed integer linear programming formulation to solve the problem. Computational experiments were done to access the numerical complexity of the problem and to compare solutions under the three criteria proposed.

7.5.7. Video streaming in 5G cellular networks

Dynamic Adaptive Streaming over HTTP (DASH) has become the standard choice for live events and on-demand video services. In fact, by performing bitrate adaptation at the client side, DASH operates to deliver the highest possible Quality of Experience (QoE) under given network conditions. In cellular networks, in particular, video streaming services are affected by mobility and cell load variation. In this context, DASH video clients continually adapt the streaming quality to cope with channel variability. However, since they operate in a greedy manner, adaptive video clients can overload cellular network resources, degrading the QoE of other users and suffer persistent bitrate oscillations. In [40] R. El-Azouzi (CERI/LIA, Univ Avignon), A. Sunny (IIT Palakkad, India), L. Zhao (Huazhong Agricultural Univ, China), E. Altman, D. Tsilimantos (Huawei Technologies, France), F. De Pellegrini (CERI/LIA Univ Avignon), and S. Valentin (Darmstadt Univ, Germany) tackle this problem using a new scheduler at base stations, named Shadow-Enforcer, which ensures minimal number of quality switches as well as efficient and fair utilization of network resources.

While most modern-day video clients continually adapt quality of the video stream, they neither coordinate with the network elements nor among each other. Consequently, a streaming client may quickly overload the cellular network, leading to poor Quality of Experience (QoE) for the users in the network. Motivated by this problem, A. Sunny (IIT Palakkad, India), R. El-Azouzi, A. Arfaoui (both from CERI/LIA, Univ Avignon), E. Altman, S. Poojary (BITS, India), D. Tsilimantos (Huawei Technologies, France) and S. Valentin (Darmstadt Univ, Germany) introduce in [24] D-VIEWS — a scheduling paradigm that assures video bitrate stability of adaptive video streams while ensuring better system utilization. The performance of D-views is then evaluated through simulations.

In [39], R. El-Azouzi, K.V. Acharya (ENS Lyon), M. Haddad (CERI/LIA, Univ Avignon), S. Poojary (BITS, India), A. Sunny (IIT Palakkad, India), D. Tsilimantos (Huawei Technologies, France), S. Valentin (Darmstadt Univ, Germany) and E. Altman, develop an analytical framework to compute the Quality-of-Experience (QoE) metrics of video streaming in wireless networks. Their framework takes into account the system dynamics that arises due to the arrival and departure of flows. They also consider the possibility of users abandoning the system on account of poor QoE. Considering the coexistence of multiple services such as video streaming and elastic flows, they use a Markov chain based analysis to compute the user QoE metrics: probability of starvation, prefetching delay, average video quality and bitrate switching. The simulation results validate the accuracy of their model and describe the impact of the scheduler at the base station on the QoE metrics.

7.5.8. A learning algorithm for the Whittle index policy for scheduling web crawlers

In [31] K. Avrachenkov and V.S. Borkar (IIT Bombay, India) have revisited the Whittle index policy for scheduling web crawlers for ephemeral content and developed a reinforcement learning scheme for it based on LSPE(0). The scheme leverages the known structural properties of the Whittle index policy.

7.5.9. Distributed cooperative caching for VoD with geographic constraints

Consider the caching of video streams in a cellular network in which each base station is equipped with a cache. Video streams are partitioned into multiple substreams and the goal is to place substreams in caches such that the residual backhaul load is minimized. In [36] K. Avrachenkov together with J. Goseling (UTwente, The Netherlands) and B. Serbetci (Eurecom) have studied two coding mechanisms for the substreams: Layered coding (LC) mechanism and multiple description coding (MDC). They develop a distributed asynchronous algorithm for deciding which files to store in which cache to minimize the residual bandwidth, i.e., the cost for downloading the missing substreams of the user's requested video with a certain video quality from the gateway (i.e., the main server). They show that their algorithm converges rapidly. Finally, they show that MDC

partitioning is better than the LC mechanism when the most popular content is stored in caches; however, their algorithm enables to use the LC mechanism as well without any performance loss.

Further, in [35], K. Avrachenkov together with J. Goseling (UTwente, The Netherlands) and B. Serbetci (Eurecom), have considered the same setting as above but maximized the expected utility. The utility depends on the quality at which a user is requesting a file and the chunks that are available. They impose alpha-fairness across files and qualities. Similarly to [36] they have developed a distributed asynchronous algorithm for deciding which chunks to store in which cache.

7.6. Applications in Social Networks

Participants: Eitan Altman, Swapnil Dhamal, Giovanni Neglia.

7.6.1. Utility from accessing an online social network

The retention of users on online social networks has important implications, encompassing economic, psychological and infrastructure aspects. In the framework of our joint team with Brazil (Thanes), G. Neglia, together with E. Hargreaves and D. Menasche (both from UFRJ, Brazil) investigated the following question: what is the optimal rate at which users should access a social network? To answer this question, they have proposed an analytical model to determine the value of an access (VoA) to the social network. In the simple setting they considered, VoA is defined as the chance of a user accessing the network and obtaining new content. Clearly, VoA depends on the rate at which sources generate content and on the filtering imposed by the social network. Then, they have posed an optimization problem wherein the utility of users grows with respect to VoA but is penalized by costs incurred to access the network. Using the proposed framework, they provide insights on the optimal access rate. Their results are parameterized using Facebook data, indicating the predictive power of the approach. This research activity led to two publications in 2019 [49], [43].

Last year, the same researchers, together with E. Altman, A. Reiffers-Masson (IISc, India), and the journalist C. Agosti (Univ of Amsterdam, Netherlands), have worked on Facebook News Feed personalization algorithm. The publication [21] complete that line of work described in NEO's 2018 technical report.

7.6.2. Optimal investment strategies for competing camps in a social network

S. Dhamal, W. Ben-Ameur (Telecom SudParis), T. Chahed (Telecom SudParis), and E. Altman have studied the problem of optimally investing in nodes of a social network in [17], wherein two camps attempt to maximize adoption of their respective opinions by the population. 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. Extensive simulations are conducted on real-world social networks for all the considered settings.

S. Dhamal, W. Ben-Ameur (Telecom SudParis), T. Chahed (Telecom SudParis), and E. Altman have studied a two-phase investment game for competitive opinion dynamics in social networks, in [18]. The existence of Nash equilibrium and its polynomial time computability is shown under reasonable assumptions. A simulation study is conducted on real-world social networks to quantify the effects of the initial biases and the weigh attributed by nodes to their initial biases, as well as that of a camp deviating from its equilibrium strategy. The study concludes that, if nodes attribute high weight to their initial biases, it is advantageous to have a high investment in the first phase, so as to effectively influence the biases to be harnessed in the second phase.

7.6.3. Extending the linear threshold model

S. Dhamal has proposed a generalization of the linear threshold model to account for multiple product features, in [38]. An integrated framework is presented 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.

7.6.4. Public retention in Youtube

There exist many aspects involved in a video turning viral on YouTube. These include properties of the video such as the attractiveness of its title and thumbnail, the recommendation policy of YouTube, marketing and advertising policies and the influence that the video's creator or owner has in social networks. E. Altman and T. Jimenez (CERI/LIA, Univ Avignon), study in [29] audience retention measurements provided by YouTube to video creators, which may provide valuable information for improving the videos and for better understanding the viewers' potential interests in them. They then study the question of when is a video too long and can gain from being shortened. They examine consistency between several existing audience retention measures. They end in a proposal for a new audience retention measure and identify its advantages.

