



IN PARTNERSHIP WITH:
Université Rennes 1

Activity Report 2015

Project-Team DIONYSOS

Dependability Interoperability and
performance aNalYsiS Of networkS

IN COLLABORATION WITH: Institut de recherche en informatique et systèmes aléatoires (IRISA)

RESEARCH CENTER
Rennes - Bretagne-Atlantique

THEME
Networks and Telecommunications

Table of contents

1. Members	1
2. Overall Objectives	2
3. Research Program	3
3.1. Introduction	3
3.2. Quality of Service and Quality of Experience	3
3.3. Stochastic modeling	4
4. Highlights of the Year	4
5. New Software and Platforms	5
5.1. IPv6 Test Toolkit	5
5.2. Passive Test Tool	5
5.3. T3DevKit	5
5.4. Interoperability Assessment	6
5.5. Performance and dependability evaluation	6
6. New Results	7
6.1. Quality of Experience	7
6.2. Analytic models	8
6.3. Performance Evaluation of Distributed Systems	9
6.4. Wireless Networks	10
6.5. Future networks and architectures	12
6.6. Network Economics	13
6.7. Monte Carlo	14
7. Bilateral Contracts and Grants with Industry	15
7.1. Bilateral Contract with Industry: ALSTOM-Inria Common Lab	15
7.2. Bilateral Contract with Industry: Participation in a CRE with Orange	16
7.3. Cifre contract on Device-Assisted Distributed Machine-Learning on Many Cores	16
7.4. Cifre contract on Small Cell Networks	16
7.5. Cifre contract on SDN for 5G mobile networks	16
7.6. DGA Grant	16
7.7. DVD2C	16
7.8. Cifre contract on a dynamic adaptive service-driven SDN architecture	17
7.9. Cifre contract on defining an open, a flexible and a unified network architecture	17
7.10. Camion	17
8. Partnerships and Cooperations	17
8.1. National Initiatives	17
8.2. European Initiatives	17
8.2.1. FINTEROP	17
8.2.2. QuEEN project	18
8.2.3. Collaborations with Major European Organizations	18
8.3. International Initiatives	18
8.3.1. CIRIC	18
8.3.2. MANAP	18
8.3.3. Inria International Partners	19
8.3.3.1. MOCQUASIN	19
8.3.3.2. Informal International Partners	19
8.3.4. Participation in other International Programs	19
8.4. International Research Visitors	20
9. Dissemination	20
9.1. Promoting Scientific Activities	20
9.1.1. Scientific events organisation	20

9.1.2. Scientific events selection	21
9.1.2.1. Chair of conference program committee	21
9.1.2.2. Member of the conference program committees	21
9.1.2.3. Reviewer	22
9.1.3. Journal	22
9.1.3.1. Member of the editorial boards	22
9.1.3.2. Reviewer - Reviewing activities	23
9.1.4. Invited talks	23
9.1.5. Research administration	24
9.2. Teaching - Supervision - Juries	24
9.2.1. Teaching	24
9.2.2. Supervision	25
9.2.3. Juries	26
9.3. Popularization	27
10. Bibliography	27

Project-Team DIONYSOS

Creation of the Project-Team: 2009 January 01

Keywords:

Computer Science and Digital Science:

- 1.2.4. - QoS, performance evaluation
- 1.3. - Distributed Systems
- 2.4.1. - Analysis
- 3.4.1. - Supervised learning
- 3.4.6. - Neural networks
- 6.2.2. - Numerical probability
- 6.2.3. - Probabilistic methods
- 6.2.4. - Statistical methods
- 7.11. - Performance evaluation
- 7.2. - Discrete mathematics, combinatorics
- 7.3. - Operations research, optimization, game theory

Other Research Topics and Application Domains:

- 1.3.1. - Understanding and simulation of the brain and the nervous system
- 6.2.1. - Wired technologies
- 6.2.2. - Radio technology
- 6.3.2. - Network protocols
- 6.3.3. - Network services
- 6.4. - Internet of things

1. Members

Research Scientists

- Gerardo Rubino [Team leader, Inria, Senior Researcher, HdR]
- Pierre L'Ecuyer [Inria, Advanced Research position]
- Bruno Sericola [Inria, Senior Researcher, HdR]
- Bruno Tuffin [Inria, Senior Researcher, HdR]

Faculty Members

- Yassine Hadjadj-Aoul [Univ. Rennes I, Associate Professor]
- Adlen Ksentini [Univ. Rennes I, Associate Professor, HdR]
- Raymond Marie [Univ. Rennes I, Emeritus, HdR]
- César Viho [Univ. Rennes I, Professor, HdR]
- Yann Busnel [external member, assistant professor at ENSAI; from April 2015]

Engineers

- Pantelis Frangoudis [Univ. Rennes I, granted by Min. de l'Economie]
- Federico Sismondi [Univ. Rennes I, from Dec 2015]
- Thiago Wanderley Matos de Abreu [Univ. Rennes I]

PhD Students

- Imad Alawe [TDF, from Nov 2015, granted by CIFRE]
- Osama Arouk [Scholarship from Syrian gov.]

Hamza Ben Ammar [Univ. Rennes I, from Mar 2015]
Btissam Er-Rahmadi [France Telecom, granted by CIFRE]
Corentin Hardy [Inria]
Nicolas Jara Carvallo [Scholarship from Chilian gouv.; from Sep 2015]
Yue Li [Orange Labs, granted by CIFRE]
Farouk Messaoudi [Inst. de Recherche Technologique B-COM]
Yves Mocquard [Univ. Rennes I, from Mar 2015]
Quang Pham Tran Anh [Univ. Rennes I]
Ajit Rai [ALSTOM, U. of Rennes 1, from May 2015, granted by CIFRE]
Jean-Michel Sanner [Orange Labs]
Louiza Yala [Univ. Rennes I, from Oct 2015]

Visiting Scientists

Miloud Bagaï [ERCIM]
Marta Barria [U. of Valparaíso, Chile]
Meriem Bouzouita [Supcom, Tunisia]
Hector Cancela [UDELAR, Uruguay]
Yassine Douga [University of Oran, Algeria]
Jorge Graneri [UDELAR, Uruguay]
Djamel-Heddine Henni [University of Oran, Algeria]
Mauro Martínez Visozo [UDELAR, Uruguay]
Leslie Murray [U. of Rosario, Argentina]
Matias Valdes Dini [UDELAR, Uruguay]
Reinaldo Vallejos [UTFSM, Chile]

Administrative Assistant

Fabienne Cuyollaa [Inria]

2. Overall Objectives

2.1. Overall objectives

The main objectives of the project are the identification, the conception and the selection of the most appropriate network architectures for a communication service, as well as the development of computing and mathematical tools for the fulfillment of these tasks. These objectives lead to two types of complementary research fields: the systems' qualitative aspects (e.g. protocol testing and design) and the quantitative aspects which are essential to the correct dimensioning of these architectures and the associated services (performance, dependability, Quality of Service (QoS), Quality of Experience (QoE) and performability).

The DIONYSOS group works on different problems related to the design and the analysis of communication services. Such services require functionality specifications, decisions about where and how they must be deployed in a system, and the dimensioning of their different components. The interests of the project concern not only particular classes of systems but also methodological aspects.

Concerning the communication systems themselves, we focus on IP networks, at different levels. Concerning the types of networks considered, we mainly work in the wireless area, in particular on sensor networks, on Content Delivery Networks for our work around measuring the perceived quality, the main component of QoE, and on some aspects of optical networks. We also work on the assessment of interoperability between specific network components, which is essential to ensure that they interact correctly before they get deployed in a real environment. Our team contributes in providing solutions (methods, algorithms and tools) which help in obtaining efficient interoperability test suites for new generation networks. From the application point of view, we also have activities in network economics methodologies, a critical multi-disciplinary area for telecommunications providers, with many defying open problems for the near future.

For most of previous mentioned problems, our work concern their quantitative aspects. The quantitative aspects we are interested in are QoE, performance, dependability, performability, QoS, vulnerability, etc. We develop techniques for the evaluation of these different aspects of the considered systems through *models* and through *measurement techniques*. In particular, we develop techniques to measure in an automatic way the quality of a video or audio communication *as perceived by the final user*. The methods we work with range from discrete event simulation and Monte Carlo procedures to analytical techniques, and include numerical algorithms as well. Our main mathematical tools are stochastic processes in general and queuing models and Markov chains in particular, optimization techniques, graph theory, combinatorics, etc.

3. Research Program

3.1. Introduction

The scientific foundations of our work are those of network design and network analysis. Specifically, this concerns the principles of packet switching and in particular of IP networks (protocol design, protocol testing, routing, scheduling techniques), and the mathematical and algorithmic aspects of the associated problems, on which our methods and tools are based.

These foundations are described in the following paragraphs. We begin by a subsection dedicated to Quality of Service (QoS) and Quality of Experience (QoE), since they can be seen as unifying concepts in our activities. Then we briefly describe the specific sub-area of model evaluation and about the particular multidisciplinary domain of network economics.

3.2. Quality of Service and Quality of Experience

Since it is difficult to develop as many communication solutions as possible applications, the scientific and technological communities aim towards providing general *services* allowing to give to each application or user a set of properties nowadays called “Quality of Service” (QoS), a terminology lacking a precise definition. This QoS concept takes different forms according to the type of communication service and the aspects which matter for a given application: for performance it comes through specific metrics (delays, jitter, throughput, etc.), for dependability it also comes through appropriate metrics: reliability, availability, or vulnerability, in the case for instance of WAN (Wide Area Network) topologies, etc.

QoS is at the heart of our research activities: We look for methods to obtain specific “levels” of QoS and for techniques to evaluate the associated metrics. Our ultimate goal is to provide tools (mathematical tools and/or algorithms, under appropriate software “containers” or not) allowing users and/or applications to attain specific levels of QoS, or to improve the provided QoS, if we think of a particular system, with an optimal use of the resources available. Obtaining a good QoS level is a very general objective. It leads to many different areas, depending on the systems, applications and specific goals being considered. Our team works on several of these areas. We also investigate the impact of network QoS on multimedia payloads to reduce the impact of congestion.

Some important aspects of the behavior of modern communication systems have subjective components: the quality of a video stream or an audio signal, *as perceived by the user*, is related to some of the previous mentioned parameters (packet loss, delays, ...) but in an extremely complex way. We are interested in analyzing these types of flows from this user-oriented point of view. We focus on the *user perceived quality*, the main component of what is nowadays called Quality of Experience (in short, QoE), to underline the fact that, in this case, we want to center the analysis on the user. In this context, we have a global project called PSQA, which stands for Pseudo-Subjective Quality Assessment, and which refers to a methodology allowing to automatically measure QoE.

Another special case to which we devote research efforts in the team is the analysis of qualitative properties related to interoperability assessment. This refers to the act of determining if end-to-end functionality between at least two communicating systems is as required by the base standards for those systems. Conformance is the act of determining to what extent a single component conforms to the individual requirements of the standard it is based on. Our purpose is to provide such a formal framework (methods, algorithms and tools) for interoperability assessment, in order to help in obtaining efficient interoperability test suites for new generation networks, mainly around IPv6-related protocols. The interoperability test suites generation is based on specifications (standards and/or RFCs) of network components and protocols to be tested.

3.3. Stochastic modeling

The scientific foundations of our modeling activities are composed of stochastic processes theory and, in particular, Markov processes, queuing theory, stochastic graphs theory, etc. The objectives are either to develop numerical solutions, or analytical ones, or possibly discrete event simulation or Monte Carlo (and Quasi-Monte Carlo) techniques. We are always interested in model evaluation techniques for dependability and performability analysis, both in static (network reliability) and dynamic contexts (depending on the fact that time plays an explicit role in the analysis or not). We look at systems from the classical so-called *call level*, leading to standard models (for instance, queues or networks of queues) and also at the *burst level*, leading to *fluid models*.

In recent years, our work on the design of the topologies of WANs led us to optimization techniques, in particular in the case of very large optimization problems, usually formulated in terms of graphs. The associated methods we are interested in are composed of simulated annealing, genetic algorithms, TABU search, etc. For the time being, we have obtained our best results with GRASP techniques.

Network pricing is a good example of a multi-disciplinary research activity half-way between applied mathematics, economy and networking, centered on stochastic modeling issues. Indeed, the Internet is facing a tremendous increase of its traffic volume. As a consequence, real users complain that large data transfers take too long, without any possibility to improve this by themselves (by paying more, for instance). A possible solution to cope with congestion is to increase the link capacities; however, many authors consider that this is not a viable solution as the network must respond to an increasing demand (and experience has shown that demand of bandwidth has always been ahead of supply), especially now that the Internet is becoming a commercial network. Furthermore, incentives for a fair utilization between customers are not included in the current Internet. For these reasons, it has been suggested that the current flat-rate fees, where customers pay a subscription and obtain an unlimited usage, should be replaced by usage-based fees. Besides, the future Internet will carry heterogeneous flows such as video, voice, email, web, file transfers and remote login among others. Each of these applications requires a different level of QoS: for example, video needs very small delays and packet losses, voice requires small delays but can afford some packet losses, email can afford delay (within a given bound) while file transfer needs a good average throughput and remote login requires small round-trip times. Some pricing incentives should exist so that each user does not always choose the best QoS for her application and so that the final result is a fair utilization of the bandwidth. On the other hand, we need to be aware of the trade-off between engineering efficiency and economic efficiency; for example, traffic measurements can help in improving the management of the network but is a costly option. These are some of the various aspects often present in the pricing problems we address in our work. More recently, we have switched to the more general field of network economics, dealing with the economic behavior of users, service providers and content providers, as well as their relations.

