



IN PARTNERSHIP WITH:  
**Université Rennes 1**

Activity Report 2013

## **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**



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## Project-Team DIONYSOS

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## 2. Overall Objectives

### 2.1. Introduction

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.

### 2.2. Highlights of the Year

This year three books produced by the team appeared: "Markov Chains. Theory, Algorithms and Applications" at Wiley, written by Bruno Sericola first in English, then in French, and "Telecommunication Network Economics: From Theory to Applications", written by Bruno Tuffin with Patrick Maillé, at Cambridge University Press.

## 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 (see 3.2).

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. Application Domains

### 4.1. Networking

Our global research effort concerns networking problems, both from the analysis point of view, and around network design issues. Specifically, this means the IP technology in general, with focus on specific types of networks seen at different levels: wireless systems, optical infrastructures, peer-to-peer architectures, Software Defined Networks, Content Delivery Networks, Content-Centric Networks, clouds.

### 4.2. Complex systems

Many of the techniques developed at Dionysos are useful for the analysis of complex systems in general, not only in telecommunications. For instance, our Monte Carlo methods for analyzing rare events have been used by different industrial partners, some of them in networking but recently also by companies building transportation systems.

## 5. Software and Platforms

### 5.1. T3devKit testing toolkit and IPv6 test suites

**Participants:** César Viho, Anthony Baire.

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). It is publicly released under the CeCILL-C License.



All these tools with associated test suites (for RIPng, DHCPv6 and examples for DNS) are freely available at <http://www.irisa.fr/tipi>.

## 5.2. Interoperability Assessment

**Participants:** César Viho, Anthony Baire.

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>.

## 5.3. 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`.

# 6. New Results

## 6.1. Quality of Experience

**Participants:** Yassine Hadjadj-Aoul, Adlen Ksentini, Gerardo Rubino, César Viho, Pantelis Frangoudis, Hyunhee Park, Kandaraj Piamrat.

We continue the development of the PSQA technology (Pseudo-Subjective Quality Assessment) in the area of Quality of Experience (QoE). PSQA is today a stable technology allowing to build measuring modules capable of quantifying the quality of a video or an audio sequence, as perceived by the user, when received through an IP network. It provides an accurate and efficiently computed evaluation of quality. Accuracy means that PSQA gives values close to those that can be obtained from a panel of human observers, under a controlled subjective testing experiment, following an appropriate standard (which depends on the type of sequence or application). Efficiency means that our measuring tool can work in real time, if necessary. Observe that perceived quality is, in general, the main component of QoE when the application or service involves video and audio, or voice. PSQA works by analyzing the networking environment of the communication and some the technical characteristics of the latter. It works without any need to the original sequence (as such, it belongs to the family of *no-reference* techniques).

It must be pointed out that a PSQA measuring or monitoring module is network-dependent and application-dependent. Basically, for each specific networking technology, application, service, the module must be built from scratch. But once built, it works automatically and efficiently, allowing if necessary its use in real time, typically for controlling purposes.

**Learning tools.** At the heart of the PSQA approach there is the statistical learning process necessary to develop measuring modules. So far we have been using Random Neural Networks (RNNs) for that purpose (see [74] for a general description), but recently, we started to explore other approaches. For instance, in the last ten years a new computational paradigm was presented under the name of *Reservoir Computing* (RC) [71] with the goal of attacking the main limitations in training time for recurrent neural networks while introducing no significant disadvantages. Two RC models have been proposed independently and simultaneously under the name of *Liquid State Machine* (LSM) [73] and *Echo State Networks* (ESN) [71]. They constitute today one of the basic paradigms for Recurrent Neural Networks modeling [72]. The main characteristic of the RC model is that it separates two parts: a static sub-structure called *reservoir* which involves the use of cycles in order to provide dynamic memory in the network, and a parametric part composed of a function such as a multiple linear regression or a classical single layer network. The reservoir can be seen as a high-dimensional dynamical system that expand the input stream in a space of states. The learning part of the model is the parametric one. In [41] we propose a new learning tool which merges the capabilities of Random Neural Networks (RNNs) with those of RC models. We keep some of the nice features of RNNs with the ability of RC models in predicting time series values. Our tool is called Echo State Queueing Network. In the paper, we illustrate its performances in predicting, in particular, Internet traffic. In [63], more results about the good behavior of our new tool are presented.

**QoE for SVC.** A recent video encoding scheme called Scalable Video Coding (SVC) provides the flexibility and the capability to adapt the video quality to varying network conditions and heterogeneous users. Last year, we started to look at the relations between the way SVC is used and the obtained perceived quality. This year we continued these efforts, together with exploring the use of QoE estimation tools for SVC video coding in network control. In [46] we evaluate different configurations for SVC-based adaptive streaming in terms of user QoE. The aim is to provide recommendations about the different rates to be used in order to create the video representation configuration. These results are part of the PhD [11]. In [25], we extended our previous work on SVC in DVB-T2, by proposing an analytical model to evaluate the performance of associating SVC with DVB-T2 and QoE. To do this, we developed a discrete time Markov Chain model which captures the system evolution in terms of number of SVC layers that need to be decoded in order to increase user QoE. In [45], we introduced a new solution to be used by a DASH client for selecting the video representation. Our proposal relies on using the PTP synchronization protocol in order to estimate the end-to-end delays between the client and the server, and hence to correlate this information with network load. The correlation between delays and load was based on a fitting function.

In [54], we focus on SVC multicast over IEEE 802.11 networks. Traditionally, multicast uses the lowest modulation resulting in a video with only base quality even for users with good channel conditions. To optimize QoE, we propose to use multiple multicast sessions with different transmission rates for different SVC layers. The goal is to provide at least the multicast session with acceptable quality to users with bad channel conditions and to provide additional multicast sessions having SVC enhancement layers to users with better channel conditions. The selection of modulation rate for each SVC layer and for each multicast session is achieved with binary integer linear programming depending on network conditions with a goal to maximize global QoE. The results show that our algorithm maximizes global QoE by providing highest quality videos to users with good channel conditions and by guaranteeing at least acceptable QoE for all users.

**VoIP.** We continued to work on the perceptual quality of voice-based applications and services. In [17], we consider a well-known and widely used *full-reference* technique for measuring speech quality called PESQ, and we propose a learning-based tool for approximating PESQ output without any need for the original signal, following the same black-box parametric PSQA approach. The procedure uses the Echo State Networks previously mentioned.

In [48], we propose a new packet loss model that differentiates loss instances depending on their perceptual impact. In particular, the model captures the differences between short and long interruptions from the perceptual quality viewpoint. In some cases, the delays and their variation have a strong impact on the perceived quality. In [49] we explore the variability of packet delays on MANETs. For that purpose, a wide range of representative scenarios are defined and simulated. The gathered traces are then inspected from qualitative and quantitative perspectives. In [50], a Markovian model is proposed to capture these and other features of delays in the same class of mobile networks.

