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IN PARTNERSHIP WITH:

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2020 ACTIVITY REPORT

Project-Team DYOGENE

Dynamics of Geometric Networks

IN COLLABORATION WITH: Département d'Informatique de l'Ecole Normale Supérieure

DOMAIN

Networks, Systems and Services, Distributed Computing

THEME

Networks and Telecommunications

Contents

Project-Team DYOGENE

Creation of the Project-Team: 2013 July 01

Keywords

Computer sciences and digital sciences

A1.2.4. – QoS, performance evaluation

A6.1.4. – Multiscale modeling

A6.2.3. – Probabilistic methods

A8.1. – Discrete mathematics, combinatorics

A8.2. – Optimization

A8.3. – Geometry, Topology

A8.6. – Information theory

A8.7. – Graph theory

A8.8. – Network science

A8.9. – Performance evaluation

A9.2. – Machine learning

A9.7. – AI algorithmics

Other research topics and application domains

B4.3. – Renewable energy production

B6.2.2. – Radio technology

B6.3.4. – Social Networks

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- Christine Fricker [Inria, Researcher, HDR]
- Ali Khezeli [Inria, Starting Research Position, from Oct 2020]
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- Marc Olivier Buob [Bell Labs (Alcatel)]
- Fabien Mathieu [Nokia, HDR]

2 Overall objectives

The general scientific focus of DYOGENE is on the development of network mathematics. The following theories lie within our research interest: dynamical systems, queuing theory, optimization and control, information theory, stochastic processes, random graphs, stochastic geometry.

Our theoretical developments are motivated by and applied in the context of communication networks (Internet, wireless, mobile, cellular, peer-to-peer), social and economic networks, power grids, and, recently, infectious diseases.

We collaborate with many industrial partners. Our current industrial relations involve EDF, Huawei, Microsoft, Nokia, Orange, Safran.

More specifically, the scientific focus of DYOGENE defined in 2013 was on geometric network dynamics arising in communications. By geometric networks we understand networks with a nontrivial, discrete or continuous, geometric definition of the existence of links between the nodes. In stochastic geometric networks, this definition leads to random graphs or stochastic geometric models.

A first type of geometric network dynamics is the one where the nodes or the links change over time according to an exogeneous dynamics (e.g. node motion and geometric definition of the links). We will refer to this as dynamics of geometric networks below. A second type is that where links and/or nodes are fixed but harbor local dynamical systems (in our case, stemming from e.g. information theory, queuing theory, social and economic sciences). This will be called dynamics on geometric networks. A third type is that where the dynamics of the network geometry and the local dynamics interplay. Our motivations for studying these systems stem from many fields of communications where they play a central role, and in particular: message passing algorithms; epidemic algorithms; wireless networks and information theory; device to device networking; distributed content delivery; social and economic networks, power grids.

3 Research program

3.1 Initial research axes

The following research axes have been defined in 2013 when the project-team was created.

- Algorithms for network performance analysis, led by A. Bouillard and A. Busic.
- Stochastic geometry and information theory for wireless network, led by F. Baccelli and B. Blaszczyszyn.
- The cavity method for network algorithms, led by M. Lelarge.

Our scientific interests keep evolving. Research areas which received the most of our attention in 2020 are summarized in the following sections.

3.2 Models of infectious diseases

Over the past year, with several researchers and collaborations with the main players in the medical system, we have looked at mathematical models of the evolution of the Covid 19 epidemic.

3.3 Distributed network control and smart-grids

Theory and algorithms for distributed control of networks with applications to the stabilization of power grids subject to high volatility of renewable energy production are being developed by A. Busic in collaboration with Sean Meyn [Prof. at University of Florida and Inria International Chair].

3.4 Mathematics of wireless cellular networks

A comprehensive approach involving information theory, queueing and stochastic geometry to model and analyze the performance of large cellular networks, validated and implemented by Orange is being led by B. Blaszczyszyn in collaboration with F. Baccelli and M. K. Karray [Orange Labs]. A new collaboration between the Standardization and Research Lab at Nokia Bell Labs and ERC NEMO led by F. Baccelli has been started in 2019.

3.5 High-dimensional statistical inference and distributed learning

We computed information theoretic bounds for unsupervised and semi-supervised learning and proved complexity bounds for distributed optimization of convex functions using a network of computing units.

3.6 Stochastic Geometry

Stochastic geometry offers a mathematical framework for the analysis of various random structures embedded in Euclidean space. This year we were studying a general fragmentation-interaction-aggregation spatial processes, Nash equilibrium on point measures, an optimal stationary marking representing various specific problems ranging from theoretical probability to applications in statistical physics, combinatorial optimization and communications, particle gradient descent model for point process generations, a processes on Delaunay neighbors in the Poisson-Voronoi tessellation, and Dirichlet measures. We collaborated with V. Anantharam (EECS at UC Berkeley), Ch. Hirsch (University of Groningen), S. Mallat (ENS/Flatiron Institute) and S. Zhang (IRIT-SC)

4 Application domains

4.1 Physical communication networks

Internet, wireless, mobile, cellular networks, transportation networks, distributed systems (cloud, call centers). In collaboration with Nokia Bell Labs and Orange Labs.

4.2 Abstract networks

Social interactions, human communities, economic networks.

4.3 Power grids

Energy networks. In collaboration with EDF and Vito (Belgium).

5 Highlights of the year

An exhaustive treatment of *Random Measures Point Processes and Stochastic Geometry* has just been proposed in a new book [21] (more than 500 pages) by F. Baccelli, B. Błaszczyszyn and M. K. Karray. The book contains two types of results: (1) structural results of stationary random measures and stochastic geometry objects, which do not rely on any parametric assumptions; (2) more computational results on the most important parametric classes of point processes, in particular Poisson or Determinantal point processes.

5.1 Awards

The paper [18] on "Stochastic Geometry for Beam Management in 5G Networks" by S. Kalamkar and F. Baccelli in collaboration with Luis G. Uzeda Garcia, Fuad Abinader and Andrea Marcano from Nokia Bell Labs Paris received a best paper award at IEEE Globecom in December 2020; see Section 25..

6 New software and platforms

6.1 New platforms

Cellular network dimensioning toolbox *CapRadio* is being developed by Orange in a long-term collaboration between TREC/DYOGENE represented by B. Błaszczyszyn, and Orange Labs, represented by M. K. Karray. This year we are working on taking into account the “massive MIMO” in 5G cellular networks; see 8.1.1.

7 New results

7.1 Models of infectious diseases

1. ***Initiative face au virus Observations sur la mobilité pendant l’épidémie de Covid-19*** [25] This report analyzes human mobility patterns in France during the first lock-down of France in March-May 2020, based on mobility data made available by Facebook through its ‘Data for Good’ programme. It highlights the impact of lockdown on various indices capturing among other things urban mobility and inter-regional mobility.

2. ***Probabilistic and mean-field model of COVID-19 epidemics with user mobility and contact tracing*** [24] We propose a detailed discrete-time model of COVID-19 epidemics coming in two flavours, mean-field and probabilistic. The main contribution lies in several extensions of the basic model that capture i) user mobility — distinguishing routing, i.e. change of residence, from commuting, i.e. daily mobility - and ii) contact tracing procedures. We confront this model to public data on daily hospitalizations, and discuss its application as well as underlying estimation procedures.

3. ***Understanding and monitoring the evolution of the Covid-19 epidemic from medical emergency calls: the example of the Paris area*** [1] We portray the evolution of the Covid-19 epidemic during the crisis of March-April 2020 inthe Paris area, by analyzing the medical emergency calls received by the EMS of the four central departmentsof this area (Centre 15 of SAMU 75, 92, 93 and 94). Our study reveals strong dissimilarities between thesedepartments. We show that the logarithm of each epidemic observable can be approximated by a piecewiselinear function of time. This allows us to distinguish the different phases

of the epidemic, and to identify thedelay between sanitary measures and their influence on the load of EMS. This also leads to an algorithm,allowing one to detect epidemic resurgences. We rely on a transport PDE epidemiological model, and weuse methods from Perron-Frobenius theory and tropical geometry.

7.2 Distributed network control and smart-grids

4. ***Adaptive Matching for Expert Systems with Uncertain Task Types*** [3]A matching in a two-sided market often incurs an externality: a matched resource maybecome unavailable to the other side of the market, at least for a while. This is especiallyan issue in online platforms involving human experts as the expert resources are often scarce.The efficient utilization of experts in these platforms is made challenging by the fact that theinformation available about the parties involved is usually limited.To address this challenge, we develop a model of a task-expert matching system where atask is matched to an expert using not only the prior information about the task but alsothe feedback obtained from the past matches. In our model the tasks arrive online while theexperts are fixed and constrained by a finite service capacity. For this model, we characterizethe maximum task resolution throughput a platform can achieve. We show that the naturalgreedy approaches where each expert is assigned a task most suitable to her skill is suboptimal,as it does not internalize the above externality. We develop a throughput optimal backpressurealgorithm which does so by accounting for the 'congestion' among different task types. Finally,we validate our model and confirm our theoretical findings with data-driven simulations vialogs of Math.StackExchange, a StackOverflow forum dedicated to mathematics.

5. ***Simultaneous Allocation and Control of Distributed Energy Resources via Kullback-Leibler-Quadratic Optimal Control*** [8] There is enormous flexibility potential in the power consumption of the majority of electric loads. This flexibility can be harnessed to obtain services for managing the grid: with carefully designed decision rules in place, power consumption for the population of loads can be ramped up and down, just like charging and discharging a battery, without any significant impact to consumers' needs. The concept is called Demand Dispatch, and the grid resource obtained from this design virtual energy storage (VES). In order to deploy VES, a balancing authority is faced with two challenges: 1. how to design local decision rules for each load given the target aggregate power consumption (distributed control problem), and 2. how to coordinate a portfolio of resources to maintain grid balance, given a forecast of net-load (resource allocation problem).Rather than separating resource allocation and distributed control, in this paper the two problems are solved simultaneously using a single convex program. The joint optimization model is cast as a finite-horizon optimal control problem in a mean-field setting, based on the new KLQ optimal control approach proposed recently by the authors.The simplicity of the proposed control architecture is remarkable: With a large portfolio of heterogeneous flexible resources, including loads such as residential water heaters, commercial water heaters, irrigation, and utility-scale batteries, the control architecture leads to a single scalar control signal broadcast to every resource in the domain of the balancing authority.

