Activity Report 2013

Project-Team RAP

Networks, Algorithms and Probability

Table of contents

Project-Team RAP

Keywords: Markovian Model, Stochastic Algorithms, Distributed Algorithms, Optical Networks

Creation of the Project-Team: 2004 February 01.

1. Members

Research Scientists
Philippe Robert [Team leader, Inria, Senior Researcher, HdR]
Nicolas Broutin [Inria, Researcher, HdR]
Christine Fricker [Inria, Researcher]

External Collaborators
Pierre Nicodème [CNRS, Researcher, from Jan 2013]
Brigitte Vallee [CNRS, Senior Researcher, until Aug 2013, HdR]
Hanène Mohamed [Univ. Paris X, Associate Professor]
Guilhem Semerjian [ENS Paris, Associate Professor, until Aug 2013]
Danielle Tibi [Univ. Paris VII, Associate Professor]
Yousra Chabchoub [Associate Professor at ISEP]

PhD Students
Renaud Dessalles [INRA, from Dec 2013]
Sarah Eugene [Inria, granted by FP7 BANGMD-ERCSKIPPERAD project, from Sep 2013]
Emanuele Leoncini [INRA]
Nada Sbihi [Doctorant, granted by ANR CONNECT project, until Dec 2013]
Minmin Wang [Doctorant]

Post-Doctoral Fellows
Jelena Pesic [Inria, granted by Min. du Redressement Productif, from Mar 2013]
Henning Sulzbach [Inria, granted by Fondation Sciences Mathématiques de Paris, from Feb 2013]

Visiting Scientist
Yuting Wen [Visiteur, from Jun 2013 until Aug 2013]

Administrative Assistant
Virginie Collette [Inria]

Others
James Roberts [Senior researcher at IRT-SystemX]
Nicolas Servel [Inria, Trainee, from Apr 2013 until Aug 2013]
Juan Pablo Vigneaux Ariztia [Inria, Trainee, from Jan 2013 until Mar 2013]

2. Overall Objectives

2.1. Overall Objectives

The research team RAP (Networks, Algorithms and Communication Networks) was created in 2004 on the basis of a long standing collaboration between engineers at Orange Labs in Lannion and researchers from Inria Paris — Rocquencourt. The initial objective was to formalize and expand this fruitful collaboration.

At France-Telecom R&D in Lannion, the members of the team are experts in the analytical modeling of communication networks as well as on some of the operational aspects of network management concerning traffic measurements on ADSL networks, for example.

At Inria Paris — Rocquencourt, the members of RAP have a recognized expertise in modeling methodologies applied to stochastic models of communication networks.

RAP also has the objective of developing new fundamental tools to investigate *probabilistic* models of complex communication networks. We believe that mathematical models of complex communication networks require a deep understanding of general results on stochastic processes. The two fundamental domains targeted are:

1. Design and analysis of algorithms for communication networks.
2. Analysis of scaling methods for Markov processes: fluid limits and functional limit theorems.

From the very beginning, it has been decided that RAP would focus on a number of particular issues over a period of three or four years. The general goal of the collaboration with Orange Labs is to develop, analyze and optimize algorithms for communication networks. Two domains are currently investigated in the framework of this collaboration:

1. Design of algorithms to allocate bandwidth in optical networks.
2. Content Centric Networks.

3. Research Program

3.1. Design and Analysis of Algorithms

Data Structures, Stochastic Algorithms

The general goal of the research in this domain is of designing algorithms to analyze and control the traffic of communication networks. The team is currently involved in the design of algorithms to allocate bandwidth in optical networks and also to allocate resources in content-centric networks. See the corresponding sections below.

The team also pursues analysis of algorithms and data structures in the spirit of the former Algorithms team. The team is especially interested in the ubiquitous divide-and-conquer paradigm and its applications to the design of search trees, and stable collision resolution protocols.