## 6.2. Network Economics

**Participant:** Bruno Tuffin.

The general field of network economics, analyzing the relationships between all actors of the digital economy, has been an important subject for years in the team.

**A new book on the subject.** We have published a book on this broad topic [61]. Presenting a balance of theory and practice, this up-to-date guide provides a comprehensive overview of the key issues in telecommunication network economics, as well as the mathematical models behind the solutions. These mathematical foundations enable the reader to understand the economic issues arising at this pivotal time in network economics, from business, research, and political perspectives. This is followed by a unique practical guide to current topics, including app stores, volume-based pricing, auctions for advertisements, search engine business models, the network neutrality debate, the relationship between mobile network operators and mobile virtual network operators, and the economics of security. The guide discusses all types of players in telecommunications, from users, to access and transit network providers; to service providers (including search engines, cloud providers or content delivery networks); to content providers, and regulatory bodies. The book is designed for graduate students, researchers, and industry practitioners working in telecommunications.

Research contributions in network economics during 2013 can be decomposed into the application of auction theory, cognitive networks, and network/search neutrality analysis.

**Auction theory.** In the next generation Internet, we have seen the convergence of multimedia services and Internet with the mobility of users. Vertical handover decision (VHD) algorithms are essential components of the mobility management architecture in mobile wireless networks. VHD algorithms help mobile users to choose the best mobile network to connect among available candidates. It also can help the network manager to optimize easily the limited resources shared among the network providers and the users. In [26], we formulate VHD algorithm as a resource allocation problem for down-link transmission power in multiple W-CDMA networks and show how combinatorial double-sided auctions can be applied to this specific problem. The proposed pricing schemes make use of the signal interference to noise ratio (SINR), achievable data rates, power allocation at mobile networks, and monetary cost as decision criteria, and our model differentiates new calls and on-going communications to take into account that the last category has somewhat more importance. Several combinatorial double-sided auction are proposed to maximize the social welfare and /or to provide incentives for mobile users and mobile operators to be truth-telling in terms of valuation or cost. Finally, the economic properties of the different proposed pricing schemes are also studied by means of simulations.

**Cognitive networks.** Cognitive radio technologies for spectrum sharing have received an enormous interest from the research community for the last decade, and more recently from regulators and mobile operators. We have studied a cognitive radio network in [47] where primary operator and an entrant secondary operator compete for users. The system is modeled using queueing and game theories. The economic viability of supporting the secondary operator service using an opportunistic access to the spectrum owned by the primary operator is assessed. Against the benchmark of the primary operator operating as a monopolist, we show that the entry of the secondary operator is desirable from an efficiency perspective, since the carried traffic increases. For a range of parameter values, a lump sum payment can be designed so that the incumbent operator has an incentive to let the secondary operator enter. Additionally, the opportunistic access setting has been compared against a leasing-based alternative, and we have concluded that the former outperforms the latter in terms of efficiency and incentive.

**Network/search neutrality analysis.** Network neutrality is the topic of a vivid and very sensitive debate, in both the telecommunication and political worlds, because of its potential impact in everyday life. That debate has been raised by Internet Service Providers (ISPs), complaining that content providers (CPs) congest the network with insufficient monetary compensation, and threatening to impose side payments to CPs in order to support their infrastructure costs. While there have been many studies discussing the advantages and drawbacks of neutrality, there is no game-theoretical work dealing with the observable situation of competitive ISPs in front of a (quasi-)monopolistic CP. However, this is a typical situation that is condemned by ISPs, and, according to them, another reason of the non-neutrality need. We develop and analyze in [23] a model describing the relations between two competitive ISPs and a single CP, played as a three-level game corresponding to three different time scales. At the largest time scale, side payments (if any) are determined. At a smaller time scale, ISPs decide their (flat-rate) subscription fee (toward users), then the CP chooses the (flat-rate) price to charge users. Users finally select their ISP (if any) using a price-based discrete choice model, and decide whether to also subscribe to the CP service. The game is analyzed by backward induction. As a conclusion, we obtain among other things that non-neutrality may be beneficial to the CP, and not necessarily to ISPs, unless the side payments are decided by ISPs.

The very related recently raised search neutrality debate questions the ranking methods implemented by search engines: when a search is performed, do they (or should they) display the web pages ordered according to the quality-of-experience (relevance) of the content? In [68], we analyze that question in a setting when content is offered for free, content providers making revenue through advertising. For content providers, determining the amount of advertising to add to their content is a crucial strategic decision. Modeling the trade-off between the revenue per visit and the attractiveness, we investigate the interactions among competing content providers as a non-cooperative game, and consider the equilibrium situations to compare the different ranking policies. Our results indicate that when the search engine is not involved with any high-quality content provider, then it is in its best interest to implement a neutral ranking, which also maximizes user perceived quality-of-experience and favors innovation. On the other hand, if the search engine controls some high-quality content, then favoring it in its ranking and adding more advertisement yields a larger revenue. This is not necessarily at the expense of user perceived quality, but drastically reduces the advertising revenues of the other content providers, hence reducing their chances to innovate.

### 6.3. Wireless and Mobile Networks

**Participants:** Yassine Hadjadj-Aoul, Adlen Ksentini, César Viho, Osama Arouk, Btissam Er-Rahmadi, Hyunhee Park, Kandaraj Piamrat.

We continue our activities around wireless and mobile networks, where we focus particularly on 4G networks as well as on a new mobile architecture known as mobile cloud.

**LTE improvements.** First part of our works concentrates on emerging applications and their impact on 4G networks. In [58], we proposed a solution to handle social network traffic, which is characterized by its elasticity and intensity in a short period of time. The proposed contribution is based on content detection systems such as Deep Packet Inspection (DPI) to identify traffic belonging to a group of users (sharing the same content) of a social network. Upon detecting the type of traffic, we proposed to control it by creating a multicast group. This would reduce the amount of traffic exchanged by switching from unicast communications to multicast communications. Another solution is to cache, at the geographically nearest base station, the shared content among users. Here we positioned ourselves in the case where the social network traffic comes from the same geographical region. We also investigated network decentralization in conjunction with the selective IP traffic offload approaches to handle such 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. Two of our solutions are based on Network Address Translation (NAT) named simple-NATing and twice-NATing, whereas a third one employs simple tunneling, and a fourth adopts multiple Access Point Names. We also proposed methods enabling user equipment devices to always have efficient packet data network connections [30]. Another aspect, we addressed is the gateway selection process, where in [59] we argue the need for other metrics to improve the

gateway selection mechanisms in distributed mobile networks. We therefore proposed to consider the end-to-end connection and the service/application type as two important additional metrics in the selection of data anchor gateways in the context of the Evolved Packet System (EPS).

