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Project-Team TREC

Theory of networks and communications

IN COLLABORATION WITH: Laboratoire d'Informatique de l'Ecole Normale Supérieure (LIENS)

RESEARCH CENTER
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THEME
Networks and Telecommunications

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Project-Team TREC

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2. Overall Objectives

2.1. Introduction

TREC is a joint INRIA-ENS project-team. It is focused on the modeling, the control and the design of communication networks and protocols. Its methodological activities are combined with projects defined with industrial partners, notably Alcatel-Lucent, Technicolor, Qualcomm and Orange. The main research directions are:

- modeling and performance analysis of wireless networks: network information theory, coverage and load analysis, power control, evaluation and optimization of the transport capacity, self organization;
- stochastic network dynamics: stability, worst-case performance analysis using the (max,plus) algebra, network calculus, perfect simulation, inverse problems, distributed consensus;
- economics of networks: epidemic risk model, incentives, security, insurance, diffusion of innovations;
- the development of mathematical tools based on stochastic geometry, random geometric graphs and spatial point processes: Voronoi tessellations, coverage processes, random spatial trees, random fields, percolation;
- combinatorial optimization and analysis of algorithms: random graphs, belief propagation.

TREC's web site at Inria http://www.inria.fr/equipes/trec and ENS http://www.di.ens.fr/~trec.

2.2. Highlights

- The collaboration of TREC and the Wireless Foundations Center of UC Berkeley became part of the inria@siliconvalley program.
- The paper "Impact of Clustering on Diffusions and Contagions in Random Networks" [33] got the best paper award of NetGCOOP 2011 : International conference on NETwork Games, COntrol and OPtimization.

3. Scientific Foundations

3.1. Scientific Foundations

- **Modeling and performance analysis of wireless networks.** Our main focus was on cellular networks, mobile ad hoc networks (MANETs) and their vehicular variants called VANETs.

  Our main advances about wireless networks have been based on the development of analytical tools for their performance analysis and on new results from network information theory.

  Concerning cellular networks, the main questions bear on coverage and capacity in large CDMA networks when taking intercell interferences and power control into account. Our main focus has been on the design of: 1) a strategy for the densification and parameterization of UMTS and future OFDM networks that is optimized for both voice and data traffic; 2) new self organization and self optimization protocols for cellular networks e.g. for power control, sub-carrier selection, load balancing, etc.

  Concerning MANETs, we investigated MAC layer scheduling algorithms, routing algorithms and power control. The MAC protocols we considered are based on Aloha and CSMA as well as their cognitive radio extensions. We investigated opportunistic routing schemes for MANETs and VANETs. The focus was on cross layer optimizations allowing one to maximize the transport capacity of multihop networks.

- **Theory of network dynamics.** TREC is pursuing the analysis of network dynamics by algebraic methods. The mathematical tools are those of discrete event dynamical systems: semi-rings, and in particular network calculus, ergodic theory, perfect simulation, stochastic comparison, inverse problems, large deviations, etc. Network calculus gives results on worst-case performance evaluation; ergodic theory is used to assess the stability of discrete event dynamical systems; inverse problem methods are used to estimate some network parameters from external observations and to design network probing strategies.
- **The development of stochastic geometry and random geometric graphs tools.** Stochastic geometry is a rich branch of applied probability which allows one to quantify random phenomena on the plane or in higher dimension. It is intrinsically related to the theory of point processes and also to random geometric graphs. Our research is centered on the development of a methodology for the analysis, the synthesis, the optimization and the comparison of architectures and protocols to be used in wireless communication networks. The main strength of this method is its capacity for taking into account the specific properties of wireless links, as well as the fundamental question of scalability.
- **Combinatorial optimization and analysis of algorithms.** In this research direction started in 2007, we build upon our expertise on random trees and graphs and our collaboration with D. Aldous in Berkeley. Sparse graph structures have proved useful in a number of applications from information processing tasks to the modeling of social networks. We obtained new results in this research direction: computation of the asymptotic for the rank of the adjacency matrix of random graphs, computation of the matching number and the b-matching number of large graphs. We also applied our result to design bipartite graph structures for efficient balancing of heterogeneous loads and to analyze the flooding time in random graphs.
- **Economics of networks** The premise of this relatively new direction of research, developed jointly with Jean Bolot [SPRINT ATL and then TECHNICOLOR] is that economic incentives drive the development and deployment of technology. Such incentives exist if there is a market where suppliers and buyers can meet. In today's Internet, such a market is missing. We started by looking at the general problem of security on Internet from an economic perspective. A new research direction started on the economic value of user localization in wireless networks. This led to an Infocom'11 paper. We also built on our expertise in random graphs to derive new insights concerning diffusion and cascading behavior in random (possibly clustered) networks.

4. Application Domains

4.1. Application Domains

We have investigated various applications of our research results with the following industrial partners and user associations:

- **Wireless Networks**
  - Alcatel-Lucent Bell Laboratories (L. Thomas and L. Roulet) on self optimization in cellular networks.
  - Qualcomm (T. Richardson and his group) on improvements of CSMA CA.
  - Orange (M. Karray) on cellular networks.
- **Network Dynamics**
  - Thalès and Real-Time-at-Work on embedded networks.
  - Grenouille on probing in access networks.
- **Networks Economics**
  - Technicolor (J. Bolot) on economic incentives and user localization.

5. Software

5.1. Gibbs' Sampler

Participant: Chung Shue Chen.

The work on the self optimization of cellular networks based on Gibbs' sampler (see Section 6.1.1.3) carried out in the joint laboratory with Alcatel-Lucent, led to the development of a software prototype that was presented by C. S. Chen at the INRIA Alcatel-Lucent joint laboratory seminar in March 2010 and demonstrated at the Alcatel-Lucent Bell Labs Open Days in May 2010. It was also demonstrated in the LINCS opening ceremony in April 2011.

5.2. PSI2

Participant: Ana Bušić.

The work on perfect sampling (see Section 6.2.3) has been partially implemented in a software tool PSI2, in collaboration with MESCAL team [INRIA Grenoble - Rhône-Alpes]; https://gforge.inria.fr/projects/psi.

6. New Results

6.1. Design and Performance Analysis of Wireless Networks

Participants: François Baccelli, Florence Bénézit, Bartłomiej Błaszczyszyn, Chung Shue Chen, Mir Omid Haji Mirsadeghi, Frédéric Morlot, Tien Viet Nguyen, Van Minh Nguyen.

CDMA/UMTS, Wireless LANs, ad hoc networks, IEEE 802.11, mesh networks, cognitive radio, Hiperlan, CSMA, TCP, MAC protocols, exponential back-off protocols, signal to interference ratio, coverage, capacity, transport capacity, admission and congestion control.

This axis bears on the analysis and the design of wireless access communication networks. Our contributions are organized in terms of network classes: cellular networks, wireless LANs and MANETs, VANETs. We also have a section on generic results that regard more general wireless networks. We are interested both in macroscopic models, which are particularly important for economic planning and in models allowing the definition and the optimization of protocols. Our approach combines several tools, queueing theory, point processes, stochastic geometry, random graphs, distributed control algorithms, self organization protocols.

6.1.1. Cellular Networks

The activity on cellular networks has several complementary facets ranging from performance evaluation to protocol design. The work is mainly based on strong collaborations with Alcatel-Lucent and Orange Labs.

6.1.1.1. Effect of Opportunistic Scheduling on the Quality of Service Perceived by the Users in OFDMA Cellular Networks

Our objective in [20] is to analyze the impact of fading and opportunistic scheduling on the quality of service perceived by the users in an Orthogonal Frequency Division Multiple Access (OFDMA) cellular network. To this end, assuming Markovian arrivals and departures of customers that transmit some given data volumes, as well as some temporal channel variability (fading), we study the mean throughput that the network offers to users in the long run of the system. Explicit formulas are obtained in the case of allocation policies, which may or may-not take advantage of the fading, called respectively opportunistic and non-opportunistic. The main practical results of the present work are the following. Firstly we evaluate for the non-opportunist allocation the degradation due to fading compared to Additive White Gaussian Noise (AWGN) (that is, a decrease of at least 13% of the throughput). Secondly, we evaluate the gain induced by the opportunistic allocation. In particular, when the traffic demand per cell exceeds some value (about 2 Mbits/s in our numerical example), the gain induced by opportunism compensates the degradation induced by fading compared to AWGN. Partial results were presented at ComNet in 2009 [62].

6.1.1.2. Impact of Shadowing on QoS in Cellular Networks

Shadowing is believed to degrade the quality of service (QoS) in wireless cellular networks. Assuming log-normal shadowing, and studying mobile's path-loss with respect to the strongest (serving) base station (BS) and the corresponding interference factor (the ratio of the sum of the path-gains form interfering BS's to the path-gain from the serving BS), which are two key ingredients of the analysis and design of the cellular networks, in [48] we discovered a more subtle reality. We observe, as commonly expected, that a strong variance of the shadowing increases the mean path-loss with respect to the serving BS, which in consequence, may compromise QoS. However, in some cases, an increase of the variance of the shadowing can significantly reduce the mean interference factor and, in consequence, improve some QoS metrics in interference limited systems, provided the handover policy selects the strongest BS as the serving one. We exemplify this phenomenon, similar to stochastic resonance, studying the blocking probability in regular, hexagonal networks in a semi-analytic manner, using a spatial version of the Erlang's loss formula combined with Kaufman-Roberts algorithm. More detailed probabilistic analysis explains that increasing variance of the log-normal shadowing amplifies the ratio between the strongest signal and all other signals thus reducing the interference. The above observations might shed new light, in particular on the design of indoor communication scenarios. Partial results were presented at IFIP WMNC'2010 [63].

6.1.1.3. Self-Optimization of Radio Resources in Cellular Networks

In [65], we developed mathematical and algorithmic tools for the self-optimization of mobile cellular networks. Scalable algorithms which are based on local measurements and do not require heavy coordination among the wireless devices were proposed. We focused on the optimization of transmit power and of user association. The method is applicable to both joint and separate optimizations. The global utility minimized is linked to potential delay fairness. The distributed algorithm adaptively updates the system parameters and achieves global optimality by measuring SINR and interference. The algorithms are built on Gibbs' sampler and offer a unified framework that can be easily used for different purposes.

In [32], we investigated the joint optimization of radio resources in heterogeneous cellular networks made of a juxtaposition of macro and small cells. We showed that within this context, it is essential to use algorithms able to simultaneously solve the problems of channel selection, user association and power control. In such networks, the unpredictability of the cell and user patterns also requires self-optimized schemes. We proposed a generalized solution which is based on Gibbs' sampler. It can be implemented in a distributed way and nevertheless achieves minimal system-wide potential delay. Results show that it is effective in both throughput and energy efficiency.