7.6.5. The medium selection game

F. Lebeau (ENS Lyon), C. Touati (Inria Grenoble-Rhone-Alpes), E. Altman and N. Abuzainab (Virginia Tech, USA) consider in [45] 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. They show that the potential is M-concave which allows them to characterize the equilibria and to propose an algorithm for computing it. They then introduce a learning mechanism which allows them to give an efficient algorithm to determine an equilibrium. They finally determine the asymptotic form of the equilibrium and discuss the implications on the social medium selection problem.

7.7. Applications to Environmental Issues

Participant: Alain Jean-Marie.

7.7.1. Sustainable management of water consumption

Continuing a series of game-theoretic studies on sustainable management of water resources, A. Jean-Marie, jointly with T. Jimenez (CERI/LIA, Univ Avignon) and M. Tidball (INRA), consider in [54] the basic groundwater exploitation problem, in the case where agents (farmers) have incomplete information about other agents' profit functions and about pumping cost functions. Farmers behave more or less myopically. The authors analyze two models where they assume that each agent relies on simple beliefs about the other agents' behavior. In a first model, a variation of their own extraction has a first order linear effect on the extractions of others. In a second model, agents consider that extraction of the others players is a proportion of the available water. Farmers' beliefs are updated through observations of the resource level over time. The paper also considers two models with a myopic feature and no learning. In the first one, agents do not know the profit function of the other agents and cost is announced before extraction. In the second one agents know the profit function of the other player and cost is announced after extraction. In this last case agents play a Nash equilibrium. The four behaviors are compared from the economic and environmental points of view.

7.7.2. Pollution permit trading

In a joint work with K. Fredj (Univ of Northern British Columbia, Canada), G. Martín-Herrán (Univ Valladolid, Spain) and Mabel Tidball (INRA), A. Jean-Marie investigated in [20] the strategic behaviour of two countries or firms that minimize costs facing emission standards. Emission standards can be reached through emission reduction, banking or borrowing, and emission trading in a given and fixed planning horizon. The authors extend classical models with: the introduction of transaction costs in tradeable emission markets on the one hand, and using a dynamic game setting, on the other hand. They analyze the case with and without transaction costs and the case with and without discount rate. They characterize socially optimal solutions and Nash equilibria in each case and, depending on the initial allocation, characterize the buyer and seller in the emission trading market. The main findings prove that the agents' equilibrium is not efficient when transaction costs are positive.

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 two ADRs: "Distributed Learning and Control for Network Analysis" (see §8.1.1) and "Rethinking the network: virtualizing network functions, from middleboxes to application" (see §8.1.2).
- Inria-QWANT joint laboratory "Smart search is privacy" (see §8.1.3);
- Inria-Orange Labs joint laboratory (see §8.1.4).

NEO has contracts with Accenture (see §8.1.5), Azursoft (see §8.1.6), MyDataModels (see §8.1.7), Huawei (see §8.1.8), and Payback Network (see §8.1.9).

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.

- 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. ADR Nokia on the topic "Rethinking the network: virtualizing network functions, from middleboxes to application" (October 2017 – September 2021)

Participants: Sara Alouf, Giovanni Neglia.

- Contractor: Nokia Bell Labs (http://www.bell-labs.com)
- Collaborators: Fabio Pianese, Massimo Gallo

A growing number of network infrastructures are being presently considered for a software-based replacement: these range from fixed and wireless access functions to carrier-grade middle boxes and server functionalities. On the one hand, performance requirements of such applications call for an increased level of software optimization and hardware acceleration. On the other hand, customization and modularity at all layers of the protocol stack are required to support such a wide range of functions. In this scope the ADR focuses on two specific research axes: (1) the design, implementation and evaluation of a modular NFV architecture, and (2) the modelling and management of applications as virtualized network functions. Our interest is in low-latency machine learning prediction services and in particular how the quality of the predictions can be traded off with latency.

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

Participants: Nicolas Allegra, Konstantin Avrachenkov, Patrick Brown.

- Contractor: Qwant
- Collaborators: Sylvain Peyronnet, Thomas Aynaud

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.

8.1.4. 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://www.orange.com/en/Infographics/Orange-and-Research/Orange-and-Research)
- 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.

8.1.5. Accenture contract on the topic "Distributed Machine Learning for IoT applications" (Dec 2019 – May 2020)

Participant: Giovanni Neglia.

- Contractor: Accenture Labs (https://www.accenture.com/fr-fr/accenture-lab-sophia-antipolis)
- Collaborators: Laetitia Kameni, Richard Vidal

IoT applications will become one of the main sources to train data-greedy machine learning models. Until now, IoT applications were mostly about collecting data from the physical world and sending them to the Cloud. Google's federated learning already enables mobile phones, or other devices with limited computing capabilities, to collaboratively learn a machine learning model while keeping all training data locally, decoupling the ability to do machine learning from the need to store the data in the cloud. While Google envisions only users' devices, it is possible that part of the computation is executed at other intermediate elements in the network. This new paradigm is sometimes referred to as Edge Computing or Fog Computing. Model training as well as serving (provide machine learning predictions) are going to be distributed between IoT devices, cloud services, and other intermediate computing elements like servers close to base stations as envisaged by the Multi-Access Edge Computing framework. The goal of this project is to propose distributed learning schemes for the IoT scenario, taking into account in particular its communication constraints. This 6-month contract prepares a CIFRE.

8.1.6. AzurSoft contract on the topic "Proof of concept on automatic detection of false alarms" (May 2019 – April 2020)

Participants: Konstantin Avrachenkov, Andrei Bobu.

- Contractor: AzurSoft (https://www.azursoft.com/)
- Collaborators: Marc Vaillant, Beatrice Escuyer

Intrusion detection or telesurveillance systems generates signals from sensors that allow to raise alarm and start a checking procedure for a potential intrusion or anomaly. Typically, one telesurveillance system surveys many sites and is challenged by a stream of false alarms. In this project, we aim to reduce the rate of false alarms by using various supervised and semi-supervised learning methods.

8.1.7. MyDataModels contract on the topic "Semi supervised variational autoencoders for versatile data" (June 2019 – May 2022)

Participants: Konstantin Avrachenkov, Mikhail Kamalov.

- Contractor: MyDataModels (https://www.mydatamodels.com/)
- Collaborators: Denis Bastiment, Carlo Fanara

Variational autoencoders are highly flexible machine learning techniques for learning latent dimension representation. This model is applicable for denoising data as well as for classification purposes. In this thesis we plan to add semi-supervision component to the variational autoencoder techniques. We plan to develop methods which are universally applicable to versatile data such as categorical data, images, texts, etc. Initially starting from static data we aim to extend the methods to time-varying data such as audio, video, time-series, etc. The proposed algorithms can be integrated into the internal engine of MyDataModels company and tested on use cases of MyDataModels.

8.1.8. 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 was 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.

8.1.9. Consulting contract with Payback Network (November 2019 - January 2020)

Participant: Giovanni Neglia.

- Contractor: Payback Network
- Collaborators: Tanguy Racinet, Anne Legencre

Consulting with the startup Payback Network on differential privacy techniques.