**M2M.** In [56], [32] we addressed another type of traffic that appeared these last years, namely Machine to machine communication or Machine Type Communication (MTC). Such traffic is known by its intensity and its impact on increasing congestion in both parts of the 4G networks, the Radio Access Network (RAN) and the core network parts. The main spirit of the proposed solutions is to proactively anticipate system overload by reducing the amount of MTC signaling messages exchanged in normal network operations. The first solution reduces the number of exchanged signaling messages when triggering MTC devices with low mobility. It enables direct triggering of MTC devices with low mobility by MTC-IWF (MTC InterWorking Function), without involving the MME (Mobility Management Entity). Second solution defines a method for controlling and anticipating network overload in case of an event/scenario whereby a mass of messages with some common Information Elements (IE) are to be exchanged on an interface between two nodes. The network overload control is achieved via dynamic creation of a profile characterizing the event/scenario and the common IEs.

**Home networks.** In-home wireless networks are now wide-spreading as today's home network is composed of at least one wireless network. The dramatic increase of traffic in such networks yields to difficulties in guaranteeing user experience especially for some specific services like IPTV. This is particularly complicated when using UDP at transport layer and traditional MAC protocol at link layer. Therefore, we investigated comparison of different combinations of transport and link layer performances for the delivery of IPTV. For validation, we use NS-3 and a realistic propagation model generated with a real house description. We analyze impact of link layer (with or without coordination) and transport layer (UDP or TCP). Then, we propose a combined solution using TCP over a coordinated MAC protocol (see [52]). The proposed solution can be easily deployed in real products and is compatible with existing devices.

Another part of our activities in wireless network are related to energy saving. Indeed, one of the biggest problem today in the wireless world is that wireless devices are battery driven, which reduce their operating lifetime. The experimental measurements we have achieved in [18], [42] revealed that operating system overhead causes a drop in performance and energy consumption properties as compared to the GPP in case of certain low video qualities. We propose, thus, a new approach for energy-aware processor switching (GPP or DSP) which takes into consideration the video quality. We show the pertinence of our solution in the context of adaptive video decoding and implement it on an embedded Linux operating system.

## 6.4. Future Networks

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

**Mobile cloud.** One of the 5G-architecture visions considers the usage of cloud to build mobile networks and help in decentralizing mobile networks on demand, elastically, and in the most cost-efficient way. This concept of carrier cloud becomes of vital importance knowing that several cloud providers are distributing their cloud/network, globally deploying more regional data centers, to meet their ever-increasing business demands. As an important enabler of the carrier cloud concept, network function virtualization (NFV) is gaining great momentum among industries. NFV aims for decoupling the software part from the hardware part of a carrier network node, traditionally referring to a dedicated hardware, single service and single-tenant box, and that is using virtual hardware abstraction. Network functions become thus a mere code, runnable on a particular, preferably any, operating system and on top of a dedicated hardware platform. The ultimate objective is to run network functions as software in standard virtual machines (VMs) on top of a virtualization platform in a general-purpose multi-service multi-tenant node (e.g., Carrier Grade Blade Server) put into the cloud. In [31], we presented and detailed the Follow Me Cloud (FMC) concept, whereby mobile services hosted in federated clouds follow mobile users as they move and according to their needs. We then provided in [55] a detailed analytical model based on continuous time Markov chain which considers to evaluate the performance of FMC in terms of service migration cost and QoS gain for user. An efficient mobile cloud cannot be built without efficient algorithms for the placement of NFV over this federated cloud. In this vein, in [57] we argued the

need for avoiding or minimizing the frequency of mobility gateway (S-GW) relocations and discussed how this gateway relocation avoidance can be reflected in an efficient network function placement algorithm for the realization of mobile cloud. The problem was modeled by an Integer Linear Problem and proved to be NP hard. Therefore, two heuristics were proposed for the creation of a NFV S-GW instance in the cloud.

**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 a hierarchical controller-based architecture handling the whole control chain.

## 6.5. Interoperability assessment and improvement

**Participants:** César Viho, Anthony Baire, Nanxing Chen.

The Internet of Things (IoT) brings new challenges to interoperability assessment by introducing the necessity to deal with non reliable environments connecting plenty billions of objects widely distributed. Therefore, in the recent period, we propose an interoperability testing methodology using a *passive* approach. It appeared more suitable for this distributed, unreliable and constrained environment brought by IoT. We have also developed a tool that implements this passive method. It has been used successfully to test CoAP implementations during the two CoAP Plugtest interoperability sessions on IoT protocols (CoAP and 6LoWPAN) organized by ETSI and IPSO Alliance. These contributions are published in [10].

## 6.6. Performance Evaluation of Distributed Systems

**Participants:** Bruno Sericola, Romaric Ludinard.

**Network Monitoring and Fault Detection.** Monitoring a system is the ability of collecting and analyzing relevant information provided by the monitored devices so as to be continuously aware of the system state. However, the ever growing complexity and scale of systems makes both real time monitoring and fault detection a quite tedious task. Thus the usually adopted option is to focus solely on a subset of information states, so as to provide coarse-grained indicators. As a consequence, detecting isolated failures or anomalies is a quite challenging issue. We propose in [38] and [60] to address this issue by pushing the monitoring task at the edge of the network. We present a peer-to-peer based architecture, which enables nodes to adaptively and efficiently self-organize according to their "health" indicators. By exploiting both temporal and spatial correlations that exist between a device and its vicinity, our approach guarantees that only isolated anomalies (an anomaly is isolated if it impacts solely a monitored device) are reported on the fly to the network operator. We show that the end-to-end detection process, *i.e.*, from the local detection to the management operator reporting, requires a logarithmic number of messages in the size of the network. These results also led to the patent [70].

**Robustness Analysis of Large Scale Distributed Systems.** In the continuation of previous work which proposed an in-depth study of the dynamicity and robustness properties of large-scale distributed systems, in [15] we analyze the behavior of a stochastic system composed of several identically distributed, but non independent, discrete-time absorbing Markov chains competing at each instant for a transition. The competition consists in determining at each instant, using a given probability distribution, the only Markov chain allowed to make a transition. We analyze the first time at which one of the Markov chains reaches its absorbing state. When the number of Markov chains goes to infinity, we analyze the asymptotic behavior of the system for an arbitrary probability mass function governing the competition. We give conditions for the existence of the asymptotic distribution and we show how these results apply to cluster-based distributed systems when the competition between the Markov chains is handled by using a geometric distribution.

**Secure Uniform Sampling in Dynamic Systems.** In [37], we consider the problem of achieving uniform node sampling in large scale systems in presence of a strong adversary. We first propose an omniscient strategy that processes on the fly an unbounded and arbitrarily biased input stream made of node identifiers exchanged within the system, and outputs a stream that preserves Uniformity and Freshness properties. We show through Markov chains analysis that both properties hold despite any arbitrary bias introduced by the adversary. We then propose a knowledge-free strategy and show through extensive simulations that this strategy accurately approximates the omniscient one. We also evaluate its resilience against a strong adversary by studying two representative attacks (flooding and targeted attacks). We quantify the minimum number of identifiers that the adversary must insert in the input stream to prevent uniformity. To our knowledge, such an analysis has never been proposed before.