6. ***Energy Packet Networks with Finite Capacity Energy Queues*** [20] Energy Packet Network (EPN) consists of a queueing network formed by n blocks, where each of them is formed by one data queue, that handles the workload, and one energy queue, that handles packets of energy. We study an EPN model where the energy packets start the transfer. In this model, energy packets are sent to the data queue of the same block. An energy packet routes one workload packet to the next block if the data queue is not empty, and it is lost otherwise. We assume that the energy queues have a finite buffer size and if an energy packet arrives to the system when the buffer is full, jump-over blocking (JOB) is performed, and therefore with some probability it is sent to the data queue and it is lost otherwise. We first provide a value of this probability such that the steady-state probability distribution of packets in the queues admits a product form solution. Moreover, in the case of a single block, we show that the number of data packets in the system decreases as the JOB probability increases.

7. ***Energy Storage Optimization for Grid Reliability*** [14] Large scale renewable energy source (RES) integration planned for multiple power grids around the world will require additional resources/reserves to achieve secure and stable grid operations to mitigate the inherent intermittency of RES. In this paper, we present formulations to understand the effect of fast storage reserves in improving grid reliability under

different cost functions. Our formulations not only aim to minimize imbalance but also maintain state-of-charge (SoC) of storage. The proposed approaches rely on a macroscopic supply-demand model of the grid with total power output of energy storage as the control variable. We show that accounting for system response due to inertia and local governor response enables a more realistic quantification of storage requirements for damping net load fluctuations. Simulation case studies are embedded in the paper by using datasets from the Elia TSO in Belgium and BPA in the USA. The numerical results benchmark the marginal effect on reliability due to increasing storage size under different system responses and associated cost functions. Further we observe myopic control of batteries proposed approximates deterministic control of batteries for faster time scale reserve operation.

8. ***Efficient distributed solutions for sharing energy resources at local level: a cooperative game approach*** [7] Local energy generation as well as local energy storage represent key opportunities for energy transition. Nevertheless , their massive deployment is being delayed mainly due to cost reasons. Sharing resources at the local level enables not only reducing these costs significantly, but also to further optimize the cost of the energy exchanged with providers external to the local community. A key question that arises while sharing resources is how to distribute the obtained benefits among the various local players that cooperate. In this paper we propose a cooperative game model, where the players are the holders of energy resources (generation and storage); they cooperate in order to reduce their individual electricity costs. We prove that the core of the game is non-empty; i.e., the proposed cooperative game has a stable solution (distribution of the payoffs among the players) for the case where all players participate in a unique community, and no strict subset of players can obtain a better gain by leaving the community. We propose a formulation of this game, based on the theory of linear production games, which lead us to the two main contributions of this paper. First, we propose an efficient (with linear complexity) centralized algorithm for finding a stable payoff. Second, we provide an efficient distributed algorithm that computes an allocation in the core of the game without any requirement for the players to share any private information. The distributed algorithm requires the exchange of intermediate solutions among players. The topology of the network that enables these exchanges is closely related to the performance of the distributed algorithm. We show, by way of simulations, which are the best topologies for these communication graphs.

9. ***Sizing and Profitability of Energy Storage for Prosumers in Madeira, Portugal*** [15] This paper proposes a framework to select the best-suited battery for co-optimizing for peak demand shaving, energy arbitrage and increase self-sufficiency in the context of power network in Madeira, Portugal. Feed-in-tariff for electricity network in Madeira is zero, which implies consumers with excess production should locally consume the excess generation rather than wasting it. Further, the power network operator applies a peak power contract for consumers which imposes an upper bound on the peak power seen by the power grid interfaced by energy meter. We investigate the value of storage in Madeira, using four different types of prosumers, categorized based on the relationship between their inelastic load and renewable generation. We observe that the marginal increase in the value of storage deteriorates with increase in size and ramping capabilities. We propose the use of profit per cycle per unit of battery capacity and expected payback period as indices for selecting the best-suited storage parameters to ensure profitability. This mechanism takes into account the consumption and generation patterns, profit, storage degradation, and cycle and calendar life of the battery. We also propose the inclusion of a friction coefficient in the original co-optimization formulation to increase the value of storage by reducing the operational cycles and eliminate low returning transactions.

10. ***Privacy Impact on Generalized Nash Equilibrium in Peer-to-Peer Electricity Market*** [44] We consider a peer-to-peer electricity market, where agents hold private information that they might not want to share. The problem is modeled as a noncooperative communication game, which takes the form of a Generalized Nash Equilibrium Problem, where the agents determine their randomized reports to share with the other market players, while anticipating the form of the peer-to-peer market equilibrium. In the noncooperative game, each agent decides on the deterministic and random parts of the report, such that (a) the distance between the deterministic part of the report and the truthful private information is bounded and (b) the expectation of the privacy loss random variable is bounded. This allows each agent to change her privacy level. We characterize the equilibrium of the game, prove the uniqueness of the Variational Equilibria and provide a closed form expression of the privacy price. In addition, we provide a

closed form expression to measure the impact of the privacy preservation caused by inclusion of random noise and deterministic deviation from agents' true values. Numerical illustrations are presented on the 14-bus IEEE network.

11. ***A mean field analysis of a stochastic model for reservation in car-sharing systems*** [12] Over the past decade, vehicle-sharing systems have appeared as a new answer to mobility challenges, like reducing congestion or pollution for numerous cities. In this paper we analyze a simple homogeneous stochastic model for station-based car-sharing systems with one-way trips where users reserve the parking space when the car is picked up. In these systems, users arrive at a station, pick up a vehicle while reserve a parking space at a destination station, use it for a while and then return it at the reserved parking space. Each station has a finite capacity and cannot host more vehicles and reserved parking spaces than its capacity. If the user cannot pick up a car or reserve at destination, he leaves the system. For this model, the large scale behavior is investigated via mean field approach. We derive asymptotics of the empirical measure process when the number of cars and stations are large together, such that their ratio tends to a constant. This gives the limiting distribution of the state of a station as the solution of a differential equation, called the Fokker-Planck equation. Then the main result is that the equilibrium point, characterized using queuing theory, exists and is unique. The proof uses a monotonicity argument as for bike-sharing systems, but also needs implicit function theorem and combinatorial arguments. It allows to study the system performance in terms of large scale stationary proportion of empty and full stations, especially the influence of the fleet size. For the optimal fleet size, we give asymptotics for this quantity in light and heavy traffic. We prove that, in light traffic case, reservation has little impact, unlike the heavy traffic case.

12. ***Optimal Control of Dynamic Bipartite Matching Models*** [32] A dynamic bipartite matching model is given by a bipartite matching graph which determines the possible matchings between the various types of supply and demand items. Both supply and demand items arrive to the system according to a stochastic process. Matched pairs leave the system and the others wait in the queues, which induces a holding cost. We model this problem as a Markov Decision Process and study the discounted cost and the average cost problem. We fully characterize the optimal matching policy for complete matching graphs and for the N-shaped matching graph. In the former case, the optimal policy consists of matching everything and, in the latter case, it prioritizes the matchings in the extreme edges and is of threshold type for the diagonal edge. In addition, for the average cost problem, we compute the optimal threshold value. For more general graphs, we need to consider some assumptions on the cost of the nodes. For complete graphs minus one edge, we provide conditions on the cost of the nodes such that the optimal policy of the N-shaped matching graph extends to this case. For acyclic graphs, we show that, when the cost of the extreme edges is large, the optimal matching policy prioritizes the matchings in the extreme edges. We also study the W-shaped matching graph and, using simulations, we show that there are cases where it is not optimal to prioritize to matchings in the extreme edges.

13. ***Risk-Averse Equilibrium Analysis and Computation*** [45] We consider two market designs for a network of prosumers, trading energy: (i) a centralized design which acts as a benchmark, and (ii) a peer-to-peer market design. High renewable energy penetration requires that the energy market design properly handles uncertainty. To that purpose, we consider risk neutral models for market designs (i), (ii), and their risk-averse interpretations in which prosumers are endowed with coherent risk measures reflecting heterogeneity in their risk attitudes. We characterize analytically risk-neutral and risk-averse equilibrium in terms of existence and uniqueness , relying on Generalized Nash Equilibrium and Variational Equilibrium as solution concepts. To hedge their risk towards uncertainty and complete the market, prosumers can trade financial contracts. We provide closed form characterisations of the risk-adjusted probabilities under different market regimes and a distributed algorithm for risk trading mechanism relying on the Generalized potential game structure of the problem. The impact of risk heterogeneity and financial contracts on the prosumers' expected costs are analysed numerically in a three node network and the IEEE 14-bus network.

14. ***Control oriented modeling of TCLs*** [35] Thermostatically controlled loads (TCLs) have the potential to be a valuable resource for the Balancing Authority (BA) of the future. Examples of TCLs include household appliances such as air conditioners, water heaters, and refrigerators. Since the rated power of

each TCL is on the order of kilowatts, to provide meaningful service for the BA, it is necessary to control large collections of TCLs. To perform design of a distributed coordination/control algorithm, the BA requires a control oriented model that describes the relevant dynamics of an ensemble. Works focusing on solely modeling the ensemble date back to the 1980's, while works focusing on control oriented modeling are more recent. In this work, we contribute to the control oriented modeling literature. We leverage techniques from computational fluid dynamics (CFD) to discretize a pair of Fokker-Planck equations derived in earlier work [51]. The discretized equations are shown to admit a certain factorization, which makes the developed model useful for control design. In particular, the effects of weather and control are shown to independently effect the system dynamics.

15. ***Kullback-Leibler-Quadratic Optimal Control*** [34] This paper presents advances in Kullback-Leibler-Quadratic (KLQ) optimal control: a stochastic control framework for Markovian models. The motivation is distributed control of large networks. As in prior work, the objective function is composed of a state cost in the form of Kullback-Leibler divergence plus a quadratic control cost. With this choice of objective function, the optimal probability distribution of a population of agents over a finite time horizon is shown to be an exponential tilting of the nominal probability distribution. The same is true for the controlled transition matrices that induce the optimal probability distribution. However, one limitation of the previous work is that randomness can only be introduced via the control policy; all uncontrolled (natural) processes must be modeled as deterministic to render them immutable under an exponential tilting. In this work, only the controlled dynamics are subject to tilting, allowing for more general probabilistic models. Another advancement is a reduction in complexity based on lossy compression using transform techniques. This is motivated by the need to consider time horizons that are much longer than the inter-sampling times required for reliable control. Numerical experiments are performed in a power network setting. The results show that the KLQ method enables the aggregate power consumption of a collection of flexible loads to track a time-varying reference signal, while simultaneously ensuring each individual load satisfies its own quality of service constraints.