9. Partnerships and Cooperations

9.1. Regional Initiatives

9.1.1. MYDATA (Sept. 2018 - Nov. 2020)

Participant: Giovanni Neglia.

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". It involves the participation of Vidhya Kannan.

9.2. National Initiatives

9.2.1. PIA ANSWER

Participants: Konstantin Avrachenkov, Abhishek Bose, Kishor Yashavant Patil.

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.

9.2.2. ANR MAESTRO5G

Participant: Eitan Altman.

Project Acronym: MAESTRO5G

Project Title: MAnagEment of Slices in The Radio access Of 5G networks

Coordinator: Orange Labs

Duration: February 2019 – January 2022

Others Partners: Nokia Bell Labs, Univ Avignon, Inria Project-Team AGORA, Sorbonne Univ, Telecom SudParis, CentraleSupélec.

Abstract: The project develops enablers for implementing and managing slices in the 5G radio access network, not only for the purpose of serving heterogeneous services, but also for dynamic sharing of infrastructure between operators. MAESTRO-5G develops a framework for resource allocation between slices and a business layer for multi-tenant slicing. It provides an orchestration framework based on Software Define Networking that manages resources and virtual functions for slices. A hardware demonstrator brings the slicing concept to reality and showcases the project's innovations.

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, Erdos-Renyi 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) - Computer Science Department - Daniel Ratton Figueiredo

Start year: 2017

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

This team is the follow-up of a joint Inria-UFRJ team (funded by FAPERJ in Rio de Janeiro, Brazil) with the same name and almost the same permanent researchers involved. During the first three years THANES has studied how services in Online Social Networks (OSNs) can be efficiently designed and managed. The joint research activity continued along the line of network science with a focus on network growth models, community detection, information spreading, and recommendation systems for online social networks. A new research axis on deep learning spawned during 2018.

9.4.2. Participation in Other International Programs

9.4.2.1. 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

Mindaugas Bloznelis, Date: 2-7 Oct, Institution: Vilnius Univ (Lithuania)

Damiano Carra, Date: 17-26 Jun, Institution: Univ of Verona (Italy)

Mahmoud El Chamie, Date: 16-20 Dec, Institution: United Technologies Research Center, East Hartford (USA)

Lasse Leskela, Date: 8-19 April, Institution: Aalto Univ (Finland)

Nelly Litvak, Date: 20 May-2 Jun, Institution: Univ of Twente (Netherlands)

Vincenzo Mancuso, Date: 16-18 Jul , Institution: IMDEA Networks Institute (Spain)

Angelia Nedich, Date: 8-10 Dec, Institution: Arizona State Univ (USA)

Sreenath Ramanath, Date: 2-7 Jul, Institution: Lekha Wireless (India)

Daniel Sadoc Menasche, Date: 24-28 Jun, Institution: UFRJ (Brazil)

Neeraja Sahasrabudhe, Date: 9 May - 4 Jun and 16-20 Dec, Institution: IIT Bombay (India)

Matteo Sereno, Date: 15-17 July, Institution: Univ of Turin (Italy)

Georgy Shevlyakov, Date: 3-17 Nov, Institution: Peter the Great St. Petersburg Polytechnic Univ (Russia)

Gugan Thoppe, Date: 25 Nov - 6 Dec, Institution: IISc Bangalore (India)

Don Towsley, Date: 1-4 Apr, Institution: UMass Amherst (USA)

Kavitha Voleti Veeraruna, Date: 27 May - 8 Jun, Institution: IIT Bombay (India)

9.5.1.2. Postdoc/PhD Students

Tejas Bodas, Date: 12-22 Apr and 11-22 Jun, Postdoc at IIS Bangalore (India)

Mikhail Grigorev, Date: 2-31 Jan, PhD student at MFTI Moscow (Russia)

Eduardo Hargreaves, Date: 24-28 Jun, PhD student at UFRJ (Brazil)

Maksim Mironov, Date: 2-31 Jan and 24 Aug - 7 Sep, PhD student at MFTI Moscow (Russia)

Maksim Ryzhov, Date: 4 Apr - 3 May, PhD student at MFTI Moscow (Russia)

Anirudh Sabnis, Date: 1 Jul - 6 Oct, PhD student at UMass Amherst (USA)

9.5.2. Internships

Note: UCA is the Univ Côte d'Azur.

Younes Ben Mazziane, Date: 19 Nov-13 Dec, Institution: PFE Master Ubinet, UCA, Supervisors: S. Alouf and G. Neglia

Vidhya Kannan, Date: from Dec, Institution: UCA, Supervisor : G. Neglia

Carlos Eduardo Marciano, Date: 13 Sep-9 Dec, Institution: Master student at UFRJ, Brazil, Supervisor: G. Neglia

Kaiyun Pan, Date: 19 Nov-13 Dec, Institution: PFE Master Ubinet, UCA, Supervisor: G. Neglia

Quentin Petitjean, Date: 11 Jun-26 Jul, Institution: ENS Cachan, Supervisors: S. Alouf and A. Jean-Marie

Vilc Queupe Rufino, Date: 17-19 Jun, Institution: Master student at UFRJ, Brazil, Supervisor: D. Sadoc Menasche (UFRJ)

Varvara Samoili, Date: 11 Jan-10 Jul, Institution: Bodossaki Foundation, Supervisor: G. Neglia

Nicola Sebastianelli, Date: 1 Mar-31 Aug, Institution: Master Ubinet, UCA, Supervisor: G. Neglia

Adeel Siddiqui, Date: until Jan 2019, Institution: UCA, Supervisor : G. Neglia

Siemo Zhang, Date: 1 Sep-30 Nov, Institution: Master student at Univ of Twente, Netherlands, Supervisor: K. Avrachenkov

9.6. Visits to International Teams

9.6.1. Research Stays Abroad

Eitan Altman

- Date: 29 January - 4 February, 28 March - 6 April, 20 June - 10 July, 18 October - 4 December, Institution: Technion and Univ Tel-Aviv (Israel)

Konstantin Avrachenkov

- Date: 17-22 February, Institution: Friedrich-Alexander Univ (Germany)
- Date: 4-15 March, Institution: Petrozavodsk State Univ (Russia)
- Date: 26-28 October, Institution: IISc Bangalore (India)
- Date: 30 October - 2 November, Institution: IIT Bombay (India)
- Date: 24-26 November, Institution: Univ Twente (The Netherlands)

Maximilien Dreveton

- Date: 24 May - 9 June, Institution: Aalto Univ (Finland)

Alain Jean-Marie

Date: 17 October - 4 November, Institution: GERAD (Montréal, Canada)

Giovanni Neglia

- Date: 20-22 February, Institution: Univ Florence and Univ Pisa (Italy)
- Date: 23-26 September, Institution: Northeastern Univ and Boston Univ (Massachusetts, United States)

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 12th EAI International Conference on Performance Evaluation Methodologies and Tools (VALUETOOLS 2019), Palma de Mallorca, Spain, 13-15 March 2019;
- Konstantin Avrachenkov co-organized the 16th Workshop on Algorithms and Models for the Web Graph (WAW 2019), University of Queensland, Brisbane, Australia, 6-7 July 2019;
- Eitan Altman is chairman of the Steering committee of the workshop NetGCoop - Networking Games, Control and Optimisation;
- Eitan Altman is member of the steering committee of the conferences WiOpt and Valuetools.