3.2. Scaling of Markov Processes

The growing complexity of communication networks makes it more difficult to apply classical mathematical methods. For a one/two-dimensional Markov process describing the evolution of some network, it is sometimes possible to write down the equilibrium equations and to solve them. The key idea to overcome these difficulties is to consider the system in limit regimes. This list of possible renormalization procedures is, of course, not exhaustive. The advantages of these methods lie in their flexibility to various situations and to the interesting theoretical problems they raised.

A fluid limit scaling is a particularly important means to scale a Markov process. It is related to the first order behavior of the process and, roughly speaking, amounts to a functional law of large numbers for the system considered.

A fluid limit keeps the main characteristics of the initial stochastic process while some second order stochastic fluctuations disappear. In "good" cases, a fluid limit is a deterministic function, obtained as the solution of some ordinary differential equation. As can be expected, the general situation is somewhat more complicated. These ideas of rescaling stochastic processes have emerged recently in the analysis of stochastic networks, to study their ergodicity properties in particular.

3.3. Structure of random networks

This line of research aims at understanding the global structure of stochastic networks (connectivity, magnitude of distances, etc) via models of random graphs. It consists of two complementary foundational and applied aspects of connectivity.

RANDOM GRAPHS, STATISTICAL PHYSICS AND COMBINATORIAL OPTIMIZATION. The connectivity of usual models for networks based on random graphs models (Erdős–Rényi and random geometric graphs) may be tuned by adjusting the average degree. There is a *phase transition* as the average degree approaches one, a *giant* connected component containing a positive proportion of the nodes suddenly appears. The phase of practical interest is the *supercritical* one, when there is at least a giant component, while the theoretical interest lies at the *critical phase*, the break-point just before it appears.

At the critical point there is not yet a macroscopic component and the network consists of a large number of connected component at the mesoscopic scale. From a theoretical point of view, this phase is most interesting since the structure of the clusters there is expected (heuristically) to be *universal*. Understanding this phase and its universality is a great challenge that would impact the knowledge of phase transitions in all high-dimensional models of *statistical physics* and *combinatorial optimization*.

RANDOM GEOMETRIC GRAPHS AND WIRELESS NETWORKS. The level of connection of the network is of course crucial, but the *scalability* imposes that the underlying graph also be *sparse*: trade offs must be made, which required a fine evaluation of the costs/benefits. Various direct and indirect measures of connectivity are crucial to these choices: What is the size of the overwhelming connected component? When does complete connectivity occur? What is the order of magnitude of distances? Are paths to a target easy to find using only local information? Are there simple broadcasting algorithms? Can one put an end to viral infections? How much time for a random crawler to see most of the network?

NAVIGATION AND POINT LOCATION IN RANDOM MESHES. Other applications which are less directly related to networks include the design of improved navigation or point location algorithms in geometric meshes such as the Delaunay triangulation build from random point sets. There the graph model is essentially fixed, but the constraints it imposes raise a number of challenging problems. The aim is to prove performance guarantees for these algorithms which are used in most manipulations of the meshes.

4. New Results

4.1. Algorithms: Bandwidth Allocation in Optical Networks

Participants: Christine Fricker, Jelena Pesic, Philippe Robert, James Roberts.

The development of dynamic optical switching is widely recognized as an essential requirement to meet anticipated growth in Internet traffic. Since September 2009, RAP has investigated the traffic management and performance evaluation issues that are particular to this technology. Our activity on optical networking is carried out in collaboration with Orange Labs with whom we have a research contract. We have also established contacts with Alcatel-Lucent Bell Labs and had fruitful exchanges with Iraj Saniee and his team on their proposed time-domain wavelength interleaved networking architecture (TWIN).

Our work on access networks proposed an original dynamic bandwidth allocation (DBA) algorithm and demonstrated its excellent performance. This DBA algorithm was then adapted to a meshed metropolitan network based on TWIN and implementing flow-aware resource sharing. Extensions using a concept called "multipath" were shown to offer an energy efficient solution for wide area networks.