In [35], we extended it to an autonomous radio resource allocation and optimization scheme that chooses the transmit power and precoding vector among codebooks for multiple antennas transmitters to improve spectral and power efficiency and provide user fairness. Network self-optimization is an essential feature for supporting the cell densification in future wireless cellular systems. Besides, we included power pricing to parametrize and to enhance the energy efficiency. Simulation results show that the proposed scheme can outperform today's default modes of operation in network throughput, energy efficiency, and user fairness.

Three patents were filed under the INRIA/Alcatel–Lucent joint laboratory.

6.1.1.4. Best Signal Quality in a Wireless Network

In a wireless network composed of randomly scattered nodes, the characterization of the distribution of the best signal quality received from a group of nodes is of primary importance for many network design problems. The thesis of Van Minh Nguyen [7] developed a framework for analyzing this distributions using shot noise models for the interference field. The joint distribution of the interference and the maximum signal strength was identified. The best signal quality can be represented as a function of these two quantities. Particular practical scenarios were also analyzed where explicit expressions can be obtained.

6.1.1.5. Cellular Network Tomography

The Foschini-Miljanic's [67] algorithm is used for power control in cellular networks whes users require a fixed bit rate. It leads to an optimal choice of power by the users in a distributed way when such a solution exists. If the users are too greedy or too many, the network saturates, and it is not possible to provide the required bit rates. We have been working on the question of residual bandwidth estimation in [61]. The residual bandwidth of a user is defined as the rate that this user should have to saturate the network when all other users stick to their initial rate requirement and all users use power control. The aim is to determine the residual bandwidth of a given user by local measurements. We showed that by simply changing their SINR target slightly and by listening to the evolution of interference, users can locally inverse Foschini-Miljanic's algorithm and compute their residual bandwidth.

6.1.1.6. Coverage in Cellular Networks

Cellular networks are usually modeled by placing the base stations according to a regular geometry such as a grid, with the mobile users scattered around the network either as a Poisson point process (i.e. uniform distribution) or deterministically. These models have been used extensively for cellular design and analysis but suffer from being both highly idealized and not very tractable. Thus, complex simulations are used to evaluate key metrics such as coverage probability for a specified target rate (equivalently, the outage probability) or average/sum rate. More tractable models have long been desirable. In a joint work with J. Andrews and R. Ganti [UT Austin, USA] [9] and [34], we developed general models for multi-cell signal-to-noise-plus-interference ratio (SINR) based on homogeneous Poisson point processes and derived the coverage probability and rate. Under very general assumptions, the resulting expressions for the SINR cumulative distribution function involve quickly computable integrals, and in some important special cases of practical interest these integrals can be simplified to common integrals (e.g., the Q-function) or even to exact and quite simple closed-form expressions. We also derived the mean rate, and then the coverage gain (and mean rate loss) from static frequency reuse. We compared the coverage predictions obtained by this approach to the standard grid model and an actual base station deployment. We observed that the proposed model is pessimistic (a lower bound on coverage) whereas the grid model is optimistic. In addition to being more tractable, the proposed model may better capture the increasingly opportunistic and dense placement of base stations in urban cellular networks with highly variable coverage radii.

Cellular networks are in a major transition from a carefully planned set of large tower-mounted base-stations (BSs) to an irregular deployment of heterogeneous infrastructure elements that often additionally includes micro, pico, and femtocells, as well as distributed antennas. In a collaboration with H. Dhillon, J. Andrews and R. Ganti [UT Austin, USA] [66], we extended the approach of we developed a model for a downlink heterogeneous cellular network (HCN) consisting of K tiers of randomly located BSs, where each tier may differ in terms of average transmit power, supported data rate and BS density. Assuming a mobile user connects to the strongest candidate BS, the resulting Signal-to-Interference-plus-Noise-Ratio (SINR) is greater than 1 when in coverage, Rayleigh fading, we derived an expression for the probability of coverage (equivalently outage) over the entire network under both open and closed access. One interesting observation for interference-limited open access networks is that at a given SINR, adding more tiers and/or BSs neither increases nor decreases the probability of coverage or outage when all the tiers have the same SINR threshold.

6.1.2. Mobile Ad Hoc Networks

A MANET is made of mobile nodes which are at the same time terminals and routers, connected by wireless links, the union of which forms an arbitrary topology. The nodes are free to move randomly and organize themselves arbitrarily. Important issues in such a scenario are connectivity, medium access (MAC), routing and stability. This year, we worked on the analysis of MAC and routing protocols in multi-hop MANETS in collaboration with Paul Mühlethaler [INRIA HIPERCOM], and on a game theoretic view of Spatial Aloha in collaboration with E. Altman and M.K. Hanawal [INRIA MAESTRO] [68].

6.1.2.1. Improvement of CSMA/CA's Spatial Reuse

The most popular medium access mechanism for such ad hoc networks is CSMA/CA with RTS/CTS. In CSMA-like mechanisms, spatial reuse is achieved by implementing energy based guard zones. In a new collaboration with Qualcomm ([26] and [14]), we considered the problem of simultaneously scheduling the maximum number of links that can achieve a given signal to interference ratio (SIR). Using tools from stochastic geometry, we studied and maximized the medium access probability of a typical link.

Our contributions are two-fold: (i) We showed that a simple modification to the RTS/CTS mechanism, viz., changing the receiver yield decision from an energy-level guard zone to an SIR guard zone, leads to performance gains; and (ii) We showed that this combined with a simple modification to the transmit power level – setting it to be inversely proportional to the square root of the link gain – leads to significant improvements in network throughput. Further, this simple power-level choice is no worse than a factor of two away from optimal over the class of all "local" power level selection strategies for fading channels, and further is optimal in the non-fading case. The analysis relies on an extension of the Matérn hard core point process which allows us to quantify both these SIR guard zones and this power control mechanism.

6.1.2.2. Opportunistic versions of CSMA/CA

In collaboration with Gustavo de Veciana and Yuchul Kim [UT Austin, ECE] we studied the benefits of channel-aware (opportunistic) scheduling of transmissions in ad-hoc networks using CSMA/CA [36]. The key challenge in optimizing the performance of such systems is finding a good compromise among three interdependent quantities, the density and channel quality of the scheduled transmitters, and the resulting interference at receivers. We propose two new channel-aware slotted CSMA protocols: opportunistic CSMA (O-CSMA) and quantile-based CSMA (QT-CSMA) and develop stochastic geometric models allowing us to quantify their performance in terms of spatial reuse and spatial fairness. When properly optimized these protocols offer substantial improvements in terms of both of these metrics relative to CSMA - particularly when the density of nodes is moderate to high. Moreover, we show that a simple version of QT-CSMA can achieve robust performance gains without requiring careful parameter optimization. The paper supports the case that the benefits associated with channel-aware scheduling in ad hoc networks, as in centralized base station scenarios, might far outweigh the associated overhead, and this can be done robustly using a QT-CSMA like protocol.

6.1.3. Cognitive Radio Networks

We wrote a survey [22] on the probabilistic framework which can be used to model and analyze cognitive radio networks using various classes of MAC protocols (including carrier sensing based multiple access schemes and Aloha schemes). For each model, analytical results were derived for important performance metrics. This leads to a quantification of the interplay between primary and secondary users in such networks.

6.1.4. Generic Wireless Networks

6.1.4.1. Power Control in Wireless Networks

In [10], in collaboration with N. Bambos, [Stanford] and N. Gast [EPFL], we formulated a delay-power control (DPC) scheme for wireless networking, which balances delay against transmitter power on each wireless link. The DPC scheme is scalable, as each link autonomously updates its power based on the interference observed at its receiver; no cross-link communication is required. It is shown that DPC converges to a unique equilibrium power and several ke properties are established, concerning the nature of channel bandwidth sharing achieved by the links. The DPC scheme is contrasted to the well-known Foschini-Miljanic (FM) formulation for transmitter power control in wireless networks, and some key advantages are established. Based on the DPC and FM schemes, two protocols are developed, which leverage adaptive tuning of DPC parameters. One of them is inspired by TCP and exhibits analogous behavior.

In [21], we studied the weighted sum rate maximization problem in wireless networks consisting of multiple source-destination pairs. The optimization problem is to maximize a weighted sum of data rates by adjusting the power of each user. The problem is in general a non-convex optimization problem that will lead to multiple local maxima. A Gauss-Seidel type iterative power control algorithm was presented. We showed by simulation that the proposed algorithm converges to the global maximum with very high probability, if we initialize the initial power allocation uniformly at random. The proposed algorithm also has the favorable properties that only simple operations are needed in each iteration, and the convergence is fast. Performance comparison under different user densities has also indicated its effectiveness. Finally, we discussed some simple and optimal power allocation strategies under special cases of the problem if the network can be represented by a certain approximation.

6.1.4.2. Simultaneous Decoding

In [15], in collaboration with A. El Gamal [Stanford, USA] and D. Tse [UC Berkeley, USA], we analyzed a network made of a collection of transmitter-receiver links where each link is considered to be part of a Multiple Access Channel (MAC) together with a collection of co-transmitters, rather than treating the messages of the latter as noise. This MAC extension is meant to improve the rate of the link and not to decode the messages of the co-transmitters. The necessary and sufficient condition for the feasibility of some rate when using successive interference cancellation and simultaneous decoding were provided. The reasons why simultaneous decoding is preferable to successive interference cancellation were also given. The gain obtained when using this type of simultaneous decoding rather than treating interference as noise was then quantified in a network made of a large random collection of such links. The gains in coverage and in rate were analyzed in terms of ensemble averages, evaluated using stochastic geometry. Closed form or integral expressions were obtained for the outage/coverage probability in networks where nodes are randomly distributed like a Poisson point process on an infinite plane. In the CDMA limit (large bandwidth, low SINR per hertz, high density), the ensemble average of the link rates tends to 0 when interference is treated as noise whereas it tends to a positive constant when simultaneous decoding of infinite order is used. The whole analysis was conducted in the AWGN case.

6.2. Network Dynamics

Participants: François Baccelli, Abir Benabid, Florence Bénézit, Anne Bouillard, Ana Bušić, Emilie Coupechoux, Nadir Farhi, Furcy-Alexandre Pin, Aleksander Wieczorek.

Queueing network, stability, inversion formula, probing, estimator, product-form, insensitivity, markov decision, max-plus algebra, network calculus.

This traditional research topic of TREC has several new threads like perfect simulation, active probing or Markov decision.

6.2.1. Network Calculus

Network calculus is a theory that aims at computing deterministic performance guarantees in communication networks. This theory is based on the (min,plus) algebra. Flows are modeled by an *arrival curve* that upper-bounds the amount of data that can arrive during any interval, and network elements are modeled by a *service curve* that gives a lower bound on the amount of service offered to the flows crossing that element. Worst-case performances are then derived by combining these curves.