10.1.1.2. Member of the Organizing Committees

- Giovanni Neglia was publicity co-chair of the 20th International Symposium on Mobile Ad Hoc Networking and Computing (ACM MobiHoc 2019), Catania, Italy, 2-5 July 2019.

10.1.2. Scientific Events: Selection

10.1.2.1. Chair of Conference Program Committees

- Konstantin Avrachenkov was the co-chair of the 16th Workshop on Algorithms and Models for the Web Graph (WAW 2019), University of Queensland, Brisbane, Australia, 6-7 July 2019.
- Konstantin Avrachenkov was the co-chair of the 9th EAI International Conference on Game Theory for Networks (GameNets 2019), Paris, France, April 25-26, 2019.

10.1.2.2. Member of the Conference Program Committees

- ACM Sigmetrics / IFIP Performance 2019 (Phoenix, Arizona, USA) (S. Alouf, K. Avrachenkov);
- ACM Sigmetrics 2020 (Boston, Massachusetts, USA) (S. Alouf);
- IEEE Intl. Conf. on Computer Communications (INFOCOM 2020, Beijing, China) (G. Neglia);
- 39th IEEE Intl. Conf. on Distributed Computing Systems (ICDCS 2019, Dallas, Texas, USA) (K. Avrachenkov);
- 27th IEEE Intl. Conf. on Network Protocols (ICNP 2019, Chicago, Illinois, USA) (K. Avrachenkov);
- 25th Intl. Conf. on Analytical & Stochastic Modelling Techniques & Applications (ASMTA 2019, Moscow, Russia) (K. Avrachenkov);
- 10th Conf. on Decision and Game Theory for Security (GameSec 2019, Stockholm, Sweden) (K. Avrachenkov);
- 8th Intl. Conf. on Complex Networks and their Applications (Lisbon, Portugal) (K. Avrachenkov);
- 26th Intl. Conf. on Telecommunications (ICT 2019, Hanoi, Vietnam) (K. Avrachenkov);
- SIAM Conf. on Control and Its Applications (CT19, Chengdu, China) (K. Avrachenkov);
- SIAM Intl. Conf. on Data Mining (SDM19, Calgary, Canada) (K. Avrachenkov);
- 20th Conf. of the Société Française de Recherche Opérationnelle et d'Aide à la Décision (ROADEF 2019, Le Havre, France) (A. Jean-Marie);
- 7th Symposium on Control, Automation, Industrial Informatics and Smart Grid (ICAIS'19, Trivandrum, Kerala, India) (K. Avrachenkov);
- 16th Intl. Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt 2019, Avignon, France) (K. Avrachenkov);
- 16th European Performance Engineering Workshop (EPEW2019, Milan, Italy) (A. Jean-Marie);
- IEEE INFOCOM Workshop on the Communications and Networking Aspects of Online Social Networks (CAOS'19, Paris, France), (G. Neglia);
- 21st Workshop on MAthematical performance Modeling and Analysis (MAMA 2019, Phoenix, USA) (A. Jean-Marie).

10.1.2.3. Reviewer

- 27th IEEE International Conference on Software Analysis, Evolution and Reengineering (SANER 2020, London, Canada) (A. Jean-Marie);
- Forum on Specification & Design Languages (FDL 2019, Southampton, UK) (S. Alouf).

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

- *ACM Transactions on Modeling and Performance Evaluation of Computing Systems (ACM ToMPECS)* (K. Avrachenkov);
- *AIMS: Journal of Dynamic Games* (E. Altman);
- *Elsevier Computer Communications (COMCOM)* (G. Neglia);
- *Elsevier International Journal of Performance Evaluation (PEVA)* (K. Avrachenkov);
- *IEEE Transactions on Mobile Computing* (G. Neglia);
- Editor at large in *IEEE/ACM Transaction of Networking* (E. Altman);
- *Probability in the Engineering and Informational Sciences* (K. Avrachenkov);
- *Springer: Dynamic Games and Applications* (E. Altman);
- *Stochastic Models* (K. Avrachenkov);
- *Wiley Transactions on Emerging Telecommunications Technologies (ETT)* (S. Alouf).

10.1.3.2. Reviewer - Reviewing Activities

- *Dynamic Games And Applications* (A. Jean-Marie);
- *Elsevier Computer Networks* (G. Neglia);
- *Elsevier International Journal of Performance Evaluation* (PEVA) (S. Alouf);
- *EURO Journal on Computational Optimization* (A. Jean-Marie);
- *IEEE Internet of Things Journal* (C. Xu);
- *IEEE Networking Letters* (G. Neglia);
- *IEEE/ACM Transactions on Mobile Computing (TMC)* (G. Neglia);
- *IEEE/ACM Transactions on Networking (ToN)* (G. Neglia);
- *Journal of Economic Dynamics and Control* (A. Jean-Marie);
- *Theoretical Computer Science (TCS)* (A. Jean-Marie).

10.1.4. Tutorials, Invited Talks

- E. Altman gave a tutorial on “Network Games” at the Workshop on Network, population and congestion games (NPCG19) 17 April, Paris, France.
- G. Neglia gave an invited talk on “Machine Learning Training: Research Challenges and Opportunities for Distributed Computing” at the International Workshop on Distributed Cloud Computing (DCC), 18 October, Budapest, Hungary.
- C. Xu gave an invited talk on "Dynamic back up workers in distributed machine learning" at Sun Yat-sen University, September 3, Guangzhou, China.

10.1.5. Leadership within the Scientific Community

S. Alouf

- has been elected for two years at the Board of Directors of ACM SIGMETRICS.
- is a member of the Equality and Diversity committee of ACM SIGMETRICS.
- is a member of the Conference Advisory committee of ACM SIGMETRICS.

E. Altman

- is a fellow member of IEEE (Class of 2010).

- is a fellow member of EAI (Class of 2019)
- is an elected member of IFIP WG 7.3 on "Computer System Modeling".
- is a member of WG 6.3 of IFIP on Performance of Communication Systems.

K. Avrachenkov

- is a member of the scientific committee for Labex UCN@Sophia;
- is a member of Conseil Scientifique & Pédagogique EUR DS4H Université Côte d'Azur;

A. Jean-Marie

- is a member of the Steering Committee of the GDR RO, a national research initiative on Operations Research sponsored by the CNRS;
- is an elected member of IFIP WG 7.3 on "Computer System Modeling".

G. Neglia is member of the scientific animation committee for the IDEX UCA$^{\text{JEDI}}$ research program "Social Interactions and Complex Dynamics" since 2017.

10.1.6. Scientific Expertise

Giovanni Neglia is a consultant for the startup Payback Network in the period November 2019 - January 2020. The consultancy is on differential privacy techniques.

10.1.7. Research Administration

S. Alouf

- 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 and pedagogical committee for the graduate school DS4H of UCA.

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 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.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Note: UNS is the Univ Nice Sophia-Antipolis, UCA is the Univ Côte d'Azur.