## 6.7. Monte Carlo

**Participants:** Gerardo Rubino, Bruno Tuffin, Pablo Sartor Del Giudice.

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, for two reasons: the need in accelerating the occurrence of those events and in getting unbiased estimators of them with a sufficiently small relative variance. This is the main problem in the area. Dionysos' work focuses then in dealing with the rare event situation. Rare event simulation has been reviewed in [22].

**Multidimensional integrals.** In [20], we present a versatile Monte Carlo method for estimating multidimensional integrals, with applications to rare-event probability estimation. The method combines two distinct and popular Monte Carlo simulation techniques, Markov chain Monte Carlo and Importance Sampling, into a single algorithm. We show that for some applied numerical examples the proposed Markov Chain Importance Sampling algorithm performs better than methods based solely on Importance Sampling or MCMC.

**Static models.** Static reliability analysis has been the topic of an extensive activity in the group for years. Exact evaluation of static network reliability parameters belongs to the NP-hard family and Monte Carlo simulation is therefore a relevant tool to provide estimations for them.

In [67], we first review a Recursive Variance Reduction (RVR) estimator which approaches the unreliability metric by recursively reducing the graph from the random choice of the first working link on selected cuts. We show that the method does not verify the bounded relative error (BRE) property as reliability of individual links goes to one, i.e., that 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 Importance Sampling technique. Two new estimators are presented: 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, tries to mimic the estimator with variance zero for this technique. We show that in both cases the BRE property is verified and, moreover, that a Vanishing Relative Error 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.

The same problem is also analyzed in [19] by a novel method that exploits a generalized splitting (GS) algorithm. We show that the proposed GS algorithm can accurately estimate extremely small unreliabilities and we exhibit large examples where it performs much better than existing approaches. Remarkably, it is also flexible enough to dispense with the frequently made assumption of independent edge failures.

On the same type of model, we propose in [51] an adaptive parameterized method to approximate the zero-variance change of measure for the evaluation of static network reliability models, with links subject to failures. The method uses two rough approximations of the unreliability function, conditional on the states of any subset of links being fixed. One of these approximation, based on mincuts, under-estimates the true unknown unreliability, whereas the other one, based on minpaths, over-estimates it. Our proposed change of

measure takes a convex linear combination of the two, estimates the optimal (graph-dependent) coefficient in this combination from pilot runs, and uses the resulting conditional unreliability approximation at each step of a dynamic Importance Sampling algorithm. This new scheme is more general and more flexible than a previously-proposed zero-variance approximation one, which is based on mincuts only and which was shown to be robust asymptotically when unreliabilities of individual links decrease toward zero. Our numerical examples show that the new scheme is often more efficient when the unreliabilities of the individual links are not so small but the overall unreliability is small because the system can fail in many ways. Part of these results are in the PhD [13].

In [43], we present a generalization of the above static models to cases for which the component failures are not independent. To model the dependence and also to develop effective simulation methods that estimate the system unreliability, we extend the static model into an auxiliary dynamic one where the components fail at random times, according to a Marshall-Olkin multivariate exponential distribution. We examine and compare different versions of this model and develop efficient unreliability estimation methods based on conditional Monte Carlo and on a generalized splitting methodology.

In [28], a different splitting algorithm is proposed for solving the same static problem, which is converted into a dynamic one by means of the Creation Process of Elperin, Gerbtsbakh and Lomonosov. The classic splitting technique is then applied, and the obtained results are explored through several numerical experiments. The relative error and the covering properties of the obtained estimator are particularly studied.

In [29], a generalization of the basic model is studied using Monte Carlo. The idea is that the system (the network) works when the terminal nodes are connected *by at least one path whose length is less than or equal to a given parameter  $d$* . This is called Diameter Constrained Reliability. If the parameter  $d$  is greater than or equal to the longest path in the network (or between terminals), the problem is the classic one. The paper proposes a variance reduction technique for the estimation of the system's reliability in this setting. In [21], we analyze the particular case of  $d = 2$  using exact techniques. These results are part of the thesis [14].

Finally, in [34] and [36] we made general presentations on the rare event problem in general, and on some of the team's results concerning the design of efficient techniques to analyze them.

## 6.8. Analytic models

**Participants:** Raymond Marie, Bruno Sericola, Gerardo Rubino, Laura Aspirot.

**New books about Markovian models and applications.** The book [65] is the french version of the book [66]. Markov chains are a fundamental class of stochastic processes. They are the main modeling tool used in our team. They are widely used to solve problems in a large number of domains such as operations research, computer science, communication networks and manufacturing systems. The success of Markov chains is mainly due to their simplicity of use, the large number of available theoretical results and the quality of algorithms developed for the numerical evaluation of many metrics of interest. The books present the theory of both discrete-time and continuous-time homogeneous Markov chains. They examine the explosion phenomenon, the Kolmogorov equations, the convergence to equilibrium and the passage time distributions to a state and to a subset of states. These results are applied to birth-and-death processes. A detailed study of the uniformization technique by means of Banach algebra results is also developed. This technique is used for the transient analysis of several queuing systems.

Another book entitled "Markov Chains and Dependability Theory" will be published soon by Cambridge University Press (see <http://www.amazon.fr/Markov-Chains-Dependability-Theory-Gerardo/dp/1107007577/>). Dependability metrics are omnipresent in every engineering field, from simple ones through to more complex measures combining performance and dependability aspects of systems. The book presents the mathematical basis of the analysis of these metrics in the most used framework, Markov models, describing both basic results and specialised techniques. It presents both discrete and continuous time Markov chains before focusing on dependability measures, which necessitate the study of Markov chains on subsets of states representing different user satisfaction levels for the modelled system. Topics covered include Markovian state lumping, analysis of sojourns on subset of states of Markov chains, analysis of most dependability



metrics, fundamentals of performability analysis, and bounding and simulation techniques designed to evaluate dependability measures. The book is of interest to graduate students and researchers in all areas of engineering where the concepts of lifetime, repair duration, availability, reliability and risk are important.

**Fluid models.** In [53] and [44] we propose a new way of transporting video flows on a peer-to-peer architecture of the Bit-Torrent type. We analyze the performance obtained by our proposal by means of fluid views of the systems, that is, by representing them using differential equations. In [53] the basic idea is to select the downloading peers according to their progress in the downloading process: a given peer only sends chunks to other peers that are downloading at least roughly in the same “area” of the stream. The system is improved in [44] where the main resource (the available bandwidth) is distributed differently among the peers, giving some kind of priority to those nodes remaining more time connected.

In [39], we look at the problem of approximating Markovian views of the Machine Repairman Model where life-times and repair times have Phase-type distributions, by differential equations. The machine population goes to infinity, and we analyze the properties of the limiting differential equation (once the Markovian sequence of models is properly scaled) and their relations with the initial models. In [63] we describe these results and other results concerning the same type of limiting processes, but concerning peer-to-peer networks. We discuss here the convergence aspects; the properties of the fluid models themselves are discussed in the two papers [53] and [44] mentioned before.