16. ***Storage Optimal Control under Net Metering Policies*** [41] Electricity prices and the end user net load vary with time. Electricity consumers equipped with energy storage devices can perform energy arbitrage, i.e., buy when energy is cheap or when there is a deficit of energy, and sell it when it is expensive or in excess, taking into account future variations in price and net load. Net metering policies indicate that many of the utilities apply a customer selling rate lower than or equal to the retail customer buying rate in order to compensate excess energy generated by end users. In this paper, we formulate the optimal control problem for an end user energy storage device in presence of net metering. We propose a computationally efficient algorithm, with worst case run time complexity of quadratic in terms of number of samples in lookahead horizon, that computes the optimal energy ramping rates in a time horizon. The proposed algorithm exploits the problem's piecewise linear structure and convexity properties for the *discretization* of optimal Lagrange multipliers. The solution has a *threshold-based structure* in which optimal control decisions are independent of past or future price as well as of net load values beyond a certain time horizon, defined as a *sub-horizon*. Numerical results show the effectiveness of the proposed model and algorithm. Furthermore, we investigate the impact of forecasting errors on the proposed technique. We consider an Auto-Regressive Moving Average (ARMA) based forecasting of net load together with the Model Predictive Control (MPC). We numerically show that adaptive forecasting and MPC significantly mitigate the effects of forecast error on energy arbitrage gains.

17. ***Flexibility can hurt dynamic matching system performance*** [33] We study the performance of general dynamic matching models. This model is defined by a connected graph, where nodes represent the class of items and the edges the compatibilities between items. Items of different classes arrive one by one to the system according to a given probability distribution. Upon arrival, an item is matched with a compatible item according to the First Come First Served discipline and leave the system immediately, whereas it is enqueued with other items of the same class, if any. We show that such a model may exhibit a non intuitive behavior: increasing the services ability by adding new edges in the matching graph may lead to a larger average population. This is similar to a Braess paradox. We first consider a quasicomplete graph with four nodes and we provide values of the probability distribution of the arrivals such that when we add an edge the mean number of items is larger. Then, we consider an arbitrary matching graph and we show sufficient conditions for the existence or non-existence of this paradox. We conclude that

the analog to the Braess paradox in matching models is given when specific independent sets are in saturation, i.e., the system is close to the stability condition.

18. ***Asynchrony and Acceleration in Gossip Algorithms*** [42] This paper considers the minimization of a sum of smooth and strongly convex functions dispatched over the nodes of a communication network. Previous works on the subject either focus on synchronous algorithms, which can be heavily slowed down by a few slow nodes (the straggler problem), or consider a historical asynchronous setting (Boyd et al., 2006), which relies on a communication model that cannot be readily implemented in practice, as it does not capture important aspects of asynchronous communications such as non-instantaneous computations and communications. We have two main contributions. 1) We introduce a new communication scheme, based on Loss-Networks, that is programmable in a fully asynchronous and decentralized fashion. We establish empirically and theoretically that it improves over existing synchronous algorithms by depending on local communication delays in the analysis instead of global worst-ones. 2) We provide an acceleration of the standard gossip algorithm in the historical asynchronous model without requiring any additional synchronization.

19. ***Arbitrage with Power Factor Correction using Energy Storage*** [2] The importance of reactive power compensation for power factor (PF) correction will significantly increase with the large-scale integration of distributed generation interfaced via inverters producing only active power. In this work, we focus on co-optimizing energy storage for performing energy arbitrage as well as local power factor corrections. The joint optimization problem is non-convex, but can be solved efficiently using a McCormick relaxation along with penalty-based schemes. Using numerical simulations on real data and realistic storage profiles, we show that energy storage can correct PF locally without reducing arbitrage gains. It is observed that active and reactive power control is largely decoupled in nature for performing arbitrage and PF correction (PFC). Furthermore, we consider a stochastic online formulation of the problem with uncertain load, renewable and pricing profiles. We develop a model predictive control based storage control policy using ARMA forecast for the uncertainty. Using numerical simulations we observe that PFC is primarily governed by the size of the converter and therefore, look-ahead in time in the online setting does not affect PFC noticeably. However, arbitrage gains are more sensitive to uncertainty for batteries with faster ramp rates compared to slow ramping batteries.

7.3 Reinforcement learning

20. ***Explicit Mean-Square Error Bounds for Monte-Carlo and Linear Stochastic Approximation*** [10] This paper concerns error bounds for recursive equations subject to Markovian disturbances.Motivating examples abound within the fields of Markov chain Monte Carlo (MCMC) andReinforcement Learning (RL), and many of these algorithms can be interpreted as special casesof stochastic approximation (SA). It is argued that it is not possible in general to obtain aHoeffding bound on the error sequence, even when the underlying Markov chain is reversibleand geometrically ergodic, such as the $M/M/1$ queue. This is motivation for the focus on meansquare error bounds for parameter estimates. It is shown that mean square error achieves theoptimal rate of $O(1/n)$, subject to conditions on the step-size sequence. Moreover, the exactconstants in the rate are obtained, which is of great value in algorithm design.

21. ***Zap Q-Learning for Optimal Stopping*** [9] This paper concerns approximate solutions to the optimal stopping problem for a geometrically ergodic Markov chain on a continuous state space. The starting point is the Galerkin relaxation of the dynamic programming equations that was introduced by Tsitsikilis and Van Roy in the 1990s, which motivated their Q-learning algorithm for optimal stopping. It is known that the convergence rate of Q-learning is in many cases very slow. The reason for slow convergence is explained here, along with a variant of "Zap-Q-learning" algorithm, designed to achieve the optimal rate of convergence. The main contribution is to establish consistency of Zap-Qlearning algorithm for a linear function approximation setting. The theoretical results are illustrated using an example from finance.

22. ***Zap Q-Learning With Nonlinear Function Approximation*** [11] The Zap stochastic approximation (SA) algorithm was introduced recently as a means to accelerate convergence in reinforcement learning algorithms. While numerical results were impressive, stability (in the sense of boundedness of parameter estimates) was established in only a few special cases. This class of algorithms is generalized in this paper,

and stability is established under very general conditions. This general result can be applied to a wide range of algorithms found in reinforcement learning. Two classes are considered in this paper: (i)The natural generalization of Watkins' algorithm is not always stable in function approximation settings. Parameter estimates may diverge to infinity even in the *linear* function approximation setting with a simple finite state-action MDP. Under mild conditions, the Zap SA algorithm provides a stable algorithm, even in the case of *nonlinear* function approximation. (ii) The GQ algorithm of Maei et. al. 2010 is designed to address the stability challenge. Analysis is provided to explain why the algorithm may be very slow to converge in practice. The new Zap GQ algorithm is stable even for nonlinear function approximation.

7.4 Mathematics of wireless cellular networks

23. ***Bandwidth Allocation and Service Differentiation in D2D Wireless Networks*** [4] Inspired by a new feature in 5G NR called bandwidth part (BWP), this paper presents a bandwidth allocation (BA) model that allows one to adapt the bandwidth allocated to users depending on their data rate needs. Specifically, in adaptive BA, a wide bandwidth is divided into chunks of smaller bandwidths and the number of bandwidth chunks allocated to a user depends on its needs or type. Although BWP in 5G NR mandates allocation of a set of contiguous bandwidth chunks, our BA model also allows other assumptions on chunk allocation such as the allocation of any set of bandwidth chunks, as in, e.g., LTE resource allocation, where chunks are selected uniformly at random. The BA model studied here is probabilistic in that the user locations are assumed to form a realization of a Poisson point process and each user decides independently to be of a certain type with some probability. This model allows one to quantify spectrum sharing and service differentiation in this context, namely to predict what performance a user gets depending on its type as well as the overall performance. This is based on exact representations of key performance metrics for each user type, namely its success probability, the meta distribution of its signal-to-interference ratio, and its Shannon throughput. We show that, surprisingly, the higher traffic variability stemming from adaptive BA is beneficial: when comparing two networks using adaptive BA and having the same mean signal and the same mean interference powers, the network with higher traffic variability performs better for all these performance metrics. With respect to Shannon throughput, we observe that our BA model is roughly egalitarian per Hertz and leads to a linear service differentiation in aggregated throughput value.

24. ***Coverage probability in wireless networks with determinantal scheduling*** [6]We propose a new class of algorithms for randomly scheduling network transmissions. The idea is to use (discrete) determinantal point processes (subsets) to randomly assign medium access to various *repulsive* subsets of potential transmitters. This approach can be seen as a natural extension of (spatial) Aloha, which schedules transmissions independently. Under a general path loss model and Rayleigh fading, we show that, similarly to Aloha, they are also subject to elegant analysis of the coverage probabilities and transmission attempts (also known as local delay). This is mainly due to the explicit, determinantal form of the conditional (Palm) distribution and closed-form expressions for the Laplace functional of determinantal processes. Interestingly, the derived performance characteristics of the network are amenable to various optimizations of the scheduling parameters, which are determinantal kernels, allowing the use of techniques developed for statistical learning with determinantal processes. Well-established sampling algorithms for determinantal processes can be used to cope with implementation issues, which is is beyond the scope of this paper, but it creates paths for further research.

25. ***Beam Management in 5G: A Stochastic Geometry Analysis*** [18] Beam management is central in the operation of beamformed wireless cellular systems such as 5G New Radio (NR) networks. Focusing the energy radiated to mobile terminals (MTs) by increasing the number of beams per cell increases signal power and decreases interference, and has hence the potential to bring major improvements on area spectral efficiency (ASE). This paper proposes a first system-level stochastic geometry model encompassing major aspects of the beam management problem: frequencies, antenna configurations, and propagation; physical layer, wireless links, and coding; network geometry, interference, and resource sharing; sensing, signaling, and mobility management. This model leads to a simple analytical expression for the effective rate that the typical user gets in this context. This in turn allows one to find the number of beams per cell and per MT that maximizes the effective ASE by offering the best tradeoff between

beamforming gains and beam management operational overheads and costs, for a wide variety of 5G network scenarios including millimeter wave (mmWave) and sub-6 GHz. As part of the system-level analysis, we define and analyze several underlying new and fundamental performance metrics that are of independent interest. The numerical results discuss the effects of different systemic tradeoffs and performance optimizations of mmWave and sub-6 GHz 5G deployments.