Licence : M. Dreveton, “Tools for biology – Statistics”, 24H, L1 Life Sciences, UNS, France;

Master : S. Alouf, “Performance Evaluation of Networks”, 27H, M2 Ubinet, UCA, France;

Master : K. Avrachenkov, “Statistical Analysis of Graphs”, 6H, M2 Data Science, UCA, France;

Master : M. Dreveton, “Statistical Analysis of Graphs”, 26H, M2 Data Science, UCA, France;

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

Master : G. Neglia, “Performance Evaluation of Networks”, 4.5H, M2 Ubinet, UCA, France;

Master : G. Neglia, responsible for the “Winter School on Hands-on Machine Learning”, 22.5H, M1 Computer Science, UNS, France.

Doctorat: A. Jean-Marie, “Queueing Systems”, 6H, Summer School ResCom 2019, Anglet, France.

10.2.2. Supervision

PhD: Zaid Allybokus, “Scalable Online Algorithms for SDN Controllers”, UCA, 11 June 2019, advisors: Konstantin Avrachenkov, Jeremie Leguay and Lorenzo Maggi (Huawei).

PhD: Dimitra Politaki, “Greening data center”, UCA, 16 July 2019, advisors: Sara Alouf and Fabien Hermenier (Nutanix).

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

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

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

PhD in progress: Mikhail Kamalov, “Semi-supervised variational autoencoders versatile data”, UCA, 1 June 2019, advisor: Konstantin Avrachenkov.

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

PhD in progress: Tareq Si Salem, “Federated Learning”, UCA, 1 October 2019, advisor: Giovanni Neglia.

PhD interrupted: Abhishek Bose, “Adaptive crawling with machine learning techniques”, 1 June 2018 – 30 Sep. 2029.

10.2.3. Juries

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

- Zaid Allybokus, “Scalable Online Algorithms for SDN Controllers”, UCA, 11 June (K. Avrachenkov as advisor);
- Lea Bayati, “Data Centers Energy Optimization”, Univ Paris-Est Créteil, 20 September (A. Jean-Marie as reviewer);
- Céline Comte, “Resource management in computer clusters: algorithm design and performance analysis”, Telecom ParisTech, 24 September (A. Jean-Marie as jury president);
- Muhammad Jawad Khokhar, “Modeling Quality of Experience of Internet Video Streaming by Controlled Experimentation and Machine Learning”, UCA, 15 October (G. Neglia as jury member)
- Xiaoyi Mai, “Methods of random matrices for large dimensional statistical learning”, CentraleSupelec, 16 October (K. Avrachenkov as jury member);
- Antonio Massaro, “Optimisation, games and learning strategies in telecommunication systems subject to structural constraints”, University of Trento, 7 May (K. Avrachenkov as reviewer);
- Dimitra Politaki, “Greening data center”, UCA, 16 July (S. Alouf as advisor);
- Yonathan Portilla, Univ Avignon, “Study of Social Networks: modelling and analysis”, 20 May (E. Altman as co-advisor);
- Arthur Vallet, “Modélisation markovienne de lasers multimodes à semiconducteurs”, Université de Montpellier, 15 October (A. Jean-Marie as jury member).

10.3. Popularization

10.3.1. Interventions

- Sara Alouf presented the Researcher profession at the *Forum des Métiers*, Collège Emile Roux, Le Cannet, on 15 March 2019, to a total of 62 students in 6 groups, aging 12-14 years.

11. Bibliography

Major publications by the team in recent years

[1] K. AVRACHENKOV, V. S. BORKAR. *Whittle Index Policy for Crawling Ephemeral Content*, in "IEEE Transactions on Control of Network Systems", March 2018, vol. 5, n° 1, pp. 446-455 [*DOI :* 10.1109/TCNS.2016.2619066], https://hal.inria.fr/hal-01937994

[2] K. AVRACHENKOV, P. CHEBOTAREV, A. MISHENIN. *Semi-supervised learning with regularized Laplacian*, in "Optimization Methods and Software", January 2017, vol. 32, n° 2, pp. 222-236 [*DOI :* 10.1080/10556788.2016.1193176], https://hal.inria.fr/hal-01671800

[3] K. AVRACHENKOV, A. Y. KONDRATEV, V. V. MAZALOV, D. RUBANOV. *Network partitioning algorithms as cooperative games*, in "Computational Social Networks", October 2018, vol. 5, n° 11 [*DOI :* 10.1186/s40649-018-0059-5], https://hal.inria.fr/hal-01935419

[4] E. LEONARDI, G. NEGLIA. *Implicit Coordination of Caches in Small Cell Networks under Unknown Popularity Profiles*, in "IEEE Journal on Selected Areas in Communications", June 2018, vol. 36, n° 6, pp. 1276-1285 [*DOI :* 10.1109/JSAC.2018.2844982], https://hal.inria.fr/hal-01956307

[5] A. R. MASSON, Y. HAYEL, E. ALTMAN. *Posting behaviour Dynamics and Active Filtering for Content Diversity in Social Networks*, in "IEEE transactions on Signal and Information Processing over Networks", 2017, vol. 3, n° 2, pp. 376-387 [*DOI :* 10.1109/TSIPN.2017.2696738], https://hal.inria.fr/hal-01536172

[6] K. P. NAVEEN, E. ALTMAN, A. KUMAR. *Competitive Selection of Ephemeral Relays in Wireless Networks*, in "IEEE Journal on Selected Areas in Communications", 2017, vol. 35, pp. 586-600 [*DOI :* 10.1109/JSAC.2017.2659579], https://hal.inria.fr/hal-01536123

[7] G. NEGLIA, D. CARRA, M. FENG, V. JANARDHAN, P. MICHIARDI, D. TSIGKARI. *Access-Time-Aware Cache Algorithms*, in "ACM Transactions on Modeling and Performance Evaluation of Computing Systems", December 2017, vol. 2, n° 4, pp. 1-29 [*DOI :* 10.1145/3149001], https://hal.inria.fr/hal-01956285

[8] G. NEGLIA, D. CARRA, P. MICHIARDI. *Cache Policies for Linear Utility Maximization*, in "IEEE/ACM Transactions on Networking", February 2018, vol. 26, n° 1, pp. 302-313 [*DOI :* 10.1109/TNET.2017.2783623], https://hal.inria.fr/hal-01956319

Publications of the year

Doctoral Dissertations and Habilitation Theses

[9] Z. ALLYBOKUS. *Real-Time Scalable Algorithms for Alpha-Fair Resource Allocation in Software Defined Networks*, Universié Côte d'Azur, 2019

[10] D. POLITAKI. *On Modeling Green Data Center Clusters*, Universié Côte d'Azur, 2019

Articles in International Peer-Reviewed Journals

[11] E. ALTMAN, D. MENASCHÉ, A. REIFFERS-MASSON, M. DATAR, S. DHAMAL, C. TOUATI, R. EL-AZOUZI. *Blockchain competition between miners: a game theoretic perspective*, in "Frontiers in Blockchain", 2019, forthcoming [*DOI :* 10.3389/FBLOC.2019.00026], https://hal.inria.fr/hal-02411738

[12] K. AVRACHENKOV, V. S. BORKAR. *Metastability in Stochastic Replicator Dynamics*, in "Dynamic Games and Applications", June 2019, vol. 9, n° 2, pp. 366-390 [*DOI :* 10.1007/S13235-018-0265-7], https://hal.inria.fr/hal-02398561

[13] K. AVRACHENKOV, P. CHEBOTAREV, D. RUBANOV. *Similarities on graphs: Kernels versus proximity measures*, in "European Journal of Combinatorics", August 2019, vol. 80, pp. 47-56 [*DOI :* 10.1016/J.EJC.2018.02.002], https://hal.inria.fr/hal-02413478