4. Highlights of the Year

4.1. Highlights of the Year

Awards

Pierre L'Ecuyer was named titan of simulation at the 2015 Winter Simulation Conference.

We had one best short paper award in 2015 on a novel access mechanism for M2M communications in LTE-Advanced Networks (see 6.4).

BEST PAPER AWARD:

[60]

M. BOUZOUITA, Y. HADJADJ-AOUL, N. ZANGAR, G. RUBINO, S. TABBANE. *Multiple Access Class Barring factors Algorithm for M2M communications in LTE-Advanced Networks*, in "18th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM)", Cancun, Mexico, November 2015, <https://hal.inria.fr/hal-01251964>

5. New Software and Platforms

5.1. IPv6 Test Toolkit

FUNCTIONAL DESCRIPTION

These test suites are developed using the TTCN-3 environment.

The packages contains the full Abstract Test Suites written in TTCN-3 and the source files for building the codecs and adapters with the help of T3DevKit.

- Participants: Cesar Pascal Viho
- Contact: Cesar Pascal Viho
- URL: <http://www.irisa.fr/tipi>

5.2. Passive Test Tool

- Participants: Cesar Pascal Viho
- Contact: Cesar Pascal Viho
- URL: <http://www.irisa.fr/tipi>

5.3. T3DevKit

SCIENTIFIC DESCRIPTION

We have built a toolkit for easing executing tests written in the standardized TTCN-3 test specification language. This toolkit is made of a C++ library together with a highly customizable CoDec generator that allows fast development of external components (that are required to execute a test suite) such as CoDec (for message Coding/Decoding), System and Platform Adapters. It also provides a framework for representing and manipulating TTCN-3 events so as to ease the production of test reports. The toolkit addresses issues that are not yet covered by ETSI standards while being fully compatible with the existing standard interfaces: TRI (Test Runtime Interfaces) and TCI (Test Control Interfaces), it has been tested with four TTCN-3 environments (IBM, Elvior, Danet and Go4IT) and on three different platforms (Linux, Windows and Cygwin).

FUNCTIONAL DESCRIPTION

T3DevKit is a free open source toolkit to ease the development of test suites in the TTCN-3 environment. It provides:

- a CoDec generator (t3cdgen) that automates the development process of the CoDec needed for coding TTCN-3 values into physically transmittable messages and decoding incoming messages
- a library (t3devlib) that provides an object oriented framework to manipulate TTCN-3 entities (values, ports, timers, external functions...)
- an implementation of the TRI and TCI standard interfaces
- default implementations for the system adapter (SA), platform adapter (PA), test management (TM), test logging (TL) and component handling (CH) modules
- default codecs
- built-in scripts for the generation of executable test suites, which are tool-independent and facilitate the distribution of test suite sources
- Participants: Cesar Pascal Viho
- Contact: Cesar Pascal Viho

5.4. Interoperability Assessment

Participant: César Viho.

Our experience in interoperability assessment (since 1996) and in using the TTCN-3 standard allowed us to develop a tool (called `ttproto`) that helps in: (i) experimenting new concepts for long term evolution of the TTCN-3 standard and (ii) facilitating new approaches and methods for interoperability assessment. For instance, new passive approaches that we developed have been implemented and validated using `ttproto`. This tool `ttproto` has been used to develop test suites for 6LoWPAN-ND (IPv6 for Low Power Networks) and CoAP (Constrained Application Protocol). The CoAP test suites have been successfully used for two Plugtest interoperability events organized by ETSI, IPSO Alliance and the FP7 PROBE-IT project. The tool `ttproto` and the test suites indicated above are freely available at <http://www.irisa.fr/tipi>.

5.5. Performance and dependability evaluation

Participants: Gerardo Rubino, Bruno Sericola, Bruno Tuffin.

We develop software tools for the evaluation of two classes of models: Markov models and reliability networks. The main objective is to quantify dependability aspects of the behaviors of the modeled systems, but other aspects of the systems can be handled (performance, performability, vulnerability). The tools are specialized libraries implementing numerical, Monte Carlo and Quasi-Monte Carlo algorithms.

One of these libraries has been developed for the Celar (DGA), and its goal is the evaluation of dependability and vulnerability metrics of wide area communication networks (WANs). The algorithms in this library can also evaluate the sensitivities of the implemented dependability measures with respect to the parameters characterizing the behavior of the components of the networks (nodes, lines).

We are also developing tools with the objective of building Markovian models and to compute bounds of asymptotic metrics such as the asymptotic availability of standard metrics of models in equilibrium, loss probabilities, blocking probabilities, mean backlogs, etc. A set of functions designed for dependability analysis is being built under the name `DependLib`.

We contribute to the development of SPNP (*Stochastic Petri Net Package*). SPNP is used by more than 200 companies and universities. The main designer is Duke University. Our contributions are on Monte Carlo methods. We plan to increase our participation in the development of this tool.

Pierre L'Ecuyer is also developing in Montreal a library, *Stochastic Simulation in Java* (SSJ), providing facilities for generating uniform and nonuniform random variates, computing different measures related to probability distributions, performing goodness-of-fit tests, applying quasi-Monte Carlo methods, collecting (elementary) statistics, and programming discrete-event simulations with both events and processes.

6. New Results

6.1. Quality of Experience

Participants: Yassine Hadjadj-Aoul, Gerardo Rubino.

QoE in mobile networks. We consider in [43] an important Quality of Experience (QoE) indicator in cellular networks that is renegeing of users due to impatience. We specifically consider a cell under heavy load conditions, modeled as a multiclass Processor Sharing system, and compute the renegeing probability by using a fluid limit analysis. In order to enhance the user QoE, we propose a radio resource allocation control scheme that minimizes the global renegeing rates. This control scheme is based on the α -fair scheduling framework and adapts the scheduler parameter depending on the traffic load. While the proposed scheme is simple, our results show that it achieves important performance gains. This work is extended in [42]. By solving the fixed point equation, we obtain a new QoE perturbation metric quantifying the impact of renegeing on the performance of the system. This metric is then used to devise a new pricing scheme accounting of renegeing. We specifically propose several flavors of this scheme around the idea of having a flat rate for accessing the network and an elastic price related to the level of QoE perturbation induced by communications.

In order to offer a high media quality and a good user satisfaction, the media streaming service requires that transport protocols can be adapted continuously to the network parameters. However, the diversity of terminals (e.g., tablets, smart phones, laptops) and their corresponding capabilities, mean that users' agnostic solutions are inefficient to cope with such diverse contexts. Indeed, the intrinsic characteristics and parameters of the terminals (i.e., devices) need to be taken into account on the video streaming adaptation process. In [17], we propose an adaptive video streaming solution to improve the user satisfaction factor by adapting the TCP parameters according to the user's parameters on mobile networks. The user satisfaction factor is calculated according to some metrics driven from the user's quality of experience (QoE). The work is validated through our proposal based on a new mobile agent developed on a Linux script platform and tested on different kinds of devices with different scenarios.

Learning tools. Our QoE measuring techniques (see 3.2) are based on statistical learning methods, and we have been using Random Neural Networks as our main learning tool. These are actually open queueing networks where customers have a "sign" and behave analogously as neural spiking signals. They have been proposed by Gelenbe in the 80s, and have been used in many areas since then. In [26], we published a survey about the tool, where we develop in some detail their use in supervised learning, not only for the case of interest in PSQA, our QoE measuring technology. We also discuss the use of powerful optimization methodology, first and second order techniques, that have proved to be very effective in the standard Neural Network area.

Recently, we started to explore new learning techniques. The first reason is not the search for more accurate tools, because ours are, we claim, as accurate as they can be, it is to improve robustness. The second reason is to extend our QoE measuring tools to richer contexts, mainly when we take into account time, that is, time series data. This comes from the observation that in many cases, the way people perceive quality has some "inertia" and depends on the quality perceived some minutes ago. In [66] we explored the capabilities of a recently proposed method called "Reservoir Computing (RC) with Random Static Projections" which combines two ideas, the now classic Reservoir Computing approach and Extreme Learning Machines (ELMs). In our paper, we replaced the ELMs by Radial Basis Functions (RBF) projections. We illustrated the good behavior of this variation of the original technique basically using known benchmarks.

In [67], we perform a detailed analysis of one of the main instances of the Reservoir Computing idea, called Echo State Network (ESN). This type of model has several parameters to adjust, that have an impact on the performances of the learning procedure. For instance, it has been shown that the spectral radius of the reservoir matrix (the recurrent network structure that doesn't learn during the process) is related to the accuracy and the memory capabilities of the technology. The size of the reservoir is also a parameter to adjust when configuring an ESN for performing some specific task. One of the results of our work is the fact that the periodic or pseudo-period nature of data is also an important factor to be taken into account when designing an ESN, since it has an influence on the impact of parameters such as the previously mentioned spectral radius.

QoE and emergency management. As a by-product of our activities around QoE, we started to work on an application where, instead of evaluating the QoE of, say, a video or voice application, we wanted to evaluate the way users perceive a service not necessarily based on audio or video content. This was related to our participation to the European project QuEEN (see 8.2.2). We finished by building a platform where we test different ideas for managing an emergency situation. In our system, we include an automatic evaluator of the perceived quality of the related voice and video communications, since in the case of some catastrophes, the communications can be seriously damaged and it is critical to automatically detect the issue in order to report the problem and to take appropriate countermeasures, when possible. In [55], we describe some of the aspects of our system and of the implemented mechanisms, and we present some design problems and their solutions, together with illustrations of the capabilities of the tool.

6.2. Analytic models

Participants: Gerardo Rubino, Bruno Sericola.

Sojourn times in Markovian models. In [74], we discuss different issues related to the time a Markov chain spends in a part of its state space. This is relevant in many application areas including those interesting Dionysos, namely, performance and dependability analysis of complex systems. For instance, in dependability, the reliability of a system subject to failures and repairs of its components, is, in terms of a discrete-space model of it, the probability that it remains in the subset of operational or up states during the whole time interval $[0, t]$. In performance, the occupancy factor of some server is the probability that, in steady state, the model belongs to the subset of states where the server is busy. This book chapter reviews some past work done by the authors on this topic, and add some new insights on the properties of these sojourn times.

Queuing systems in equilibrium. In the late 70s, Leonard Kleinrock proposed a metric able to capture the tradeoff between the work done by a system and its cost, or, in terms of queueing systems, between throughput and mean response time. The new metric was called *power* and among its properties, it satisfies a nice one informally called “keep the pipe full”, specifying that the operation point of some queues (mainly the $M/M/1$ one) giving the maximal possible value to the power is when the mean backlog is 1. In [56], we took back this idea to explore what happens when we consider Jackson queueing networks. After showing that the same property holds for them and exploring other ones, we show that the power metric has some drawbacks when considering multiserver queues and networks of queues. We then propose a new metric that we called *effectiveness*, identical to power when there is a single queue with a single server, but different otherwise, that avoids these drawbacks. We analyze it and, in particular, we show that the same “keep the pipe full” holds for it.

Transient analysis of queueing systems. In a well-known book [86], today out of press, a concept of dual of a birth-and-death process is proposed, based on stochastic monotonicity. In past work [88] we showed that this concept coupled with the classical randomization or uniformization of continuous time Markov chains and lattice path combinatorics, allowed to derive analytical expressions of the transient distribution of several Markovian queueing systems. Recently, we discovered two new things: first, that this dual concept can be generalized to arbitrary systems of ordinary differential equations (ODEs) and still keep its main properties; second, that we can define a similar transformation than uniformization, that can be applied to arbitrary systems of ODEs and again, holding similar properties than the former. We respectively called pseudo-dual and pseudo-randomization the two concepts and associated methods. In [69], we presented these ideas and first results about them. We illustrated their use, and how they allow to obtain analytical expressions of transient queues’ distributions in cases where Anderson’s dual doesn’t exist (see [87]).

In [68], we present results concerning some aspects of the behavior of a queueing system observed during a fixed time period of the form $[0, t]$. The two aspects we looked at in this work are the loss process of a finite capacity model during the considered $[0, t]$, and the maximal backlog reached at a queue over the interval. Following the classical procedure mentioned below, consisting in using uniformization to go to discrete time and then, combinatorial techniques, we develop numerical schemes to analyze both aspects of some basic queueing systems.

Network reliability. In [28], we consider the classical network design “Capacitated m -Ring Star Problem” (CmRSP), where we look for m rings connecting two nodes in a network at minimum cost. We add to this model the fact that links can fail, and propose a new paradigm that we call “Capacitated m -Ring Star Problem with Diameter Constrained Reliability” (in short, CmRSP-DCR), where we look again for a minimal cost spanning graph of the set of nodes in the network that connects the selected source and terminal, *while satisfying a Diameter Constrained Reliability (DCR) condition*. The DCR is the probability that the two nodes can communicate by means of paths having lengths bounded by some fixed value d . We prove that this problem is NP-hard, and we propose a GRASP-based approach to solve it.

Fluid models. In [19] we study congestion periods in a finite fluid buffer when the net input rate depends upon a recurrent Markov process; congestion occurs when the buffer content is equal to the buffer capacity. We consider the duration of congestion periods as well as the associated volume of lost information. We derive their distributions in a typical stationary busy period of the buffer. Our goal is to compute the exact expression of the loss probability in the system, which is usually approximated by the probability that the occupancy of the infinite buffer is greater than the buffer capacity under consideration. Moreover, by using general results of the theory of Markovian arrival processes, we show that the duration of congestion and the volume of lost information have phase-type distributions.

6.3. Performance Evaluation of Distributed Systems

Participants: Bruno Sericola, Yann Busnel, Pierre L’Ecuyer.