In 2013, we contributed to the Celtic Plus project called SASER/SAVENET. This project was approved by the EU in 2012 and funding has been obtained for our participation from the French authorities. The project kickoff meeting was held in November 2012. Our contribution relates to the use of TWIN to create an extended metropolitan optical network. Our partners in the corresponding work package task are Orange, Telecom Bretagne and the engineering school ENSSAT. Overall responsibility for the work package (where alternative optical network architectures are also evaluated) is with Alcatel-Lucent Bell Labs.

In 2013, Inria edited the M12 milestone document of Task 6.4 "TWIN implementations and preliminary MAC protocol specifications". A paper on applying the network architecture and MAC/DBA protocols proposed by the team to the domain of data center interconnects has been submitted.

RAP has continued to work on a two-year research contract with Orange Labs on further developing the multi-path architecture (20012-2013). The main contribution in 2013 has been to propose the use of tunable receivers in addition to tunable transmitters. This technological evolution is possible with recent developments in coherent transmission and offers greater flexibility and enhanced efficiency. Work is continuing on evaluating this architecture by simulation (using Onmet++) and by analytical modelling.

4.2. Algorithms: Content-Centric Networking

Participants: Christine Fricker, Philippe Robert, James Roberts, Nada Sbihi.

RAP participated in an ANR project named CONNECT which contributed to the definition and evaluation of a new paradigm for the future Internet: an information-centric network (ICN) where, rather than interconnecting remote hosts like IP, the network directly manages the information objects that users publish, retrieve and exchange. The project ended in December 2012 but we have continued to work on information-centric networking in 2013.

RAP is participating in an ANR project named CONNECT which contributes to the definition and evaluation of a new paradigm for the future Internet: a content-centric network (CCN) where, rather than interconnecting remote hosts like IP, the network directly manages the information objects that users publish, retrieve and exchange. CCN has been proposed by Van Jacobson and colleagues at the Palo Alto Research Center (PARC). In CCN, content is divided into packet-size chunks identified by a unique name with a particular hierarchical structure. The name and content can be cryptographically encoded and signed, providing a range of security levels. Packets in CCN carry names rather than addresses and this has a fundamental impact on the way the network works. Security concerns are addressed at the content level, relaxing requirements on hosts and the network. Users no longer need a universally known address, greatly facilitating management of mobility and intermittent connectivity. Content is supplied under receiver control, limiting scope for denial of service attacks and similar abuse. Since chunks are self-certifying, they can be freely replicated, facilitating caching and bringing significant bandwidth economies. CCN applies to both stored content and to content that is dynamically generated, as in a telephone conversation, for example. RAP is contributing to the design of CCN in two main areas:

- the design and evaluation of traffic controls, recognizing that TCP is no longer applicable and queue management will require new, name-based criteria to ensure fairness and to realize service differentiation;
- the design and evaluation of replication and caching strategies that realize an optimal trade-off of expensive bandwidth for cheap memory.

The team also contributes to the development of efficient forwarding strategies and the elaboration of economic arguments that make CCN a viable replacement for IP. CONNECT partners are Alcatel-Lucent (lead), Orange, Inria/RAP, Inria/PLANETE, Telecom ParisTech, UPMC/LIP6.

A paper describing a proposed flow-aware approach for CCN traffic management and its performance evaluation has been presented at the conference Infocom 2012. We have reviewed the literature on cache performance (dating from early work on computer memory management) and identified a practical and versatile tool for evaluating the hit rate (proportion of requests that are satisfied from the cache) as a function of cache size and the assumed object popularity law. This approximate method was first proposed in 2002 by Che, Tung and Wang for their work on web caching. We applied this approximation to evaluate CCN caching performance taking into account the huge population and diverse popularity characteristics that make other approaches ineffective. The excellent accuracy of this method over a wide range of practically relevant traffic models has been explained mathematically. CONNECT ends in December 2012. We are currently defining a new project proposal that should be submitted to the ANR INFRA call in February 2013.

4.3. Scaling Methods: Fluid Limits in Wireless Networks

Participant: Philippe Robert.