[14] K. AVRACHENKOV, V. EJOV, J. FILAR, A. MOGHADDAM. *Zero-Sum Stochastic Games over the Field of Real Algebraic Numbers*, in "Dynamic Games and Applications", December 2019, vol. 9, n° 4, pp. 1026-1041 [*DOI :* 10.1007/S13235-018-00293-W], https://hal.inria.fr/hal-02413402

[15] A. CHATTOPADHYAY, B. BŁASZCZYSZYN, E. ALTMAN. *Location Aware Opportunistic Bandwidth Sharing between Static and Mobile Users with Stochastic Learning in Cellular Networks*, in "IEEE Transactions on Mobile Computing", 2019, vol. 18, n° 8, pp. 1802-1815, https://arxiv.org/abs/1608.04260 - 16 Pages, 1 Figure, 1 Table [*DOI :* 10.1109/TMC.2018.2867037], https://hal.inria.fr/hal-01401007

[16] A. CHATTOPADHYAY, B. BŁASZCZYSZYN, E. ALTMAN. *Two-tier cellular networks for throughput maximization of static and mobile users*, in "IEEE Transactions on Wireless Communications", 2019, vol. 18, n° 2, pp. 997-1010, https://arxiv.org/abs/1605.07341 - title of the previous version: "Cell planning for mobility management in heterogeneous cellular networks", forthcoming [*DOI :* 10.1109/TWC.2018.2887386], https://hal.inria.fr/hal-01331936

[17] S. DHAMAL, W. BEN-AMEUR, T. CHAHED, E. ALTMAN. *Optimal investment strategies for competing camps in a social network: a broad framework*, in "IEEE Transactions on Network Science and Engineering", October 2019, vol. 6, n° 4, pp. 628-645, https://arxiv.org/abs/1706.09297 [*DOI :* 10.1109/TNSE.2018.2864575], https://hal.inria.fr/hal-01712288

[18] S. DHAMAL, W. BEN-AMEUR, T. CHAHED, E. ALTMAN. *A two phase investment game for competitive opinion dynamics in social networks*, in "Information processing & management", March 2020, vol. 57, n° 2, pp. 102064:1-20 [*DOI :* 10.1016/J.IPM.2019.102064], https://hal.inria.fr/hal-01924838

[19] V. FEDCHENKO, G. NEGLIA, B. RIBEIRO. *Feedforward Neural Networks for Caching : Enough or Too Much?*, in "ACM SIGMETRICS Performance Evaluation Review", January 2019, vol. 46, n° 3, pp. 139-142 [*DOI :* 10.1145/3308897.3308958], https://hal.inria.fr/hal-02411461

[20] K. FREDJ, A. JEAN-MARIE, G. MARTÍN-HERRÁN, M. TIDBALL. *Effects of transaction costs and discount rate on the banking decision of emission permits trading*, in "Advances in Economics and Business", 2020, vol. 8, n° 1, pp. 63-71 [*DOI :* 10.13189/AEB.2020.080106], https://hal.inria.fr/hal-02372292

[21] E. HARGREAVES, C. AGOSTI, D. MENASCHÉ, G. NEGLIA, A. REIFFERS-MASSON, E. ALTMAN. *Fairness in Online Social Network Timelines : Measurements, Models and Mechanism Design*, in "ACM SIGMETRICS Performance Evaluation Review", January 2019, vol. 46, n° 3, pp. 68-69 [*DOI :* 10.1145/3308897.3308928], https://hal.inria.fr/hal-02411262

[22] E. HARGREAVES, C. AGOSTI, D. MENASCHÉ, G. NEGLIA, A. REIFFERS-MASSON, E. ALTMAN. *Fairness in Online Social Network Timelines: Measurements, Models and Mechanism Design*, in "Performance Evaluation", February 2019, vol. 129, pp. 15-39 [*DOI :* 10.1016/J.PEVA.2018.09.009], https://hal.inria.fr/hal-01927550

[23] G. IACOBELLI, D. FIGUEIREDO, G. NEGLIA. *Transient and slim versus recurrent and fat: Random walks and the trees they grow*, in "Journal of Applied Probability", September 2019, vol. 56, n° 03, pp. 769-786 [*DOI :* 10.1017/JPR.2019.43], https://hal.inria.fr/hal-02411250

[24] A. SUNNY, R. EL-AZOUZI, A. ARFAOUI, E. ALTMAN, S. POOJARY, D. TSILIMANTOS, S. VALENTIN. *Enforcing Bitrate-Stability for Adaptive Streaming Traffic in Cellular Networks*, in "IEEE Transactions on Network and Service Management", December 2019, vol. 16, n° 4, pp. 1812-1825 [*DOI :* 10.1109/TNSM.2019.2941450], https://hal.inria.fr/hal-02418530

[25] Y. XU, Z. XIAO, T. NI, J. H. WANG, X. WANG, E. ALTMAN. *On The Robustness of Price-Anticipating Kelly Mechanism*, in "IEEE/ACM Transactions on Networking", 2019 [*DOI :* 10.1109/TNET.2019.2926304], https://hal.inria.fr/hal-02295981

International Conferences with Proceedings

[26] E. ALTMAN, S. BOULAROUK, D. JOSSELIN. *Constrained Markov Decision Processes with Total Expected Cost Criteria*, in "VALUETOOLS 2019 - 12th EAI International Conference on Performance Evaluation Methodologies and Tools", Palma, Spain, ACM Press, March 2019, pp. 191-192 [*DOI :* 10.1145/3306309.3306342], https://hal.inria.fr/hal-02053360

[27] E. ALTMAN, M. DATAR, G. BURNSIDE, C. TOUATI. *Normalized equilibrium in Tullock rent seeking game*, in "GameNets 2019 - Game Theory for Networks", Paris, France, Springer, April 2019, pp. 109-116 [*DOI :* 10.1007/978-3-030-16989-3_8], https://hal.inria.fr/hal-02291549

[28] E. ALTMAN, R. EL-AZOUZI, D. S. MENASCHE, Y. XU. *Forever Young: Aging Control For Smartphones in Hybrid Networks*, in "MobiHoc 2019 - 20th International Symposium on Mobile Ad Hoc Networking and Computing", Catania, Italy, ACM Press, May 2019, vol. 19, pp. 91-100, https://arxiv.org/abs/1009.4733 [*DOI :* 10.1145/3323679.3326507], https://hal.inria.fr/hal-02297281

[29] E. ALTMAN, T. JIMENEZ. *Measuring Audience Retention in YouTube*, in "VALUETOOLS 2019 - 12th EAI International Conference on Performance Evaluation Methodologies and Tools", Palma, Spain, ACM Press, March 2019, pp. 79-85 [*DOI :* 10.1145/3306309.3306322], https://hal.inria.fr/hal-02053300

[30] K. AVRACHENKOV, A. BOBU. *Cliques in high-dimensional random geometric graphs*, in "COMPLEX NETWORKS 2019 - 8th International Conference on Complex Networks and Their Applications", Lisbon, Portugal, December 2019 [*DOI :* 10.1007/978-3-030-36687-2_49], https://hal.inria.fr/hal-02397338