Detection of distributed deny of service attacks. A Deny of Service (DoS) attack tries to progressively take down an Internet resource by flooding this resource with more requests than it is capable to handle. A Distributed Deny of Service (DDoS) attack is a DoS attack triggered by thousands of machines that have been infected by a malicious software, with as immediate consequence the total shut down of targeted web resources (e.g., e-commerce websites). A solution to detect and to mitigate DDoS attacks is to monitor network traffic at routers and to look for highly frequent signatures that might suggest ongoing attacks. A recent strategy followed by the attackers is to hide their massive flow of requests over a multitude of routes, so that locally, these flows do not appear as frequent, while globally they represent a significant portion of the network traffic. The term “iceberg” has been recently introduced to describe such an attack as only a very small part of the iceberg can be observed from each single router. The approach adopted to defend against such new attacks is to rely on multiple routers that locally monitor their network traffic, and upon detection of potential icebergs, inform a monitoring server that aggregates all the monitored information to accurately detect icebergs [36]. Now to prevent the server from being overloaded by all the monitored information, routers continuously keep track of the c (among n) most recent high flows (modeled as items) prior to sending them to the server, and throw away all the items that appear with a small probability. Parameter c is dimensioned so that the frequency at which all the routers send their c last frequent items is low enough to enable the server to aggregate all of them and to trigger a DDoS alarm when needed. This amounts to compute the time needed to collect c distinct items among n frequent ones. A thorough analysis of the time needed to collect c distinct items appears in [12], [11].

Stream Processing Systems. Stream processing systems are today gaining momentum as tools to perform analytics on continuous data streams. Their ability to produce analysis results with sub-second latencies, coupled with their scalability, makes them the preferred choice for many big data companies.

A stream processing application is commonly modeled as a direct acyclic graph where data operators, represented by nodes, are interconnected by streams of tuples containing data to be analyzed, the directed edges (the arcs). Scalability is usually attained at the deployment phase where each data operator can be parallelized using multiple instances, each of which will handle a subset of the tuples conveyed by the operators’ ingoing stream. Balancing the load among the instances of a parallel operator is important as it yields to better resource utilization and thus larger throughputs and reduced tuple processing latencies. We have proposed a new key grouping technique targeted toward applications working on input streams characterized by a skewed value distribution [53]. Our solution is based on the observation that when the values used to perform the grouping have skewed frequencies, the few most frequent values (the *heavy hitters*) drive the load distribution, while

the remaining largest fraction of the values (the *sparse items*) appear so rarely in the stream that the relative impact of each of them on the global load balance is negligible. We have shown, through a theoretical analysis, that our solution provides on average near-optimal mappings using sub-linear spaces in the number of tuples read from the input stream in the learning phase and the support (value domain) of the tuples. In particular this analysis presents new results regarding the expected error made on the estimation of the frequency of heavy hitters.

Randomized Message-Passing Test-and-Set. In [37], we have presented a solution to the well-known Test&Set operation in an asynchronous system prone to process crashes. Test&Set is a synchronization operation that, when invoked by a set of processes, returns yes to a unique process and returns no to all the others. Recently, many advances in implementing Test&Set objects have been achieved. However, all of them target the shared memory model. In this paper we propose an implementation of a Test&Set object in the message passing model. This implementation can be invoked by any number $p \leq n$ of processes where n is the total number of processes in the system. It has an expected individual step complexity in $O(\log p)$ against an oblivious adversary, and an expected individual message complexity in $O(n)$. The proposed Test&Set object is built atop a new basic building block, called selector, that allows to select a winning group among two groups of processes. We propose a message-passing implementation of the selector whose step complexity is constant. We are not aware of any other implementation of the Test&Set operation in the message passing model.

Population Protocol Model. The population protocol model, introduced by Angluin and his colleagues in 2006, provides theoretical foundations for analyzing global properties emerging from pairwise interactions among a large number of anonymous agents. In the population protocol model, agents are modeled as identical and finite state machines, i.e each agent can be in a finite number of states while waiting to execute a transition. When two agents interact, they communicate their local state, and can move from one state to another according to a transition function. The ultimate goal of population protocols is for all the agents to converge to the same value. Examples of systems whose behavior can be modeled by population protocols range from molecule interactions of a chemical process to sensor networks in which agents, which are small devices embedded for instance in animals, interact each time two animals are in the same radio range.

In this work, we focus on a quite important related question. Namely, is there a population protocol that exactly counts the difference κ between the number of agents that initially set their state to A and the one that initially set it to B , and can it be solved in an efficient way, that is with the guarantee that each agent should converge to the exact value of κ after having triggered a sub-linear number of interactions in the size of the system [49]? We answer this question by the affirmative by presenting a $O(n^{3/2})$ -state population protocol that allows each agent to converge to the exact solution by interacting no more than $O(\log n)$ times. The proposed protocol is very simple (as is true for most known population protocols), but is general enough to be used to solve different types of tasks.

Call centers. We develop research activities around the analysis and design of call centers, from a performance perspective. The effective management of call centers is a challenging task mainly because managers are consistently facing considerable uncertainty. Among important sources of uncertainty are call arrival rates which are typically time-varying, stochastic, dependent across time periods and across call types, and often affected by external events. Accurately modeling and forecasting future call arrival volumes is a complicated issue which is critical for making important operational decisions, such as staffing and scheduling, in the call center. In [20] we review the existing literature on modeling and forecasting call arrivals. We also develop in [58] customer delay predictors for multi-skill call centers that take as inputs the queueing state upon arrival and the waiting time of the last customer served. Barely any predictor currently exists for the multi-skill case. We introduce two new predictors that use cubic regression splines and artificial neural networks, respectively, and whose parameters are optimized (or learned) from observation data obtained by simulation.

6.4. Wireless Networks

Participants: Osama Arouk, Btissam Er-Rahmadi, Adlen Ksentini, Meriem Bouzouita, Pantelis Frangoudis, Yassine Hadjadj-Aoul, Gerardo Rubino.

We are continuing our activities around wireless and mobile networks, by focusing more on leveraging the current mobile and wireless architecture toward building the 5G systems.

LTE improvements. One of the 5G objectives is to support a high number of devices. This not only concerns User Equipment (UE) devices, but also other devices such as sensors and actuators (known also as Internet of Things (IoT)). Sensor and actuator devices communicate generally with a remote server in an automatic way, without any human intervention. This type of communication is known as Machine to Machine (M2M) communication, or Machine Type Communication (MTC). The corresponding traffic is known by its intensity and impact on increasing congestion in both main parts of 4G networks, the Radio Access Network (RAN) and the Core Network. To improve the current LTE system to support MTC, we did several contributions. We proposed in [51] an important enhancement to the Group Paging (GP) mechanism, which is responsible for relaying requests to sensors, in order to gather data. After modeling analytically the GP procedure, we proposed a mechanism that, instead of paging all MTC devices in the same period, calculates the appropriate number of MTCs that reduces the collision probability as well as increases the success probability. In [52], we modeled the Radio Access Channel (RACH) procedure when the MTC devices are activated in a highly synchronized manner during a certain period (synchronized traffic), which is represented by a Beta distribution. The proposed model estimates for each period the exact number of MTC devices that may win the contention.

To control the Random Access Network (RAN) overload and alleviate the access network congestion, 3GPP developed the Access Class Barring (ACB) procedure that depends on an access probability called the ACB factor, without proposing a procedure for calculating such probability. In [72], we have proposed a fluid-based random access model for M2M communications, which was used to determine dynamically the value of the ACB factor that avoids system overload and the radio resources' underutilization at the same time. We proposed in [60] a novel implementation of the ACB mechanism in the context of multiple M2M traffic classes. Based on a scheduling algorithm, we have applied a PID controller to adjust dynamically multiple ACB factors related to each class category, guaranteeing a number of devices around an optimal value that maximizes the Random Access (RA) success probability. In [61], we first present a simple fluid model of MTC devices' random access. This model is then used to derive a novel adaptive regulator of the ACB factor, somehow in contrast with previous existing contributions which generally rely on heuristics. The main advantages of the proposed approach are twofold. First, the proposal is fully compliant with the standard while it reduces significantly the computation and the signaling overheads. Second, it provides an efficient mean to regulate adaptively the ACB factor as it guarantees having an optimal number of MTC devices accessing concurrently to the RAN. The obtained results based on simulations show clearly the robustness of the proposed approach, and its superiority compared to existing proposals.

Another important objective of 5G mobile networks is to accommodate a diverse and ever-increasing number of user equipments (UEs). Coping with the massive signaling overhead expected from UEs is an important hurdle to tackle so as to achieve this objective. In [38], we devised an efficient tracking area list management framework that aims for finding optimal distributions of tracking areas (TAs) in the form of TA lists (TALs) and assigning them to UEs. The objective is to minimize two conflicting metrics: paging overhead and tracking area update (TAU) overhead. We used bargaining games to find the Pareto optimal solution that satisfies both objectives.

WiFi networks improvements. It is well established that WiFi is complementing LTE connections to ensure, wirelessly, high data rate. One idea to improve WiFi towards high data rates is to multiple users' transmissions on both directions, i.e. on the Down Link (DL) and the Up Link (UL). In [50] we devised a novel solution to enhance the TXOP Sharing mechanism, introduced in the 802.11ac amendment, to achieve efficient Down-Link Multi-User Multiple-Input Multiple-Output (DL-MU-MIMO) transmission. First, we give new definitions about both events of successful and failed DL-MU-MIMO transmission. Then, we devise a revised Backoff procedure for the primary Access Category (AC). In [40] we proposed a novel 802.11ax MAC protocol aiming at reducing the elapsed time in managing the establishment of an UL-MU communication, thus enhancing considerably the system's performance.

On the other hand, the volume of mobile multimedia traffic is fast-growing, challenging the radio and backhaul network infrastructure and calling for alternative content dissemination schemes. To improve user experience and reduce infrastructure load, we exploit implicit social relationships among users and take into account content popularity, proposing push-based prefetching mechanisms which take advantage of the caching and mobile ad hoc networking capabilities of user devices. We use, in [65], bloom filters as summaries of user caches, and design mechanisms to estimate the social distance between users and the popularity of content items, which drive our algorithms. Our simulation-based evaluation shows that our scheme brings caching performance improvements in an order of 10% in terms of absolute cache hit ratio in most of the cases studied, and from 3% to 82% in terms of normalized cache hit ratio gain.

Network selection. With the explosion of mobile data traffic, the Fixed and Mobile Converged (FMC) network are being heavily required. Mobile devices have the capability of connecting to different access networks in the FMC architecture simultaneously. Access network selection becomes an issue when mobile devices are under coverage of different access networks, since a bad selection may lead to network congestion and degrade the QoE of users. In order to address this problem, we model and analyze, in [62] and [63], the interface selection procedure using control theory in the FMC architecture. Based on our model, we designed a controller which can send to mobile devices a network selection command calculated instantly for the access network selection. In [29], we investigated network decentralization in conjunction with the selective IP traffic offload approaches to handle the increased data traffic. We first devised different approaches based on a per-destination-domain-name basis, which offer operators a fine-grained control to determine whether a new IP connection should be offloaded or accommodated via the core network.

Energy efficiency. Due to the ever-growing gap between battery lifetime and hardware/software complexity in addition to application's computing power needs, the energy saving issue becomes crucial. In this context, we proposed, in [13], an end-to-end study of video decoding on different architectures. The study was achieved thanks to a two steps methodology: (1) a comprehensive characterization and evaluation of the performance and the energy consumption of video decoding, (2) an accurate high level energy model based on the characterization step. In [24], we proposed to apply data fragmentation, in slotted CSMA/CA, in a way to allow improving the bandwidth occupation while reducing the latency. We proposed to introduce a network allocation vector (NAV) in the fragmentation mechanism to reduce energy consumption in IEEE 802.15.4. A Markov chain-based analytical model of the fragmentation mechanism was given as well as an analytical model of the energy consumption using a NAV. The analytical results show that the fragmentation technique improves at the same time the throughput, the access delay and the bandwidth occupation. They also show that the NAV mechanism reduces energy consumption when applying the fragmentation technique in slotted CSMA-CA for IEEE 802.15.4.

6.5. Future networks and architectures

Participants: Adlen Ksentini, Yassine Hadjadj-Aoul, Jean-Michel Sanner.

SDN. We started an activity on Software Defined Networking (SDN), a recent idea proposed to handle network management problems. SDN are becoming an important issue with the ever-increasing network complexity. They are proposed as an alternative to the current architecture of the Internet, which cannot meet the supported services requirements such as Quality of Service/Experience (Qos/QoE), security and energy consumption. We particularly address the scalability issue by proposing in [70] an automated hierarchical controller-based architecture handling the whole control chain.

Mobile cloud. One of the 5G-architecture visions considers the usage of cloud to ease mobile networks evolution towards more flexibility and elasticity for handling resources; building the concept of carrier cloud. Software Defined Networking (SDN) and Network Function Virtualization (NFV) represent the key enabler of carrier cloud. In [57], we addressed the problem of Virtual Network Function (VNF) placement in the carrier cloud. Indeed, we proposed a placement solution that has two main design goals: i) minimizing path between users and their respective data anchor gateways and ii) optimizing their sessions' mobility. The two design goals effectively represent two conflicting objectives that we deal with considering the mobility features and service usage behavioral patterns of mobile users, in addition to the mobile operators' cost in terms of the

total number of instantiated VNFs to build a Virtual Network Infrastructure (VNI). We modeled this problem using an optimization formulation having these conflicting objectives, and then used Bargaining Game to find the Pareto optimal solution. We are continuing our improvement to the Follow Me Cloud (FMC), which was devised by our team conjointly with NEC labs. In [33], we proposed a FMC architecture that relies on PMIPv6 to handle mobility, and SDN to update the flow table of the anchor routers when a service has moved from one Data Center to another. In [10] and [32], we addressed the challenge of flow table scalability problem, which may arise in FMC to high number of mobile users. To this aim, we proposed a two-level hierarchical SDN controllers architecture in order to distribute the SDN/OpenFlow control plane. Another objective of 5G is to reduce network latency to 1ms, which will ease computation offloading. Thus, it will be possible to run applications on UE device, even if the latter has low computation capability, by offloading part of the code to a remote server. In [44], we were interested on studying the opportunities to offload part of one of the well known game engine in the literature, i.e. Unity 3D. We built a data set representing the CPU-GPU use of several games; allowing us to understand which modules might be offloaded to a remote server in the Mobile Cloud.