26. ***Crowd-networking: modelling Device-to-Device connectivity on street systems using percolation theory, and economic consequences*** [23] The fifth generation of cellular networks is expected to provide coverage for an unprecedented number of devices over large areas. One of the main paradigms investigated to address this challenge, called Device-to-Device (D2D) communication, consists in allowing for short-range direct communications between network devices. An application of significant economic interest for operators is the one of the uberisation of networks, where an operator having no (or very few) network infrastructure could build a mobile network relying only on its end-devices (users). In this thesis, we study new mathematical models of D2D networks in urban environments. We see the street system of a city as a planar Poisson-Voronoi tessellation (PVT). Network users are given by a Cox process supported by the edges of the PVT while additional network relays are given by a Bernoulli process on the vertices of the PVT. The network is then modelled by a connectivity graph as follows: vertices are the atoms of both these processes and fixed-range connections between them possible only along the PVT edges or between network nodes located on adjacent PVT edges. Percolation of this random graph (existence of an infinite connected component with positive probability) is interpreted as good connectivity of the network. Using renormalisation techniques, we prove the existence of phase transitions between different connectivity regimes, in particular those where percolation can be solely ensured by the relays or, on the contrary, where a sufficient density of users is essential. Performing numerical simulations with original path-finding algorithms, we estimate critical parameters (e.g. the density of relays and users) allowing for good connectivity of the network. Finally, we also introduce appropriate cost models and use our numerical estimates to study the economic feasibility of uberisation scenarios of telecommunications networks.

27. ***Relay-assisted Device-to-Device Networks: Connectivity and Uberization Opportunities*** [19] It has been shown that deploying device-to-device (D2D) networks in urban environments requires equipping a considerable proportion of crossroads with relays. This represents a necessary economic investment for an operator. In this work, we tackle the problem of the economic feasibility of such relay-assisted D2D networks. First, we propose a stochastic model taking into account a positive surface for streets and crossroads, thus allowing for a more realistic estimation of the minimal number of needed relays. Secondly, we introduce a cost model for the deployment of relays, allowing one to study operators' D2D deployment strategies. We investigate the example of an uberizing neo-operator willing to set up a network entirely relying on D2D and show that a return on the initial investment in relays is possible in a realistic period of time, even if the network is funded by a very low revenue per D2D user. Our results bring quantitative arguments to the discussion on possible uberization scenarios of telecommunications networks.

28. ***Randomised Geographic Caching and its Applications in Wireless Networks*** [40] The randomised (or probabilistic) geographic caching is a proactive content placement strategy that has attracted a lot of attention, because it can simplify a great deal cache-management problems at the wireless edge. It diversifies content placement over caches and applies to scenarios where a request can be possibly served by multiple cache memories. Its simplicity and strength is due to randomisation. It allows one to formulate continuous optimisation problems for content placement over large homogeneous geographic areas. These can be solved to optimality by standard convex methods, and can even provide closed-form solutions for specific cases. This way the algorithmic obstacles from NP-hardness are avoided and optimal solutions can be derived with low computational cost. Randomised caching has a large spectrum of applications in real-world wireless problems, including femto-caching, multi-tier networks, device-to-device communications, mobility, mm-wave, security, UAVs, and more. In this chapter we will formally present the main policy with its applications in various wireless scenarios. We will further introduce some very useful extensions related to unequal file-sizes and content placement with neighbourhood dependence.

29. ***Characterizing the Energy Trade-Offs of End-to-End Vehicular Communications using an Hyperfractal Urban Modelling*** [43] We characterize trade-offs between the end-to-end communication delay and the energy in urban vehicular communications with infrastructure assistance. Our study exploits the self-similarity of the location of communication entities in cities by modeling them with an innovative model called "hyperfractal". We show that the hyperfractal model can be extended to incorporate roadside infrastructure and provide stochastic geometry tools to allow a rigorous analysis. We compute theoretical bounds for the end-to-end communication hop count considering two different energy-minimizing goals: either total accumulated energy or maximum energy per node. We prove that the hop count for an endto-end transmission is bounded by $O(n^{1-\alpha/(d_F-1)})$ where $\alpha < 1$ and $d_F > 2$ is the fractal dimension.

7.5 High-dimensional statistical inference

30. ***From tree matching to sparse graph alignment*** [13] In this paper we consider alignment of sparse graphs, for which we introduce the Neighborhood Tree Matching Algorithm (NTMA). For correlated Erdős-Rényi random graphs, we prove that the algorithm returns – in polynomial time – a positive fraction of correctly matched vertices, and a vanishing fraction of mismatches. This result holds with average degree of the graphs in $O(1)$ and correlation parameter s that can be bounded away from 1, conditions under which random graph alignment is particularly challenging. As a byproduct of the analysis we introduce a matching metric between trees and characterize it for several models of correlated random trees. These results may be of independent interest, yielding for instance efficient tests for determining whether two random trees are correlated or independent.

31. ***Sharp threshold for alignment of graph databases with Gaussian weights*** [38] We study the fundamental limits for reconstruction in weighted graph (or matrix) database alignment. We consider a model of two graphs G, G', where G and G' have correlated Gaussian edge weights, and then G is relabeled according to a random uniform permutation. We prove that there is a sharp information-theoretic threshold for exact recovery of the planted permutation. This threshold is the same as the one obtained for detection in a recent work by Y. Wu, J. Xu and S. Yu: in other words, for Gaussian weighted graph alignment, the problem of reconstruction is not more difficult than that of detection. The study is based on the analysis of the MAP estimator, and proofs rely on proper use of the correlation structure of energies of permutations.

32. ***Spectral alignment of correlated Gaussian random matrices*** [39] In this paper we analyze a simple method ($EIG1$) for the problem of matrix alignment, consisting in aligning their leading eigenvectors: given A and B, we compute v_1 and v_1' two leading eigenvectors of A and B. The algorithm returns a permutation $\hat{\Pi}$ such that the rank of the coordinate $\hat{\Pi}(i)$ in v_1 is the rank of the coordinate i in v_1' (up to the sign of v_1'). We consider a model where A belongs to the Gaussian Orthogonal Ensemble (GOE), and $B = \Pi^T(A + \sigma H)\Pi$, where Π is a permutation matrix and H is an independent copy of A. We show the following 0-1 law: under the condition $\sigma N^{7/6+\epsilon} \to 0$, the $EIG1$ method recovers all but a vanishing part of the underlying permutation Π. When $\sigma N^{7/6-\epsilon} \to \infty$, this algorithm cannot recover more than $o(N)$ correct matches. This result gives an understanding of the simplest and fastest spectral method for matrix alignment (or complete weighted graph alignment), and involves proof methods and techniques which could be of independent interest.

33. ***Detection thresholds in very sparse matrix completion*** [29] Let A be a rectangular matrix of size $m \times n$ and A_1 be the random matrix where each entry of A is multiplied by an independent $\{0,1\}$-Bernoulli random variable with parameter $1/2$. This paper is about when, how and why the non-Hermitian eigen-spectra of the randomly induced asymmetric matrices $A_1(A - A_1)^*$ and $(A - A_1)^* A_1$ captures more of the relevant information about the principal component structure of A than via its SVD or the eigen-spectra of AA^* and A^*A respectively. Hint: the asymmetry inducing randomness breaks the echo-chamber effect that cripples the SVD. We illustrate the application of this striking phenomenon on the low-rank matrix completion problem for the setting where each entry is observed with probability d/n, including the very sparse regime where d is of order 1, where matrix completion via the SVD of A fails or produces unreliable recovery. We determine an asymptotically exact, matrix-dependent, non-universal detection threshold above which reliable, statistically optimal matrix recovery using a new, universal data-driven

matrix-completion algorithm is possible. Averaging the left and right eigenvectors provably improves the recovered matrix but not the detection threshold. We define another variant of this asymmetric procedure that bypasses the randomization step and has a detection threshold that is smaller by a constant factor but with a computational cost that is larger by a polynomial factor of the number of observed entries. Both detection thresholds shatter the seeming barrier due to the well-known information theoretical limit $d \asymp \log n$ for matrix completion found in the literature.

34. ***A simpler spectral approach for clustering in directed network*** [36] We study the task of clustering in directed networks. We show that using the eigenvalue/eigenvector decomposition of the adjacency matrix is simpler than all common methods which are based on a combination of data regularization and SVD truncation, and works very well down to the very sparse regime where the edge density has constant order. This simple approach was largely unnoticed in the mathematics and network science communities. Our analysis is based on a Master Theorem describing sharp asymptotics for isolated eigenvalues/eigenvectors of sparse, non-symmetric matrices with independent entries. We also describe the limiting distribution of the entries of these eigenvectors; in the task of digraph clustering with spectral embeddings, we provide numerical evidence for the superiority of Gaussian Mixture clustering over the widely used k-means algorithm.

35. ***Markovian linearization of random walks on groups*** [30] In operator algebra, the linearization trick is a technique that reduces the study of a non-commutative polynomial evaluated at elements of an algebra $\mathscr{A}$ to the study of a polynomial of degree one, evaluated on the enlarged algebra $\mathscr{A} \otimes M_r(\mathbb{C})$, for some integer r. We introduce a new instance of the linearization trick which is tailored to study a finitely supported random walk on a group G by studying instead a nearest-neighbor colored random walk on $G \times \{1, \dots, r\}$, which is much simpler to analyze. As an application we extend well-known results for nearest-neighbor walks on free groups and free products of finite groups to colored random walks, thus showing how one can obtain explicit formulas for the drift and entropy of a finitely supported random walk.

36. ***Who started this rumor? Quantifying the natural differential privacy guarantees of gossip protocols*** [5] Gossip protocols are widely used to disseminate information in massive peer-to-peer networks. These protocols are often claimed to guarantee privacy because of the uncertainty they introduce on the node that started the dissemination. But is that claim really true? Can the source of a gossip safely hide in the crowd? This paper examines, for the first time, gossip protocols through a rigorous mathematical framework based on differential privacy to determine the extent to which the source of a gossip can be traceable. Considering the case of a complete graph in which a subset of the nodes are curious, we study a family of gossip protocols parameterized by a "muting" parameter s: nodes stop emitting after each communication with a fixed probability $1 - s$. We first prove that the standard push protocol, corresponding to the case $s = 1$, does not satisfy differential privacy for large graphs. In contrast, the protocol with $s = 0$ achieves optimal privacy guarantees but at the cost of a drastic increase in the spreading time compared to standard push, revealing an interesting tension between privacy and spreading time. Yet, surprisingly, we show that some choices of the muting parameter s lead to protocols that achieve an optimal order of magnitude in both privacy and speed. We also confirm empirically that, with appropriate choices of s, we indeed obtain protocols that are very robust against concrete source location attacks while spreading the information almost as fast as the standard (and non-private) push protocol.