6.2.1.1. Performance bounds networks with static priorities

In cooperation with Aurore Junier [INRIA/IRISA], we present in [29] algorithms to compute worst-case performance upper bounds when the service policy is static priorities, using linear programming. Linear programming does not lead to tight bounds, but when combining this method with (min,plus) methods, we obtain bounds that outperform the already known bounds. Also, we prove that in tandem networks, the the worst-case performance bound under arbitrary multiplexing can be obtain by a policy with static priorities, the “shortest-destination first” policy.

6.2.1.2. Feed-forward networks with wormhole routing discipline

In collaboration with Bruno Gaujal [INRIA Rhone Alpes] and Nadir Farhi [IFFSTAR] we are working on a model of performance bound calculus on feed-forward networks where data packets are routed under wormhole routing discipline. We are interested in determining maximum end-to-end delays and backlogs for packets going from a source node to a destination node, through a given virtual path in the network. Our objective is to give a “network calculus” approach to calculate the performance bounds. For this, we propose a new concept of curves that we call *packet curves*. The curves permit to model constraints on packet lengths for data flows, when the lengths are allowed to be different. We used this new concept to propose an approach for calculating residual services for data flows served under non preemptive service disciplines. This notion also enabled us to differentiate different classes of service policies: those that are based on a packet count (like round-robin and its generalized version), where the packet curve will be useful to tighten the bounds computed, and those that are based on the amount of data served (FIFO, priorities), where it won’t be useful. These results can be found in [44] and have been presented in ILAS 2011.

6.2.1.3. Composition of service curves in Network Calculus

In envelope-based models for worst-case performance evaluation like Network Calculus or Real-Time Calculus, several types of service curves have been introduced to quantify some deterministic service guarantees. We compare those different classes of service curves regarding the composition (servers in tandem) and individual service curves (when several flows share a server, what service curve can be guaranteed to each of the flows?). In short, there are two main classes of service curves, simple and strict service curves. Individual service curve can not always be computed when simple service curves are considered, and strict service curves is not a stable class regarding the two operations described. We show that there can be no equivalence between the two main classes of service curves and that no notion of service curve in-between can be defined, that behaves well for the composition. We complete this study by studying other classes of service curves from this viewpoint. These results have been presented in [28]

6.2.1.4. Residuation in (max,plus) automata

With Éric Badouel, Philippe Darondeau [INRIA/IRISA] and Jan Komenda [Institute of Mathematics, Brnó], we study in [27] the decidability of existence and the rationality of delay controllers for systems with time weights in the tropical and interval semirings. Depending on the (max,+) or (min,+)-rationality of the series specifying the controlled system and the control objective, cases are identified where the controller series defined by residuation is rational, and when it is positive (i.e., when delay control is feasible). When the control objective is specified by a tolerance, i.e. by two bounding rational series, a nice case is identified in which the controller series is of the same rational type as the system specification series.

6.2.2. Queueing Theory and Active Probing

6.2.2.1. Inverse Problems

Active probing began by measuring end-to-end path metrics, such as delay and loss, in a direct measurement process which did not require inference of internal network parameters. The field has since progressed to measuring network metrics, from link capacities to available bandwidth and cross traffic itself, which reach deeper and deeper into the network and require increasingly complex inversion methodologies. The thesis of B. Kauffmann [6] investigates this line of thought as a set of inverse problems in queueing theory. Queueing theory is typically concerned with the solution of direct problems, where the trajectory of the queueing system, and laws thereof, are derived based on a complete specification of the system, its inputs and initial conditions. Inverse problems aim to deduce unknown parameters of the system based on partially observed trajectories. A general definition of the inverse problems in this class was provided and the key variants were mapped out: the analytical methods, the statistical methods and the design of experiments. We also show how this inverse problem viewpoint translates to the design of concrete Internet probing applications.

Inverse problems in bandwidth sharing networks theory were also investigated. A bandwidth sharing networks allocates the bandwidth to each flow in order to maximize a given utility function (typically an α-fairness), with the constraints given by the capacity of the different servers. In particular, it has been shown that the equilibrium distribution of the bandwidth allocated by TCP to many competing connections is oscillating around an α-fair allocation. As such, the theory of bandwidth sharing network is a high-level viewpoint of networks. The meaning of inverse problems in this theory, and their relation to the active probing paradigm are analyzed. In two simple examples of network, the capacity of the different servers and the flow population can estimated, and an algorithm to perform this estimation was proposed.

6.2.2.2. Internet Tomography

Most active probing techniques suffer of the “Bottleneck” limitation: all characteristics of the path after the bottleneck link are erased and unreachable. we are currently investigating a new tomography technique, based on the measurement of the fluctuations of point-to-point end-to-end delays, and allowing one to get insight on the residual available bandwidth along the whole path. For this, we combined classical queueing theory models with statistical analysis to obtain estimators of residual bandwidth on all links of the path. These estimators were proved to be tractable, consistent and efficient. In [59] we evaluated their performance with simulation and trace-based experiments.

Lately this method has been generalized in [72] to a probing multicast tree instead of a single path. This work deals with the complexity of the combinatorials in trees, and gives an explicit formula for the iteration of the Expectation-Maximization (E-M) algorithm. The E-M algorithm is notoriously slow, and we provided three speed-up techniques which are effective in our case (up to a factor 10^3 in the computation time). These techniques are general, and can be applied to other instances of E-M, or even several other iterative algorithms.

6.2.3. Perfect Sampling of Queueing Systems

Propp and Wilson introduced in 1996 a perfect sampling algorithm that uses coupling arguments to give an unbiased sample from the stationary distribution of a Markov chain on a finite state space $\mathcal{X}$. In the general case, the algorithm starts trajectories from all $x \in \mathcal{X}$ at some time in the past until time $t = 0$. If the final state is the same for all trajectories, then the chain has coupled and the final state has the stationary distribution of the Markov chain. Otherwise, the simulations are started further in the past. This technique is very efficient if all the events in the system have appropriate monotonicity properties. However, in the general (non-monotone) case, this technique requires that one consider the whole state space, which limits its application only to chains with a state space of small cardinality.

6.2.3.1. Piecewise Homogeneous Events

In collaboration with Bruno Gaujal [INRIA Grenoble - Rhone-Alpes], we proposed in [47] a new approach for the general case that only needs to consider two trajectories. Instead of the original chain, we used two bounding processes (envelopes) and we showed that, whenever they couple, one obtains a sample under the stationary distribution of the original chain. We showed that this new approach is particularly effective when the state space can be partitioned into pieces where envelopes can be easily computed. We further showed that most Markovian queueing networks have this property and we propose efficient algorithms for some of them.

The envelope technique has been implemented in a software tool PSI2 (see Section 5.2).

6.2.3.2. Acceleration of Perfect Sampling by Skipping Events

In collaboration with Bruno Gaujal [INRIA Grenoble - Rhone-Alpes], we proposed a new method to speed up perfect sampling of Markov chains by skipping passive events during the simulation [38]. We showed that this can be done without altering the distribution of the samples. This technique is particularly efficient for the simulation of Markov chains with different time scales such as queueing networks where certain servers are much faster than others. In such cases, the coupling time of the Markov chain can be arbitrarily large while the runtime of the skipping algorithm remains bounded. This was further illustrated by several experiments that also show the role played by the entropy of the system in the performance of our algorithm.

6.2.3.3. Aggregated Envelopes

When the cardinality of the state space is so huge that even storing the state of the Markov chain becomes challenging, we propose to combine the ideas of bounding processes and the aggregation of Markov chains [30]. We illustrate the proposed approach of aggregated envelope bounding chains on queueing models with joint arrivals and joint services, often referred to in the literature as assemble-to-order systems. Due to the finite capacity, and coupling in arrivals and services, the exact solving techniques are inefficient for larger problem instances. For instance, for the service tools model proposed by Vliegen and Van Houtum (2009), the aggregated envelope method reduces exponentially the dimension of the state space and allows effective perfect sampling algorithms. We also provide bounds for the coupling time, under the high service rate assumptions.

6.2.4. Markov Chains and Markov Decision Processes

Solving Markov chains is in general difficult if the state space of the chain is very large (or infinite) and lacking a simple repeating structure. One alternative to solving such chains is to construct models that are simple to analyze and provide bounds for a reward function of interest. The bounds can be established by using different qualitative properties, such as stochastic monotonicity, convexity, submodularity, etc. In the case of Markov decision processes, similar properties can be used to show that the optimal policy has some desired structure (e.g. the critical level policies).

6.2.4.1. Stochastic Monotonicity

g In collaboration with Jean-Michel Fourneau [PRiSM, Université de Versailles Saint-Quentin] we consider two different applications of stochastic monotonicity in performance evaluation of networks [18]. In the first one, we assume that a Markov chain of the model depends on a parameter that can be estimated only up to a certain level and we have only an interval that contains the exact value of the parameter. Instead of taking an approximated value for the unknown parameter, we show how we can use the monotonicity properties of the Markov chain to take into account the error bound from the measurements. In the second application, we consider a well known approximation method: the decomposition into submodels. In such an approach, models of complex networks are decomposed into submodels whose results are then used as parameters for the next submodel in an iterative computation. One obtains a fixed point system which is solved numerically. In general, we have neither an existence proof of the solution of the fixed point system nor a convergence proof of the iterative algorithm. Here we show how stochastic monotonicity can be used to answer these questions. Furthermore, monotonicity properties can also help to derive more efficient algorithms to solve fixed point systems.

6.2.4.2. Componentwise Bounds

In collaboration with Jean-Michel Fourneau [PRiSM, Université de Versailles Saint-Quentin] we proposed an iterative algorithm to compute component-wise bounds of the steady-state distribution of an irreducible and aperiodic Markov chain [17]. These bounds are based on very simple properties of $(max, +)$ and $(min, +)$ sequences. We showed that, under some assumptions on the Markov chain, these bounds converge to the exact solution. In that case we have a clear tradeoff between computation and the tightness of bounds. Furthermore, at each step we know that the exact solution is within an interval, which provides a more effective convergence test than usual iterative methods.

6.2.4.3. Markov Reward Processes and Aggregation

In a joint work with I.M. H. Vliegen [University of Twente, The Netherlands] and A. Scheller-Wolf [Carnegie Mellon University, USA] [19], we presented a new bounding method for Markov chains inspired by Markov reward theory: Our method constructs bounds by redirecting selected sets of transitions, facilitating an intuitive interpretation of the modifications of the original system. We show that our method is compatible with strong aggregation of Markov chains; thus we can obtain bounds for an initial chain by analyzing a much smaller chain. We illustrated our method by using it to prove monotonicity results and bounds for assemble-to-order systems.

6.2.4.4. Critical Level Policies in Controlled Queuing Systems

In a joint work with Emmanuel Hyon [University of Paris Ouest Nanterre La Defense and LIP6] [39], we consider a single-item lost sales inventory model with different classes of customers. Each customer class may have different lost sale penalty costs. We assume that the demands follow a Poisson process and we consider a single replenishment hypoexponential server. We give a Markov decision process associated with this optimal control problem and prove some structural properties of its dynamic programming operator. This allows us to show that the optimal policy is a critical level policy. We also discuss some possible extensions to other replenishment distributions and give some numerical results for the hyperexponential server case.