## 7. Bilateral Contracts and Grants with Industry

### 7.1. Cifre contract on Small Cell Networks

**Participants:** Adlen Ksentini, César Viho, Btissam Er-Rahmadi.

This is a Cifre contract (2013-2016) including a 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.

### 7.2. Cifre contract on LOCARN: Low Opex and Capex Architecture for Resilient Networks

**Participants:** Adlen Ksentini, Bruno Sericola, Yassine Hadjadj-Aoul, Damien Le Quééré.

This is a Cifre contract (2012-2015) including a PhD thesis supervision, done with Orange Labs, on evaluating and developing a new plug-and-play routing protocol (called Low Opex and Capex Architecture for Resilient Networks – LOCARN), which do not require any network management or configuration.

### 7.3. Data aggregation for large-scale distributed networks

**Participants:** Bruno Sericola, Romaric Ludinard.

This is a 3-year (2011 – 2014) bilateral project with Technicolor R & D, France, on data aggregation for large-scale distributed networks. Along with the ubiquity of data and computing devices, comes the complexity of extracting and gathering relevant information for management purposes. The very distributed nature of sources of data (be they partially local applications at the user end, or hardware as gateways), as well as their ever increasing number prohibit a systematic and exhaustive gathering on a single (or few) central server for offline analysis. In this context, collaborative data aggregation, where some computing resources collaborate securely to provide digests, appears as an interesting application for both scalability and efficiency. Moreover, collecting information at a large scale poses the problem of privacy and data aggregation may allow preserving the privacy while collecting data.

### 7.4. IPChronos

**Participants:** Adlen Ksentini, Yassine Hadjadj-Aoul, Bruno Sericola, Pantelis Frangoudis.

We are working in the 3-year (September 2011 – September 2014) FUI Project IPChronos, where the main focus is in the use of the IEEE 1588 synchronization protocol over IP. Our contribution focuses on developing analytical models to estimate, based on the IEEE 1588 protocol, the end-to-end delay. IPChronos is led by ORALIA SPECTRACOM, and the partners are IPIlabel and our team.

## 7.5. Celtic QuEEN

**Participants:** Sofiene Jelassi, Pantelis Frangoudis, Gerardo Rubino.

QuEEN (Quality of Experience Estimators in Networks) is a large 3-year Celtic project going from end 2011 to end 2014. Its objectives are to develop automatic QoE measurement modules for Web services and applications, and to organize 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 is involved in most of the activities of the project, and it is expected that QuEEN will benefit from our experience in developing the PSQA technology. QuEEN involves many companies and academic institutions (22 European partners); the project leader is Orange Labs, in Sophia Antipolis.

## 8. Partnerships and Cooperations

### 8.1. International Research Visitors

#### 8.1.1. Inria International Chair

**Participants:** Bruno Tuffin, Pierre L'Ecuyer.

Title: Methods and Tools for Effective Stochastic Simulation

Period: Nov 2013 - Oct 2018

The activity deals with mathematical models that represent uncertainty in the dynamic behavior of complex systems, algorithms for efficient simulation of these systems on a computer, eventually with the aim of optimizing management decisions taken with respect to these systems, and computer software that concretely implements these methods efficiently. It applies to several types of systems that involve uncertainty, in all areas. The main part of the work is on general-purpose methodology and tools, and their mathematical analysis. Another part focuses on specific classes of applications in the areas of communications networks, reliability, finance, revenue management and network economics, and service systems such as call center or health care management. It has connections with computer science, operations research, industrial engineering, applied probability, statistics, and numerical analysis. Stochastic simulation is a key tool in practically all areas of science, engineering, and management. Its use keeps growing quickly, and new research issues pop up along the way, as the amount of available digital data on complex stochastic systems is literally exploding. Effective ways of using this large flow of data for better stochastic modeling, simulation, and decision making for those systems need to be developed, and this gives rise to large challenges.

### 8.2. European Initiatives

#### 8.2.1. FP7 Projects

##### 8.2.1.1. FP7 PROBE-IT

**Participants:** César Viho, Anthony Baire, Nanxing Chen.

PROBE-IT was a two years European project that aims at supporting exploitation of European research advances in IoT deployments. The work plan was split in three main areas : benchmarking, roadmap and interoperability testing. PROBE-IT comprised ten international partners from Europe, China, Brazil and Africa. Dionysos was leader of the work-package WP4 dedicated to testing roadmap and solutions to provide stakeholders with elements to validate technologies conformance and interoperability. The project ended in September 2013 See <http://www.probe-it.eu>

### 8.2.2. Collaborations with Major European Organizations

Partner 1: FTW, Vienna (Austria)  
 We work with FTW on network economics.  
 Partner2: Universidad Politécnica de Valencia  
 We work with UPV on network economics.  
 Partner 3: Vrije University (The Netherlands)  
 We work with Vrije University on rare event simulation.

## 8.3. International Initiatives

### 8.3.1. Inria Associate Teams

#### 8.3.1.1. MANAP

Title: Markovian ANalysis and APplications  
 Inria principal investigator: Gerardo Rubino  
 International Partner (Institution - Laboratory - Researcher):  
 Technical University Federico Santa María (UTFSM), Valparaíso, Chile – Electronics  
 Department – Prof. Reinaldo Vallejos  
 Starting: 2013  
 From the theoretical side, MANAP addresses the main problem when using Markov models today in order to analyze complex communication systems, the combinatorial explosion of the state space and its negative consequences on the cost of the associated solving procedures. We focus on the design of acceleration methods capable of reducing the computational complexity of the evaluation of metrics defined on these models. From the application viewpoint, the focus is on (i) the performance analysis of WDM communication infrastructures, taking into account the possibility of failing components, and (ii) the dependability analysis of Wireless Local Area Networks (WLANs). The activities started in 2013, where we launched a project around a new idea for solving numerically basic Markov problems: the computation of the distribution of the model in transient and in steady-state.  
 See also: <http://people.rennes.inria.fr/Gerardo.Rubino/RESEARCH/MANAP/manap.html>

#### 8.3.1.2. MOCQUASIN

Title: Monte Carlo and Quasi-Monte Carlo for rare event simulation  
 Inria principal investigator: Bruno Tuffin  
 International Partner (Institution - Laboratory - Researcher):  
 University of Montreal (Canada) - Département d'informatique et recherche opérationnelle  
 - Pierre L'Ecuyer  
 Duration: 2008 - 2013  
 See also: [http://www.irisa.fr/dionysos/pages\\_perso/tuffin/MOCQUASIN/](http://www.irisa.fr/dionysos/pages_perso/tuffin/MOCQUASIN/)  
 The goal of MOCQUASIN is to design efficient Monte Carlo and quasi-Monte Carlo simulation methods and to apply them to models in telecommunications. Simulation is indeed often the only method to analyse complex and/or large systems, but also suffers from inefficiency. Two specific situations on which we will focus are rare events, and revenue management. In the two cases, we want to deal with dependent individual events or decisions, a realistic situation requiring adapted solution techniques. The inefficiency of the standard simulation is a known issue to compute the probability of rare event since getting it only once requires in average a long simulation time, but most of the literature has up to now assumed independence in the models. The other framework, revenue management in telecommunications, is the situation of providers trying to define valid offers and capacity investments in front of complex demand models. Here too, a change in the decision of an actor has an impact on the others that has to be taken into account.