This is a collaboration with Amandine Veber (CMAP, École Polytechnique). The goal is to investigate the stability properties of wireless networks when the bandwidth allocated to a node is proportional to a function of its backlog: if a node of this network has x requests to transmit, then it receives a fraction of the capacity proportional to $\log(1 + x)$, the logarithm of its current load. A fluid scaling analysis of such a network is presented. We have shown that the interaction of several time scales plays an important role in the evolution of such a system, in particular its coordinates may live on very different time and space scales. As a consequence, the associated stochastic processes turn out to have unusual scaling behaviors which give an interesting fairness property to this class of algorithms. A heavy traffic limit theorem for the invariant distribution has also been proved. A generalization to the resource sharing algorithm for which the $\log$ function is replaced by an increasing function.

This year we completed the analysis of a star network topology with multiple nodes. Several scalings were used to describe the fluid limit behaviour.

4.4. Stochastic Modeling of Biological Networks

Participants: Emanuele Leoncini, Philippe Robert.

This is a collaboration with Vincent Fromion from INRA Jouy en Josas, which started on October 2010.

The goal is to propose a mathematical model of the production of proteins in prokaryotes. Proteins are biochemical compounds that play a key role in almost all the cell functions and are crucial for cell survival and for life in general. In bacteria the protein production system has to be capable to produce abut 2500 different types of proteins in different proportions (from few dozens for the replication machinery up to 100000 for certain key metabolic enzymes). Bacteria uses more than the 85% of their resources to the protein production, making it the most relevant process in these organisms. Moreover this production system must meet two opposing problems: on one side it must provide a minimal quantity for each protein type in order to ensure the smooth-running of the cell, on the other side an "overproduction policy" for all the proteins is infeasible, since this would impact the global performance of the system and of the bacterium itself.

Gene expression is intrinsically a stochastic process: gene activation/deactivation occurs by means the encounter of polymerase/repressor with the specific gene, moreover many molecules that take part in the protein production act at extremely low concentrations. We have restated mathematically the classical model using Poisson point processes (PPP). This representation, well-known in the field of queueing networks but, as far as we know, new in the gene expression modeling, allowed us to weaken few hypothesis of the existing models, in particular the Poisson hypothesis, which is well-suited in some cases, but that, in some situations, is far from the biological reality as we consider for instance the protein assemblage.

The theoretical environment of Poisson point processes has lead us to propose a new model of gene expression which captures on one side the main mechanisms of the gene expression and on the other side it tries to consider hypothesis that are more significant from a biological viewpoint. In particular we have modeled: gene activation/deactivation, mRNA production and degradation, ribosome attachment on mRNA, protein elongation and degradation. We have shown how the probability distribution of the protein production and the protein lifetime may have a significant impact on the fluctuations of the number of proteins. We have obtained analytic formulas when the duration of protein assemblage and degradation follows a general probability distribution, i.e. without the Poisson hypothesis. In particular, by using a PPP representation we have been able to include the deterministic continuous phenomenon of protein degradation, which is the main protein degradation mechanism for stable proteins. We have showed moreover that this more realistic description is surprisingly identical in distribution with the classic assumption of protein degradation by means of a degrading protein (*proteosome*). We have used our model also to compare the variances resulting by choosing different hypotheses for the probability elongation, in particular we have hypothesize the protein assembly to be deterministic. This assumption is justified because of the elongation step, which consists of a large number of elementary steps, can be described by the sum of exponential steps and the resulting distribution is well approximated by a Gaussian distribution because of the central limit theorem. Under the hypothesis of small variance of the resulting Gaussian distribution, we can assume the elongation step to be deterministic. The

model has showed how, under the previous hypothesis, the variance on the number of proteins is bigger than the classical model with the Poisson hypothesis.

We have developed a C++ stochastic simulator for our general model, which has allowed the computation of variance when it was not possible to derive explicit analytic close formulas and the simulation of some extension of the actual model.