37. ***Non-backtracking spectra of weighted inhomogeneous random graphs*** [46] We study a model of random graphs where each edge is drawn independently (but not necessarily identically distributed) from the others, and then assigned a random weight. When the mean degree of such a graph is low, it is known that the spectrum of the adjacency matrix A deviates significantly from that of its expected value $\mathbb{E}A$. In contrast, we show that over a wide range of parameters the top eigenvalues of the non-backtracking matrix B – a matrix whose powers count the non-backtracking walks between two edges – are close to those of $\mathbb{E}A$, and all other eigenvalues are confined in a bulk with known radius. We also obtain a precise characterization of the scalar product between the eigenvectors of B and their deterministic counterparts derived from the model parameters. This result has many applications, in domains ranging from (noisy) matrix completion to community detection, as well as matrix perturbation theory. In particular, we establish as a corollary that a result known as the Baik-Ben Arous-Péché phase transition, previously

established only for rotationally invariant random matrices, holds more generally for matrices A as above under a mild concentration hypothesis.

7.6 Distributed optimization for machine learning

38. ***Statistically Preconditioned Accelerated Gradient Method for Distributed Optimization*** [17] We consider the setting of distributed empirical risk minimization where multiple machines compute the gradients in parallel and a centralized server updates the model parameters. In order to reduce the number of communications required to reach a given accuracy, we propose a precon-ditioned accelerated gradient method where the preconditioning is done by solving a local optimization problem over a subsampled dataset at the server. The convergence rate of the method depends on the square root of the relative condition number between the global and local loss functions. We estimate the relative condition number for linear prediction models by studying uniform concentration of the Hessians over a bounded domain , which allows us to derive improved convergence rates for existing preconditioned gradient methods and our accelerated method. Experiments on real-world datasets illustrate the benefits of acceleration in the ill-conditioned regime.

39. ***Dual-Free Stochastic Decentralized Optimization with Variance Reduction*** [16] We consider the problem of training machine learning models on distributed data in a decentralized way. For finite-sum problems, fast single-machine algorithms for large datasets rely on stochastic updates combined with variance reduction. Yet, existing decentralized stochastic algorithms either do not obtain the full speedup allowed by stochastic updates, or require oracles that are more expensive than regular gradients. In this work, we introduce a Decentralized stochastic algorithm with Variance Reduction called DVR. DVR only requires computing stochastic gradients of the local functions, and is computationally as fast as a standard stochastic variance-reduced algorithms run on a $1/n$ fraction of the dataset, where n is the number of nodes. To derive DVR, we use Bregman coordinate descent on a well-chosen dual problem, and obtain a dual-free algorithm using a specific Bregman divergence. We give an accelerated version of DVR based on the Catalyst framework, and illustrate its effectiveness with simulations on real data.

40. ***Concentration of Non-Isotropic Random Tensors with Applications to Learning and Empirical Risk Minimization*** [37] Dimension is an inherent bottleneck to some modern learning tasks, where optimization methods suffer from the size of the data. In this paper, we study non-isotropic distributions of data and develop tools that aim at reducing these dimensional costs by a dependency on an effective dimension rather than the ambient one. Based on non-asymptotic estimates of the metric entropy of ellipsoids-that prove to generalize to infinite dimensions-and on a chaining argument, our uniform concentration bounds involve an effective dimension instead of the global dimension, improving over existing results. We show the importance of taking advantage of non-isotropic properties in learning problems with the following applications: i) we improve state-of-the-art results in statistical preconditioning for communication-efficient distributed optimization, ii) we introduce a non-isotropic randomized smoothing for nonsmooth optimization. Both applications cover a class of functions that encompasses empirical risk minization (ERM) for linear models.

41. ***Conditioned Text Generation with Transfer for Closed-Domain Dialogue Systems*** [22] Scarcity of training data for task-oriented dialogue systems is a well known problem that is usually tackled with costly and time-consuming manual data annotation. An alternative solution is to rely on automatic text generation which, although less accurate than human supervision, has the advantage of being cheap and fast. Our contribution is two fold. First we show how to optimally train and control the generation of intent-specific sentences using a conditional variational auto encoder. Then we introduce a new protocol called query transfer that allows to leverage a large unlabelled dataset, possibly containing irrelevant queries, to extract relevant information. Comparison with two different baselines shows that this method, in the appropriate regime, consistently improves the diversity of the generated queries without compromising their quality. We also demonstrate the effectiveness of our generation method as a data augmentation technique for language modelling tasks.

7.7 Stochastic Geometry

42. ***Random Measures, Point Processes, and Stochastic Geometry*** [21] This book is centered on the mathematical analysis of random structures embedded in the Euclidean space or more general topological spaces, with a main focus on random measures, point processes, and stochastic geometry. Such random structures have been known to play a key role in several branches of natural sciences (cosmology, ecology, cell biology) and engineering (material sciences, networks) for several decades. Their use is currently expanding to new fields like data sciences. The book was designed to help researchers finding a direct path from the basic definitions and properties of these mathematical objects to their use in new and concrete stochastic models. The theory part of the book is structured to be self-contained, with all proofs included, in particular on measurability questions, and at the same time comprehensive. In addition to the illustrative examples which one finds in all classical mathematical books, the document features sections on more elaborate examples which are referred to as models in the book. Special care is taken to express these models, which stem from the natural sciences and engineering domains listed above, in clear and self-contained mathematical terms. This continuum from a comprehensive treatise on the theory of point processes and stochastic geometry to the collection of models that illustrate its representation power is probably the main originality of this book. The book contains two types of mathematical results: (1) structural results on stationary random measures and stochastic geometry objects, which do not rely on any parametric assumptions; (2) more computational results on the most important parametric classes of point processes, in particular Poisson or Determinantal point processes. These two types are used to structure the book. The material is organized as follows. Random measures and point processes are presented first, whereas stochastic geometry is discussed at the end of the book. For point processes and random measures, parametric models are discussed before non-parametric ones. For the stochastic geometry part, the objects as point processes are often considered in the space of random sets of the Euclidean space. Both general processes are discussed as, e.g., particle processes, and parametric ones like, e.g., Poisson Boolean models of Poisson hyperplane processes. We assume that the reader is acquainted with the basic results on measure and probability theories. We prove all technical auxiliary results when they are not easily available in the literature or when existing proofs appeared to us not sufficiently explicit. In all cases, the corresponding references will always be given.

43. ***Replica-Mean-Field Limits of Fragmentation-Interaction-Aggregation Processes*** [26] Network dynamics with point-process-based interactions are of paramount modeling interest. Unfortunately, most relevant dynamics involve complex graphs of interactions for which an exact computational treatment is impossible. To circumvent this difficulty, the replica-mean-field approach focuses on randomly interacting replicas of the networks of interest. In the limit of an infinite number of replicas , these networks become analytically tractable under the so-called "Poisson Hypothesis". However, in most applications, this hypothesis is only conjectured. Here, we establish the Poisson Hypothesis for a general class of discrete-time, point-process-based dynamics, that we propose to call fragmentation-interaction-aggregation processes, and which are introduced in the present paper. These processes feature a network of nodes, each endowed with a state governing their random activation. Each activation triggers the fragmentation of the activated node state and the transmission of interaction signals to downstream nodes. In turn, the signals received by nodes are aggregated to their state. Our main contribution is a proof of the Poisson Hypothesis for the replica-mean-field version of any network in this class. The proof is obtained by establishing the propagation of asymptotic independence for state variables in the limit of an infinite number of replicas. Discrete time Galves-Löcherbach neural networks are used as a basic instance and illustration of our analysis.

44. ***Nash equilibrium structure of Cox process Hotelling games*** [47] We study an N-player game where a pure action of each player is to select a non-negative function on a Polish space supporting a finite diffuse measure, subject to a finite constraint on the integral of the function. This function is used to define the intensity of a Poisson point process on the Polish space. The processes are independent over the players, and the value to a player is the measure of the union of its open Voronoi cells in the superposition point process. Under randomized strategies, the process of points of a player is thus a Cox process, and the nature of competition between the players is akin to that in Hotelling competition games. We characterize when such a game admits Nash equilibria and prove that when a Nash equilibrium exists, it is unique and comprised of pure strategies that are proportional in the same proportions as the total

intensities. We give examples of such games where Nash equilibria do not exist. A better understanding of the criterion for the existence of Nash equilibria remains an intriguing open problem.

45. ***Optimal stationary markings*** [28] Many specific problems ranging from theoretical probability to applications in statistical physics, combinatorial optimization and communications can be formulated as an optimal tuning of local parameters in large systems of interacting particles. Using the framework of stationary point processes in the Euclidean space, we pose it as a problem of an optimal stationary marking of a given stationary point process. The quality of a given marking is evaluated in terms of scores calculated in a covariant manner for all points in function of the proposed marked configuration. In the absence of total order of the configurations of scores, we identify intensity-optimality and local optimality as two natural ways for defining optimal stationary marking. We derive tightness and integrability conditions under which intensity-optimal markings exist and further stabilization conditions making them equivalent to locally optimal ones. We present examples motivating the proposed, general framework. Finally, we discuss various possible approaches leading to uniqueness results.

46. ***Particle gradient descent model for point process generation*** [31] This paper introduces a generative model for planar point processes in a square window, built upon a single realization of a stationary, ergodic point process observed in this window. Inspired by recent advances in gradient descent methods for maximum entropy models, we propose a method to generate similar point patterns by jointly moving particles of an initial Poisson configuration towards a target counting measure. The target measure is generated via a deterministic gradient descent algorithm, so as to match a set of statistics of the given, observed realization. Our statistics are estimators of the multi-scale wavelet phase harmonic covariance, recently proposed in image modeling. They allow one to capture geometric structures through multi-scale interactions between wavelet coefficients. Both our statistics and the gradient descent algorithm scale better with the number of observed points than the classical k-nearest neighbour distances previously used in generative models for point processes, based on the rejection sampling or simulated-annealing. The overall quality of our model is evaluated on point processes with various geometric structures through spectral and topological data analysis.

47. ***On Point Processes Defined by Angular Conditions on Delaunay Neighbors in the Poisson-Voronoi Tessellation*** [27] Consider a homogeneous Poisson point process of the Euclidean plane and its Voronoi tessellation. The present note discusses the properties of two stationary point processes associated with the latter and depending on a parameter θ. The first one is the set of points that belong to some one-dimensional facet of the Voronoi tessellation and are such that the angle with which they see the two nuclei defining the facet is θ. The main question of interest on this first point process is its intensity. The second point process is that of the intersections of the said tessellation with a straight line having a random orientation. Its intensity is well known. The intersection points almost surely belong to one-dimensional facets. The main question here is about the Palm distribution of the angle with which the points of this second point process see the two nuclei associated with the facet. The note gives answers to these two questions and briefly discusses their practical motivations. It also discusses natural extensions to dimension three.