6.2.5. Dynamic Systems with Local Interactions

Dynamic systems with local interactions can be used to model problems in distributed computing: gathering a global information by exchanging only local information. The challenge is two-fold: first, it is impossible to centralize the information (cells are indistinguishable); second, the cells contain only a limited information (represented by a finite alphabet $\mathcal{A}$; $\mathcal{A} = \{0, 1\}$ in our case). Two natural instantiations of dynamical systems are considered, one with synchronous updates of the cells, and one with asynchronous updates. In the first case, time is discrete, all cells are updated at each time step, and the model is known as a *Probabilistic Cellular Automaton (PCA)* (e.g. Dobrushin, R., Kryukov, V., Toom, A.: *Stochastic cellular systems: ergodicity, memory, morphogenesis*, 1990). In the second case, time is continuous, cells are updated at random instants, at most one cell is updated at any given time, and the model is known as a (finite range) *Interacting Particle System (IPS)* (e.g. Liggett, T.M.: *Interacting particle systems*, 2005).

6.2.5.1. Density Classification on Infinite Lattices and Trees

In a joint work with N. Fatès [INRIA Nancy – Grand-Est], J. Mairesse and I. Marcovici [LIAFA, CNRS and Université Paris 7] [46] we consider an infinite graph with nodes initially labeled by independent Bernoulli random variables of parameter p. We address the density classification problem, that is, we want to design a (probabilistic or deterministic) cellular automaton or a finite-range interacting particle system that evolves on this graph and decides whether p is smaller or larger than $1/2$. Precisely, the trajectories should converge (weakly) to the uniform configuration with only $0's$ if $p < 1/2$, and only $1's$ if $p > 1/2$. We present solutions to that problem on $\mathbb{Z}^d$, for any $d \geq 2$, and on the regular infinite trees. For $\mathbb{Z}$, we propose some candidates that we back up with numerical simulations.

6.2.6. Stochastic Stability

6.2.6.1. Ergodicity of Probabilistic Cellular Automata

In a joint work with J. Mairesse and I. Marcovici [LIAFA, CNRS and Université Paris 7] [31], we considered ergodicity properties of probabilistic cellular automata (PCA). A classical cellular automaton (CA) is a particular case of PCA. For a 1-dimensional CA, we proved that ergodicity is equivalent to nilpotency, and is therefore undecidable. We then proposed an efficient perfect sampling algorithm for the invariant measure of an ergodic PCA. Our algorithm does not assume any monotonicity properties of the local rule. It is based on a bounding process which is shown to be also a PCA. We then focused on the PCA Majority, whose asymptotic behavior is unknown, and performed numerical experiments using the perfect sampling procedure.

6.2.6.2. Spatial Queues

In a joint work with S. Foss [Heriot–Watt University, UK] [13], we considered a queue where the server is the Euclidean space, the customers are random closed sets of the Euclidean space arriving according to a Poisson rain and where the discipline is a hard exclusion rule: no two intersecting random closed sets can be served at the same time. We use the max plus algebra and Lyapunov exponents to show that under first come first serve assumptions, this queue is stable for a sufficiently small arrival intensity. We also discuss the percolation properties of the stationary regime of the random closed sets in the queue.

6.3. Economics of Networks

Participants: François Baccelli, Emilie Coupechoux, Marc Lelarge.

6.3.1. Diffusion and Cascading Behavior in Random Networks

The spread of new ideas, behaviors or technologies has been extensively studied using epidemic models. In [69], we considered a model of diffusion where the individuals' behavior is the result of a strategic choice. We studied a simple coordination game with binary choice and give a condition for a new action to become widespread in a random network. We also analyze the possible equilibria of this game and identify conditions for the coexistence of both strategies in large connected sets. Finally we look at how can firms use social networks to promote their goals with limited information.

Our results differ strongly from the one derived with epidemic models. In particular, we showed that connectivity plays an ambiguous role: while it allows the diffusion to spread, when the network is highly connected, the diffusion is also limited by high-degree nodes which are very stable. In the case of a sparse random network of interacting agents, we computed the contagion threshold for a general diffusion model and showed the existence of (continuous and discontinuous) phase transitions. We also computed the minimal size of a seed of new adopters in order to trigger a global cascade if these new adopters can only be sampled without any information on the graph. We showed that this minimal size has a non-trivial behavior as a function of the connectivity. Our analysis extends methods developed in the random graphs literature based on the properties of empirical distributions of independent random variables, and leads to simple proofs.

6.3.2. Impact of Clustering on Diffusions and Contagions in Random Networks

In [33] we extend some results of the previous results to a model of random graphs having both a given degree distribution and a tunable clustering coefficient. This work shed new light on the impact of clustering on the spread of new ideas, technologies, viruses or worms. We consider two types of growth processes: the (classical SI) diffusion model, and the contagion model, which is inspired by a simple coordination game played on the network and is characterized by a threshold rule and a random seed. While clustering inhibits the diffusion process (on regular graphs), its impact for the contagion process is more subtle and depends on the connectivity of the graph: in a low connectivity regime, clustering also inhibits the contagion, while in a high connectivity regime, clustering favors the appearance of global cascades but reduces their size.

6.3.3. Economic Value of User Localization in Wireless Networks

The defining characteristic of wireless and mobile networking is user mobility, and related to it is the ability for the network to capture (at least partial) information on where users are located and how users change location over time. Information about location is becoming critical, and therefore valuable, for an increasingly larger number of location-based or location-aware services. A key open question, however, is how valuable exactly this information is. Our goal in this paper is to help understand and estimate the economics, or the value of location information.

In a joint work with J. Bolot [Sprint ATL, USA], [25], we addressed in particular the value of different granularities of location information, for example how much more valuable is it to know the GPS location of a mobile user compared to only knowing the access point, or the cell tower, that the user is associated with. We made three main contributions. First, we presented novel models, which capture the location-based economic activity of mobile users. Second, we derived closed-form analytic solutions for the economic value generated by those users. Third, we augmented the models to consider uncertainty about the users' location, and derived expressions for the economic value generated with different granularities of location information.

6.4. Point Processes, Stochastic Geometry and Random Geometric Graphs

Participants: François Baccelli, Bartłomiej Błaszczyszyn, Pierre Brémaud, Yogeshwaran Dhandapani, Kumar Gaurav, Mir Omid Haji Mirsadeghi, Justin Salez.

stochastic geometry, point process, shot-noise, Boolean model, random tessellation, percolation, stochastic comparison

6.4.1. Comparison of Clustering and Percolation of Point Processes and Random Graphs

Heuristics indicate that point processes exhibiting clustering of points have larger critical radius r_c for the percolation of their continuum percolation models than spatially homogeneous point processes. It has already been shown in [64], [73] that the *directionally convex* (dcx) ordering of point processes is suitable to compare their clustering tendencies. Hence, it was tempting to conjecture that r_c is increasing in dcx order. Some numerical evidences support this conjecture for a special class of point processes, called perturbed lattices, which are "toy models" for determinantal and permanental point processes. However the conjecture is not true in full generality. In 2011 we have prepared three publications on this subject.

6.4.1.1. On comparison of clustering properties of point processes

In [52] we provide a large class of perturbed lattice point processes, monotone in dcx order and comparable to Poisson point processes that is commonly considered as the reference model in the comparative study of clustering phenomena. We also introduce a weaker order based on the comparison of only void probabilities and factorial moment measures. We prove that determinantal and permanental processes, as well as, more generally, negatively and positively associated point processes are comparable in this weaker sense to the Poisson point process of the same mean measure.

6.4.1.2. Clustering and percolation of point processes

In [49] we show that simple, stationary point processes of a given intensity on $\mathbb{R}^d$, having void probabilities and factorial moment measures smaller than those of a homogeneous Poisson point process of the same intensity, admit uniformly non-degenerate lower and upper bounds on the critical radius r_c for the percolation of their continuum percolation models. Examples are negatively associated point processes and, more specifically, determinantal point processes. More generally, we show that point processes dcx smaller than a homogeneous Poisson point processes (for example perturbed lattices) exhibit phase transitions in certain percolation models based on the level-sets of additive shot-noise fields of these point processes. Examples of such models are k-percolation and SINR-percolation models. We also construct a Cox point process with degenerate critical radius $r_c = 0$, that is dcx larger than a given homogeneous Poisson point process. This is a counterexample for the aforementioned conjecture in the full generality.

6.4.1.3. Ordering of non-standard critical radii

As explained above, heuristically one expects finiteness of the critical radii for percolation of sub-Poisson point processes. However, in [49] we have show that it is non-zero as well. In a more elaborate paper [50] we present a reasoning as to why this non-triviality is to be expected. Specifically, we defined two (nonstandard) critical radii for percolation of the Boolean model, called the lower and upper critical radii, and related, respectively, to the finiteness of the expected number of void circuits around the origin and asymptotic of the expected number of long occupied paths from the origin in suitable discrete approximations of the continuum model. These radii sandwich the usual critical radius r_c for percolation of the Boolean model. We show that dcx order preserves the upper critical radii and *reverses* the lower critical radii.

6.4.1.4. Local weak convergence and stochastic comparison

Many random models are parametrized by the size of the model, and the essential properties of the model are the asymptotic ones as the size of the graph tends to infinity. In the master thesis [57] we show that the theory of local weak converge provides a natural setting to investigate stochastic (convex) ordering of such models. We consider both the geometric context of [71] and the discrete one of Galton-Watson branching process and Configuration Model, cf [5]. In this latter case we define and study a convex order in the context of random trees and graphs which converge in the local weak sense. In particular, we're interested in the effect of ordering on percolation. It turns out that while in the case of Galton-Watson trees, convex ordering leads to the ordering of percolation probabilities, we cannot conclude this in the case of configuration model. In this case, we could only obtain the ordering of percolation thresholds.

6.4.1.5. AB random geometric graphs

We investigated percolation in the AB Poisson-Boolean model in d-dimensional Euclidean space, and asymptotic properties of AB random geometric graphs on Poisson points in $[0,1]^d$. The AB random geometric graph we studied is a generalization to the continuum of a bi-partite graph called the AB percolation model on discrete lattices. Such an extension is motivated by applications to secure communication networks and frequency division duplex networks. The AB Poisson Boolean model is defined as a bi-partite graph on two independent Poisson point processes of intensities λ and μ in the d-dimensional Euclidean space in the same manner as the usual Boolean model with a radius r. We showed existence of AB percolation for all $d \geq 2$, and derived bounds for a critical intensity. Further, in $d = 2$, we characterize a critical intensity. The set-up for AB random geometric graphs is to construct a bi-partite graph on two independent Poisson point process of intensities n and cnin the unit cube. We provided almost sure asymptotic bounds for the connectivity threshold for all $c > 0$ and a suitable choice of radius cut-off functions $r_n(c)$. Further for $c < c_0$, we derived a weak law result for the largest nearest neighbor radius. This work, which was a part of the PhD thesis [73] will appear in [23].