6.6. Network Economics

Participant: Bruno Tuffin.

The general field of network economics, analyzing the relationships between all acts of the digital economy, has been an important subject for years in the team. The whole problem of network economics, from theory to practice, describing all issues and challenges, is described in our book “Telecommunication Network Economics From Theory to Applications” (P. Maillé and B. Tuffin, Cambridge U. Press, 2014).

Network neutrality. Among the topics we have particularly focused on, the network neutrality debate was a major concern in 2015. In [23], [80], [83] we recall the debate and highlight the fact that neutrality principles can be bypassed in many ways without violating the rules currently evoked in the debate. For example via Content Delivery Networks (CDNs), which deliver content on behalf of content providers for a fee, or via search engines, which can hinder competition and innovation by affecting the visibility and accessibility of content. In [23], we challenge the definition of net neutrality as it is generally discussed. Our goal there is to initiate a relevant debate for net neutrality in an increasingly complex Internet ecosystem, and to provide examples of possible neutrality rules for different levels of the delivery chain, this level separation being inspired by the OSI layer model.

As particular ways to bypass the current neutrality principles, we have particularly focused on CDNs. We for example investigate in [47] the impact of decisions made by a CDN willing to maximize its revenue through the management of cache servers. Based on a model with two network providers, we highlight that revenue-oriented management policies can affect the user-perceived quality of experience, impacting the competition among network access providers in favor of the largest one. Since this contradicts the principle underpinning network neutrality?although not with the technical net neutrality rules?we discuss the necessity to regulate CDN activity. Also, one of the main argument toward neutrality being that it favors innovation, we study in [46] the impact of CDNs" activity on other actors of the supply chain. Our findings indicate that vertically integrating a CDN helps Internet Service Providers (ISPs) collect fees from Content Providers (CPs), hence circumventing the interdiction of side payments coming from net neutrality rules. However, this outcome is socially much better in terms of user quality and innovation fostering than having separate actors providing the access and CDN services: in the latter case double marginalization (both ISP and CDN trying to get some value from the supply chain) leads to suboptimal investments in CDN storage capacities and higher prices for CPs, resulting in reduced innovation.

Another model we have developed is for understanding the behavior of some big providers actually paying side payment to ISPs while still officially in favor of neutrality. To better understand this strategical behavior, we have presented a simple model in [59] providing some insight on whether or not paying side payments for an incumbent provider is a way to create barriers to entry for competitors. It also investigates the economic consequences on all actors: incumbent and new entrant content providers, users, and the Internet Service Provider. It then describes how the side payment can be determined as a Nash bargaining solution.

Pricing access networks. Access networks in a competitive context has been a topic of research for a while. In the Internet, the data charging scheme has usually been flat rate. But more recently, especially for mobile data traffic, we have seen more diversity in the pricing offers, such as volume-based ones or cap-based ones. We study in [48] the behavior of heterogeneous users facing two offers: a volume-based one and a flat-rate one. On top of that selection, we investigate 1) the relevance for an ISP to propose the two types of offers, and optimize the corresponding prices, and 2) the existence of a solution to the pricing game when the offers come from competing providers.

Sponsored auctions. Advertisement in dedicated webpage spaces or in search engines sponsored slots is usually sold using auctions, with a payment rule that is either per view or per click. But advertisers can be both sensitive to being viewed (brand awareness effect) and being clicked (conversion into sales). In [84], we generalize the auction mechanism by including both pricing components: the displayed advertisers are charged when their ad is displayed, and pay an additional price if the ad is clicked. Applying the results for Vickrey-Clarke-Groves (VCG) auctions, we show how to compute payments to ensure incentive compatibility from advertisers as well as maximize the total value of the advertisement slot(s). We provide tight upper bounds for the loss of efficiency due to applying only pay-per-click (or pay-per-view) pricing instead of our scheme. Those bounds depend on the joint distribution of advertisement visibility and population likelihood to click on ads, and can help identify situations where our mechanism yields significant improvements. We also describe how the commonly used generalized second price (GSP) auction can be extended to this context.

6.7. Monte Carlo

Participants: Pierre L'Ecuyer, Gerardo Rubino, Bruno Tuffin.

We maintain a research activity in different areas related to dependability, performability and vulnerability analysis of communication systems, using both the Monte Carlo and the Quasi-Monte Carlo approaches to evaluate the relevant metrics. Monte Carlo (and Quasi-Monte Carlo) methods often represent the only tool able to solve complex problems of these types. However, when the events of interest are rare, simulation requires a special attention, to accelerate the occurrence of the event and get unbiased estimators of the event of interest with a sufficiently small relative variance. This is the main problem in the area. Dionysos' work focuses then on dealing with the rare event situation. For example, [39] presents an exponential tilting method for exact simulation from the truncated multivariate student-t distribution in high dimensions as an alternative to approximate Markov Chain Monte Carlo sampling.

A non-negligible part of our activity on the application of rare event simulation was about the evaluation of static network reliability models. Our paper [16] focuses on a technique known as Recursive Variance Reduction (RVR) which approaches the unreliability by recursively reducing the graph from the random choice of the first working link on selected cuts. This previously known method is shown to not verify the bounded relative error (BRE) property as reliability of individual links goes to one, i.e., the estimator is not robust in general to high reliability of links. We then propose to use the decomposition ideas of the RVR estimator in conjunction with the IS technique. Two new estimators are presented in the paper: the first one, called Balanced Recursive Decomposition estimator, chooses the first working link on cuts uniformly, while the second, called Zero-Variance Approximation Recursive Decomposition estimator, combines RVR and our zero-variance IS approximation. We show that in both cases BRE property is verified and, moreover, that a vanishing relative error (VRE) property can be obtained for the Zero-Variance Approximation RVR under specific sufficient conditions. A numerical illustration of the power of the methods is provided on several benchmark networks. In [54], we explore the use of the same powerful RVR idea, but applied in a very general context, where the system is model by a monotone structure function. In the paper, we illustrate the approach with a very widely used model, a series of k -out-of- m modules.

In a static network reliability model one typically assumes that the failures of the components of the network are independent. This simplifying assumption makes it possible to estimate the network reliability efficiently via specialized Monte Carlo algorithms. Hence, a natural question to consider is whether this independence assumption can be relaxed, while still attaining an elegant and tractable model that permits an efficient Monte Carlo algorithm for unreliability estimation. In [14] we provide one possible answer by considering a static

network reliability model with dependent link failures, based on a Marshall-Olkin copula, which models the dependence via shocks that take down subsets of components at exponential times, and propose a collection of adapted versions of permutation Monte Carlo (PMC, a conditional Monte Carlo method), its refinement called the turnip method, and generalized splitting (GS) methods, to estimate very small unreliabilities accurately under this model. The PMC and turnip estimators have bounded relative error when the network topology is fixed while the link failure probabilities converge to 0, whereas GS does not have this property. But when the size of the network (or the number of shocks) increases, PMC and turnip eventually fail, whereas GS works nicely (empirically) for very large networks, with over 5000 shocks in our examples. In [41] we focus on a method proposed by Fishman making use of bounds on the structure function describing in terms of configurations of (independent) link states if the considered nodes are connected. The bounds are based on the computation of (independent) mincuts disconnecting the set of nodes and (independent) minpaths ensuring that they are connected. We analyze here the robustness of the method when the unreliability of links goes to zero. We show that the conditions provided by Fishman are based on a bound and are therefore only sufficient, and provide more insight and examples on the behavior of the method.

PMC is an effective way of estimating the unreliability of a static network when this unreliability is very small and the network is not too large. We generalize the method in [31] to cover a wider range of applications, in which an estimation problem can be reframed in terms of the hitting time of a given set of states by a continuous-time Markov chain. The estimator is then defined as a function of the sample path of the underlying discrete time chain only, via Conditional Monte Carlo. We prove that the method gives bounded relative error for rare event probability estimation in certain settings. We show how it can be used to estimate the cumulative distribution function, or the density, or some moment of the hitting time. We provide examples for which the method can be applied and we give numerical illustrations.

Another family of models of interest in the group are the highly reliable Markovian systems, where a Markov chain models the evolution of a multicomponent system with failures and repairs of its components. In [27] we explore a new approach in the context of these models, and in the rare event case, called Conditional Monte Carlo with Intermediate Estimations (CMIE). The target are models with complex structures, where it is hard to design a good *importance function* dealing to good Importance Sampling schemes. The paper shows that the method belongs to the variance reduction family, and some examples illustrate its performances. It can be seen as a generalization of the class of splitting simulation procedures.

Finally, in Quasi-Monte Carlo (QMC), we reviewed in [64] the recent development on array-RQMC, a randomized quasi-Monte Carlo method for we had developed estimating the state distribution at each step of a Markov chain with totally ordered (discrete or continuous) state space. It can be used in particular to obtain a low-variance unbiased estimator of the expected total cost up to some random stopping time, when state-dependent costs are paid at each step. In [21], a combination of sequential MC with RQMC to accelerate convergence proposed by Gerber and Chopin is compared with our array-RQMC.

But simulation requires the use of pseudo-random generators. In [45] we provide a review of the state of the art on the design and implementation of random number generators (RNGs) for simulation, on both sequential and parallel computing environments. A general review of pseudo-random and quasi-random number generation is also provided in [73]. A tool for the generation of rank-1 lattice rules is described in [22].

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contract with Industry: ALSTOM-Inria Common Lab

Participants: Bruno Tuffin, Gerardo Rubino.

Bruno Tuffin is the co-director of ALSTOM-Inria common Lab.

The group currently manages a project with ALSTOM on system availability simulation taking into account logistic constraints. Current ALSTOM Transport and Power contracts, especially service-level agreements, impose stringent system availability objectives. Non-adherence to the required performance levels often leads to penalties, and it is therefore critical to assess corresponding risk already at a tender stage. The challenge is to achieve accurate results in a reasonable amount of time. Monte Carlo simulation provides estimates of the quantities it is desired to predict (e.g., availability). Since we deal with rare events, variance reduction techniques, specifically Importance Sampling (IS) here, is used. The goal of the project is to establish the feasibility of IS for solving problems relevant to ALSTOM and to develop the corresponding mathematical tools.

7.2. Bilateral Contract with Industry: Participation in a CRE with Orange

Participant: Bruno Tuffin.

We are participating to a CRE (managed by Telecom Bretagne) with Orange on the strategies of Content Delivery Networks (CDNs) and their impact on the overall Internet economy and regulation. In this study, we focus on the CDN as an economic actor. The goals are 1) to analyze CDNs' caching strategies from an economic point of view, 2) to study the strategies of an integrated CDN actor, and 3) to study the impact of CDNs in the net neutrality debate.

7.3. Cifre contract on Device-Assisted Distributed Machine-Learning on Many Cores

Participants: Corentin Hardy, Bruno Sericola.

This is a Cifre contract including a PhD thesis supervision, done with Technicolor. The starting point of this thesis would be to consider the possibility to deploy machine-learning algorithms over many cores, but out of the datacenter: on the devices (home-gateways) deployed by Technicolor in users' homes. In this device-assisted view, an initial processing step in the device may significantly reduce the burden on the datacenter back-end. Problems are numerous (power consumption, CPU power, network bandwidth and latency), but costs for the operator can be lowered and scale may bring some new level in data processing.

7.4. Cifre contract on Small Cell Networks

Participants: Adlen Ksentini, César Viho.

This is a Cifre contract (2013-2016) including PhD thesis supervision, done with Orange Labs, on cooperation and self-* small cell networks. The aim is to define architectures and protocols for deploying small cell networks in AMEA (Africa, Middle East and Asia) countries.

7.5. Cifre contract on SDN for 5G mobile networks

Participant: Adlen Ksentini.

This is a Cifre contract (2015-2018) including PhD thesis supervision, done with TDF, on cooperation the use SDN for the 5 generation of mobile network. The objective of the thesis is to study and devise appropriate solutions to introduce SDN with the current LTE architecture toward 5G.

7.6. DGA Grant

Participant: Adlen Ksentini.

This DGA grant, with Cidre Inria team, is for the PhD supervision of Florient Grandhomme.

7.7. DVD2C

Participants: Adlen Ksentini, Pantelis Frangoudis.

We are working in the 3-year (September 2014 – September 2017) FUI Project DVD2C, which aims to virtualize CDN through the Cloud and Network Function Virtualization concept. DVD2C is led by Orange labs., and the partners are two SMEs (Viotech and Resonate) and two academics (our team and Télécom Paris Sud).

7.8. Cifre contract on a dynamic adaptive service-driven SDN architecture

Participants: Jean-Michel Sanner, Yassine Hadjadj-Aoul, Gerardo Rubino.

This is a Cifre contract (2013-2016) including the supervision and work of the PhD thesis of Jean-Michel Sanner, done with Orange Labs, on defining a dynamic adaptive service-driven network architectures based on the SDN concept.