### 8.3.2. "International activity" action from the University Rennes 1

Action funded by the University of Rennes 1 studying ads ranking (e-commerce, search engines) with their economic impact. Collaboration with Pierre L'Ecuyer (Université de Montréal).

### 8.3.3. Inria International Partners

Our other main international partners are:

- Peter Reichl (from FTW, Vienna, Austria), on pricing and security issues;
- Héctor Cancela and Franco Robledo (from Univ. of the Republic, Montevideo, Uruguay), on simulation issues (see 8.3.5.1);
- Tarik Taleb (from NEC Europe), on LTE issues;
- Alan Krinik, CalPoly, California, USA, on transient analysis of Markovian queues;
- Reinaldo Vallejo, UTFSM, Valparaíso, Chile, on networking and modeling problems (see 8.3.1.1 and 8.3.5.1).

### 8.3.4. Inria International Labs

In the context of CIRIC, we cooperate with the team of Reinaldo Vallejo, professor at the UTFSM, Valparaíso, Chile, on different topics related to networking and modeling issues. Specifically, these activities are organized around two collaborative projects, 8.3.1.1 and 8.3.5.1, where one can find the scientific details.

### 8.3.5. Participation In other International Programs

#### 8.3.5.1. Stic AmSud with UDELAR, Uruguay, and UTFSM, Chile

Program: Stic AmSud

Title: Accelerating Markov Models for analysis and design of dynamic WDM optical networks (AMMA)

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. 2013 – Dec. 2014

This project has two main scientific goals: (i) to develop methods capable of solving Markov models faster than with state-of-the-art techniques, and (ii) to apply these techniques to the design of fault-tolerant optical networks. The rationale behind (i) is that the group has ideas and some preliminary promising unpublished results that makes it expect that its approach will be effective in producing new nice solving procedures. Concerning (ii), we have already produced results in simpler cases (without taking into account failures), and we also have results on all the associated areas (dependability analysis, combinatorial optimization, etc.). These main research lines are completed with other goals all concerned with the quantitative analysis of such complex communication systems.

#### 8.3.5.2. Math AmSud with UDELAR, Uruguay, and UV, Chile

Program: Math AmSud

Title: Stochastic Analysis, Statistics Inference, Numerical Analysis (SIN)

Inria principal investigator: Gerardo Rubino

Main International Partners (Institution - Laboratory - Researcher):

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

University of Valparaíso, Chile — Prof. Soledad Torres

Duration: 2 years, Jan. 2013 – Dec. 2014

Stochastic calculus with respect to the standard Brownian motion or more generally with respect to semi-martingales is currently one of the most important components of international research in probability theory. The applications of this theory largely exceed the original probabilistic framework and have repercussions in various fields, including differential geometry, differential partial equations, theoretical physics, modeling in finance, hydrology, telecommunications and biology. Recently, many authors have been interested in developing a stochastic calculus with respect to Gaussian processes which are not necessarily semi-martingales, as for instance the well known fractional Brownian motion. This research project is articulated around the analysis and the applications of stochastic differential equations driven by long memory processes.

SIN is a large project with many partners. Our team participates in looking at differential equations and stochastic differential equations as limits of discrete Markov processes.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

#### 8.4.1.1. Professors

Pr. Luis Guijarro

Subject: Economics of cognitive radio networks

Institution: UP Valencia (Spain)

Duration: 1/06/2013 - 31/07/2013

Pr. Héctor Cancela

Subject: network reliability (see [8.3.5.1](#))

Institution: UDELAR, Montevideo, Uruguay

Duration: 10 days, Jul 2013

Pr. Reinaldo Vallejo and Marta Barría

Subject: network modeling and Markov chain analysis (see [8.3.5.1](#), [8.3.1.1](#), [8.3.4](#))

Institutions: UTFSM and UV, Valparaíso, Chile

Duration: two weeks, Sep 2013

#### 8.4.2. Visits to International Teams

- G. Rubino visited the Design and Analysis of Communication Systems (DACs) at the University of Twente, The Netherlands, where he gave a seminar.
- C. Viho visited the Institute of Computer Science at the University of Goettingen (Germany) and the Computer Science and Engineering Department of BUPT (Beijing University of Post and Telecommunications), China, where he gave seminars.

## 9. Dissemination

### 9.1. Scientific Animation

#### 9.1.1. International memberships

- R. Marie and G. Rubino are members of the IFIP WG 7.3 (Working Group in Computer Performance Modeling and Analysis).
- Gerardo Rubino is a member of the Technical Committee on Multimedia Communications of IEEE.
- Adlen Ksentini is a member of the Technical Committee on Multimedia Communications and Wireless of IEEE.

- Adlen Ksentini is vice-chair of the Interest Group on QoE of the Technical Committee on Multimedia (IEEE Communication Society).

### 9.1.2. Seminar presentations

- B. Tuffin (with P. Maillé). Title: An analysis of ISP Inter-Relations: Traffic Exchange, Revenue Sharing, and Disconnection Threat. Colloquium Rennais des Sciences du Numérique, 4 Juillet 2013.
- A. Ksentini. Title: QoE-based in-network adaptation of SVC video streams. FP7 Envision project workshop, Orange labs Lannion, Sept. 2013.
- Y. Hadjadj-Aoul. Title: Streaming Vidéo sur Internet: Architectures, Protocoles et Services. University of Oran's Winter School, Oran, Algeria, Dec. 2013.
- C. Viho. Title: QoE (Quality of Experience): a new paradigm for multimedia networking. Institute of Computer Science, University of Goettingen (Germany), Jan 23, 2013.
- C. Viho. Title: Passive interoperability testing is the way to go for Internet of Things. BUPT, Beijng, China, Oct 15, 2013.
- C. Viho. Title: Internet of Things: Internet of challenges. IC-BNMT, Guilin, China, Nov 19, 2013.
- G. Rubino. Title: Context Delivery Networks in Dionysos. At the in Kick-off DTC ICT Labs, Rennes, France, March 22, 2013.
- G. Rubino. ITCE Distinguished Lecture, Postech, Pohang, Korea. Title: Automatic measuring of perceptual quality on the Internet. May 14, 2013.
- G. Rubino. Title: Transient queueing analysis. AMMA workshop, UDELAR, Montevideo, Uruguay, Sep 4, 2013.
- G. Rubino. Title: On fluid models in performance and dependability analysis. At the Design and Analysis of Communication Systems (DACs) group, University of Twente, Netherlands, Dec 6, 2013.