[31] K. AVRACHENKOV, V. S. BORKAR. *A learning algorithm for the Whittle index policy for scheduling web crawlers*, in "Allerton 2019 - 57th Annual Conference on Communication, Control, and Computing",

Monticello, France, IEEE, September 2019, pp. 1001-1006 [*DOI :* 10.1109/ALLERTON.2019.8919743], https://hal.inria.fr/hal-02416599

[32] K. AVRACHENKOV, A. BORODINA. *On the Escape Probability Estimation in Large Graphs*, in "IEEE FRUCT 2019 - 24th Conference of Open Innovations Association FRUCT", Moscow, Russia, April 2019 [*DOI :* 10.23919/FRUCT.2019.8711919], https://hal.inria.fr/hal-02413569

[33] K. AVRACHENKOV, L. COTTATELLUCCI, M. HAMIDOUCHE. *Eigenvalues and Spectral Dimension of Random Geometric Graphs in Thermodynamic Regime*, in "Complex Networks 2019 - 8th International Conference on Complex Networks and Their Applications", Lisbon, Portugal, December 2019 [*DOI :* 10.1007/978-3-030-36687-2_80], https://hal.inria.fr/hal-02397383

[34] K. AVRACHENKOV, M. DREVETON. *Almost Exact Recovery in Label Spreading*, in "WAW 2019 - 16th Workshop on Algorithms and Models for the Web Graph", Brisbane, Australia, July 2019 [*DOI :* 10.1007/978-3-030-25070-6_3], https://hal.inria.fr/hal-02397060

[35] K. AVRACHENKOV, J. GOSELING, B. SERBETCI. *Distributed Cooperative Caching for Utility Maximization of VoD Systems*, in "SPAWC 2019 - 20th anniversary edition, the IEEE International Workshop on Signal Processing Advances in Wireless Communications", Cannes, France, July 2019 [*DOI :* 10.1109/SPAWC.2019.8815571], https://hal.inria.fr/hal-02132439

[36] K. AVRACHENKOV, J. GOSELING, B. SERBETCI. *Distributed Cooperative Caching for VoD with Geographic Constraints*, in "WiOpt 2019 - 17th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks", Avignon, France, June 2019, https://hal.inria.fr/hal-02132461

[37] D. CARRA, G. NEGLIA, P. MICHIARDI. *TTL-based Cloud Caches*, in "IEEE INFOCOM 2019 - IEEE Conference on Computer Communications", Paris, France, IEEE, April 2019, pp. 685-693 [*DOI :* 10.1109/INFOCOM.2019.8737546], https://hal.inria.fr/hal-02411168

[38] S. DHAMAL. *An Integrated Framework for Competitive Multi-channel Marketing of Multi-featured Products*, in "COMSNETS 2019 - 11th International Conference on Communication Systems & Networks", Bangalore, India, January 2019, pp. 391-394, https://hal.inria.fr/hal-01767317

[39] R. EL-AZOUZI, K. ACHARYA, S. POOJARY, A. SUNNY, M. HADDAD, E. ALTMAN, D. TSILIMANTOS, S. VALENTIN. *Analysis of QoE for Adaptive Video Streaming over Wireless Networks with User Abandonment Behavior*, in "WCNC 2019 - IEEE Wireless Communications and Networking Conference", Marrakesh, Morocco, IEEE, April 2019, pp. 1-8 [*DOI :* 10.1109/WCNC.2019.8885491], https://hal.inria.fr/hal-02418543

[40] R. EL-AZOUZI, A. SUNNY, L. ZHAO, E. ALTMAN, D. TSILIMANTOS, F. DE PELLEGRINI, S. VALENTIN. *Dynamic DASH Aware Scheduling in Cellular Networks*, in "WCNC 2019 - IEEE Wireless Communications and Networking Conference", Marrakesh, Morocco, IEEE, April 2019, pp. 1-8 [*DOI :* 10.1109/WCNC.2019.8885788], https://hal.inria.fr/hal-02418538

[41] M. GARETTO, E. LEONARDI, G. NEGLIA. *Similarity Caching: Theory and Algorithms*, in "IEEE INFOCOM 2020 - IEEE Conference on Computer Communications", Beijing, China, April 2020, https://hal.inria.fr/hal-02411268

[42] M. HAMIDOUCHE, L. COTTATELLUCCI, K. AVRACHENKOV. *Spectral Analysis of the Adjacency Matrix of Random Geometric Graphs*, in "Allerton 2019 - 57th Annual Allerton Conference on Com-

munication, Control, and Computing", Monticello, United States, IEEE, September 2019, pp. 208-214 [*DOI :* 10.1109/ALLERTON.2019.8919798], https://hal.inria.fr/hal-02416590

[43] E. HARGREAVES, D. S. MENASCHE, G. NEGLIA. *How Often Should I Access My Online Social Networks?*, in "2019 IEEE 27th International Symposium on Modeling, Analysis, and Simulation of Computer and Telecommunication Systems (MASCOTS)", Rennes, France, IEEE, October 2019, pp. 189-200 [*DOI :* 10.1109/MASCOTS.2019.00028], https://hal.inria.fr/hal-02411170

[44] V. KAVITHA, M. MAHESHWARI, E. ALTMAN. *Acquisition Games with Partial-Asymmetric Information*, in "Allerton - 57th Annual Allerton Conference on Communication, Control, and Computing", Allerton, United States, September 2019 [*DOI :* 10.1109/ALLERTON.2019.8919935], https://hal.inria.fr/hal-02290737

[45] F. LEBEAU, C. TOUATI, E. ALTMAN, N. ABUZAINAB. *The Social Medium Selection Game*, in "NETGCOOP 2018 - International Conference on NETwork Games, COntrol and OPtimisation", New York, United States, Springer, February 2019, pp. 249-269 [*DOI :* 10.1007/978-3-030-10880-9_15], https://hal.inria.fr/hal-02418516

[46] D. MENASCHÉ, K. TRIVEDI, E. ALTMAN. *Rejuvenation and the Age of Information*, in "WoSAR 2019 - 11th International Workshop on Software Aging and Rejuvenation", Berlin, Germany, October 2019, https://hal.inria.fr/hal-02293628

[47] G. NEGLIA, G. CALBI, D. TOWSLEY, G. VARDOYAN. *The Role of Network Topology for Distributed Machine Learning*, in "IEEE INFOCOM 2019 - IEEE Conference on Computer Communications", Paris, France, IEEE, April 2019, pp. 2350-2358 [*DOI :* 10.1109/INFOCOM.2019.8737602], https://hal.inria.fr/hal-02411164

[48] G. NEGLIA, C. XU, D. TOWSLEY, G. CALBI. *Decentralized gradient methods: does topology matter?*, in "AISTATS 2020 - 23rd International Conference on Artificial Intelligence and Statistics", Palermo, Italy, June 2020, https://hal.inria.fr/hal-02430485

National Conferences with Proceedings

[49] E. HARGREAVES, D. MENASCHÉ, G. NEGLIA. *Com que frequência devo acessar as minha redes sociais?*, in "BraSNAM 2019 - 8th Brazilian Workshop on Social Network Analysis and Mining", Belem, Brazil, July 2019, https://hal.inria.fr/hal-02411237