7.9. Cifre contract on defining an open, a flexible and a unified network architecture

Participants: Yue Li, Yassine Hadjadj-Aoul, Gerardo Rubino.

This is a Cifre contract (2013-2016) including the supervision and work of the PhD thesis of, done with Orange Labs, on designing an open, flexible and unified network architecture.

7.10. Camion

Participants: Yassine Hadjadj-Aoul, César Viho, Raymond Marie, Thiago Wanderley Matos de Abreu.

We are working in the 2-year (October 2014 to October 2016) Eurostars European Project Camion, which aims at offering cost-efficient, QoE-optimized content delivery, allowing for faster content access, as well as offline operation, while improving wireless network capacity and coverage. Camion is led by JCP-Connect, and the partners are a SME (FON) and our team.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ANR

- Adlen Ksentini is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Yassine Hadjadj-Aoul is participating at 20% of his time to the IRT BCOM granted by the ANR.

8.2. European Initiatives

8.2.1. FINTEROP

Program: H2020-ICT-12-2015

Project acronym: F-Interop

Project title: FIRE+ online interoperability and performance test tools to support emerging technologies from research to standardization and market launch

Duration: November 2015 – October 2018

Coordinator: UPMC-LIP6

Other partners: 9 partners including (C. Viho (Dionysos); T. Watteyne (Eva))

Abstract: The goal of F-Interop is to extend FIRE+ with online interoperability and performance test tools supporting emerging IoT-related technologies from research to standardization and to market launch for the benefit of researchers, product development by SME, and standardization processes.

8.2.2. *QuEEN project*

Program: CELTIC

Project acronym: QuEEN

Project title: Quality of Experience Estimators in Networks

Duration: October 2011 - January 2015

Coordinator: Orange Labs

Other partners: 24 partners in many European partners

Abstract: QuEEN was a large 3-year Celtic project going from end 2011 to January 2015. The project's outputs include the development of automatic QoE measurement modules for Web services and applications, and the organization of these measurement modules as a network of cooperative agents in order to allow each agent to take advantage of the measurements done by the others. Dionysos was involved in most of the activities of the project, and QuEEN partners have benefit from our experience in developing the PSQA technology. QuEEN involved many companies and academic institutions (24 European partners); the project leader was Orange Labs, in Sophia Antipolis.

For more details, visit <http://celtic-queen.inria.fr/dokuwiki/doku.php?id=start>

8.2.3. *Collaborations with Major European Organizations*

Partner 1: FTW, Vienna (Austria)

We work with FTW on network economics.

8.3. International Initiatives

8.3.1. *CIRIC*

In the context of CIRIC, we cooperate with the team of Reinaldo Vallejos, professor at the UTFSM, Valparaíso, Chile, on different topics related to networking and modeling issues. Specifically, these activities have been organized around two collaborative projects, 8.3.2 and 8.3.4.1 below, where one can find the scientific details. We start to work also with Javiera Barrera's team at the University Adolfo Ibañez, Santiago de Chile, on stochastic optimization problems.

CIRIC stopped its activities in some whole areas such as telecommunications, but our cooperative work continues without interruption.

Inria Chile

Associate Team involved in the International Lab:

8.3.2. *MANAP*

Title: MANAP (Markovian ANalysis and APplications)

International Partner (Institution - Laboratory - Researcher):

Universidad Tecnica Federico Santa Maria (Chile) - Telematics - Vallejos Reinaldo

Start year: 2013

See also: <http://people.rennes.inria.fr/Gerardo.Rubino/RESEARCH/MANAP/manap.html>

This project had two goals. The main one was to develop techniques allowing to accelerate solving techniques for Markov models, both in equilibrium and in their transient phases. The applications behind these efforts are the evaluation of performance, dependability and performability properties of complex communication systems. The second goal was to apply these solving techniques to specific problems in networking, concerning optical and wireless infrastructures. On both cases there was some emphasis on dependability aspects: fault tolerance routing schemes in the first case, complex dependability characteristics and their analysis in the second one. A third explicit objective was

to start the design of a software tool implementing the techniques coming from the main research direction of the project, designed to be used both by engineers and researchers.

We achieved some of these objectives, which made us decide to interrupt the associate team and to study the idea of proposing a new one at the end of 2016 or 2017 (see 8.3.4.1). A supplementary reason to do so is to rebuild some structure like MANAP but in a three-country scheme, including a group in Uruguay with which we worked during all MANAP's life.

8.3.3. Inria International Partners

8.3.3.1. MOCQUASIN

Title: Monte Carlo and Quasi- Monte Carlo for rare event simulation

International Partner (Institution - Laboratory - Researcher):

University of Montreal (Canada)

Duration: 2013 - . . .

See also: http://www.irisa.fr/dionysos/pages_perso/tuffin/MOCQUASIN/

The goal of this team is to compute integrals, sums or to solve equations or optimization problems by means of Monte Carlo methods, which are statistical tools used when the models have a high complexity (for instance a large dimension). They are unavoidable tools in areas such as finance, electronics, seismology, computer science, engineering, physics, transport, biology, social sciences... Nonetheless, they have the reputation of being slow, i.e. to require a large computational time to reach a given precision. The goal of the project is to work on acceleration techniques, meaning methods allowing to reach the targeted precision in a shorter computational time. A typical framework is that of rare event simulation for which getting even only one occurrence of the event could require a very long time. In this case, there are two main acceleration techniques: importance sampling and splitting, on which we work.

8.3.3.2. Informal International Partners

We restarted the cooperation of G. Rubino with the Cal Poly at Pomona, California, specifically with professor Alan Krinik, Head of the Mathematics Department. The topic is the transient analysis of stochastic processes. See [69] and [68], and the description made in 6.2, page 6.2.

8.3.4. Participation in other International Programs

8.3.4.1. Stic AmSud with UDELAR, Uruguay, and UTFSM, Chile

Program: Stic AmSud

Title: Dependability Analysis Tool (DAT)

Inria principal investigator: Gerardo Rubino

International Partners (Institution - Laboratory - Researcher):

University of the Republic (UDELAR), Montevideo, Uruguay – Computer Science at the Engineering Faculty – prof. Héctor Cancela

Technical University Federico Santa María (UTFSM), Valparaíso, Chile – Electronics Department – Prof. Reinaldo Vallejos

Duration: 2 years, Jan. 2015 – Dec. 2016

The main scientific objective of this project is to develop new techniques to assess the most important dependability properties of a complex system subject to the failures and possible repairs of its components. The central argument behind our proposal is our previous work in the area and some unpublished preliminary and promising results that we believe deserve deep exploration and that should lead to faster evaluation procedures than those available today. This constitute the main achievements of the associated team MANAP (see 8.3.2). We also intend to implement these techniques in an integrated software package usable both in industry and for teaching purposes. Concerning applications, again based on the skills of the participating teams and our past common work, we will illustrate our findings on problems coming from the wireless and optical networking domains.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

8.4.1.1. Academic visitors

- Reinaldo Vallejos, full professor
Date: 5/9/15 – 24/9/15
Institution: UTFSM, Valparaíso, Chile
- Marta Barría, full professor
Date: 5/9/15 – 24/9/15
Institution: University of Valparaíso, Chile
- Héctor Cancela, full professor
Date: 9/9/15 – 18/9/15
Institution: UDELAR, Uruguay
- Jorge Graneri, assistant professor
Date: 15/11/15 – 15/1/16
Institution: Institution: UDELAR, Uruguay
- Leslie Murray, assistant professor
Date: 21/11/15 – 11/12/15
Institution: University of Rosario, Argentina

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events organisation

9.1.1.1. Member of the organizing committees

Pierre L'Ecuyer was a member of the following groups:

- Steering Committee for the IMACS Seminar on Monte Carlo Methods (biennial conference), since 2009.
- Steering Committee for the International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing, since 2006.
- Selection committee for the INFORMS Simulation Society Distinguished Service Award, 2012-2015.

G. Rubino and B. Tuffin are members of the Steering Committee of the International Workshop on Rare Event Simulation (RESIM).

Y. Hadjadj-Aoul is a member of the steering committee of the International Conference on Information and Communication Technologies for Disaster Management (ICT-DM) from December 2015.

R. Marie and G. Rubino are members of the IFIP WG 7.3 (Working Group in Computer Performance Modeling and Analysis).

9.1.2. Scientific events selection

9.1.2.1. Chair of conference program committee

- Bruno Tuffin served as coordinator of Analysis Methodology track at the 48th Winter Simulation Conference, Huntington Beach, CA, December 2015.
- Adlen Ksentini served as Technical Program Committee Chair of the 1st IEEE on Standards for Communications and Networking (CSNC)
- Adlen Ksentini is serving as Symposium Chair of Mobile and Wireless Network Symposium of IEEE ICC 2016, Kuala Lumpur, Malaysia.
- Yassine Hadjadj-Aoul served as Technical Program Committee Chair of the 2nd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM).

9.1.2.2. Member of the conference program committees

Pierre L'Ecuyer was a member of the program committee of the following events:

- MCM'2015: Tenth IMACS Seminar on Monte Carlo Methods, Linz, Austria, July 2015.
- SIMUL 2015: Seventh International Conference on Advances in System Simulation, Barcelona, Nov. 2015.
- SIMULTECH 2015: International Conference on Simulation and Modeling Methodologies, Technologies and Applications, Colmar, France, July 2015.
- BIRS Workshop on Applied Probability Frontiers: Computational and Modeling Challenges, Banff, Canada, June 2015.

Bruno Tuffin was a member of the program committee of the following events:

- IEEE ICC 2015 - Communications Software, Services and Multimedia Applications Symposium, London, UK, June 8-12, 2015.
- NetEcon 2015: the 10th Workshop on the Economics of Networks, Systems and Computation, Portland, Oregon, USA, in conjunction with ACM SIGMETRICS, June 2015.
- 2015 ACM SIGSIM Conference on Principles of Advanced Discrete Simulation (ACM SIGSIM PADS 2015), the University of Westminster, London, UK, June 15-17, 2015.
- 4th Workshop on Smart Data Pricing (SDP 2015), Workshop of IEEE INFOCOM 2015, Hong Kong, May 1st, 2015.
- 10th IMACS Seminar on Monte Carlo Methods (MCM 2015), Linz, Austria, July 2015.
- 8th International Workshop on Simulation, Vienna, Austria, September 21-25, 2015.
- The International Conference on Wireless Networks and Mobile Communications (WINCOM'15), Marrakech, Morocco, October 20-23, 2015.

Bruno Sericola served in the Program Committee of the following conferences:

- ASMTA 2015, 22nd International Conference on Analytical & Stochastic Modelling Techniques & Applications, Albena, (Varna) Bulgaria, 26-29 May 2015.
- MACOM 2015, 8th International Workshop on Multiple Access Communications, Helsinki, Finland, 3-4 September 2015.
- INTERNET 2015, 7th International Conference on Evolving Internet, St. Julians, Malta, 11-16 October 2015.

Adlen Ksentini was member of the program committee of the following events:

- IEEE ICC 2015 Mobile Wireless Networks Symposium, London, UK, 2015.
- IEEE Globecom 2015 Mobile Wireless Networks Symposium, San Diego, USA, 2015.
- IEEE WCNC 2015, New Orleans, USA, 2015.

Yassine Hadjadj-Aoul was a member of the program committee of the following events:

- IEEE ICC 2015 Mobile Wireless Networks Symposium, London, UK, 2015.
- IEEE Globecom 2015 Mobile Wireless Networks Symposium, San Diego, USA, 2015.
- IEEE WCNC 2015, New Orleans, USA, 2015.
- IEEE CSCN 2015 IEEE Conference on Standards for Communications & Networking, Tokyo, Japan, 2015.

Gerardo Rubino served or serves at the program committee of the following conferences:

- QEST 2015: 12th International Conference on Quantitative Evaluation of SysTems, Madrid, Spain, August 2015.
- ComTel 2015: VIII Congreso Internacional de Computación y Telecomunicaciones, Lima, Perú, September 2016
- ComTel 2016: VIII Congreso Internacional de Computación y Telecomunicaciones, Lima, Perú, September 2016
- MASCOTS 2016: The 24th IEEE conference in Modelling, Analysis and Simulation of Computer and Telecommunications Systems, London, England, September 2016.
- Networking 2015: The 14th IFIP Networking Conference, Toulouse, France, May 2015.
- Networking 2016: The 15th IFIP Networking Conference, Vienna, Austria, May 2016.

9.1.2.3. Reviewer

César Viho has reviewed project proposals for the ANR and for CIFRE contracts for the ANRT. He has reviewed papers for the journals IEEE Transaction on Wireless Communication, IEEE Transactions on Vehicular Communications, IEEE Communications Magazine, and for the following international conferences: IWCNC'15, Globecom'15, CCNC'16.

Adlen Ksentini has reviewed papers in 2015 for Transaction Paralel Distributed Systems-TPDS, Transaction on Wireless Communication - TWC, Transaction on Vehicular Technology - TVT, Wireless Communication Magazine, Elsevier Computer Communication.

Yassine Hadjadj-Aoul has reviewed papers in 2015 for Transaction on Vehicular Technology-TVT, Wireless Communication Magazine, Elsevier Computer Communication and for the following international conferences: Globecom'15, ICC'15, WCNC'15.

9.1.3. Journal

9.1.3.1. Member of the editorial boards

Bruno Tuffin is an associate editor for the following journals:

- INFORMS Journal on Computing, since 2007.
- Mathematical Methods of Operations Research, since November 2008.
- ACM Transactions on Modeling and Computer Simulation, since July 2009.

Pierre L'Ecuyer is an associate editor for the following journals:

- ACM Transactions on Mathematical Software, since August 2004.
- Statistics and Computing (Springer-Verlag), since June 2003.
- International Transactions in Operational Research, since May 2007.