48. ***A stochastic geometry characterization of Pitman-Yor processes*** [48] In this master's thesis, we give a new integral characterization of Pitman-Yor processes. It is inspired by a similar characterization for Dirichlet processes given by G. Last in 2019. The proof makes use of classical point processes theory arguments and is based on a key result found by T. Lehéricy in his 2015 master's thesis [50]

8 Bilateral contracts and grants with industry

8.1 Bilateral contracts with industry

8.1.1 CRE with Orange

Two year contract titled *Taking into account the "massive MIMO" in the assessment of QoS and the dimensioning of 5G cellularnetworks* between Inria and Orange Labs started 2019. It is a part of a long-term collaboration between TREC/DYOGENE, represented by B. Błaszczyszyn and Orange Labs,

represented by M. K. Karray on the development of analytic tools and methods allowing one to capture macroscopic relation between antennas roll-out, frequency allocation, volume of traffic carried on the network and quality of service parameters such as the average and the variation of bandwidth available to end users. This work addresses crucial technical and economical issues related to the operator core business, particularly related to the current evolution of the cellular network technology (4G⇒5G). The developed solutions are implemented by Orange Labs in the internal toolbox *CapRadio* (see 6.1) and used by the Direction of Regulatory Affairs of Orange.

8.1.2 Contract with EDF

Collaborative research in the area of demand dispatch of flexible loads. PI : A. Busic.

8.1.3 CIFRE with Orange

Contract with Orange started in 2017 and finished in 2020 for the co-advising by B. Błaszczyszyn of a PhD student of Orange, Quentin Le Gall, who defended his thesis [23].

9 Partnerships and cooperations

9.1 International initiatives

9.1.1 Inria international partners

Informal international partners

- University of Florida; Collaborations with Prof Sean Meyn (ECE), Associate Prof Prabir Barooah (MAE), and the PhD students: A. Devraj (ECE), A. Coffman (MAE), N. Cammardella (ECE), J. Mathias (ECE).
- Sharif University, Tehran; Collaborations with O. Mirsadeghi.
- UC Berkeley; Collaborations with V. Anantharam.
- Lehigh University; Collaborations with J. E. Yukich.
- University of Groningen; Collaborations with Ch. Hirsch.
- Polytechnique Montréal; Collaborations with Martin Trépanier.

9.1.2 Participation in other international programs

Indo-French Center of Applied Mathematics IFCAM Project “Geometric statistics of stationary point processes” B. Błaszczyszyn and Yogeshwaran D. from Indian Statistical Institute (ISI), Bangalore, have got in 2018 the approval from Indo-French Centre for Applied Mathematics (IFCAM), for their joint project on “Geometric statistics of stationary point processes" for the period 2018–2021. B. Błaszczyszyn was visiting Indian Statistical Institute (ISI), Bangalore, in two weeks in January 2020. 2019.

Microsoft Research-Inria collaboration Microsoft Research-Inria collaboration: Laurent Massoulié heads the Microsoft Research-Inria Joint Centre, and also participates to the “Distributed Machine Learning” project of the Joint Centre, together with Francis Bach (Inria), Sébastien Bubeck and Lin Xiao (MSR Redmond), and PhD student Hadrien Hendrikx.

Fall 2020 program Theory of Reinforcement Learning At Simons Institute for the Theory of Computing, UC Berkeley, Aug. 19 – Dec. 18, 2020. https://simons.berkeley.edu/programs/rl20. Due to the pandemics, the program was entirely online. A. Busic is a long term participant of this program.

Inria International Chairs

- **IIC- MEYN Sean**
- Title: Distributed Control and Smart Grid
- International Partner: University of Florida (United States) - Department of Electrical and Computer Engineering - Sean Meyn
  - University of Florida (United States) - Department of Electrical and Computer Engineering - Sean Meyn
- Duration: 2019 – 2023
- Start year: 2019
- See also: https://www.inria.fr/sites/default/files/2019-12/HoldersChairesInt_EN.pdf
  TOPIC: "Distributed Control and Smart Grid"

9.2 European initiatives

9.2.1 Collaborations in European programs, except FP7 and H2020

ERC NEMO NEMO, NEtwork MOtion https://cordis.europa.eu/project/id/788851, https://project.inria.fr/ercnemo is an ERC Advanced Grant (2019 – 2024, PI François Baccelli). It is an inter-disciplinary proposal centered on network dynamics. The inter-disciplinarity spans from communication engineering to mathematics, with an innovative interplay between the two. NEMO's aim is to introduce dynamics in stochastic geometry. General mathematical tools combining stochastic geometry, random graph theory, and the theory of dynamical systems will be developed. NEMO will leverage interactions of Inria with Ecole Normale Supérieure on the mathematical side, and with Nokia Bell Labs and Orange on the engineering side.

This year we hired A. Khezeli at the Starting Research Position in DYOGENE in relation to ERC-NEMO since October 1, 2020. Also, a PhD student P. Popineau was hired in February 2020.

9.2.2 Collaborations with major European organizations

Partner: VITO (Belgium); https://vito.be/en. Co-advising of PhD student I. Shilov. Started: Nov 2019. Topic: "Algorithmic Games and Distributed Learning for Peer-to-Peer Energy Trading". PhD scholarship by VITO.

9.3 National initiatives

9.3.1 GdR GeoSto

Members of Dyogene participate in Research Group GeoSto (Groupement de recherche, GdR 3477) http://gdr-geostoch.math.cnrs.fr/ on Stochastic Geometry led by and David Coupier [Université de Valenciennes].

This is a collaboration framework for all French research teams working in the domain of spatial stochastic modeling, both on theory development and in applications.

9.3.2 GdR RO

Members of Dyogene participate in GdR-RO (Recherche Opérationelle; GdR CNRS 3002), http://gdrro.lip6.fr/, working group COSMOS (Stochastic optimization and control, modeling and simulation), lead by A. Busic and E. Hyon (LIP 6); http://gdrro.lip6.fr/?q=node/78

9.3.3 ANR JCJC PARI

Probabilistic Approach for Renewable Energy Integration: Virtual Storage from Flexible Loads. The project started in January 2017. PI — A. Bušić. This project is motivated by current and projected needs of a power grid with significant renewable energy integration. Renewable energy sources such as wind and solar have a high degree of unpredictability and time variation, which makes balancing demand and supply challenging. There is an increased need for ancillary services to smooth the volatility of renewable power. In the absence of large, expensive batteries, we may have to increase our inventory of responsive fossil-fuel generators, negating the environmental benefits of renewable energy. The proposed approach addresses this challenge by harnessing the inherent flexibility in demand of many types of loads. The objective of the project is to develop decentralized control for automated demand dispatch, that can be used by grid operators as ancillary service to regulate demand-supply balance at low cost. We call the resource obtained from these techniques virtual energy storage (VES). Our goal is to create the necessary ancillary services for the grid that are environmentally friendly, that have low cost and that do not impact the quality of service (QoS) for the consumers. Besides respecting the needs of the loads, the aim of the project is to design local control solutions that require minimal communications from the loads to the centralized entity. This is possible through a systems architecture that includes the following elements: i) local control at each load based on local measurements combined with a grid-level signal; ii) frequency decomposition of the regulation signal based on QoS and physical constraints for each class of loads.

9.4 Regional initiatives

9.4.1 Laboratory of Information, Networking and Communication Sciences (LINCS)

Dyogene participates in LINCS https://www.lincs.fr, a research centre co-founded by Inria, Institut Mines- Télécom, UPMC and Alcatel-Lucent Bell Labs (currently Nokia Bell Labs) dedicated to research and innovation in the domains of future information and communication networks, systems and services.

10 Dissemination

10.1 Promoting scientific activities

10.1.1 Scientific events: organisation

EPI seminar A weekly seminar on Monday, 2.30 pm, organized by S. Coste.
Invited speakers:
Eliza O'Reilly, Benedikt Jahnel, Zakhar Kabluchko, David Dereudre, Pablo Ferrari, Georgina Hall, Viet Chi Tran, Romain Couillet, Frédéric Lavancier, Sixin Zhang, Michel Davydof, Kevin Scaman and Ali Khezeli.

10.1.2 Scientific events: selection

Member of the conference program committees S. S. Kalambar:
IEEE Global Communications Conference (GLOBECOM) 2020;
The Workshop on Spatial Stochastic Models for Wireless Networks (SPASWIN) 2020.

Reviewer H. Hendrikx :
Conferences: NeurIPS 2020, ICML2020, AISTATS2021;
Journals: SIOPT, IEEE Transactions on Signal Processing, Automatica.

10.1.3 Journal

Member of the editorial boards S. S. Kalambar: Sensors - Topic editor, Sensors - Editor for the special issue on "Energy-Efficient Communications for beyond 5G Green Networks"

Reviewer - reviewing activities All members of the team act as reviewers for numerous scientific journals.

10.1.4 Invited talks

- Invited series of lectures on Network Dynamics, Weierstrass Institute, Berlin, November 2020, F. Baccelli.
- Invited lecture at the Montevideo Probability Seminar, November 2020 (on SIS point process dynamics), F. Baccelli.
- Invited lecture at LINCS, Paris, on spatial game theory, Sept. 2020, F. Baccelli.
- Keynote lecture at IEEE WiOpt-Spaswin, June 2020 (talk on vehicular wireless networks), Volos, Greece, F. Baccelli.
- Invited lecture at IISC Bangalore, Symposium on Advances in Communication Networks, July 2020 (talk on the SIS point process dynamics), F. Baccelli.
- Invited lecture at the Indian Statistical Institute, (on the dimension of infinite graphs), January 2010, F. Baccelli.
- Invited lecture at the Indian Statistical Institute, (Optimal stationary markings), January 2010, B. Błaszczyszyn.
- Talk at SNAPP (Stochastic Networks, Applied Probability, and Performance) online seminar series, (Optimal Control in Dynamic Matching Systems), September 2020, A. Busic.
- Invited talk at the Math and Physics seminar at Université de Genève, 9/2/2021, S. Coste.
- Invited talk at the working group *point processes and applications* à Lille, 12/2/2021, S. Coste.
- Invited talk at MAP5, March 2020, S. Coste.
- Invited talk at Spectra, Algorithms and Random Walks on Random Networks, January 2020, CIRM, S. Coste.
- Talk at Ulm universität, February 2020, S. Coste.
- Short talk at Discussion meeting on Stochastic Analysis, Geometry, and Random Fields, Bangalore, January 2020, S. Coste.
- Invited talk at Federated Learning One World Seminar, online series, June 2020, (Statistical Preconditioning for Federated Learning), H. Hendrikx.
- Invited talk at EPFL, online seminar, October 2020, H. Hendrikx.
- Invited lecture at LINCS, Paris, on Beam Management in 5G, May 2020, S. S. Kalamkar.
- Seminar at GIPSA lab, May 2020, L. Massoulié.
- Talk at workshop on “Dynamics over networks: epidemics, opinions and information”, September 2020, L. Massoulié.
- Seminar at Georgia Tech, October 2020, L. Massoulié.
- talk on Covid19, at event for startups organized by ‘Challenges’ and ‘Sciences et Avenir’ newspapers, June 2020, L. Massoulié.
- Demi-heure de science at Inria Paris, work on Covid19, November 2020, L. Massoulié.
- Keynote on Covid19 work at ‘France is AI’, November 2020, L. Massoulié.
- Presentation at COLT conference, Luca Ganassali (July 2020).
- Presentation at ICML, July 2020, and Neurips, December 2020, conferences, Hadrien Hendrikx.
- Invited talk at Polytechnique Montreal-Communauto workshop, July 2020, T. Popescu.

