TREC 2003–2011

THEORIE DES RESEAUX ET COMMUNICATIONS
http://www.di.ens.fr/~trec

INRIA/ENS/CNRS

Conseil Scientifique du DI, 11–12 Mai 2011
SUMMARY

1. Context
2. Staff
3. Research
4. Teaching
5. Future
TREC: Context

Since its creation in 2001,
- Research Group of Département d’Informatique of ENS
- EPI of INRIA Paris–Rocquencourt Networks, Systems and Services, Distributed Computing/Networks

From January 1, 2008:
- Part of the CNRS-ENS-INRIA UMR of ENS

Located at
- Ecole Normale Supérieure until 2009,
- INRIA Place d’Italie since 2009,
- Place d’Italie, 4 & 5 from 2010 (in connection with the foundation of the LINCS laboratory).
## TREC: Scientific Staff beginning of 2011

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<th>ENS</th>
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TREC: Members, 2010

Hélène Milome Adm. INRIA
Hamed Amini Ph.D. AMX → EPFL
François Baccelli DR INRIA
Bartek Błaszczyszyn DR INRIA
Florence Bénézit Posdoc ANR–ENS
Pierre Brémaud Scientific Adviser
Anne Bouillard MdC ENS, from Sept. 10
Ana Busic CR INRIA
Calvin Chen Postoc INRIA–ALU → Bell Labs
Emilie Coupechoux Ph.D. P7
Yogeshwaran Dhandapani Postdoc. EADS → Technion
Nadir Fahri Postdoc. ANR → IRST
Bruno Kauffmann Ph.D. AMN → FT Labs
Matthieu Leconte CIFRE Technicolor
Marc Lelarge CR INRIA
Mir Omid Mirsadeghi Ph.D. INRIA–Sharif
Frédéric Morlot Part time Ph.D. (FT)
Tien Viet Nguyen Ph.D. AMN
Van Minh Nguyen Ph.D. Cifre ALU–INRIA → Ericsson
Ilkka Norros Invited Professor, VTT (ICT Labs)
Justin Salez Ph.D. AMN → UC Berkeley
Darryl Veitch Invited Professor, INRIA
TREC: Former Members

- **Former Permanent Members**
  - Thomas Bonald (FT) → FT R& D → Telecom ParisTech
  - Dohy Hong (INRIA) → N2Nsoft, France,
  - Ki-Baek Kim (ALCATEL) → Samsung, Research, S-Korea,

- **Former Postdocs**
  - Prasanna Chaporkar → Assistant professor at the IIT Bombay, India,
  - Vivek Mhatre → Bell Laboratories Bangalore, India, → Motorola Labs USA.
  - Božidar Radunović → Microsoft Research Cambridge, UK.
Former Ph.D. Students

- Paola Bermolen: **Prof. Univ. Montevideo**, Uruguay
- Charles Bordenave: **Postdoc Berkeley → CR CNRS**
- Giovanna Carofiglio: **Researcher at Bell Laboratories Fr**
- Augustin Chaintreau: **Technicolor Labs, Fr → Prof. Columbia Univ. USA**
- Matthieu Jonkheere: **Prof. Univ. Eindhoven, NL → Prof. Univ. Buenos Aires, Arg.**
- Quynh Nguyen: **Ernst–Young**
- Julien Reynier: **Motorola Labs → Crédit Suisse, London**
- Emmanuel Roy: **Prof. Univ. Paris 13**
- Minh Anh Tran: **Postdoc Stanford → Prof. Univ. Paris 12**
Mathematics of Networks

Three main research directions, at the interface between mathematics and CS

1. Theory of network dynamics (TND) ↓ ↔ ↑
2. Stochastic geometry and information theory (SG) ↑ ↔ ↔
3. Random graphs (RG) ↔ ↑ ↑
Research 1: Theory of Network Dynamics

- Topics, initially based on algebraic framework for network dynamics:
  - Rare Events in Stochastic Networks, [03,07]
  - Congestion Control, [03,09] → contribution to Alcatel’s DSLAM design
  - Inverse Problems, [06,11] → contribution to active Internet probing, ANR project
  - Network Calculus, [10,11] → ANR project
  - Simulation, [03,04] → Startup on discrete event simulation, [10,11] → PEPS INS2I project on perfect simulation
**ZOOM 1.1: Exact Worst-Case Performance Bounds**