6.4.2. Random Packing Models

Random packing models (RPM) are point processes (p.p.s) where points which "contend" with each other cannot be simultaneously present. These p.p.s play an important role in many studies in physics, chemistry, material science, forestry and geology. For example, in microscopic physics, chemistry and material science, RPMs can be used to describe systems with hard-core interactions. Applications of this type range from reactions on polymer chains, chemisorption on a single-crystal surface, to absorption in colloidial systems. In these models, each point (molecule, particle,$\cdots$) in the system occupies some space, and two points with overlapping occupied space contend with each other. Another example is the study of seismic and forestry data patterns, where RPMs are used as a reference model for the data set under consideration. In wireless communications, RPMs can be used to model the users simultaneously accessing the medium in a wireless network using Carrier Sensing Medium Access (CSMA). In this context, each point (node, user, transmitter,$\cdots$) does not occupy space but instead generates interference to other points in the network. Two points contend with each other if either of them generates too much interference to the other. Motivated by this kind of application, we studied in [70] the generating functionals of several models of random packing processes: the classical Matérn hard-core model; its extensions, the k-Matérn models and the ∞-Matérn model, which is an example of random sequential packing process. The main new results are: 1) A sufficient condition for the ∞-Matérn model to be well-defined (unlike the other two, the ∞-Matérn model may not be well-defined on unbounded space); 2) the generating functional of the resulting point process which is given for each of the three models as the solution of a differential equation; 3) series representation and bounds on the generating functional of the packing models; 4) moment measures and other useful properties of the considered packing models which are derived from their generating functionals.

6.4.3. Extremal and Additive Matérn Point Processes

In the simplest Matérn point processes, one retains certain points of a Poisson point process in such a way that no pairs of points are at distance less than a threshold. This condition can be reinterpreted as a threshold condition on an extremal shot–noise field associated with the Poisson point process. In a joint work with P. Bermolen (Universidad de la República, Montevideo, Uruguay) [11], we studied extensions of Matérn point processes where one retains points that satisfy a threshold condition based on an *additive* shot–noise field of the Poisson point process. We provide an analytical characterization of the intensity of this class of point processes and we compare the packing obtained by the extremal and additive schemes and certain combinations thereof.

6.4.4. Spatial Birth and Death Point Processes

In collaboration with F. Mathieu [INRIA GANG] and Ilkka Norros [VTT, Finland], we started studying a new spatial birth and death point process model where the death rate is a shot noise of the point configuration [60]. We showed that the spatial point process describing the steady state exhibits repulsion. We studied two asymptotic regimes: the fluid regime and the hard–core regime. We derived closed form expressions for the mean (and in some cases the law) of the latency of points as well as for the spatial density of points in the steady state of each regime.

6.4.5. Information Theory and Stochastic Geometry

In a joint work with V. Anantharam [UC Berkeley], [58], we studied the Shannon regime for the random displacement of stationary point processes. Let each point of some initial stationary point process in n-dimensional Euclidean space give rise to one daughter point, the location of which is obtained by adding a random vector to the coordinates of the mother point, with all displacement vectors independently and identically distributed for all points. The decoding problem is then the following one: the whole mother point process is known as well as the coordinates of some daughter point; the displacements are only known through their law; can one find the mother of this daughter point? The Shannon regime is that where the dimension n tends to infinity and where the logarithm of the intensity of the point process is proportional to n. We showed that this problem exhibits a sharp threshold: if the sum of the proportionality factor and of the differential entropy rate of the noise is positive, then the probability of finding the right mother point tends to 0 with n for all point processes and decoding strategies. If this sum is negative, there exist mother point processes, for instance Poisson, and decoding strategies, for instance maximum likelihood, for which the probability of finding the right mother tends to 1 with n. We then used large deviations theory to show that in the latter case, if the entropy spectrum of the noise satisfies a large deviation principle, then the error probability goes exponentially fast to 0 with an exponent that is given in closed form in terms of the rate function of the noise entropy spectrum. This was done for two classes of mother point processes: Poisson and Matérn. The practical interest to information theory comes from the explicit connection that we also establish between this problem and the estimation of error exponents in Shannon's additive noise channel with power constraints on the codewords.

We currently investigate extensions of this approach to network information theoretich channels.

6.4.6. *Navigation on Point Processes and Graphs*

In [12], we studied optimal navigations in wireless networks in terms of first passage percolation on some space-time SINR graph. We established both "positive" and "negative" results on the associated the percolation delay rate (delay per unit of Euclidean distance, also called time constant in the classical terminology of percolation). The latter determines the asymptotics of the minimum delay required by a packet to progress from a source node to a destination node when the Euclidean distance between the two tends to infinity. The main negative result states that the percolation delay rate is infinite on the random graph associated with a Poisson point process under natural assumptions on the wireless channels. The main positive result states that when adding a periodic node infrastructure of arbitrarily small intensity to the Poisson point process, the percolation delay rate is positive and finite.

A new direction of research was initiated aiming at defining a new class of measures on a point process which are invariant under the action of a navigation on this point process. This class of measures has properties similar to Palm measures of stationary point processes; but they cannot be defined in the classical framework of Palm measures.

6.5. Random Graphs and Combinatorial Optimization

Participants: Hamed Amini, Emilie Coupechoux, Mathieu Leconte, Marc Lelarge, Justin Salez.

random graphs, combinatorial optimization, local weak convergence, diffusion, network games.

6.5.1. *Rank of Large Random Graphs*

In [16], with Charles Bordenave [CNRS-Université de Toulouse], we investigated the rank of the adjacency matrix of large diluted random graphs: for a sequence of graphs converging locally to a Galton-Watson tree, we provided an explicit formula for the asymptotic multiplicity of the eigenvalue 0 in terms of the degree generating function. In the first part, we showed that the adjacency operator associated with a Galton-Watson tree is self-adjoint with probability one ; we analyzed the associated spectral measure at the root and characterize the distribution of its atomic mass at 0. In the second part, we established a sufficient condition for the expectation of this atomic mass to be precisely the normalized limit of the dimension of the kernel of the adjacency matrices of the sequence of graphs. Our proofs borrow ideas from analysis of algorithms, functional analysis, random matrix theory, and statistical physics.

6.5.2. *Matchings in infinite graphs*

In [43], we proved that for any sequence of (deterministic or random) graphs converging locally, the corresponding sequence of normalized matching numbers converges, and this limit depends only on the limit of the graph sequence. In the particular case where this limit is a unimodular Galton Watson tree, we were able to compute explicitly the value for the limit of the sequence of (normalized) matching numbers. This leads to an explicit formula that considerably extends the well-known one by Karp and Sipser for Erdős-Rényi random graphs.

We considered a natural family of Gibbs distributions over matchings on a finite graph, parameterized by a single positive number called the temperature. The correlation decay technique can be applied for the analysis of matchings at positive temperature and allowed us to establish the weak convergence of the Gibbs marginal as the underlying graph converges locally. However for the zero temperature problem (i.e. maximum matchings), we showed that there is no correlation decay even in very simple cases. By using a complex temperature and a half-plane property due to Heilmann and Lieb, we were able to let the temperature tend to zero and obtained a limit theorem for the asymptotic size of a maximum matching in the graph sequence.

6.5.3. Counting spanning subgraphs subject to local constraints

In [53], we use negative association and local weak convergence to establish the validity of the cavity method for counting spanning subgraphs subject to local constraints. Specifically, the normalized logarithm of the associated generating polynomial (or partition function) is shown to converge along any sequence of graphs whose random weak limit is a tree, and the limit is directly expressed in terms of the unique solution to a limiting cavity equation. On a Galton-Watson tree, the latter simplifies into a recursive distributional equation which can be solved explicitly. As an illustration, we provide an asymptotic formula for the maximal size of a spanning subgraph with maximal degree b in the Erdős-Rényi model with fixed average degree and diverging size, for any $b \in N$.

6.5.4. Bipartite graph structures for efficient balancing of heterogeneous loads

With Laurent Massoulié [Technicolor], we extend the results obtained previously on the asymptotic size of maximum matchings in random graphs converging locally to Galton-Watson trees to so-called b-matchings (with non-unitary capacity at vertices as well as constraints on individual edges). Compared to the matching case, this involves studying the convergence of a message passing algorithms which transmits vectors instead of single real numbers. We also look further into an application of these results to large scale distributed content service platforms, such as peer-to-peer video-on-demand systems. In this context, the density of maximum b-matchings corresponds to the maximum fraction of simultaneously satisfiable requests, when the service resources are limited and each server can only handle requests for a predetermined subset of the contents which it has stored in memory. An important design aspect of such systems is the content placement strategy onto the servers depending on the estimated content popularities; the results obtained allow to characterize the efficiency of such placement strategies and the optimal strategies in the limit of large storage capacity at servers are determined.

6.5.5. Flooding in Weighted Random Graphs

In a joint work [24] with Moez Draief [Imperial College London], we studied the impact of the edge weights on distances in diluted random graphs. We interpret these weights as delays, and take them as i.i.d exponential random variables. We analyzed the edge flooding time defined as the minimum time needed to reach all nodes from one uniformly chosen node, and the edge diameter corresponding to the worst case edge flooding time. Under some regularity conditions on the degree sequence of the random graph, we showed that these quantities grow as the logarithm of n, when the size of the graph n tends to infinity. We also derived the exact value for the prefactors.

These allowed us to analyze an asynchronous randomized broadcast algorithm for random regular graphs. Our results show that the asynchronous version of the algorithm performs better than its synchronized version: in the large size limit of the graph, it will reach the whole network faster even if the local dynamics are similar on average.

7. Contracts and Grants with Industry

7.1. ANR CMON

Participants: François Baccelli, Florence Bénézit, Bruno Kauffmann, Darryl Veitch.

TREC is a partner of the 3-year ANR project called CMON, jointly with Technicolor, LIP6, the INRIA project-team Planète and the community http://www.grenouille.com. This project is focused on the development of end-to-end measurement for Internet that can be deployed by end-users, without any support from ISP. A postdoc (F. Bénézit) was hired through this grant from January 2010 till July 2011. The main contribution of this year was the definition of the "Grenouille Cohérente", a scheme allowing one to globally synchronize Grenouille client, jointly with A. Schmidt [Grenouille].

7.2. ANR PEGASE

Participants: Abir Benabid, Anne Bouillard, Nadir Farhi.