10.1.5 Leadership within the scientific community

A. Busic: co-lead (with E. Hyon, LIP 6) of the research group COSMOS (Stochastic optimization and control, modeling and simulation) of the GDR-RO; http://gdrro.lip6.fr/?q=node/78.

10.2 Teaching - Supervision - Juries

10.2.1 Teaching

- Licence: B. Błaszczyszyn (Cours) Théorie de l'information et du codage 24 heqTD, L3, ENS Paris.
- Licence: A. Busic (Cours) and S. Samain (TD) Structures et algorithmes aléatoires 60 heqTD, L3, ENS Paris.
- Licence: L. Massoulié (Cours) Social and Communication networks 60 heqTD, L3, l'X.
- Master: B. Błaszczyszyn (Cours) Modèles géométriques aléatoires 39heqTD, M2 Probabilités et Modèles Aléatoires, UPMC.
- Master: A. Busic (Cours) and L. Stephan (TD) Modèles et algorithmes de réseaux 60 heqTD, M1, ENS Paris.
- Master: A. Busic and L. Massoulié (Cours) Fondements de la modélisation des réseaux 7.5 heqTD, M2 MPRI.
- Master: M. Lelarge (Cours) Deep Learning Do it Yourself, M1, ENS Paris, X, X-HEC. https://mlelarge.github.io/dataflowr-web/
- Master: L. Massoulié (Cours) Inference in large random graphs, M2 Université d'Orsay.
- Préparation à l'agrégation: S. Coste (Cours+TD) Cours de statistiques, agrégation de sciences sociales, ENS Paris-Saclay.
- MPSI: S. Coste (Interrogations) maths.

10.2.2 Supervision

- PhD: Alexis Galland, Deep Learning on Graphs, since 2017, advised by M. Lelarge; defended in December 2020 http://www.theses.fr/s201830; (In the Bibliography the dissertation is still missing due to the delay in the preparation of the manuscripts accepted by the doctoral school.)
- PhD: Quentin Le Gall "Crowd networking : modélisation de la connectivité D2D" since October 2017; PhD CIFRE co-advised by B. Błaszczyszyn and E. Cali (Orange); defended in Octobre 2020; [23].
- PhD in progress: Antoine Brochard "Signal processing for point processes and statistical learning for telecommunications", since September 2018; PhD CIFRE co-advised by B. Błaszczyszyn and Georgios Paschos (Huawei).
- PhD in progress: Sébastien Samain, "Monte Carlo methods for performance evaluation and reinforcement learning", since November 2016, advised by A. Busic.
- PhD in progress: Arnaud Cadas, "Dynamic matching models", since October 2017, supervised by A. Busic.
- PhD in progress: Michel Davydov, since September 2019, F. Baccelli.
- PhD in progress: Luca Ganassali, since September 2019, supervised by L. Massoulié.
- PhD in progress: Hadrien Hendrikx, since 2019, supervised by L. Massoulié.
- PhD in progress: Sayeh Khaniha, since 2019, supervised by F. Baccelli.

- PhD in progress: Pierre Popineau, since 2019, supervised by F. Baccelli.
- PhD in progress: Bharath Roy, since 2019, supervised by F. Baccelli and B. Błaszczyszyn.
- PhD in progress: Ilia Shilov, since 2019, supervised by A. Busic.
- PhD in progress: Ludovic Stephan, since 2018 supervised by L. Massoulié.
- PhD in progress: Maxime Leiber, since 2020 CIFRE thesis with SAFRAN supervised by L. Massoulié.
- PhD in progress: Bastien Dubail, since 2020 co-mentored with Charles Bordenave (CNRS, Marseille).
- PhD in progress: Roman Gambelin, since 2020, supervised by B. Błaszczyszyn.
- Master 2: Roman Gambelin, Université Paris Dauphine-PSL; [48]
- Master 2: Mathieu Even.
- Master 1: Teodora Popescu, Ecole Polytechnique.
- 4th year at ENS : Mathieu Even supervised by L. Massoulié.

10.2.3 Juries

- F. Baccelli: member of PhD thesis committee of **Mateo Sfragara**, Leiden University, Oct. 20; member of PhD thesis committee of **Patrick Lambein**, Ecole Polytechnique, Dec. 20; HDR jury member of **Anastasios Giovanidis**, UPMC, Dec. 20.
- B. Błaszczyszyn: reviewer of HDR of **Pawel Lorek**, University of Wroclaw, Jun 2020; reviewer of HDR of **Daniel Edward Clark**, Université de Paris Saclay, October 2020.
- A. Busic: PhD jury member of **Diego Kiedanski**, Telecom Paris.
- C. Fricker: member of PhD thesis committee of **Santi Duran**, june 2020, Université de Toulouse.
- L. Massoulié: member of PhD thesis committee of **Yann Issartel**, Université de Paris Saclay.

10.3 Visit to international teams

- S. Coste: Ulm Universitat (one week, February 2020).
- B. Błaszczyszyn: Indian Statistical Institute (ISI), Bangalore (two weeks, January 2020).

11 Scientific production

11.1 Publications of the year

International journals

[1] S. Gaubert, M. Akian, X. Allamigeon, M. Boyet, B. Colin, T. Grohens, L. Massoulié, D. P. Parsons, F. Adnet, É. Chanzy, L. Goix, F. Lapostolle, É. Lecarpentier, C. Leroy, T. Loeb, J.-S. Marx, C. Télion, L. Treluyer and P. Carli. 'Understanding and monitoring the evolution of the Covid-19 epidemic from medical emergency calls: the example of the Paris area'. In: *Comptes Rendus Mathématique* 358.7 (16th Nov. 2020), pp. 843–875. DOI: 10.5802/crmath.99. URL: https://hal.inria.fr/hal-02648075.

[2] M. U. Hashmi, D. Deka, A. Bušić, L. Pereira and S. Backhaus. 'Arbitrage with Power Factor Correction using Energy Storage'. In: *IEEE Transactions on Power Systems* 35.4 (2020), pp. 2693–2703. DOI: 10.1109/TPWRS.2020.2969978. URL: https://hal.archives-ouvertes.fr/hal-02425982.

[3] V. Shah, L. Gulikers, L. Massoulié and M. Vojnović. 'Adaptive Matching for Expert Systems with Uncertain Task Types'. In: *Operations Research* 68.5 (Sept. 2020), pp. 1403–1424. DOI: 10.1287/opre.2019.1954. URL: https://hal.archives-ouvertes.fr/hal-03129324.

International peer-reviewed conferences

[4] F. Baccelli and S. Kalamkar. 'Bandwidth Allocation and Service Differentiation in D2D Wireless Networks'. In: IEEE INFOCOM 2020 - IEEE Conference on Computer Communications. Toronto / Virtual, Canada, 6th July 2020, pp. 2116–2125. DOI: 10.1109/INFOCOM41043.2020.9155469. URL: https://hal.archives-ouvertes.fr/hal-03107740.

[5] A. Bellet, R. Guerraoui and H. Hendrikx. 'Who started this rumor? Quantifying the natural differential privacy guarantees of gossip protocols'. In: DISC 2020 - 34th International Symposium on Distributed Computing. Freiburg / Virtual, Germany, 2020. URL: https://hal.inria.fr/hal-02166432.

[6] B. Błaszczyszyn, A. Brochard and H. P. Keeler. 'Coverage probability in wireless networks with determinantal scheduling'. In: WiOPT 2020 - 18th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks. Volos / Virtual, Greece: https://ieeexplore.ieee.org/document/9155329, 15th June 2020. URL: https://hal.inria.fr/hal-03001399.

[7] A. Bušić, D. Kiedanski, D. Kofman and A. Orda. 'Efficient distributed solutions for sharing energy resources at local level: a cooperative game approach'. In: CDC 2020 - 59th IEEE Conference on Decision and Control. Proceedings of the 59th IEEE Conference on Decision and Control. Jeju Island / Virtual, South Korea, 14th Dec. 2020. URL: https://hal.archives-ouvertes.fr/hal-02520203.

[8] N. Cammardella, A. Bušić and S. Meyn. 'Simultaneous Allocation and Control of Distributed Energy Resources via Kullback-Leibler-Quadratic Optimal Control'. In: ACC 2020 - American Control Conference. Proceedings of the 2020 American Control Conference (ACC). Denver / Virtual, United States, 2020, pp. 514–520. DOI: 10.23919/ACC45564.2020.9147402. URL: https://hal.archives-ouvertes.fr/hal-03094313.

[9] S. Chen, A. Devraj, A. Bušić and S. Meyn. 'Zap Q-Learning for Optimal Stopping'. In: ACC 2020 - American Control Conference. Proceedings of the 2020 American Control Conference (ACC). Denver / Virtual, United States, 2020, pp. 3920–3925. DOI: 10.23919/ACC45564.2020.9147481. URL: https://hal.archives-ouvertes.fr/hal-03094388.

[10] S. Chen, A. M. Devraj, A. Bušić and S. Meyn. 'Explicit Mean-Square Error Bounds for Monte-Carlo and Linear Stochastic Approximation'. In: AISTATS 2020: 23rd International Conference on Artificial Intelligence and Statistics. Proceedings of the 23rdInternational Conference on Artifi-cial Intelligence and Statistics (AISTATS) 2020, Palermo,Italy. PMLR: Volume 108. Palermo / Virtual, Italy, 2020. URL: https://hal.archives-ouvertes.fr/hal-03094275.

[11] S. Chen, A. M. Devraj, F. Lu, A. Bušić and S. P. Meyn. 'Zap Q-Learning With Nonlinear Function Approximation'. In: NeurIPS 2020: Thirty-fourth Conference on Neural Information Processing Systems. Proceedings of the 2020 Conference on Neural Information Processing Systems. Vancouver / Virtual, Canada, 2020. URL: https://hal.archives-ouvertes.fr/hal-02425985.