**Network calculus:** computing guaranteed performance bounds in networks based on the $(\min,\plus)$ algebra and on the propagation on flow constraints.

\[
\begin{align*}
A_i, \alpha_i & \quad \beta \quad B_i, f(\beta, \{\alpha_j\}) \\
\end{align*}
\]

$(\min,\plus)$ algebra $\rightarrow$ over-pessimistic
linear programming $\rightarrow$ achievable bounds

- tandem networks: polynomial algorithm;

A. Bouillard, INFOCOM 10
The buffers capacity is small compared to the packet sizes ⇒ can create interblockings.

- introduction of the notion of packet curves;
- generalization of the feedback control.

■ Ongoing work with Thales (ANR)
ZOOM 1.2: Perfect Simulation

- Provides an unbiased sample from the stationary distribution of an ergodic Markov chain.
- **Difficulty:** state space explosion problem.
- Detection of coupling without considering all initial states.
ZOOM 1.2: Results of A. Busic

- **Theory:**
  - Envelope Perfect Sampling (non-monotone case).
  - Bounds on the coupling time.
  - How to sample faster than the coupling time?

- **Applications:**
  * performance of queueing networks;
  * sampling of combinatorial objects (ANR MAGNUM).

- **Software:**
  * CAPS - envelope simulation for queueing networks Furcy Pin (ENS);
  * EPCA - simulation tool for probabilistic cellular automata.
Research 2: Stochastic Geometry and Information Theory

- Topics, based on IT type fundamental limitations:
  - **Stochastic comparison**, [08,11] thanks to a grant from EADS
  - **Gibbs’ Self Optimization**, [05] with INTEL and [09,11] → transfer to ALU
  - **Error Exponents in IT**, [08,11] → INRIA–UC Berkeley project
ZOOM 2: (F.B. and B.B) SINR SG IN A NUTSHELL

- Interference $\leftrightarrow$ Shot Noise Fields (Stochastic Geometry)
- MAC Contention $\leftrightarrow$ Gibbs Fields (Statistical Physics)
- Connectivity $\leftrightarrow$ Percolation (Random Graphs)
- Routing $\leftrightarrow$ First Passage Percolation (Random Graphs)
ZOOM 2: ACADEMIC IMPACT

- Academia groups now working in the field
  - Chalmers U.
  - Karlsruhe IT
  - Notre Dame U.
  - U.C. Berkeley
  - U. Minnesota
  - U.T. Austin
  - Stanford U.
  - Yonsei U. (Korea)

- DARPA ITMANET
- NOW Books
- Special Issue of J. Selected Areas in Communications
ZOOM 2: INDUSTRY IMPACT OF SINR SG

Industry

- **Alcatel Lucent**: Gibbsian Self Organization in Cellular Networks; 2 patents, joint papers, one demonstrator planned prototype for LTE.

- **Technicolor**: Gibbsian Self Organization in Mesh Networks; 1 patent, joint papers, one demonstrator.

- **Orange**: Dimensioning of CDMA Cellular Networks; 3 patents, several joint papers, SERT and UTRANDIM Software.

- **Qualcomm**: Ongoing joint work on FlasLink, joint papers.
ZOOM 2: NETWORK–INFORMATION–THEORY SG

- Considers a “gas” of transmitter-receiver pairs and analyzes ensemble averages from local IT interactions between them
- Refrains from treating interference as noise
- Evaluates ensemble averages over large random populations of transmitters and receivers for each Network–IT paradigm
- Provides macroscopic laws for a systematic comparison/optimization of the basic architecture/protocol options.
- Leverages time/space fluctuations to produce adaptive and scalable protocols
ZOOM 2: MAC Simultaneous Decoding Example

- The tagged transmitter and the tagged receiver are at a distance $r_0$ from each other.
- The strong interferers are within a distance of $r_0$ from the tagged receiver.
- The strong interferers and the tagged transmitter form a MAC with Simultaneous Decoding

F.B. A. El Gamal, D. Tse, IEEE TR. IT 11
ZOOM 2: A RECENT RESULT

- **Setting** A Poisson network on the Euclidean plane with density $\lambda$
  - Some shared bandwidth $B$
  - Some required rate per user
  - Channel path loss exponent: $\beta > 2$

- **Result** as the bandwidth $B$ grows:
  - The density $\lambda$ that can be supported by treating interference as noise can scale **no faster than** $B^{2/\beta}$
  - The density $\lambda$ that can be supported by using simultaneous decoding can scale **linearly with** $B$. 