This year we have investigated a mathematical model of the production of proteins in prokaryotic cells. Up to now most of the mathematical used to study these problems concern the production of *one* fixed class of proteins. When several classes of proteins are considered, each class requires in fact a fraction of the common and limited resources of the cell. One has therefore to understand how the allocation of the resources within the cell is done. Due to the fact that the cytoplasm of the cell is a quite disorganized medium where the components of the cell move, the whole production process has an important stochastic component. A model describing the allocation of the ribosomes of the cell to produce proteins is investigated via a Markovian representation. Asymptotic results for the equilibrium and for the transient behavior have been obtained under a scaling procedure and a reasonable biological assumption of saturation, i.e. when resources of the cell are tight. The equilibrium and the transient behavior have been investigated, it has been shown in particullar that, in the limit, the number of free ribosomes converges in distribution to a Poisson distribution whose parameter satisfies a fixed point equation.

4.5. Stochastic networks: large bike sharing systems

Participants: Christine Fricker, Hanène Mohamed, Nicolas Servel.

This is a collaboration with Nicolas Gast (EPFL). Bike sharing systems were launched by numerous cities to be a urban mode of transportation, for example Velib in Paris. One of the major issues is the availability of the resources: bikes or free slots to return the bikes. These systems became a hot topic in Operation Research and now the importance of stochasticity of such system behavior is commonly admitted. The problem is to understand their behavior and how to manage them in order to provide both resources to users.

Our model is the first one taking into account the finite number of spots at the stations. In a homogeneous model, mean field limit theorems give the dynamic of a large system. Analytical results are obtained and convergence proved in a standard model via Lyapunov functions. It allows to find the best ratio of bikes per station and to measure the improvement of incentive mechanisms, as choosing among two stations for example. We investigate also redistribution of bikes by trucks. Further results deal with heterogeneous system. By mean field techniques, analytical results were recently obtained on systems consisting in several clusters. In a work with Nicolas Servel, we discuss the improvement of choosing between two stations in the same cluster. Our goal is to propose, via a theoretical study and tests, simple algorithms to improve the system behavior.

With Hanene Mohamed, we study the problem of impact of geometry on incentive mechanisms. Our first model under investigation is very close from the Gates-Westcott crystal growth model with its underlying random deposition process.

4.6. Random Graphs

Participants: Nicolas Broutin, Henning Sulzbach.

4.6.1. *Connectivity in models of wireless networks*

This is joint work with S. Boucheron (Paris 7), L. Devroye (McGill), N. Fraiman (McGill), and G. Lugosi (Pompeu Fabra).

The traditional models for wireless networks rely on geometric random graphs. However, if one wants to ensure that the graph be fully connected the radius of influence (hence the power necessary, and number of links) is too large to be fully scalable. Recently some models have been proposed that skim the neighbours and only retain a random subset for each node, hence creating a sparser overlay that would hopefully be more scalable. The first results on the size of the subsets which guarantee connectivity of overlay (the irrigation graph) confirm that the average number of links per node is much smaller, but it remains large. These results motivate further investigations on the size of the largest connected component when one enforces a constant average degree which are in the process of being written.

4.6.2. *Random graphs and minimum spanning trees*

This is a long term collaboration with L. Addario-Berry (McGill), C. Goldschmidt (Oxford) and G. Miermont (ENS Lyon).

The random graph of Erdős and Rényi is one of the most studied models of random networks. Among the different ranges of density of edges, the "critical window" is the most interesting, both for its applications to the physics of phase transitions and its applications to combinatorial optimization (minimum spanning tree, constraint satisfaction problems). One of the major questions consists in determining the distribution of distances between the nodes. A limit object (a scaling limit) has been identified, that allows to describe precisely the first order asymptotics of pairwise distances between the nodes. This limit object is a random metric space whose definition allows to exhibit a strong connection between random graphs and the continuum random tree of Aldous. A variety of questions like the diameter, the size of cycles, etc, may be answered immediately by reading them on the limit metric space.

In a stochastic context, the minimum spanning tree is tigthly connected to random graphs via Kruskal's algorithm. Random minimum spanning trees have attracted much research because of their importance in combinatorial optimization and statistical physics; however, until now, only parameters that can be grasped by local arguments had been studied. The scaling limit of the random graphs obtained permits to describe precisely the metric space scaling limit of a random minimum spanning tree, which identifies a novel continuum random tree which is truely different from that of Aldous.