[12] C. Fricker, H. Mohamed and C. Bourdais. 'A mean field analysis of a stochastic model for reservation in car-sharing systems'. In: MAMA - ACM SIGMETRICS 2020 Workshop on MAthematical performance Modeling and Analysis. Vol. 48. 2. Boston / Virtual, United States: ACM, 23rd Nov. 2020, pp. 18–20. URL: https://hal.inria.fr/hal-03127674.

[13] L. Ganassali and L. Massoulié. 'From tree matching to sparse graph alignment'. In: Conference on Learning Theory (COLT) 2020. Graz, Austria, 4th Feb. 2020. URL: https://hal.archives-ouvertes.fr/hal-02941092.

[14] M. U. Hashmi, A. Bušić, D. Deka and L. Pereira. 'Energy Storage Optimization for Grid Reliability'. In: e-Energy '20: The Eleventh ACM International Conference on Future Energy Systems. Proceedings of The Eleventh ACM International Conference on Future Energy Systems. Melbourne / Virtual, Australia, 2020, pp. 516–522. DOI: 10.1145/3396851.3402123. URL: https://hal.archives-ouvertes.fr/hal-03094465.

[15] M. U. Hashmi, J. Cavaleiro, L. Pereira and A. Bušić. 'Sizing and Profitability of Energy Storage for Prosumers in Madeira, Portugal'. In: 2020 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT). Proceedings of the 2020 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT). Washington DC, United States, 17th Feb. 2020. DOI: 10.1109/ISGT45199.2020.9087772. URL: https://hal.archives-ouvertes.fr/hal-02425980.

[16] H. Hendrikx, F. Bach and L. Massoulié. 'Dual-Free Stochastic Decentralized Optimization with Variance Reduction'. In: NeurIPS 2020 - 34th Conference on Neural Information Processing Systems. Advances in Neural Information Processing Systems Proceedings. Vancouver / Virtual, Canada, 2020. URL: https://hal.archives-ouvertes.fr/hal-02974237.

[17] H. Hendrikx, L. Xiao, S. Bubeck, F. Bach and L. Massoulié. 'Statistically Preconditioned Accelerated Gradient Method for Distributed Optimization'. In: ICML 2020 - Thirty-seventh International Conference on Machine Learning. Proceedings of Machine Learning Research. Vienna / Virtual, Austria, 2020. URL: https://hal.archives-ouvertes.fr/hal-02974232.

[18] S. S. Kalamkar, F. Baccelli, F. M. Abinader Jr., A. S. M. Fani and L. G. U. Garcia. 'Beam Management in 5G: A Stochastic Geometry Analysis'. In: IEEE Globecom. Proceedings IEEE Globecom. Taipei, Taiwan, 7th Dec. 2020. URL: https://hal.archives-ouvertes.fr/hal-03107757.

[19] Q. Le Gall, B. Błaszczyszyn, E. Cali and T. En-Najjary. 'Relay-assisted Device-to-Device Networks: Connectivity and Uberization Opportunities'. In: WCNC 2020 - IEEE Wireless Communications and Networking Conference. Seoul / Virtual, South Korea, 19th June 2020. URL: https://hal.archives-ouvertes.fr/hal-02320085.

[20] S. Samain, J. Doncel, A. Bušić and J.-M. Fourneau. 'Energy Packet Networks with Finite Capacity Energy Queues'. In: VALUETOOLS '20: 13th EAI International Conference on Performance Evaluation Methodologies and Tools. Proceedings of the 13th EAI International Conference on Performance Evaluation Methodologies and Tools. Tsukuba / Virtual, Japan, 2020, pp. 142–149. DOI: 10.1145/3388831.3388841. URL: https://hal.archives-ouvertes.fr/hal-03094615.

Scientific books

[21] F. Baccelli, B. Błaszczyszyn and M. Karray. *Random Measures, Point Processes, and Stochastic Geometry*. Jan. 2020. URL: https://hal.inria.fr/hal-02460214.

Scientific book chapters

[22] S. d'Ascoli, A. Coucke, F. Caltagirone, A. Caulier and M. Lelarge. 'Conditioned Text Generation with Transfer for Closed-Domain Dialogue Systems'. In: *International Conference on Statistical Language and Speech Processing*. 26th Sept. 2020, pp. 23–34. DOI: 10.1007/978-3-030-59430-5_2. URL: https://hal.archives-ouvertes.fr/hal-03116563.

Doctoral dissertations and habilitation theses

[23] Q. Le Gall. 'Crowd-networking : modelling Device-to-Device connectivity on street systems using percolation theory, and economic consequences'. Université Paris sciences et lettres, 6th Oct. 2020. URL: https://tel.archives-ouvertes.fr/tel-02998605.

Reports & preprints

[24] M. Akian, L. Ganassali, S. Gaubert and L. Massoulié. *Probabilistic and mean-field model of COVID-19 epidemics with user mobility and contact tracing*. 16th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02941123.

[25] J. Atif, O. Cappé, A. Kazakçi, Y. Léo, L. Massoulié and O. Mula. *Initiative face au virus Observations sur la mobilité pendant l'épidémie de Covid-19*. Université PSL, 25th May 2020. URL: https://hal.archives-ouvertes.fr/hal-02921194.

[26] F. Baccelli, M. Davydov and T. Taillefumier. *Replica-Mean-Field Limits of Fragmentation-Interaction-Aggregation Processes*. 16th May 2020. URL: https://hal.archives-ouvertes.fr/hal-02607064.

[27] F. Baccelli and S. S. Kalamkar. *On Point Processes Defined by Angular Conditions on Delaunay Neighbors in the Poisson-Voronoi Tessellation*. 12th Jan. 2021. URL: https://hal.archives-ouvertes.fr/hal-03107916.

[28] B. Błaszczyszyn and C. Hirsch. *Optimal stationary markings*. 27th Jan. 2020. URL: https://hal.inria.fr/hal-02457091.

[29] C. Bordenave, S. Coste and R. R. Nadakuditi. *Detection thresholds in very sparse matrix completion*. 28th Nov. 2020. URL: https://hal.archives-ouvertes.fr/hal-03029291.

[30] C. Bordenave and B. Dubail. *Markovian linearization of random walks on groups*. 10th Dec. 2020. URL: https://hal.archives-ouvertes.fr/hal-03029424.

[31] A. Brochard, B. Błaszczyszyn, S. Mallat and S. Zhang. *Particle gradient descent model for point process generation*. 27th Oct. 2020. URL: https://hal.archives-ouvertes.fr/hal-02980486.

[32] A. Cadas, J. Doncel and A. Bušić. *Optimal Control of Dynamic Bipartite Matching Models*. 10th Sept. 2020. URL: https://hal.inria.fr/hal-02935921.

[33] A. Cadas, J. Doncel, J.-M. Fourneau and A. Bušić. *Flexibility can hurt dynamic matching system performance*. Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-03095292.

[34] N. Cammardella, A. Bušić and S. Meyn. *Kullback-Leibler-Quadratic Optimal Control*. 2020. URL: https://hal.archives-ouvertes.fr/hal-03095318.

[35] A. R. Coffman, A. Bušić and P. Barooah. *Control oriented modeling of TCLs*. Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-03095248.

[36] S. Coste and L. Stephan. *A simpler spectral approach for clustering in directed networks*. 10th Feb. 2021. URL: https://hal.archives-ouvertes.fr/hal-03137583.

[37] M. Even and L. Massoulié. *Concentration of Non-Isotropic Random Tensors with Applications to Learning and Empirical Risk Minimization*. 5th Feb. 2021. URL: https://hal.archives-ouvertes.fr/hal-03132566.

[38] L. Ganassali. *Sharp threshold for alignment of graph databases with Gaussian weights*. 12th Feb. 2021. URL: https://hal.inria.fr/hal-03139777.

[39] L. Ganassali, M. Lelarge and L. Massoulié. *Spectral alignment of correlated Gaussian random matrices*. 16th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02941069.

[40] A. Giovanidis and B. Błaszczyszyn. *Randomised Geographic Caching and its Applications in Wireless Networks*. 30th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02994177.

[41] M. U. Hashmi, A. Mukhopadhyay, A. Bušić and J. Elias. *Storage Optimal Control under Net Metering Policies*. Feb. 2020. URL: https://hal.archives-ouvertes.fr/hal-03095350.

[42] H. Hendrikx, L. Massoulié and M. Even. *Asynchrony and Acceleration in Gossip Algorithms*. 10th Feb. 2021. URL: https://hal.archives-ouvertes.fr/hal-02989459.

[43] D. Popescu, P. Jacquet, B. Mans and B. Błaszczyszyn. *Characterizing the Energy Trade-Offs of End-to-End Vehicular Communications using an Hyperfractal Urban Modelling*. 1st Dec. 2020. URL: https://hal.archives-ouvertes.fr/hal-03034848.

[44] I. Shilov, H. Le Cadre and A. Bušić. *Privacy Impact on Generalized Nash Equilibrium in Peer-to-Peer Electricity Market*. 17th Jan. 2021. URL: https://hal.inria.fr/hal-03112775.

[45] I. Shilov, H. Le Cadre and A. Bušić. *Risk-Averse Equilibrium Analysis and Computation*. 6th Apr. 2020. URL: https://hal.inria.fr/hal-02532786.

[46] L. Stephan and L. Massoulié. *Non-backtracking spectra of weighted inhomogeneous random graphs*. 15th Feb. 2021. URL: https://hal.inria.fr/hal-03140329.

Other scientific publications

[47] V. Anantharam and F. Baccelli. *Nash equilibrium structure of Cox process Hotelling games*. Aug. 2020. URL: https://hal.archives-ouvertes.fr/hal-03107798.

[48] R. Gambelin. 'A stochastic geometry characterization of Pitman-Yor processes'. Université Paris Dauphine - PSL, Sept. 2020. URL: https://hal.inria.fr/hal-03022834.

11.2 Other

Patents

[49] S. Meyn and A. Bušić. 'Using loads with discrete finite states of power to provide ancillary services for a power grid'. 23rd June 2020. URL: https://hal.archives-ouvertes.fr/hal-01968598.

11.3 Cited publications

[50] T. Lehéricy. 'Une propriété caractéristique des processus de Poisson-Dirichlet'. MA thesis. LPMA - Laboratoire de Probabilités et Modèles Aléatoires, Sept. 2015, p. 37. URL: https://hal.inria.fr/hal-01233285.

[51] R. Malhame and C.-Y. Chong. 'Electric load model synthesis by diffusion approximation of a high-order hybrid-state stochastic system'. In: *IEEE Transactions on Automatic Control* 30.9 (1985), pp. 854–860.