Conferences without Proceedings

[50] V. BUCAREY, A. JEAN-MARIE, E. DELLA VECCHIA, F. ORDÓÑEZ. *On the Value Iteration method for dynamic Strong Stackelberg Equilibria*, in "ROADEF 2019 - 20ème congrès annuel de la société Française de Recherche Opérationnelle et d'Aide à la Décision", Le Havre, France, February 2019, https://hal.inria.fr/hal-02191809

[51] V. BUCAREY, A. JEAN-MARIE, E. DELLA VECCHIA, F. ORDÓÑEZ. *The operator approach to dynamic Strong Stackelberg Equilibria*, in "12th International ISDG Workshop", St Petersbourg, Russia, July 2019, The ISDG12-GTM2019 International Meeting on Game Theory: joint meeting of "12th International ISDG Workshop" and "13th International Conference on Game Theory and Management", https://hal.inria.fr/hal-02191785

[52] F. CAZALS, J. ROUX, A. JEAN-MARIE, D. MAZAURIC, G. SALES SANTA CRUZ. *Source-Target Proximity Analysis in Protein Networks Using Random Walks with Restart; Applications to Cancer Drug Resistance*

Prediction from Single-Cell Data, in "SophI.A 2019 - Springboard for Artificial Intelligence", Sophia-Antipolis, France, Université Côte d'Azur, November 2019, https://hal.inria.fr/hal-02432552

[53] L. FLORES LUYO, A. AGRA, R. FIGUEIREDO, E. ALTMAN, E. OCAÑA ANAYA. *Vehicle routing problem for information collection in wireless networks*, in "ICORES 2019 - 8th International Conference on Operations Research and Enterprise Systems", Prague, Czech Republic, February 2019, https://hal.archives-ouvertes.fr/hal-02176511

[54] A. JEAN-MARIE, T. JIMENEZ, M. TIDBALL. *Myopia and learning applied to water management*, in "12th International ISDG Workshop", Saint-Petersbourg, Russia, International Society on Dynamic Games, July 2019, https://halshs.archives-ouvertes.fr/halshs-02291240

Scientific Books (or Scientific Book chapters)

[55] G. ACCONGIAGIOCO, E. ALTMAN, E. GREGORI, L. LENZINI. *Peering vs transit: A game theoretical model for autonomous systems connectivity*, in "Multilevel Strategic Interaction Game Models for Complex Networks", E. ALTMAN, K. AVRACHENKOV, F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors), Springer International Publishing, 2019, pp. 201-237 [*DOI :* 10.1007/978-3-030-24455-2_11], https://hal.inria.fr/hal-02413046

[56] E. ALTMAN, C. TOUATI, N. MISHRA, H. KAMEDA. *Load Balancing Congestion Games and Their Asymptotic Behavior*, in "Advances in Dynamic Games", Springer, 2019, pp. 1-10, forthcoming, https://hal.inria.fr/hal-02401223

[57] K. AVRACHENKOV, V. V. SINGH. *Stochastic Coalitional Better-Response Dynamics for Finite Games with Application to Network Formation Games*, in "Multilevel Strategic Interaction Game Models for Complex Networks", E. ALTMAN, K. AVRACHENKOV, F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors), Springer International Publishing, October 2019, pp. 185-199 [*DOI :* 10.1007/978-3-030-24455-2_10], https://hal.inria.fr/hal-02372761

[58] I. BRUNETTI, R. EL-AZOUZI, E. ALTMAN. *Altruism in groups*, in "Multilevel Strategic Interaction Game Models for Complex Networks", E. ALTMAN, K. AVRACHENKOV, F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors), Springer International Publishing, October 2019, pp. 5-23 [*DOI :* 10.1007/978-3-030-24455-2_1], https://hal.inria.fr/hal-02413230

[59] I. BRUNETTI, Y. HAYEL, E. ALTMAN. *Coupled State Policy Dynamics in Evolutionary Games*, in "Multilevel Strategic Interaction Game Models for Complex Networks", E. ALTMAN, K. AVRACHENKOV, F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors), Springer International Publishing, October 2019, pp. 95-107 [*DOI :* 10.1007/978-3-030-24455-2_5], https://hal.inria.fr/hal-02413146

[60] R. BURRA, C. SINGH, J. KURI, E. ALTMAN. *Routing on a Ring Network*, in "Game Theory for Networking Applications", J. B. SONG, H. LI, M. COUPECHOUX (editors), Springer International Publishing, August 2019, pp. 25-36 [*DOI :* 10.1007/978-3-319-93058-9_3], https://hal.inria.fr/hal-02417278

[61] M. DREVETON, J. LHABOUZ. *Leçons pour l'agrégation de mathématiques - Préparation à l'oral*, Ellipses, May 2019, https://hal.archives-ouvertes.fr/hal-02420203

[62] R. EL-AZOUZI, E. ALTMAN, I. BRUNETTI, M. HADDAD, H. GAIECH. *From egoism to altruism in groups*, in "Multilevel Strategic Interaction Game Models for Complex Networks", E. ALTMAN, K. AVRACHENKOV,

F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors), Springer International Publishing, 2019, pp. 25-43 [*DOI :* 10.1007/978-3-030-24455-2_2], https://hal.inria.fr/hal-02413190

[63] A. REIFFERS-MASSON, Y. HAYEL, E. ALTMAN, T. JIMENEZ. *A Net Neutrality Perspective for Content Down-Streaming over the Internet*, in "Multilevel Strategic Interaction Game Models for Complex Networks", E. ALTMAN, K. AVRACHENKOV, F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors), Springer International Publishing, October 2019, pp. 239-259 [*DOI :* 10.1007/978-3-030-24455-2_12], https://hal.inria.fr/hal-02413101

Books or Proceedings Editing

[64] E. ALTMAN, K. AVRACHENKOV, F. DE PELLEGRINI, R. EL-AZOUZI, H. WANG (editors). *Multilevel Strategic Interaction Game Models for Complex Networks*, Springer International Publishing, 2019 [*DOI :* 10.1007/978-3-030-24455-2], https://hal.inria.fr/hal-02372730

[65] K. AVRACHENKOV, L. HUANG, J. R. MARDEN, M. COUPECHOUX, A. GIOVANIDIS (editors). *Game Theory for Networks: 8th International EAI Conference, GameNets 2019, Proceedings*, 2019 [*DOI :* 10.1007/978-3-030-16989-3], https://hal.archives-ouvertes.fr/hal-02081868

[66] K. AVRACHENKOV, P. PRALAT, Y. NAN (editors). *Algorithms and Models for the Web Graph : 16th International Workshop, WAW 2019, Brisbane, QLD, Australia, July 6–7, 2019, Proceedings*, June 2019 [*DOI :* 10.1007/978-3-030-25070-6], https://hal.inria.fr/hal-02413524

Research Reports

[67] V. BUCAREY, E. DELLA VECCHIA, A. JEAN-MARIE, F. ORDÓÑEZ. *Stationary Strong Stackelberg Equilibrium in Discounted Stochastic Games*, Inria, May 2019, n^{o} RR-9271, 62 p. , https://hal.inria.fr/hal-02144095

Other Publications

[68] S. DHAMAL, W. BEN-AMEUR, T. CHAHED, E. ALTMAN, A. SUNNY, S. POOJARY. *A stochastic game framework for analyzing computational investment strategies in distributed computing*, November 2019, https://arxiv.org/abs/1809.03143 - working paper or preprint, https://hal.inria.fr/hal-01870871