### 9.1.3. Editorial activity

- Bruno Tuffin is associate Editor for INFORMS Journal on Computing.
- Bruno Tuffin is associate Editor for Mathematical Methods of Operations Research.
- Bruno Tuffin is associate Editor for ACM Transactions on Modeling and Computer Simulation.
- Bruno Tuffin was the co-chair of the 8th International Workshop on Advanced Internet Charging and QoS technologies (ICQT'13), Zurich, Switzerland, 2013.
- Bruno Sericola is associate editor for The Open Operational Research Journal.
- Bruno Sericola is associate editor for International Journal of Stochastic Analysis.
- Bruno Sericola is associate editor for ISRN Probability and Statistics.
- Adlen Ksentini is guest editor in IEEE Wireless Communication Magazine for the special issue "Research & Standards: Leading the Evolution of Telecom Network Architectures", June 2014.
- Adlen Ksentini is Associate Editor of Hindawei International Journal of Digital Multimedia Broadcasting
- Yassine Hadjadj-Aoul is a member of the editorial board of the International Journal of Computer Networks (IJCN)

### 9.1.4. Program committees

Bruno Tuffin served as TPC member for

- 9th International Workshop on Resource Allocation, Cooperation and Competition in Wireless Networks (RAWNET/WNC3), Tsukuba Science City, Japan, May 13-17, 2013.
- 7th workshop on Simulation, Rimini, Italy, May 21-25, 2013.
- IFIP Networking 2013 Conference, Brooklyn, New York, USA, May 22-24, 2013.

- 27th ACM/IEEE/SCS Workshop on Principles of Advanced and Distributed Simulation (SIGSIM/PADS), 2013.
- Joint Workshop on Pricing and Incentives in Networks and Systems (W-PIN + NETECON 2013), in conjunction with ACM SIGMETRICS 2013, Pittsburg, USA, June 21, 2013.
- 3rd International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH), Reikjavik, Iceland, 29-31 July 2013.
- 9th IMACS Seminar on Monte Carlo Methods, Annecy, France, July 15-19, 2013.
- 10th International Workshop on Economics of Grids, Clouds, Systems and Services (GECON'2013), Zaragoza, Spain September 18-20, 2013.
- 4th International Symposium on Information and Communication Technology (SoICT), Danang city, Vietnam, December 5-6, 2013.

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

- ASMTA 2013, 20th International Conference on Analytical and Stochastic Modelling Techniques and Applications, Ghent, Belgium, 8–10 July 2013.
- ACCESS 2013, 4th International Conference on Access Networks, Nice, France, 21-26 July 2013.

Adlen Ksentini served as TPC member for

- IEEE Global Communication Conference, GLOBECOM 2013 Wireless Network Symposium, December 2013, Atlanta, USA
- IEEE International Conference on Communication, ICC 2013 Wireless Network Symposium, June 2013, Budapest, Hungary
- IEEE Wireless Communication and Networking Conference, April 2013, Paris, France
- IEEE International Conference on Multimedia and Expo ICME 2013,

Yassine Hadjadj-Aoul served as TPC member for

- IEEE Global Communication Conference, GLOBECOM 2013, Wireless Network and communications QoS symposiums, December 2013, Atlanta, USA
- IEEE International Conference on Communication, ICC 2012 Wireless Network and communication software symposiums, June 2013, Budapest, Hungary
- IEEE Wireless Communication and Networking Conference, April 2013, Paris, France

Cesar Viho served as TPC member for

- The 25th IFIP International Conference on Testing Software and Systems (ICTSS 2013), Nov 13-15, 2013, Istanbul, Turkey. C. Viho was Tutorials Chair.
- IEEE International Conference on Broadband Network & Multimedia Technology (IC-BNMT 2013), Nov 17-19, Guilin, China. C. Viho was general co-chair.

Gerardo Rubino served or serves as TPC member of

- e-Health'13: International workshop of e-Health Pervasive Wireless Applications and Services, Lyon, France, Oct 2013.
- MAM8: 8th International Conference on Matrix Analytic Methods in Stochastic Models, Calicut, India, Jan 6-10,
- Networking 2014: IFIP Networking 2014 Conference, Trondheim, Norway, Jun 2–4
- Resim 2014: 10th International Workshop on Rare Event Simulation, Amsterdam, Netherlands, Aug 27–29, 2014.
- QUEST 2014: 11th International Conference on Quantitative Evaluation of SysTems, Florence, Italy, Sep 8–12, 2014.
- CLEI 2014, XL Conferencia Latinoamericana de Informática (Latin-American Informatics Conference), Montevideo, Uruguay, Sep 15–19, 2014.

### 9.1.5. Managing research activities

- B. Tuffin is a member of the Steering Committee of the International Workshop on Rare Event Simulation (RESIM).
- B. Tuffin was a member of Inria Rennes' PhD thesis selection committee, 2013.
- Bruno Sericola is responsible for the Inria Rennes - Bretagne Atlantique budget.
- Bruno Sericola is 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.
- B. Sericola was a member of the juries for the recruitment of young graduate scientists and senior researchers at Inria.
- Cesar Viho was responsible of the Network, Telecommunication and Services department and member of the scientific council of IRISA till June 2013.
- Cesar Viho is deputy director of the MATISSE (Mathematics, Electronics and Computer Sciences) doctoral school in charge of managing the recruitment of PhD students and their activities during their doctorate, in all the concerned areas of the school.
- G. Rubino was a member for years of the Steering Committee of the international conference QEST (Quantitative Evaluation of SysTems). This membership ended mid-2013.
- G. Rubino is a member of the Steering Committee of the International Workshop on Rare Event Simulation (RESIM).
- 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 served as international evaluator of NWO projects for the Netherlands Organisation for Scientific Research, for the 2013 Program.

## 9.2. Teaching - Supervision - Juries

### 9.2.1. Teaching

Licence L3: Introduction to networks, 20 hours, Istic/University of Rennes 1, France

Master M1: Introduction to networks, 24 hours, Esir/University of Rennes 1, France

Master M1: Wireless networking, 46 hours, Esir/University of Rennes 1, France

Master M1: Networks and protocols, 24 hours, Istic/University of Rennes 1, France

Master M1: Computer networks, 24 hours, Esir/University of Rennes 1, France

Master M1: Algorithms and graphs, 48 hours, Esir/University of Rennes 1, France

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

Master M1: Introduction to graph theory, 14 hours, Esir/University of Rennes 1, France

Master M1: Introduction to networks, 20 hours, Esir/University of Rennes 1, France



Master M1: Wireless Networks, 48 hours, Esir/University of Rennes 1, France  
 Master M2: Multimedia transmission, 48 hours, Esir/University of Rennes 1, France  
 Master M2: Introduction to C language, 12 hours, Istic/University of Rennes 1, France  
 Master M2: Validation and tests, 6 hours, Istic/University of Rennes 1, France  
 Master M2: Quality of service and multimedia, 6 hours, Istic/University of Rennes 1, France  
 Master M2: Multimedia transmission, 18 hours, Istic/University of Rennes 1, France  
 Master M2: Performance evaluation, 26 hours, Istic/University of Rennes 1, France  
 Master M2: Network security, 14 hours, Istic/University of Rennes 1, France  
 Master M2: Dependability analysis, 15 hours, Supelec, Rennes, France  
 Master M2: Simulation, 5 hours, Telecom Bretagne, Rennes, 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: Logistic and performance, 8 hours, Faculté de Sciences économiques/University of Rennes 1, France.  
 PhD class: Introduction to Monte Carlo simulation, 12 hours, Matisse PhD school, France  
 PhD class: Network economics, 6 hours, Matisse PhD school, France

### 9.2.2. Supervision

HdR : Adlen Ksentini; title: “Building the bridges between QoS and QoE for network control mechanisms”; University Rennes 1; date: July 3, 2013.