4.6.3. *Analysis of recursive partitions*

This is joint work with R. Neininger (Frankfurt)

The techniques that we developed in order to estimate the cost of partial match queries in random quad trees have been used to solve an open question about the recursive lamination of the disk. We have proved that the planar dual of the lamination, which is a tree, converges almost surely when suitably rescaled to a compact random tree encoded by a continuous function. We also pinned down the fractal dimension of the limit object.

5. Bilateral Contracts and Grants with Industry

5.1. Contracts

- CRE with Orange Labs " Dynamical Optical Networking in the Internet". Contract on bandwidth allocation algorithm in optical networks. Duration 2 years starting from 01/01/12.

- CELTIC-Plus Saser "Safe and Secure European Routing" submitted. RAP participates in the section on optical networks. Participants include Orange labs, Alcatel-Lucent, Telecom Institute, ENSSAT as well as a number of German laboratories. Duration three years.

- ANR Project "CONNECT: Content-Oriented Networking: a New Experience for Content Transfer". The proposal submitted to the VERSO programme has been accepted. The planned starting date is January 2011 and the project is scheduled to last 2 years. The lead partner is Alcatel-Lucent Bell Labs France and the other partners are RAP, Inria/PLANETE, Orange LAbs, TelecomParisTech, UPMC.

- PGMO project "Systèmes de véhicules en libre-service: Modélisation, Analyse et Optimisation" with G-Scop (CNRS lab, Grenoble) and Ifsttar. From 1 to 3 years. Starting at 1/10/2013.
- The ANR Boole contract (Models for random Boolean functions and applications) has been transferred from the Algorithms project, and the funding will last until August 2013.
- PhD grant CJS (Contrat Jeune Scientifique) Frontières du vivant of INRA for Emanuele Leoncini.
- PhD grant CJS (Contrat Jeune Scientifique) Frontières du vivant of INRA for Renaud Dessalles.

5.2. Bilateral Grants

- A bilateral project PHC Tournesol funded by Campus France (formerly Egide) will cover the costs of exchanges between *Nicolas Broutin* and Stefan Langerman (FNRS, UL Brussels). The topic of the collaboration is coloration of random hypergraphs for channel assignment in networks.

6. Partnerships and Cooperations

6.1. International Research Visitors

RAP team has received the following people:

- Louigi Addario-Berry (McGill)
- Jit Bose (Carleton)
- Vida Dujmovic (Carleton)
- Christina Goldschmidt (Oxford)
- Stefan Langerman (UL Bruxelles)
- Gabor Lugosi (Pompeu Fabra)
- Cecile Mailler (UVSQ)
- Kavita Ramanan (Brown)
- Yuting Wen (McGill)

6.2. National Research Visitors

RAP team has received the following people:

- Thomas Bonald (Telecom ParisTech, Paris)
- Fabrice Guillemin (Orange Labs)
- Esther le Rouzic (Orange Labs)

7. Dissemination

7.1. Leadership within scientific community

Christine Fricker is member of the jury of agrégation.

Philippe Robert is Associate Editor of the Book Series "Mathématiques et Applications" edited by Springer Verlag and Associate Editor of the journal "Queueing Systems, Theory and Applications". He is member of the scientific council of EURANDOM. He is also associate Professor at the École Polytechnique in the department of applied mathematics where he is in charge of lectures on mathematical modeling of networks.

James Roberts is a Fellow (membre émérite) of the SEE. He is an associate editor of IEEE Transactions on Networking.

7.2. Teaching

Nicolas Broutin has taught at the Master Parisien de Recherche en Informatique (MPRI), in the course 2.15 on Analysis of Algorithms. He also gave a series of tutorials on the continuum random tree at the Adama summer school in Mahdia, Tunisia.

Christine Fricker is member of the jury of agrégation.