TREC is a partner of the 3-year ANR project called PEGASE, jointly with ENS Lyon, the INRIA project-team MESCAL, ONERA, Real-Time-at-Work (start-up) and Thalès. This project is focused on the analysis of critical embedded networks using algebraic tools. The aim is to apply these techniques to AFDX and Spacewire architectures. Nadir Farhi was a post-doc hired through this grant until January 2011, and Abir Benabid was hired in March 2011.

7.3. ANR MAGNUM

Participant: Ana Bušić.

Ana Bušić is participating (20%) in the 4-year ANR project MAGNUM (Méthodes Algorithmiques pour la Génération aléatoire Non Uniforme: Modèles et applications), 2010 – 2014; http://www.lix.polytechnique.fr/~rossin/ANR/Magnum/www/?page_id=4. The central theme of the MAGNUM project is the elaboration of complex discrete models that are of broad applicability in several areas of computer science. A major motivation for the development of such models is the design and analysis of efficient algorithms dedicated to simulation of large discrete systems and random generation of large combinatorial structures.

7.4. CIFRE Grant of Technicolor

Participants: Mathieu Leconte, Marc Lelarge, Laurent Massoulié.

The CIFRE grant of Mathieu started in January 2011. The topic bears on information dissemination and recommendation in social networks. The distribution of multimedia content and the use of social networks like Facebook, Orkut, etc.. are booming in today's networks. These social networks are also increasingly used for dissemination and recommendation of content. The objective of the thesis will be to develop an understanding of how information disseminates in social networks based on the type of information, user tastes, and the topological structure of these networks. This study will result in developing methods for more effective dissemination of content.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. LINCS

TREC participates in the Laboratory of Information, Networking and Communication Sciences (LINCS); http://www.lincs.fr/ created on October 28th, 2010, by three French institutions of higher education and research: INRIA, Institut Télécom and UPMC. Alcatel-Lucent joined the LINCS in February 2011 as a strategic partner. The LINCS was officially launched by Ms Valérie P'ecresse, the French Minister of Research, on May 2nd, 2011; see http://www.inria.fr/actualite/mediacenter/laboratoire-commun-internet-du-futur.

8.1.2. Digiteo ACRON

Participant: Bartłomiej Błaszczyszyn.

Project *Analyse et Conception de Réseaux Sans Fil Auto-Organisés* (ACRON) started in 2011. Coordinator: Supélec (Télécommunications), Partners: Inria HIPERCOM, Université Paris-Sud, IEF. Trec is associated partner.

The objective of this project is to work on characterization of the fundamental performance limits of large self-organizing wireless networks and develop distributed and self-organizing communication techniques that will approach the theoretical limits.

8.2. National Initiatives

8.2.1. ARC OCOQS

Participant: Ana Bušić.

Two-year Inria Collaborative action *Action de recherche collaborative (ARC)* OCOQS “Optimal threshold policies in COntrolled Queuing Systems” OCOQS started in 2011. Coordinator: Ana Bušić, Participants: Alain Jean-Marie (MAESTRO, INRIA Sophia-Antipolis), Emmanuel Hyon (University of Paris Ouest and LIP6), Ingrid Vliegen (University of Twente); http://www.di.ens.fr/~busic/OCOQS. The research subject is the optimal control of stochastic processes, with applications to the control of networks and manufacturing systems. The principal aim is to widen the set of mathematical techniques that can be used to prove that optimal policies are of threshold type, thereby widening the set of classes of models that can be effectively solved exactly or numerically handled in practice.

8.2.2. GdR Stochastic Geometry

Participants: François Baccelli, Bartłomiej Błaszczyszyn.

TREC has participated in the mounting of the Research Group (Groupement de recherche, GdR) on Stochastic Geometry led by Pierre Calka (Université de Rouen). This GdR is going to be a collaboration framework for all French research teams working in the domain of *spatial stochastic modeling*, both on theory development and in applications. This year the application has been accepted by the National Committee of CNRS and the group will be officially created in 2012.

8.2.3. PEPS INS2I MonoSimPa

Participants: Anne Bouillard, Ana Bušić.

Exploratory research (Projet Exploratoire Premier Soutien (PEPS)) of INS2I CNRS titled “Simulation Temps Paralléle, Simulation Parfaite et Monotonie” (MonoSimPa) is a one year exploratory project on parallel and perfect simulation. It is a joint project with PRiSM, Versailles (UMR 8144) and LIG, Grenoble (UMR 5217).

8.3. European Initiatives

8.3.1. Collaborations in European Programs FP7

Participant: All Trec.

European Network of Excellence (NoE), http://euronf.enst.fr/en_accueil.html;

Project acronym: Euro-NF;

Duration: January 2008 - June 2012;

Coordinator: D. Kofman (Intitut Télécom);

Partners: about 30 partners;

Abstract: This NoE is focused on the next generation Internet. Its main target is to integrate the research effort of the partners to be a source of innovation and a think tank on possible scientific, technological and socio-economic trajectories towards the network of the future. Euro-NF is supported by the theme "Information and Communication Technologies (ICT)" under the 7th Framework Programme of the European Community for RTD. Euro-NF is a continuation of Euro-NGI

8.3.2. Collaborations in European Programs, except FP7

Participants: François Baccelli, Bartłomiej Błaszczyszyn, Marc Lelarge.

EIT ICT Labs Action Line: Internet Technologies and Architectures.

Project acronym: FUN

Project title: Fundamentals of Networking

Duration: January 2011 - December 2011

Coordinator: INRIA TREC

Partners: the partners are INRIA TREC and INRIA GANG (Fabien Mathieu) in France, VTT (Ilkka Norros, Samuli Aalto) and Aalto University (Pekka Orponen) in Finland, Eindhoven University (Sem Borst, Onno Boxma and Remco van der Hofstad) in the Netherlands.

Abstract: The aim of this project is to build a community of researchers focusing on fundamental theoretical issues of future networking. The topics of interest include: communication theory, network information theory, distributed algorithms, self-organization and game theory, modeling of large random and complex networks and structures. The proposal builds upon collaborations within the EURONF Network of Excellence, where the three institutions are partners and where the researchers have had fruitful scientific interactions.

8.4. International Initiatives

8.4.1. INRIA Associate Teams

8.4.1.1. IT-SG-WN

Title: Information Theory, Stochastic Geometry, Wireless Networks

INRIA principal investigator: François Baccelli

International Partner:

Institution: University of California Berkeley (United States)

Laboratory: EECS Department

Researcher: Venkat Anantharam, Anant Sahai, David Tse.

International Partner:

Institution: Stanford University (United States)

Laboratory: EE

Researcher: Abbas El Gamal.

Duration: 2011 - 2013

See also: http://www.di.ens.fr/~baccelli/IT_SG_WN_web_site.htm

The activity of this proposal is centered on the inter-play between stochastic geometry and network information theory, whith a particular emphasis on wireless networks. In terms of research, three main lines of thought will be pursued:1. Error exponents and stochastic geometry2. Stochastic geometry and network Information Theory3. Cognitive radio and stochastic geometry

8.4.2. INRIA International Partners

8.4.3. Visits of International Scientists

8.4.3.1. Internships

Aleksander Wieczorek

Subject: Optimal control of an inventory system

Institution: Poznan University of Technology (Poland)

Mir Omid Haji Mirsadeghi (from Jan 2011 until Sep 2011)

Subject: Graph matching based on semi-definite positive relaxation

Institution: Sharif University of Technology (Iran, Islamic Republic of)

9. Dissemination

9.1. Animation of the scientific community

TREC's seminar The following scientists gave talks on Trec's seminar in 2011 (see http://www.di.ens.fr/~trec/seminar.html for details)

Michel Mandjes (University of Amsterdam) /Nov 30/ Talking on: "Birthday surprises",

Prashant Mehta (University of Illinois at Urbana-Champaign) /Oct 14/ Talking on: "Feedback Particle Filter: A New Formulation for Nonlinear Filtering based on Mean-field Theory",

Anastasios Giovanidis (TREC) /Sep 23/ Talking on: "Measurement Based Self-Optimization in Random Access Communications",

Anne Bouillard (TREC) /Sep 22/ Talking on: "Residuation of tropical series: rationality issues",

Naoto Miyoshi (Tokyo Institute of Technology) /Sep 7/ Talking on: "Limiting size index distributions for ball-bin models with Zipf-type frequencies",

Justin Salez (TREC), PhD thesis defense /Jul 4/ Talking on: "Quelques conséquences de la convergence locale faible pour les graphes aléatoires",

Hamed Amini (TREC), PhD thesis defense /Jun 24/ Talking on: "Epidémies et Percolation dans les Graphes Aléatoires",

Shenghao Yang (INC, The Chinese University of Hong Kong) /Jun 23/ Talking on: "BATS Codes: when Network Coding Meets Digital Fountain",

Van Minh Nguyen (TREC), PhD thesis defense /Jun 20/ Talking on: "Wireless Link Quality Modelling and Mobility Management Optimisation for Cellular Networks",

I-Hong Hou (University of Illinois at Urbana-Champaign) /Jun 15/ Talking on: "Supporting Delay Guarantees over Unreliable Wireless Channels",

Giovanni Luca Torrisi (IAC Mauro Picone Italy) /May 26/ Talking on: "Density estimation of functionals of spatial point processes with application to wireless networks",

Richard Emilion (Université d'Orléans) /May 16/ Talking on: "Hierarchical Dirichlet Models",

Kristen Woyach (UC Berkeley) /Apr 29/ Talking on: "Crime and Punishment for Cognitive Radios",

Martin Haenggi (University of Notre Dame) /Apr 14/ Talking on: "A Geometric Approach to Security in Wireless Systems",

Amin Coja-Oghlan (University of Warwick) /Apr 8/ Talking on: "Phase transitions and computational complexity",

Ilkka Norros (VTT, Finland) /Mar 30/ Talking on: "Stability problems of two-chunk file-sharing systems",

Michel Mandjes (University of Amsterdam & EURANDOM & CWI) /Mar 25/ Talking on: "Resource dimensioning through buffer sampling",

Bruno Kauffmann (Orange Labs and INRIA/ENS), PhD thesis defense /Mar 24/ Talking on: "Inverse Problems in Networks",

Darryl Veitch (University of Melbourne) /Mar 23/ Talking on: "La synchronisation d'horloges à travers l'internet",

Irene Marcovici (LIAFA) /Feb 17/ Talking on: "Probabilistic cellular automata, invariant measures, and perfect sampling",

Stefan Haar (LSV) /Feb 10/ Talking on: "When you don't have a Free Choice",

Victor Bapst (Laboratoire de Physique Théorique, ENS) /Jan 26/ Talking on: "On the spectrum of random regular graphs with random edges weights",

Armand Makowski (University of Maryland) /Jan 24/ Talking on: "Recent results for random key graphs: Connectivity, triangles, etc.",

Nicolas Broutin (INRIA) /Jan 13/ Talking on: "La limite d'échelle des graphes aléatoires critiques",

Nadir Farhi (TREC, INRIA/ENS) /Jan 7/ Talking on: "Packetization and aggregate service in network calculus"

TREC's Reading group The reading group on Random Graphs is animated by A. Bouillard and A. Giovanidis; see http://www.di.ens.fr/~bouillar/GdL/index.html

9.2. Teaching

ENS Paris

- Undergraduate course (master level, MMFAI) by M. Lelarge and J. Salez, on Information Theory and Coding (24h + 24h of exercise session).
- Course on Communication Networks (master level, MMFAI) by F. Baccelli, A. Bouillard and A. Bušić (24h + 24h of exercice sessions).
- Course on Network Modeling (master level, MPRI) by F. Baccelli and A. Bouillard (24h)
- Undergraduate course (master level, MMFAI) by F. Baccelli, A. Bouillard and P. Brémaud, on Random Structures and Algorithms (35h + 28h of exercise session).
- Undergraduate exercise session (master level, MMFAI) by A. Bouillard on formal languages, computability and complexity (28h).