TREC
Multimedia traffic accessed via the Internet: already order of $10^{18}$ bytes per month

Example: Video-on-Demand application: critical resources at the servers are storage space and bandwidth

Objective: Content placement strategies which maximally offload data centers and adjust to the popularity of contents
ZOOM 3: Graph Structures for Efficient Balancing

- **Storage space:** server 1 stores contents $A, B, C, D, E$.
- **Bandwidth:** each server can serve only one request per content.
- **Allocation:** subgraph with degree constraints.
- **How to design a graph** in a decentralized way in order to allow a maximal allocation knowing only the statistics on the content requests?
ZOOM 3: Mathematical Tools

- **Random graphs**: each server chooses its cache independently (thesis of Émilie Coupechoux: random hypergraphs)

- **Local weak convergence**: Nb of servers and contents $\to \infty$ while the degrees (i.e. cache sizes) are bounded (coll. Charles Bordenave [08-.])

- **Combinatorial Optimization**: allocation = generalization of matching (thesis of Justin Salez: interplay with LWC)

- **Statistical physics**: study of Gibbs measure = rigorous formulation of the ’cavity method’ (coll. Guilhem Semerjian ENS Physics)
A first step with Mathieu Leconte PhD CIFRE and Laurent Massoulié (TECHNICOLOR)

- Analytic formula for the asymptotic size and structure of the optimal allocation.

- A popular strategy, proportional placement, is outperformed by uniform placement in many cases!

- Optimization problem for the optimal graph. Not convex, currently under investigation...
ZOOM 3:... and Some Perspectives

- Adding capacity to the servers?
- Decentralized algorithm building an optimal graph?
- Dynamic vs Static: what happens when requests arrive and leave? Queueing?
- Algorithm building the cache while learning the popularities? coupling it with the social graph?
- Game theory perspective: what happen if servers are selfish? how to incentivize reciprocity?
- Peer-to-Peer architectures to support growth more cheaply than by scaling up the size of data centers.
TREC: Interplay Between the Three Research Directions

- TND plays a key role in the "time space" branch of SG
- RG and SG have a rich interface
- Many tools are common to TND and SG: point processes, ergodic theory, Markov chains, perfect simulation
- Books 5 (including 2 second editions),
- IEEE CDC, DYSPAN, INFOCOM 15, ISIT 2, ICC, ACM IMC, Sigmetrics 4, Sigcomm, IFIP Performance, WMNC, ITC, QEST, SODA.
- Patents, 7.
TREC: Teaching

- Paris Universities
  - Graduate Course (M2) at MPRI on Dynamics and Algorithms of Communication Networks
  - Graduate Course (M2) on Point processes, stochastic geometry and random graphs (Master de Sciences et Technologies de Paris 6),

- Ecole Normale Supérieure
  - (L3) on Applied Probability
  - (L3) on Information Theory
  - (L3) on Communication Networks
TREC: Ongoing Structured Collaborations

- **FT** (Bartek) SG
- **Technicolor** (Marc) RG
- **ALU** (François) SG
- **ANR CMON** (Darryl and François) TND
- **ANR PEGASE** (Anne) TND
- **ARC** (Ana, starting) TND
- **Qualcomm** (François, starting) SG
- **UC Berkeley** (Bartek and François, starting) SG
- **NoE EuroNF** all
- **EIT ICT Labs** SG

- Partial participation in **ANR MAGNUM, Digiteo**
TREC’s Future – Global

- Tension between
  - The necessity of a **broader scientific scope** for the needs of ENS students
  - The necessity of a **more narrow scope** for the needs of INRIA (for INRIA, **TREC ends in 2012** and should redefine its structure and scope w.r.t. the other INRIA groups).

- Tension between
  - The potential **absorption by mathematics**, eg through the development of the **Maths-CS** curriculum at ENS
  - The potential **absorption by engineering**, eg through the creation of the **LINCS** laboratory