Philippe Robert gives Master2 lectures in the laboratory of the Probability of the University of Paris VI. He is also giving lectures in the "Programme d'approfondissement de Mathématiques Appliquées et d'Informatique" on Networks and Algorithms at the École Polytechnique.

7.3. Conference and workshop committees, invited conferences

Nicolas Broutin is member of the steering committee of the international meeting on analysis of algorithms (AofA).

Nicolas Broutin has given invited lectures at annual meeting of the ANR presage, the annual meeting of the workgroup ALEA of the GDR-Im, and at the Oberwolfach workshop on extremes of branching random walk and branching Brownian motion. He has presented his results in seminars to the complex networks team at LIP6, in Paris X Nanterre, Nancy, ETH Zürich, Bell Labs France, and Frankfurt university. He has visited the computer science department of UL in Brussels, the mathematics institute of the Universität Zürich and of the mathematics institute of the Universität Frankfurt.

Nicolas Broutin has defended and obtained the HDR in July.

Philippe Robert has been a member of the technical programme committee of the conferences ACM Sigmetrics(2013) ICCCN (2013). He gave a talk at the PDMP workshop in Rennes in May. He gave an invited conference at the workshop "Modern probabilistic techniques for stochastic systems and networks" in Cambridge in August 2013 and in Eindhoven at the occasion of the 15th anniversary on December 11.

James Roberts was a member of the technical programme committee of the following conferences: NOMEN, CoNext, ITC. He gave keynote talks at Infocom (March), SaCoNeT (June) and ValueTools (December), invited talks at Rescom (February), Bell Labs France (October) and AINTEC (November), and a tutorial at ITC 25 (September).

8. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] N. BROUTIN. , *Random trees, graphs and recursive partitions*, Université Pierre et Marie Curie - Paris VI, July 2013, Habilitation à Diriger des Recherches, http://hal.inria.fr/tel-00842019

[2] E. LEONCINI. , *Vers une compréhension globale et systémique de la production des protéines chez les procaryotes*, Ecole Polytechnique X, December 2013, http://hal.inria.fr/pastel-00924232

Articles in International Peer-Reviewed Journals

[3] N. BROUTIN, R. NEININGER, H. SULZBACH. *A limit process for partial match queries in random quadtrees and 2-d trees*, in "Annals of Applied Probability", 2013, vol. 23, pp. 2560-2603 [*DOI :* 10.1214/12-AAP912], http://hal.inria.fr/hal-00773363

[4] M. FEUILLET, P. ROBERT. *A Scaling Analysis of a Transient Stochastic Network*, in "Advances in Applied Probability", 2014, vol. 46, n⁰ 2, http://hal.inria.fr/hal-00684697

[5] V. FROMION, E. LEONCINI, P. ROBERT. *Stochastic Gene Expression in Cells: A Point Process Approach*, in "SIAM Journal on Applied Mathematics", 2013, vol. 73, n° 1, pp. 195-211 [*DOI :* 10.1137/120879592], http://hal.inria.fr/hal-00708096

International Conferences with Proceedings

[6] J. ROBERTS, N. SBIHI. *Exploring the Memory-Bandwidth Tradeoff in an Information-Centric Network*, in "ITC 25 - 25th International Teletraffic Congress", Shanghai, China, September 2013, http://hal.inria.fr/hal-00870506

Research Reports

[7] N. BROUTIN, O. DEVILLERS, R. HEMSLEY. , *Efficiently Navigating a Random Delaunay Triangulation*, Inria, February 2014, n^o RR-8464, 46 p. , http://hal.inria.fr/hal-00940743

Other Publications

[8] L. ADDARIO-BERRY, N. BROUTIN, C. GOLDSCHMIDT, G. MIERMONT. , *The scaling limit of the minimum spanning tree of the complete graph*, 2013, 60 p. , http://hal.inria.fr/hal-00773360

[9] J. ROBERTS. *The Cloud is the future Internet: how can we engineer a cloud?*, in "Infocom 2013 - 32nd IEEE International Conference on Computer Communications", Torino, Italy, April 2013, http://hal.inria.fr/hal-00815959