ENS Cachan - Antenne de Bretagne

- Preparation to the oral exams of the agregation of mathematics (computer science option) by A. Bouillard (12h).

UPMC, Paris 6

- Graduate Course on point processes, stochastic geometry and random graphs (program "Master de Sciences et Technologies"), B. Błaszczyszyn and L. Massoulié (45h).
- Undergraduate course onconception of algorithms and applications (Licence Informatique, 3rd year), A. Bušić (24h)

Université Paris 10

- Preparation to the *certification C2i* by A. Benabid (36h)

Université de Versailles Saint-Quentin-en-Yvelines

- Graduate course on simulation (M2 COSY), A. Bušić (6h).

Tutorials

- Lectures on Clustering, percolation and convex ordering of point processes, during Summer Academy on "Stochastic Analysis, Modelling and Simulation of Complex Structures", Söllerhaus, Austria, September 2011; http://www.uni-ulm.de/mawi/summer-academy-2011/ by B. Błaszczyszyn (4h).
- Ecole de Recherche ENS Lyon 10-14 janvier 2011. 25 hours of lectures of F. Baccelli on stochastic geometry.
- Kyoto University, January 2011, Department of Systems Science, 3 lectures of F. Baccelli on "Stochastic Geometry and Wireless Networks".
- Chinese University of Hong Kong, July 2011, EECS Dept., 3 lecture of F. Baccelli on "Stochastic Geometry and Information Theory".
- Fields Mitacs Workshop "Probabilistic Methods in Wireless Networks", August 2011, http://www.fields.utoronto.ca/programs/scientific/11-12/wirelessnet/. 2 lectures on "Stochastic Geometry and Wireless Networks" by F. Baccelli.

PhD advising

PhD: **Bruno Kauffmann**, "Inverse Problems in Networks", **defended** on March 24, 2011; adviser F. Baccelli; see [6]

PhD: **Van Minh Nguyen**, "Modélisation des Liens de Communication Radio et Optimisation de la Gestion de Mobilité dans les Réseaux Cellulaires", **defended** on Jun 20, 2011; adviser F. Baccelli; see [7]

PhD: **Hamed Amini**, "Epidémies et Percolation dans les Graphes Aléatoires", **defended** on Jun 24, 2011; adviser F. Baccelli and M. Lelarge; see [5]

PhD: **Justin Salez**, "Quelques conséquences de la convergence locale faible pour les graphes aléatoires", **defended** on July 4, 2011; adviser F. Baccelli and M. Lelarge; see [8]

PhD in progress: **Emilie Coupechoux**, "Analysis of large random graphs", started in September 2009, adviser M. Lelarge, F. Baccelli;

PhD in progress: **Kumar Gaurav**, " Convex comparison of network architectures" started in October 2011, adviser B. Błaszczyszyn;

PhD in progress: **Mir Omid Haji Mirsadeghi**, "Routing on Point Processes", started in 2009, adviser F. Baccelli;

PhD in progress: **Mathieu Leconte**, "Propagation d'information et recommandations dans les réseaux sociaux", started in January 2011, adviser M. Lelarge, F. Baccelli;

PhD in progress: **Frédéric Morlot**, "Mobility Models for Communication Networks", started in 2008, adviser F. Baccelli;

PhD in progress: **Tien Viet Nguyen**, "Random Packing Models", started in 2009, adviser F. Baccelli.

9.3. Invitations and Participation in Conferences

François Baccelli

- Keynote or Colloquium Lectures at the
  * Queuing Theory Symposium of the Operations Research Society of Japan, January 2011. Lecture on "Spatial Queuing".

    - Conférence SMAI 2011, Guidel, France, May 2011, http://smai.emath.fr/smai2011/. Lecture on “Géométrie Stochastique et Théorie de l’Information”.
    - Colloquium, Department of Mathematics, UT Austin, October 2011. Lecture on “Phase Transitions in Stochastic Network Dynamics”.
    - Markov Lecture 2011, Informs 2011 Conference, Charlotte, North Carolina, October 2011 http://www.informs.org/Community/APS/Markov-Lecture-Slides. Lecture on “Routing on Point Processes”.
- Presentations in the following conferences or seminars
    - Séances publique de l’Académie des sciences “ A l’heure des grands réseaux”, March 2011, http://www.academie-sciences.fr/video/v290311.htm. Lecture on “Réseaux de Communication Radio, Internet de Proximité et Géométrie Stochastique”.
    - Workshop on stochastic geometry - Université de Lille, April 2011. Lecture on “Information–Theoretic Capacity and Error Exponents of Stationary Point Processes under Random Additive Displacements”.
    - Wiopt–Spaswin Workshop, Princeton, May 2011. Lecture on “Optimizing CSMA for Wide Area Ad-hoc Networks”.
    - ISCIS Conference 2011, Royal Society, London, September 2011. Lecture on “Performance of P2P Networks with Spatial Interactions of Peers”.
    - UT Austin, ECE Department, October 2011. Lecture on “Performance Evaluation and Design of Communication Networks with Random Spatial Components”.
    - ICERM Workshop “Novel Applications of Kinetic Theory”, Brown University, USA, October 2011. Lecture on “Transport Equations for Internet Transmission Control”.
    - EIT ICT Labs Workshop “Fundamentals of Networking”, VTT, Helsinki, Finland, November 2011. Lecture on “Self Organization in Large CSMA Networks”.
- Member of the TPC of IEEE Infocom 2011.

Abir Benabid

- Participation in the following conferences:
    - WCTT 2011, Vienna, Austria, November 2011; http://www.wctt.info/

Bartłomiej Błaszczyszyn

- Presentation in the following conferences or seminars
    - Conference on “Stochastic Networks and Related Topics III”, Będlewo, Poland, May 2011; http://www.math.uni.wroc.pl/~lorek/bedlewo2011/
    - 16th Workshop on Stochastic Geometry, Stereology and Image Analysis, SGSIA 2011 at Sandbjerg Estate, Sonderborg, Denmark, June 2011; http://csgb.dk/events/2011/sgsia11/
    - Summer Academy on “Stochastic Analysis, Modelling and Simulation of Complex Structures”, Söllerhaus, Austria, September 2011; http://www.uni-ulm.de/mawi/summer-academy-2011/; invited talk
    - Journé scientifique "Graphes aléatoires", l’Institut Elie Cartan, Nancy, October 2011; http://www.iecn.u-nancy.fr/~chassain/homepage/Graphes aléatoires et réseaux sans fil; invited talk

- * NetGCooP, Paris, October 2011; http://netgcoop.imag.fr/; invited talk,
- * Journé GdR ISIS “Modèles spatiaux stochastiques pour les réseaux”,Télécom ParisTech, December 2011; invited talk http://gdr-isis.fr/index.php?page=reunion&idreunion=159; invited talk

Anne Bouillard

- Member of the program committee of the WCTT workshop (worst-case traversal time) affiliated with the RTSS2011 conference
- Presentation in the following conferences or seminars:
  - * WCTT 2011, Vienna, Austria, November 2011; http://www.wctt.info/
  - * LSV seminar, ENS Cachan, March 2011; http://www.lsv.ens-cachan.fr/Seminaires/
  - * TREC seminar, INRIA Paris, September 2011; http://www.di.ens.fr/~trec/seminar.html
  - * 68NQRT seminar, INRIA/IRISA, September 2011; http://68nqrt.inria.fr/
  - * WEED annual meeting, INRIA Paris, November 2011; http://afsec.asr.cnrs.fr/?p=212
  - * SDA2 annual meeting, Caen, June 2011; https://jsda2-2011.greyc.fr/node/3
- Participation in the following conferences:
  - * Valuetools 2011, Cachan, May 2011; http://valuetools.org/2011/

Ana Bušić

- Presentation in the following conferences or seminars:
  - * 16th INFORMS Applied Probability Society Conference, Stockholm, Sweden, July 2011; http://www.informs.org/Community/Conferences/APS2011
  - * 49th Annual Allerton Conference on Communication, Control, and Computing, Monticello, IL, USA, September 2011; http://www.csl.uiuc.edu/allerton/
  - * 5th Young European Queueing Theorists (YEQT) workshop, October 2011 (invited); http://www.eurandom.tue.nl/events/workshops/2011/YEQTV/
  - * Probability Seminar, Department of Mathematics, University of Zagreb, Croatia, May 2011; http://web.math.hr/~goranc/seminar/
  - * LACL seminar, University Paris 12, France, January 2011; http://lacl.univ-paris12.fr/Labo/seminaire.html
- Participation in the following conferences:
  - * Valuetools 2011, Cachan, France, May 2011; http://valuetools.org/2011/
  - * EPEW 2011, Borrowdale, The English Lake District, UK, October 2011; http://homepages.cs.ncl.ac.uk/nigel.thomas/EPEW2011/

Chung Shue Chen

- Member of the program committee of international conferences: IEEE ICC (2011), IEEE Globecom (2011), IEEE WCNC (2011), IEEE CCNC (2011), IEEE INFOCOM Workshop on Cognitive and Cooperative Networks (2011), IEEE ICCT (2011).
- Editor of European Transactions on Telecommunications (Journal)
- International Editorial Broad of Internet of Things (Journal)
- Presentation in the following conferences or seminars:

  * IEEE VTC international workshop on Self-Organizing Networks, Hungary, May 2011; http://www.ieeevtc.org/vtc2011spring/workshops.php
  * INRIA-Alcatel-Lucent Joint Laboratory 3rd Anniversary Meeting (Seminar), Centre de Conference Paris Victoire, France, Jan 2011;http://www.inria.fr/en/news/news-from-inria/inria-and-alcatel-lucent-bell-labs-are-celebrating-the-third-anniversary-of-their-joint-laboratory