Bruno Sericola is an associate editor for the following journals:

- International Journal of Stochastic Analysis.
- Performance Evaluation.

Bruno Sericola is Editor in Chief of the books series "Stochastic Models in Computer Science and Telecommunications Networks", ISTE/WILEY.

Adlen Ksentini is Associate Editor of IEEE Access Journal.

Yassine Hadjadj-Aoul is guest editor for the Hindawi's Special Issue on "Wireless and Mobile Technologies for the Internet of Things".

Yassine Hadjadj-Aoul is a member of the editorial board of the CSC Journal's "International Journal of Computer Networks (IJCN)" since 2012.

9.1.3.2. Reviewer - Reviewing activities

In addition to the reports done during his associate editor and conference TPC member duties, Bruno Tuffin has reviewed papers in 2015 for ACM TOMPECS, Computers & Operations Research, IEEE Network Magazine, Operations Research, Statistics & Computing.

Bruno Sericola has reviewed papers for several major international journals and conferences.

Yassine Hadjadj-Aoul has reviewed papers for several major international journals and conferences such as: Security and Communication Networks (Wiley), IEEE Communication Magazine, and IEEE Transaction on Vehicular Technologies (TVT).

Gerardo Rubino has reviewed papers for several major international journals and conferences, including Performance Evaluation, RAIRO, book chapters, and the reviewing activities related to the service at different program committees.

9.1.4. Invited talks

- B. Tuffin. "Rare event simulation applied to dependability analysis". Université de Pau, May 2015.
- B. Tuffin (joint work with P. L'Ecuyer, P. Maillé, N. Stier-Moses). "Revenue-Maximizing Rankings for Online Platforms with Quality-Sensitive Consumers". GRD COS, Toulouse, September 2015.
- B. Tuffin (joint work with P. Maillé, G. Simon). "On revenue-oriented Content Delivery Networks and their impact on Net Neutrality". GEARD, Université de Montréal, Canada, Sept. 2015.
- B. Tuffin. "Rare event simulation applied to dependability analysis". GDR MASCOT-NUM, IHP Paris, October 2015.
- B. Tuffin (joint work with P. L'Ecuyer, P. Maillé, N. Stier-Moses). "Stochastic Optimization for Search Engines: Revenue-Maximizing Rankings with Quality-Sensitive Consumers". NTNU, Trondheim, Norway, November 2015.
- A. Ksentini, "On the Cloudification of mobile networks", Tutorial at IEEE Globecom, December 2015, San Diego, USA.
- A. Ksentini, "Cloud and mobile network, the marriage", Invited Seminar, Univ. Reims, October, 2015
- A. Ksentini, "SDN and NFV", Tutorial in the International School on Cloud Computing, Tunis, Tunisia, April 2015.
- C. Viho, "Quality of Experience(QoE)-based resource management in wireless networks", plenary talk at the 2nd International Congress on Telematics, Computing and Communications (WITCOM 2015), Mexico DF, Mexico, November 4, 2015.
- C. Viho, "How to Deal with Interoperability Testing in The Challenging and Ever-changing Context of IoT", invited talk at the 2nd EAI International Conference on Interoperability in IoT (InterIoT 2015), Roma, Italy, October 26, 2015.
- G. Rubino, "Random Neural Networks: some applications and extensions", invited speaker in Imperial College Seminar in honor of Prof. Erol Gelenbe, London, September November 2015.
- G. Rubino, "Automatic measuring of perceptual quality, a major QoE component of video- and audio-based services", plenary speaker in Soft Computing Methods for the Design, Deployment, and Reliability of Networks and Network Applications (SOFTNET 2015), Paris, France, July 2015.

- G. Rubino, “Statistical Learning and Queuing Models: an Hybrid Approach for Performance Evaluation”, plenary speaker in 15th International Conference on Hybrid Intelligent Systems (HIS 2015), Séoul, Korea, November 2015.
- G. Rubino, “Risk and loss, prediction and analysis: probabilistic approaches”, keynote speaker in 2nd Int. Conference on Information and Communication Technologies for Disaster Management, Rennes, France, December 2015.

9.1.5. Research administration

- Bruno Tuffin was a member of Inria-MITACS selection committee, 2015.
- Bruno Sericola is responsible for the Inria Rennes-Bretagne Atlantique budget.
- Bruno Sericola has been (until August 2015) a member of the Inria Evaluation Committee which role is to assess the calibre of research conducted at Inria and to guarantee the quality of its hiring and internal promotions.
- Bruno Sericola is the leader of the research group MAPI (Math Appli Pour l’Info) the goal of which is to improve the collaboration between computer scientists and mathematicians.
- Bruno Sericola has been member of the HCERES (Haut Conseil de l’Évaluation de la recherche et de l’enseignement supérieur) Evaluation Committee for the scientific evaluation of the CITI (Centre of Innovation in Telecommunications and Integration of service), Lyon, France, in February 2015;
- Adlen Ksentini is the secretary of the IEEE ComSoc Technical Committee on Software.
- Adlen Ksentini is the the secretary of the IEEE ComSoc France Section.
- Gerardo Rubino is a member of the Technical Committee on Multimedia Communications of IEEE.
- G. Rubino has been appointed as the Inria representative at the Scientific Committee of the IFCAM (Indo-French Center for Applied Mathematics), a joint international unit between Indian Ministry of Science and Technology and several French institutions including CNRS, Inria, École Polytechnique, École Normale Supérieure, Inria, Nice Sophia Antipolis University and University of Toulouse III.
- Gerardo Rubino is a member of the Research Commission of TELECOM Bretagne (advisory board for the research activities of the institution).
- Gerardo Rubino is a member of the CSV (Selection and Validation Committee) of the “Images et Réseaux” (Images and networks) cluster in the French Brittany Region. The cluster includes most companies and academic institutions working in networking and in image-based applications in Western France.
- Gerardo Rubino has been appointed as a member of the Scientific Advisory Board of the Center for Uncertainty Quantification in Computational Science and Engineering, of KAUST, Saudi Arabia, since January 2014.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master and PhD at NTNU (Trondheim, Norway): 25 hours intensive course on Game Theory and Network Economics

Undergraduate students, Probability, 40 hours, University of Science and Technology of Hanoi, Vietnam

Master M1: Performance and dependability evaluation of computer systems, 54 hours, Istic/University of Rennes 1, France

Master M2: Mathematics, 12 hours Istic/University of Rennes 1, France

Master M2: Logistic and performance, 8 hours, Faculté de sciences économiques/University of Rennes 1, France

Master M1: Computer networks, 24 hours, Esir/University of Rennes 1, France
 Master M1: Wireless Networks, 48 hours, Esir/University of Rennes 1, France
 Master M1: Introduction to graph theory, 14 hours, Esir/University of Rennes 1, France
 Master M2: Dependability analysis, 15 hours, SUPELEC Engineering School, Rennes, France
 Master M1: Networks and protocols, 24 hours, Istic/University of Rennes 1, France
 Master M2: Multimedia streaming over IP (MMR), 50 hours, Esir/University of Rennes 1, France
 Master M2: Multimedia services in IP networks (RSM), 29 hours, Esir/University of Rennes 1, France
 Master M2: Software Defined Networks, 4 hours, Istic/University of Rennes 1, France

9.2.2. Supervision

PhD in progress: Ajit Rai, “Availability prediction with logistics”, started in May 2015; advisor: B. Tuffin & G. Rubino, University Rennes 1.

Master: Yves Mocquard, “On population protocols”; advisors: Bruno Sericola and Emmanuelle Anceaume, University of Rennes 1.

PhD in progress: Corentin Hardy, “Device-Assisted Distributed Machine-Learning on Many Cores”, started on November 2015; advisors: Bruno Sericola, University of Rennes 1.

PhD in progress: Yves Mocquard, “Analyse de flux de données massifs dans les systèmes distribués large échelle”, started on September 2015; advisors: Bruno Sericola and Emmanuelle Anceaume, University of Rennes 1.

Bitssam Errahmadi; Cifre Grant, Orange Labs; title: “Coopération et auto-* dans un réseau de small cells”; PhD started on January 2013; advisors: C. Viho and A. Ksentini; University Rennes 1.

Osama Arouk; title: “Cellular-based M2M communication: congestion control”; PhD started on December 2012; advisors: C. Viho and A. Ksentini; University Rennes 1.

Farouk Messaoudi, title: “Orchestration et la virtualisation des ressources de terminaux, la vision Global OS”; PhD started on October 2014, advisor: A. Ksentini, P. Bertin; University Rennes 1.

Florient Grandhomme, title: “Etudes de protocoles de routage dynamique externe de type BGP dans un environnement réseaux tactiques adhoc mobiles : faisabilité, performances, qualité de service, et passage à l’échelle.”, PhD started on October 2014, advisors: A. Ksentini, G. Guette; University Rennes 1.

Louiza Yala, title: “CDNaaS: Content Delivery Network as a Service”, PhD started on October 2015, advisors: A. Ksentini; University Rennes 1.

Imad Awad, title: “Mobile SDN architecture for 5G”, PhD started on October 2015, advisors: A. Ksentini, P. Bertin; University Rennes 1.

Jean-Michel Sanner; Cifre Grant, Orange Labs, “SDN technologies for network services performances adaptation of carriers networks”; started on January 2013; Advisors: Y. Hadjadj-Aoul and G. Rubino; University Rennes 1.

Yue Li; Cifre Grant, Orange Labs; title: “Elaboration d’une architecture réseau unifiée, ouverte et flexible”, started on October 2013; Advisors: Y. Hadjadj-Aoul and G. Rubino; University Rennes 1.

Meriem Bouzouita; cotutelle between University of Rennes 1 and Carthage University; title: “Optimized random access for M2M communications in LTE-Advanced Networks”, started on October 2012; Advisors: Y. Hadjadj, N. Zangar, S. Tabbane, C. Viho; Carthage University, University Rennes 1.

Hamza Ben Ammar; University of Rennes 1; title: “Socially-aware network and cache resources optimization for efficient media content delivery in Content Centric Networks (CCN)”, started on October 2015; Advisors: Y. Hadjadj, A. Kentini, S. Ait-Chellouche; University of Rennes 1.

Nicolas Jara Carvallo; joint PhD between the University of Rennes 1 in France and the UTFSM in Chile; title: “Fault tolerant design of dynamic WDM optical networks”, started on October 2015; Advisors: R. Vallejos in Chile, G. Rubino in France.

Laura Aspirot; PhD from the University of the Republic, Uruguay; title: “Fluid Approximations for Stochastic Telecommunication Models”; co-advisors: E. Mordecki from UDELAR and G. Rubino in France.

Jorge Graneri; PhD from the University of the Republic, Uruguay; title: “Mathematical models for semantic memory pathologies”; co-advisors: E. Mizraji from UDELAR and G. Rubino in France.

9.2.3. *Juries*

Bruno Tuffin was a member of the following Habilitation defense committees:

- Pascal Redou. Modèles formels pour l’analyse et la simulation *in virtuo* de systèmes complexes d’inspiration biologique. Université de Bretagne Occidentale, Brest, 2015, rapporteur.
- P. Maillé. Insights from economic studies of telecommunication networks. Telecom Bretagne Rennes, Octobre 2015.

Gerardo Rubino was a member of the following Habilitation defense committee:

- Gwendal Simon. Massive Interactive Multimedia Services Over the Internet. HDR of the University of Rennes 1, Rennes, France. April 7, 2015. President of the jury.

Bruno Tuffin was a member of the following PhD defense committees:

- Josu Doncel. Efficiency of Distributed Queueing Games and of Path Discovery Algorithms. LAAS-CNRS, March 2015.
- Christelle Vergé. Modèle d’îlots de particules et application en fiabilité. École Polytechnique, Juillet 2015, rapporteur.
- Jeanne Demgne. Modélisation d’actifs industriels pour l’optimisation robuste des stratégies de maintenance. Université de Pau et de l’Amour, Octobre 2015, rapporteur.
- Vincent Moutoussamy. Contributions à l’analyse de fiabilité structurale : prise en compte de contraintes de monotonie pour les modèles numériques. Université de Toulouse, Novembre 2015, rapporteur.
- Yangyang Chen. Performance Analysis of Mobile Relays for LTE. Telecom Bretagne, December 2015.

Bruno Sericola was a member of the following:

- The jury for the recruitment of young graduate scientists.
- The jury for allocating the Inria Ph.D. and Research Supervising Bonus.
- The jury for allocating the university students’ thesis grants.
- The PhD defense committee of Mathilde Pascal, “Oral health in children and young adults after renal transplantation”, UFR d’odontologie, university of Rennes 1, December 2015, examinateur.

Adlen Ksentini was member of the following PhD defense committees:

- Mamadou Tourad DIALLO, Qualité d’expérience et adaptation de service vidéo. Institut Mines-Télécom Sud Paris, Juin 2015, rapporteur.
- Shengyang Chen, Etude des méthodes d’ordonnement sur les réseaux de capteurs sans fil, Univ. Reims, Octobre 2015, rapporteur.

C. Viho was a member of the juries for the recruitment of young Associate Professors and senior Professors at ISTIC-Université Rennes 1. He was a member of the following PhD defense committees:

- Tanguy Ropitault, “Routage et performances dans les réseaux CPL pour le Smart Grid”, Telecom Bretagne, June 2015, president.
- Roudy Dagher, “Sur la radionavigation dans les villes intelligentes du futur : Le cas des réseaux de capteurs sans-fils”, Université de Lille 1, June 2015, rapporteur.