Emilie Coupechoux

- Presentation in the following conferences or seminars:
  * APS Conference, Stockholm (Sweden), July 2011; http://www.informs.org/Community/Conferences/APS2011
  * NetGCooP Conference, Paris, October 2011; http://netgcoop.imag.fr/
  * Séminaire de Probabilités, Nanterre, November 2011; http://www.u-paris10.fr/61454289/0/fiche___pagelibre/
  * Séminaire des Doctorants, Rocquencourt, December 2011; https://intranet.paris-rocquencourt.inria.fr/pratique/chercheurs/doctorants/seminaire-des-doctorants/

Nadir Farhi

- Presentation in the following conferences or seminars:
  * ILAS(International Linear Algebra Society Conference), Braunschweig, Germany, August 2011 http://ilas2011.de/

Yogeshwaran Dhandapani

- Presentation in the following seminars:
  * University of Rouen, Rouen, France. February 2011.
  * University of Bath, Bath, UK. April 2011.
  * University of Orleans, Orleans, France. May 2011.
  * Indian Statistical Institute, Bangalore, India. July 2011.
  * Indian Institute of Science, Bangalore, India. July 2011.
  * TIFR Centre for Applicable Mathematics, Bangalore, India. August 2011.
  * Indian Institute of Technology-Bombay, Mumbai, India. August 2011.
- Participation in the following conferences:
  * Random Structures and Dynamics, Oxford, April 2011 ; http://www.maths.ox.ac.uk/events/conferences/random-structures-and-dynamics

Marc Lelarge

- On sabbatical in the Electrical Engineering Department of Stanford University from September to December 2011, working with Andrea Montanari on message passing algorithms for compressed sensing.
- Presentation in the following conferences or seminars:
  * Journées de l'ANR A3, Nancy, February, 2011; http://www.iecn.u-nancy.fr/~chassain/homepage/index.php?page=Programme
  * Stochastic Activity Month EURANDOM, Eindhoven, April, 2011; http://www.eurandom.tue.nl/events/workshops/2011/SAM/Seminars/Seminars_SAM.html#Lelarge
  * WIDS MIT, Boston, June, 2011; http://wids.lids.mit.edu/

    * SIGMETRICS workshop: MAMA, San Jose, 2011; http://www.sigmetrics.org/sigmetrics2011/mama_schedule.shtml
    * Berkeley seminar, Berkeley, October, 2011; http://www.truststc.org/seminar.htm
    * ISL colloquium, Stanford, November, 2011; http://stanford.edu/group/isl/cgi-bin/wordpress/?p=1879

Mir Omid Haji Mirsadeghi

- Participation in the following conferences:
    * Stochastic Geometry days, Lille, March 2011; http://math.univ-lille1.fr/~heinrich/geostoch2011/

Frédéric Morlot

- Presentation in the following conferences or seminars:
    * III Edición Curso Ciencia de las Redes, Politécnica Madrid, November 2011; http://catedra-orange.upm.es/index.php?id=61
- Participation in the following conferences:
    * NETSCI 2011, Budapest (Hungary), June 2011; http://netsci2011.net

Van Minh Nguyen

- Member of the organization committee of VnTelecom conference http://conferences.vntelecom.org/home
- Member of the program committee of ICC 2011,
- Presentation in the following conferences or seminars:
    * VnTelecom conference, Paris, November, 2011
    * ICC, Kyoto, June 2011; http://www.ieee-icc.org/2011/

Furcy Pin

- Presentation in the following conferences or seminars:
    * Valuetools 2011, Cachan, France, May 2011; http://valuetools.org/2011/

Justin Salez

- Presentation in the following conferences or seminars:
    * Seminaire de Probabilites de l'Institut Elie Cartan, Nancy (France), January 2011; http://www.iecn.u-nancy.fr/~probstat/Les-Seminaires
    * Seminaire de Combinatoire du LIAFA, Paris (France), March 2011; http://liafa.jussieu.fr/web9/manifsem/listmanifannee_en.php?typecongres=9
    * Workshop on Stochastic Networks and Related Topics, Bedlewo (Poland), May 2011 ; http://www.math.uni.wroc.pl/~lorek/bedlewo2011/
    * Seminaire de l'equipe INRIA Reseaux, Algorithmes et Probabilites, Rocquencourt (France), June 2011 ; https://www-roc.inria.fr/twiki/bin/view/RAP/PastSeminars2011
    * The 16th Applied Probability Society Conference, Stockholm (Sweden), June 2011 ; http://www.informs.org/Community/Conferences/APS2011
    * UC Berkeley Probability Seminar, Berkeley (USA), September 2011 ; http://www.stat.berkeley.edu/cgi-bin/events.cgi?se=776&period=past_future

Aleksander Wieczorek

- Presentation in the following conferences or seminars:
  - EPEW 2011, Borrowdale, The English Lake District, UK, October 2011; http://homepages.cs.ncl.ac.uk/nigel.thomas/EPEW2011/

10. Bibliography

Major publications by the team in recent years

[1] F. BACCELLI, B. BŁASZCZYSZYN. *Stochastic Geometry and Wireless Networks, Volume I — Theory*, Foundations and Trends in Networking, NoW Publishers, 2009, vol. 3, No 3–4, http://hal.inria.fr/inria-00403039.

[2] F. BACCELLI, B. BŁASZCZYSZYN. *Stochastic Geometry and Wireless Networks, Volume II — Applications*, Foundations and Trends in Networking, NoW Publishers, 2009, vol. 4, No 1–2, http://hal.inria.fr/inria-00403040.

[3] P. BRÉMAUD. *Point Processes and Queues: Martingale Dynamics*, Springer-Verlag, 2005.

[4] P. BRÉMAUD. *Initiation aux Probabilites et aux chaines de Markov*, Springer-Verlag, 2009.

Publications of the year

Doctoral Dissertations and Habilitation Theses

[5] H. AMINI. *Epidémies et Percolation dans les Graphes Aléatoires*, Université Pierre et Marie Curie, Paris, France, 2011.

[6] B. KAUFFMANN. *Inverse Problems in Networks*, Université Pierre et Marie Curie, Paris, France., 2011, https://edite-de-paris.fr/public/person/see/2604606.

[7] V. M. NGUYEN. *Modélisation des Liens de Communication Radio et Optimisation de la Gestion de Mobilité dans les Réseaux Cellulaires*, Télécom ParisTech, 2011, https://edite-de-paris.fr/public/person/see/5270125.

[8] J. SALEZ. *Quelques conséquences de la convergence locale faible pour les graphes aléatoires*, Université Pierre et Marie Curie, Paris, France, 2011, http://tel.archives-ouvertes.fr/tel-00637130.

Articles in International Peer-Reviewed Journal

[9] J. G. ANDREWS, F. BACCELLI, R. K. GANTI. *Tractable Approach to Coverage and Rate in Cellular Networks*, in "IEEE Transactions on Communications", 2011, vol. 59, n^{o} 11, p. 3122-3134, http://arxiv.org/abs/1009.0516.

[10] F. BACCELLI, N. BAMBOS, N. GAST. *Distributed Delay-Power Control Algorithms for Bandwidth Sharing in Wireless Networks*, in "IEEE/ACM Trans. Netw.", 2011, vol. 19, n^{o} 5, p. 1458-1471.

[11] F. BACCELLI, P. BERMOLEN. *Extremal versus Additive Matérn Point Processes*, in "Queuing Systems", 2012.

[12] F. BACCELLI, B. BŁASZCZYSZYN, M. O. H. MIRSADEGHI. *Optimal Paths on the Space-Time SINR Random Graph*, in "Advances in Applied Probability", 2011, vol. 43, n^{o} 1, p. 131-150 [*DOI :* 10.1239/AAP/1300198516], http://hal.inria.fr/inria-00433825/en.

[13] F. BACCELLI, S. FOSS. *Poisson Hail on a Hot Ground*, in "Journal of Applied Probability", 2011, vol. 48, n^o 1, http://arxiv.org/abs/1105.2070.

[14] F. BACCELLI, J. LI, T. RICHARDSON, S. SUBRAMANIAN, X. WU, S. SHAKKOTTAI. *On optimizing CSMA for wide area ad-hoc networks*, in "Queuing Systems", 2012.

[15] F. BACCELLI, A. EL GAMAL, D. TSE. *Interference Networks With Point-to-Point Codes*, in "IEEE Transactions on Information Theory", 2011, p. 2582-2596.

[16] C. BORDENAVE, M. LELARGE, J. SALEZ. *The rank of diluted random graphs.*, in "Ann. Probab.", 2011, vol. 39, n^o 3, p. 1097-1121 [*DOI :* 10.1214/10-AOP567], http://hal.inria.fr/hal-00630917/en.

[17] A. BUŠIĆ, J.-M. FOURNEAU. *Iterative component-wise bounds for the steady-state distribution of a Markov chain*, in "Numerical Linear Algebra with Applications", 2011, vol. 18, n^o 6, p. 1031–1049, http://dx.doi.org/10.1002/nla.824.

[18] A. BUŠIĆ, J.-M. FOURNEAU. *Monotonicity and performance evaluation: applications to high speed and mobile networks*, in "Cluster Computing", 2011, Online first, http://dx.doi.org/10.1007/s10586-011-0160-0.

[19] A. BUŠIĆ, I. VLIEGEN, A. SCHELLER-WOLF. *Comparing Markov chains: Aggregation and precedence relations applied to sets of states, with applications to assemble-to-order systems*, in "Mathematics of Operations Research", 2011, to appear.

[20] B. BŁASZCZYSZYN, M. K. KARRAY. *Effect of Opportunistic Scheduling on the Quality of Service Perceived by the Users in OFDMA Cellular Networks*, in "Annales des telecommunications-annals of telecommunications", 2011 [*DOI :* 10.1007/s12243-011-0265-8], http://hal.inria.fr/inria-00590367/en.

[21] CHUNG SHUE. CHEN, K. W. SHUM, C. W. SUNG. *Round-robin power control for the sum rate maximization of wireless networks*, in "European Transactions on Telecommunications", 2011, p. 1–13.

[22] T. V. NGUYEN, F. BACCELLI. *A Stochastic Geometry Model for Cognitive Radio Networks*, in "The Computer Journal", 2011, http://dx.doi.org/10.1093/comjnl/bxr049.

[23] K. I. SRIKANTH, D. YOGESHWARAN. *Percolation and connectivity in AB random geometric graphs*, in "Adv. in Appl. Probab.", 2012, vol. 44, to appear, http://arxiv.org/abs/0904.0223.

International Peer-Reviewed Conference/Proceedings

[24] H. AMINI, M. DRAIEF, M. LELARGE. *Flooding in weighted random graphs*, in "SIAM workshop on Analytic Algorithmics and Combinatorics", 2011, p. 1–15.

[25] F. BACCELLI, J. BOLOT. *Modeling the economic value of the location data of mobile users*, in "INFOCOM", 2011, p. 1467-1475.

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