Gerardo Rubino was a member of the following PhD defense committees:

- Thiago Wanderlay Matos de Abreu. “Modélisation et analyse de performances des réseaux en chaîne basés sur IEEE 802.11”. ENS Lyon, March 2015. Reviewer.
- Pedro Vilanova. “Multilevel approximations of Markovian jump processes with applications in communication networks”. Center for Uncertainty Quantification, Stochastic Numerics Research Group, KAUST, Saudi Arabia, May 2015.

9.3. Popularization

- In [80], [83], Bruno Tuffin and his co-author Patrick Maillé discuss for a large audience the issues and challenges of network neutrality.
- Bruno Sericola and Emmanuelle Anceaume made a presentation to students of the ENS (Ecole Normale Supérieure) Rennes on their works on the performance evaluation of data streaming analysis algorithms.
- G. Rubino makes regular presentations to high school students about the research work in general, and specific technical topics in particular. Current talks:
 - Randomness as a tool
 - Internet as a research problem
 - Great challenges in maths: the Riemann Hypothesis
 - Great challenges in math/computer science: the “P versus NP” problem

10. Bibliography

Major publications by the team in recent years

- [1] G. RUBINO, B. TUFFIN (editors). *Rare Event Simulation using Monte Carlo Methods*, John Wiley & Sons, 2009
- [2] N. BOUABDALLAH, A.-L. BEYLOT, E. DOTARO, G. PUJOLLE. *Resolving the Fairness Issues in Bus-Based Optical Access Networks*, in "IEEE Journal on Selected Areas in Communications", 2005, vol. 23, n^o 8, pp. 1444–1457
- [3] Y. HADJADJ-AOUL, T. TALEB. *An adaptive fuzzy-based CAC scheme for uplink and downlink congestion control in converged IP and DVB-S2 networks*, in "IEEE Transactions on Wireless Communications", Feb. 2009, vol. 8, n^o 2, pp. 816–825
- [4] Y. HAYEL, D. ROS, B. TUFFIN. *Less-than-Best-Effort Services: Pricing and Scheduling*, in "23rd IEEE Infocom Conference", Hong-Kong, China, March 2004
- [5] P. LEGUESDRON, J. PELLAUMAIL, G. RUBINO, B. SERICOLA. *Transient analysis of the M/M/1 queue*, in "Advances in Applied Probability", September 1993, vol. 25, n^o 3, pp. 702–713
- [6] H. NABLI, B. SERICOLA. *Performability analysis: a new algorithm*, in "IEEE Transactions on Computers", 1996, vol. 45, n^o 4, pp. 491–494
- [7] A. NAFAA, A. KSENTINI. *On Sustained QoS Guarantees in Operated IEEE 802.11 Wireless LANs*, in "IEEE Transactions on Parallel and Distributed Systems", 2008, vol. 19, n^o 8, pp. 1020–1033

- [8] G. RUBINO, B. SERICOLA. *A finite characterization of weak lumpable Markov processes. Part II: The continuous time case*, in "Stochastic Processes and their Applications", 1993, vol. 45, pp. 115–126
- [9] B. TUFFIN. *Bounded Normal Approximation in Highly Reliable Markovian Systems*, in "Journal of Applied Probability", 1999, vol. 36, n^o 4

Publications of the year

Articles in International Peer-Reviewed Journals

- [10] A. ABDELKADER, A. KSENTINI, G. ABDELHAK, T. TALEB. *Towards Elastic Distributed SDN/NFV Controller for 5G Mobile Cloud Management Systems*, in "IEEE Access", December 2015, vol. Volume 3, <https://hal.inria.fr/hal-01253137>
- [11] E. ANCEAUME, Y. BUSNEL, E. SCHULTE-GEERS, B. SERICOLA. *Optimization Results for a Generalized Coupon Collector Problem*, in "Journal of Applied Probability", June 2015, 9 p. , <https://hal.archives-ouvertes.fr/hal-01189578>
- [12] E. ANCEAUME, Y. BUSNEL, B. SERICOLA. *New results on a generalized coupon collector problem using Markov chains*, in "Journal of Applied Probability", 2015, 17 p. [DOI : 10.1239/JAP/1437658606], <https://hal.archives-ouvertes.fr/hal-01189564>
- [13] Y. BENMOUSSA, J. BOUKHOBZA, E. SENN, Y. HADJADJ-AOUL, D. BENAZZOZ. *A Methodology for Performance/Energy Consumption Characterization and Modeling of Video Decoding on Heterogeneous SoC and its Applications*, in "Journal of Systems Architecture", January 2015, vol. 61, n^o 1, pp. 49–70 [DOI : 10.1016/J.SYSARC.2014.11.003], <http://hal.univ-brest.fr/hal-01097122>
- [14] Z. I. BOTEV, P. L'ECUYER, R. SIMARD, B. TUFFIN. *Static Network Reliability Estimation under the Marshall-Olkin Copula*, in "ACM Transactions on Modeling and Computer Simulation", 2015, <https://hal.inria.fr/hal-01096393>
- [15] J. BOUKHOBZA, P. OLIVIER, S. RUBINI, L. LEMARCHAND, Y. HADJADJ-AOUL, A. LAGA. *MaCACH: An adaptive cache-aware hybrid FTL mapping scheme using feedback control for efficient page-mapped space management*, in "Journal of Systems Architecture", March 2015, vol. 61, n^o 3-4, pp. 157-171 [DOI : 10.1016/J.SYSARC.2015.03.001], <http://hal.univ-brest.fr/hal-01141031>
- [16] H. CANCELA, M. EL KHADIRI, G. RUBINO, B. TUFFIN. *Balanced and Approximate Zero-Variance Recursive Estimators for the Static Communication Network Reliability Problem*, in "ACM Transactions on Modeling and Computer Simulation", 2015, vol. 25, n^o 1, 19 p. , <https://hal.inria.fr/hal-00908567>
- [17] Y. DOUGA, B. MALIKA, A. MELLOUK, Y. HADJADJ-AOUL. *TCP based-user-parameters control for adaptive video streaming*, in "Multimedia Tools and Applications Journal", August 2015 [DOI : 10.1007/s11042-015-2857-1], <https://hal.inria.fr/hal-01251949>
- [18] P. FRANGOUDIS, G. C. POLYZOS. *Reputation-based crowdsourced Wi-Fi topology discovery*, in "Computer Networks", 2015, 0 p. , <https://hal.inria.fr/hal-01104533>
- [19] F. GUILLEMIN, B. SERICOLA. *Volume and Duration of Losses in Finite Buffer Fluid Queues*, in "Journal of Applied Probability", 2015, vol. 52, n^o 3, 15 p. , <https://hal.inria.fr/hal-01194532>

- [20] R. IBRAHIM, H. YE, P. L'ECUYER, H. SHEN. *On the modeling and forecasting of call center arrivals*, in "International Journal of Forecasting", 2015 [DOI : 10.1109/WSC.2012.6465292], <https://hal.inria.fr/hal-01240166>
- [21] P. L'ECUYER. *Comment on "Sequential Quasi-Monte Carlo Sampling"*, in "Journal of the Royal Statistical Society: Series B", 2015, <https://hal.inria.fr/hal-01240158>
- [22] P. L'ECUYER, D. MUNGER. *LatticeBuilder: A General Software Tool for Constructing Rank-1 Lattice Rules*, in "ACM Transactions on Mathematical Software", 2015, <https://hal.inria.fr/hal-01240168>
- [23] P. MAILLÉ, G. SIMON, B. TUFFIN. *Toward a Net Neutrality Debate that Conforms to the 2010s*, in "IEEE Communications Magazine", 2015, <https://hal.inria.fr/hal-01127958>
- [24] A. MOULOUD, D. AISSANI, Y. HADJADJ-AOUL. *Towards Bandwidth and Energy Optimization in IEEE 802.15.4 Wireless Sensor Networks*, in "International Journal of Distributed Sensor Networks", January 2015, <https://hal.inria.fr/hal-01251952>
- [25] Q. T. A. PHAM, K. PIAMRAT, S. KAMAL DEEP, C. VIHO. *QoE-based routing algorithms for H.264/SVC video over Ad-hoc networks*, in "Wireless Networks", November 2015 [DOI : 10.1007/s11276-015-1103-0], <https://hal.inria.fr/hal-01253420>
- [26] G. RUBINO, S. BASTERRECH. *Random Neural Network Model for Supervised Learning Problems*, in "accepted for publication in Neural Network World Journal", 2016, <https://hal.inria.fr/hal-01261181>
- [27] G. RUBINO, H. CANCELA, L. MURRAY. *Conditional Monte Carlo with Intermediate Estimations for simulation of Markovian systems*, in "Electronic Notes in Theoretical Computer Science", 2016, <https://hal.inria.fr/hal-01261168>
- [28] G. RUBINO, F. R. PADULA, P. ROMERO, A. MAUTTONE. *Capacitated m Ring Star Problem under Diameter Constrained Reliability*, in "Electronic Notes in Theoretical Computer Science", 2016, <https://hal.inria.fr/hal-01261161>
- [29] T. TALEB, Y. HADJADJ-AOUL, K. SAMDANIS. *Efficient Solutions for Enhancing Data Traffic Management in 3GPP Networks*, in "IEEE Systems Journal", June 2015, <https://hal.inria.fr/hal-01251953>

Invited Conferences

- [30] E. ANCEAUME, Y. BUSNEL, N. RIVETTI. *Estimating the Frequency of Data Items in Massive Distributed Streams*, in "IEEE 4th Symposium on Network Cloud Computing and Applications (NCCA)", Munich, Germany, June 2015, 9 p., <https://hal.archives-ouvertes.fr/hal-01194529>
- [31] Z. I. BOTEV, P. L'ECUYER, R. SHAH, B. TUFFIN. *Conditioning by Permutation Monte Carlo for Continuous-Time Markov Chains*, in "Eighth International Workshop on Simulation", Vienna, Austria, September 2015, <https://hal.inria.fr/hal-01239565>

International Conferences with Proceedings

- [32] A. ABDELKADER, A. KSENTINI, G. ABDELHAK. *An Efficient Elastic Distributed SDN Controller for Follow-Me Cloud*, in "IEEE Wireless and Mobility Conference (WiMob) 2015", Abu Dhabi, United Arab Emirates, October 2015, <https://hal.inria.fr/hal-01253192>
- [33] A. ABDELKADER, A. KSENTINI, G. ABDELHAK. *PMIPv6-based Follow Me Cloud*, in "IEEE Globecom 2015", San Diego, United States, December 2015, <https://hal.inria.fr/hal-01253198>
- [34] E. ANCEAUME, Y. BUSNEL. *Estimer la corrélation à la volée entre flux massifs est possible avec très peu de mémoire*, in "ALGOTEL 2015 — 17èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Beaune, France, June 2015, <https://hal.archives-ouvertes.fr/hal-01147072>
- [35] E. ANCEAUME, Y. BUSNEL, P. LAJOIE-MAZENC, G. TEXIER. *Reputation for Inter-Domain QoS Routing*, in "International Symposium on Network Computing and Applications (NCA)", Boston, United States, IEEE, September 2015, 5 p. , <https://hal.archives-ouvertes.fr/hal-01190451>
- [36] E. ANCEAUME, Y. BUSNEL, N. RIVETTI, B. SERICOLA. *Identifying Global Icebergs in Distributed Streams*, in "34th International Symposium on Reliable Distributed Systems (SRDS)", Montreal, Canada, September 2015, 10 p. , <https://hal.archives-ouvertes.fr/hal-01194511>
- [37] E. ANCEAUME, F. CASTELLA, A. MOSTEFAOUI, B. SERICOLA. *A Message-Passing and Adaptive Implementation of the Randomized Test-and-Set Object*, in "International Symposium on Network Computing and Applications (NCA)", Boston, United States, September 2015, 9 p. , <https://hal.archives-ouvertes.fr/hal-01190379>
- [38] M. BAGAA, T. TALEB, A. KSENTINI. *Efficient Tracking Area Management in Carrier Cloud*, in "IEEE Globecom 2015", San Diego, United States, December 2015, <https://hal.inria.fr/hal-01253193>
- [39] Z. I. BOTEV, P. L'ECUYER. *Efficient estimation and simulation of the truncated multivariate student-t distribution*, in "2015 Winter Simulation Conference", Huntington Beach, United States, L. YILMAZ, M. CHAN, I. MOON, T. M. K. ROEDER, C. MACAL, M. ROSSETTI (editors), December 2015, <https://hal.inria.fr/hal-01240154>
- [40] E. BTISSAM, A. KSENTINI, D.-E. MEDDOUR. *Wait-to-Pick-As-Available (W2PAA): a New MAC Protocol for Uplink Multi-Users Transmissions in WLAN*, in "IEEE Wireless and Mobility Conference (WiMob) 2015", Abu Dhabi, United Arab Emirates, October 2015, <https://hal.inria.fr/hal-01253159>
- [41] H. CANCELA, M. EL KHADIRI, G. RUBINO, B. TUFFIN. *On the robustness of fishman's bound-based method for the network reliability problem*, in "Winter Simulation Conference", Huntington Beach, United States, December 2015, <https://hal.inria.fr/hal-01239546>
- [42] S. EDDINE ELAYOUBI, C. FRICKER, F. GUILLEMIN, P. ROBERT, B. SERICOLA. *Impatience in mobile networks and its application to data pricing*, in "IEEE ICC 2015 – Communications QoS, Reliability and Modeling Symposium", London, United Kingdom, IEEE, June 2015, 6 p. , <https://hal.archives-ouvertes.fr/hal-01082038>
- [43] S.-E. ELAYOUBI, C. FRICKER, F. GUILLEMIN, P. ROBERT, B. SERICOLA. *Controlling impatience in cellular networks using QoE-aware radio resource allocation*, in "27th ITC International Teletraffic Congress (ITC 27)", Ghent, Belgium, September 2015, <https://hal.inria.fr/hal-01179377>

- [44] M. FAROUK, G. SIMON, A. KSENTINI. *Dissecting Games Engines: the Case of Unity3D*, in "ACM Netgames 2015", Zagreb, Croatia, December 2015, <https://hal.inria.fr/hal-01253200>
- [45] P. L'ECUYER. *Random number generation with multiple streams for sequential and parallel computing*, in "2015 Winter Simulation Conference", Huntington Beach, United States, L. YILMAZ, W. K. V. CHAN, I. MOON, T. M. K. ROEDER, C. MACAL, M. ROSSETTI (editors), December 2015, <https://hal.inria.fr/hal-01240131>
- [46] P. MAILLÉ, B. TUFFIN. *Impact of Content Delivery Networks on service and content innovation*, in "NetEcon 2015 : the 10th Workshop on the Economics of Networks, Systems and Computation", Portland, United States, June 2015, pp. 1 - 4, <https://hal.archives-ouvertes.fr/hal-01217929>
- [47] P. MAILLÉ, G. SIMON, B. TUFFIN. *Impact of Revenue-Driven CDN on the Competition among Network Operators*, in "11th International Conference on Network and Service Management (CNSM)", Barcelona, Spain, IEEE (editor), November 2015, <https://hal.inria.fr/hal-01239544>
- [48] P. MAILLÉ, B. TUFFIN. *Users facing volume-based and flat-rate-based charging schemes at the same time*, in "8th Latin American Network Operations and Management Symposium (LANOMS 2015)", Joao Pessoa, Brazil, I. EXPLORE (editor), October 2015, <https://hal.inria.fr/hal-01113322>
- [49] Y. MOCQUARD, E. ANCEAUME, J. ASPNES, Y. BUSNEL, B. SERICOLA. *Counting with Population Protocols*, in "International Symposium on Network Computing and Applications (NCA)", Boston, United States, IEEE, September 2015, 9 p. , <https://hal.archives-ouvertes.fr/hal-01189596>
- [50] Y. MOHAND, A. KSENTINI, L. BOUALLOUCHE-MEDJKOUNE, D. AISSANI. *Enhancement of the TXOP Sharing designed for DL-MU-MIMO IEEE 802.11ac WLANs*, in "IEEE Wireless Communications and Networks Conference (WCNC)", New Orleans, United States, March 2015, <https://hal.inria.fr/hal-01253142>
- [51] A. OSAMA, A. KSENTINI, T. TALEB. *Group Paging Optimization For Machine-Type-Communications*, in "IEEE International Conference on Communications (ICC'15)", Londre, United Kingdom, June 2015, <https://hal.inria.fr/hal-01253155>
- [52] A. OSAMA, A. KSENTINI, T. TALEB. *Performance Analysis of RACH procedure with Beta Traffic-Activated Machine-Type-Communication*, in "IEEE Globecom 2015", San Diego, United States, December 2015, <https://hal.inria.fr/hal-01253196>
- [53] N. RIVETTI, L. QUERZONI, E. ANCEAUME, Y. BUSNEL, B. SERICOLA. *Efficient Key Grouping for Near-Optimal Load Balancing in Stream Processing Systems* , in "The 9th ACM International Conference on Distributed Event-Based Systems (DEBS)", Oslo, Norway, June 2015 [DOI : 10.1145/2675743.2771827], <https://hal.archives-ouvertes.fr/hal-01194518>
- [54] G. RUBINO, E. CANALE, H. CANCELA, P. ROMERO, P. E. SARTOR DEL GIUDICE, J. PICCINI, F. ROBLEDO. *Recursive Variance Recursion Method in Stochastic Monotone Binary Systems*, in "IFIP/IEEE 7th International Workshop on Reliable Networks Design and Modeling (RNDM'15)", Munich, Germany, IEEE (editor), October 2015, <https://hal.archives-ouvertes.fr/hal-01261210>
- [55] G. RUBINO, S. JELASSI. *YouSOS: A victim-centered management solution of rescue operations*, in "2nd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM 2015)", Rennes, France, December 2015, <https://hal.archives-ouvertes.fr/hal-01261209>

- [56] G. RUBINO. *Power and effectiveness in queueing systems*, in "12th International Conference on Quantitative Evaluation of SysTems (QEST 2015)", Madrid, Spain, August 2015, <https://hal.archives-ouvertes.fr/hal-01261207>
- [57] T. TALEB, M. BAGAA, A. KSENTINI. *User Mobility-Aware Virtual Network Function Placement for Virtual Mobile Network Infrastructure*, in "IEEE ICC 2015", Londre, United Kingdom, June 2015, <https://hal.inria.fr/hal-01253149>
- [58] M. THIONGANE, W. CHAN, P. L'ECUYER. *Waiting time predictors for multi-skill call centers*, in "2015 Winter Simulation Conference", Huntington Beach, United States, L. YILMAZ, M. CHAN, I. MOON, T. M. K. ROEDER, C. MACAL, M. ROSSETTI (editors), December 2015, <https://hal.inria.fr/hal-01240150>
- [59] B. TUFFIN. *Side Payments as Barriers to Entry in Non-Neutral Networks*, in "12th Conference of Telecommunication, Media and Internet Techno-Economics (CTTE)", Munich, Germany, November 2015, <https://hal.inria.fr/hal-01149214>

Conferences without Proceedings

- [60] *Best Paper*
M. BOUZOUITA, Y. HADJADJ-AOUL, N. ZANGAR, G. RUBINO, S. TABBANE. *Multiple Access Class Barring factors Algorithm for M2M communications in LTE-Advanced Networks*, in "18th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM)", Cancun, Mexico, November 2015, <https://hal.inria.fr/hal-01251964>.
- [61] M. BOUZOUITA, Y. HADJADJ-AOUL, N. ZANGAR, G. RUBINO, S. TABBANE. *Applying nonlinear optimal control strategy for the access management of MTC devices*, in "13th Annual IEEE Consumer Communications & Networking (CCNC)", Las Vegas, United States, January 2016, <https://hal.inria.fr/hal-01252011>
- [62] Y. LI, Y. HADJADJ-AOUL, P. BERTIN, G. RUBINO. *Control Theory Based Interface Selection Mechanism in Fixed-Mobile Converged Network*, in "Int. Conf. on High Performance Switching and Routing", Budapest, Hungary, IEEE, July 2015, <https://hal.inria.fr/hal-01251959>
- [63] Y. LI, Y. HADJADJ-AOUL, P. BERTIN, G. RUBINO. *A control theoretic strategy for intelligent network interface selection in heterogeneous environments*, in "13th Annual IEEE Consumer Communications & Networking", Las Vegas, United States, IEEE, January 2016, <https://hal.inria.fr/hal-01252008>
- [64] C. LÉCOT, P. L'ECUYER, B. TUFFIN. *Recent developments on Array-RQMC*, in "IMACS MCM 2015 Conference", Linz, Austria, July 2015, <https://hal.inria.fr/hal-01239553>
- [65] G. MOUALLA, P. FRANGOUDIS, Y. HADJADJ-AOUL, S. AÏT-CHELLOUCHE. *A bloom-filter-based socially aware scheme for content replication in mobile ad hoc networks*, in "13th Annual IEEE Consumer Communications & Networking", Las Vegas, United States, IEEE, January 2016, <https://hal.inria.fr/hal-01252001>
- [66] G. RUBINO, S. BASTERRECH, V. SNASEL. *Experimental Analysis of a Hybrid Reservoir Computing Technique*, in "15th International Conference on Hybrid Intelligent Systems (HIS 2015)", Séoul, South Korea, November 2015, <https://hal.inria.fr/hal-01261184>

- [67] G. RUBINO, S. BASTERRECH, V. SNASEL. *Sensitivity Analysis of Echo State Networks for Forecasting Pseudo-Periodic Time Series*, in "Soft Computing and Pattern Recognition (SOCPAR 2015)", Fukuoka, Japan, November 2015, <https://hal.inria.fr/hal-01261188>
- [68] G. RUBINO, A. KRINIK. *Analyzing extreme values and loss parameters of queuing models in a finite time interval*, in "8th International Conference on Lattice Path Combinatorics and Applications", Pomona, California, United States, August 2015, <https://hal.archives-ouvertes.fr/hal-01261212>
- [69] G. RUBINO, A. KRINIK. *The concept of pseudo-dual of any (finite or infinite) linear system of differential equations*, in "8th International Conference on Lattice Path Combinatorics and Applications", Pomona, California, United States, August 2015, <https://hal.archives-ouvertes.fr/hal-01261211>
- [70] J.-M. SANNER, M. OUZZIF, Y. HADJADJ-AOUL. *DICES: a Dynamic adaptive service-driven SDN architecture*, in "IEEE Conference on Network Softwarization", Londre, United Kingdom, IEEE, April 2015, <https://hal.inria.fr/hal-01251958>

Scientific Books (or Scientific Book chapters)

- [71] *2015 2nd International Conference on Information and Communication Technologies for Disaster Management (ICT-DM)*, December 2015, <https://hal.inria.fr/hal-01252014>
- [72] M. BOUZOUITA, Y. HADJADJ-AOUL, N. ZANGAR, S. TABBANE, C. VIHO. *A random access model for M2M communications in LTE-advanced mobile networks*, in "Modeling and simulation of computer networks and systems", Elsevier/Morgan Kofmann, January 2015, <https://hal.inria.fr/hal-01251957>
- [73] P. L'ECUYER. *Random Number Generation and Quasi-Monte Carlo*, in "Wiley StatsRef: Statistics Reference Online", John Wiley, 2015, <https://hal.inria.fr/hal-01098541>
- [74] G. RUBINO, B. SERICOLA. *Sojourn Times in Dependability Modeling*, in "Principles of Performance and Reliability Modeling and Evaluation", L. FIONDELLA, A. PULIAFITO (editors), Springer International, 2016, <https://hal.inria.fr/hal-01258121>

Research Reports

- [75] E. ANCEAUME, Y. BUSNEL, N. RIVETTI, B. SERICOLA. *Identifying Global Icebergs in Distributed Streams*, Cnrs ; Inria Rennes ; Université de Nantes, April 2015, <https://hal.archives-ouvertes.fr/hal-01141829>
- [76] E. ANCEAUME, Y. BUSNEL, E. SCHULTE-GEERS, B. SERICOLA. *Optimization results for a generalized coupon collector problem*, Inria Rennes ; Cnrs, January 2015, <https://hal.archives-ouvertes.fr/hal-01141577>
- [77] Y. BUSNEL. *D.4.1 – Application scenarii and Design of infrastructure*, LINA-University of Nantes, May 2015, This report has been written by all members of the consortium, <https://hal.archives-ouvertes.fr/hal-01168810>
- [78] N. RIVETTI, E. ANCEAUME, Y. BUSNEL, L. QUERZONI, B. SERICOLA. *Proactive Online Scheduling for Shuffle Grouping in Distributed Stream Processing Systems*, LINA-University of Nantes ; Sapienza Università di Roma (Italie), December 2015, <https://hal.inria.fr/hal-01246701>

- [79] N. RIVETTI, Y. BUSNEL, A. MOSTEFAOUI. *Efficiently Summarizing Distributed Data Streams over Sliding Windows*, LINA-University of Nantes ; Centre de Recherche en Économie et Statistique ; Inria Rennes Bretagne Atlantique, June 2015, 19 pages, <https://hal.archives-ouvertes.fr/hal-01073877>

Scientific Popularization

- [80] B. TUFFIN, P. MAILLÉ. *La neutralité du Net : le débat est-il bien posé ? (1)*, November 2015, The Conversation, <https://hal.inria.fr/hal-01239569>

Other Publications

- [81] E. ANCEAUME, F. CASTELLA, A. MOSTEFAOUI, B. SERICOLA. *A Message-Passing and Adaptive Implementation of the Randomized Test-and-Set Object*, August 2015, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01075650>
- [82] P. L'ECUYER, P. MAILLÉ, N. STIER-MOSES, B. TUFFIN. *Revenue-Maximizing Rankings for Online Platforms with Quality-Sensitive Consumers*, September 2015, working paper or preprint, <https://hal.inria.fr/hal-00953790>
- [83] P. MAILLÉ, B. TUFFIN. *Neutralité du Net : une approche plus large est nécessaire (2)*, December 2015, The Conversation, <https://hal.inria.fr/hal-01239570>
- [84] P. MAILLÉ, B. TUFFIN. *Auctions for online ad space among advertisers sensitive to both views and clicks*, December 2015, working paper or preprint, <https://hal.inria.fr/hal-01241308>
- [85] Y. MOCQUARD, E. ANCEAUME, J. ASPNES, Y. BUSNEL, B. SERICOLA. *Counting with Population Protocols*, July 2015, working paper or preprint, <https://hal.archives-ouvertes.fr/hal-01170575>

References in notes

- [86] W. J. ANDERSON. *Continuous-Time Markov Chains*, Springer, 1991
- [87] M. L. GREEN, A. KRINIK, C. MORTENSEN, G. RUBINO, R. J. SWIFT. *Transient Probability Functions: A Sample Path Approach*, in "Discrete Mathematics and Theoretical Computer Science", 1997, vol. 1, n^o 1, pp. 1–16
- [88] A. KRINIK, G. RUBINO, D. MARCUS, R. J. SWIFT, H. KASFY, H. LAM. *Dual processes to solve single server systems*, in "Journal of Statistical Planning and Inference", November 2005, vol. 135, n^o 1, pp. 121–147