PhDs defended in Dionysos, in 2013:

- Wael Cherif; title: “Adaptation de contexte basée sur la qualité d’expérience dans les réseaux Internet du Futur”; advisors: A. Ksentini and G. Rubino; University Rennes 1; date: June 19, 2013.
- Nanxing Chen; title: “On passive approach for interoperability testing”; advisor: C. Viho, University of Rennes 1; date: June 24, 2013.
- Samira Saggadi; title: “Rare event simulation with applications in telecommunications”; advisor: B. Tuffin; University Rennes 1; date: July 8, 2013.
- Pablo Sartor del Giudice; title: “Propriétés et méthodes de calcul de la fiabilité diamètre-bornée des réseaux”; advisor: G. Rubino; University Rennes 1; date: Dec 18, 2013.

PhDs defended out of Dionysos, in 2013, with participation of team’s members as co-advisors:

- Selim Ellouze; title “Mécanismes de collaboration entre réseaux et services applicatifs pour l’optimisation des ressources et des services”; co-advisor: G. Rubino; University Rennes 1; July 2, 2013.
- Isabel Amigo; title “Métrologie et Ingénierie du Trafic pour la QoS de bout-en-bout dans un réseau multi-domaine”; co-advisor: G. Rubino; Telecom Bretagne, Brest, July 12, 2013.

PhDs in progress in the team:

- Romaric Ludinard; title: “Data aggregation for large-scale distributed networks”; PhD started on April 2011; advisors: B. Sericola from Inria/Dionysos and E. Anceaume from Inria/Cidre; University Rennes 1.
- Damien Le Queré; Cifre Grant, Orange Labs; title: “Conception et étude des performances d’une solution auto-configurable pour les réseaux de transport du futur”; PhD started on January 2012; advisors: B. Sericola and A. Ksentini; University Rennes 1.

- Btissam Errahmadi; Cifre Grant, Orange Labs; title: “Coopération et auto-\* dans un réseau de small cells network”; PhD started on January 2013; advisors: C. Viho and A. Ksentini; University Rennes 1.
- Leila Ghazzai; title: “Replication and caching strategies for adaptive video streaming in future information centric networks”; PhD started on October 2012; advisors: G. Rubino, Y. Hadjadj-Aoul; University Rennes 1.
- Osam Arouk; title: “Cellular-based M2M communication: congestion control”; PhD started on December 2012; advisors: C. Viho and A. Ksentini; University Rennes 1.
- Quang Tran Anh Pham; title: “Dynamic QoE based resource management in heterogeneous networks”; PhD started on October 2013; advisors: C. Viho; University Rennes 1.
- Laura Aspirot; title: “Fluid limits of some Markovian models used in performance and dependability analysis”; PhD started in Dec 2010; advisors: E. Mordecki and G. Rubino; University of the Republic, Uruguay. Expected defense in Sep 2014.
- Leslie Murray; title: “New Monte Carlo variance reduction techniques with applications in dependability”; PhD started in Dec 2010; advisors: H. Cancela and G. Rubino; University of the Republic, Uruguay. Defense in May 2014.

### 9.2.3. *Juries (PhD and HDR)*

- B. Sericola was a reviewer of the PhD thesis of Alessio Angius, from the university of Torino, Italy; title: “Handling large state spaces in transient analysis of Markovian processes” date: May 7, 2013.
- B. Tuffin was the president of the PhD jury of Isabel Amigo; title “Métrologie et ingénierie du trafic pour la QoS de bout-en-bout dans un réseau multi-domaine”; Telecom Bretagne, Brest, July 12, 2013.
- B. Tuffin was a member (as advisor) of the PhD jury of Samira Saggadi (advisor); title: “Rare event simulation with applications in telecommunications”; Université Rennes 1; July 8, 2013.
- B. Tuffin was a member of the PhD jury of Pablo Sartor del Giudice; title: “Propriétés et méthodes de calcul de la fiabilité diamètre-bornée”; Université de la République, Montevideo, Uruguay, and Université Rennes 1 (defense at Montevideo, Uruguay), December 18, 2013.
- C. Viho was Member of the Jury of HDR of Adlen Ksentini; title: “Building the bridges between QoS and QoE for network control mechanisms”; University Rennes 1; date: July 3, 2013.
- C. Viho was member/reviewer of the PhD of Thomas Ring, from University of Goettingen (Germany); title: “Assessing and Improving Interoperability of Distributed Systems”; date: January 23, 2013.
- C. Viho was the president of the PhD Jury of Wael Cherif; title: “Adaptation de contexte basée sur la Qualité d’Expérience dans les réseaux Internet du Futur”; date: June 19, 2013.
- C. Viho was the president of the PhD Jury of Lucien Loiseau, from Telecom Bretagne; title: “Exploitation des réceptions opportunistes dans les mécanismes de relayage pour les réseaux sans-fils”; date: December 6, 2013.
- C. Viho was the president of the Jury of PhD of Luis Alberto Suárez Rivera, from Telecom Bretagne; title: “Optimisation des techniques et déploiements radio pour les réseaux efficaces en énergie”; date: December 13, 2013.
- G. Rubino was a member of the Jury of HDR of Adlen Ksentini; title: “Building the bridges between QoS and QoE for network control mechanisms”; University Rennes 1; July 3, 2013.
- G. Rubino was the president of the PhD jury of Samira Saggadi; title: “Rare event simulation with applications in telecommunications”; University Rennes 1; July 8, 2013.
- G. Rubino was the president of the Jury of HDR of Daniel Negru; title: “A Networked Media Ecosystem based on \*-Awareness for Future Media Internet”; University of Bordeaux 1; December 5, 2013.

- G. Rubino was member/reviewer of the PhD of Daniël Reijbergen, at the University of Twente, Netherlands; title: “Assessing and Improving Interoperability of Distributed Systems”; December 6, 2013.
- G. Rubino was a member (as advisor) of the PhD jury of Pablo Sartor del Giudice; title: “Propriétés et méthodes de calcul de la fiabilité diamètre-bornée”. Université de la République, Montevideo, Uruguay, and Université Rennes 1 (defense at Montevideo, Uruguay), December 18, 2013.

### 9.3. Popularization

- G. Rubino makes regular presentations to high school students about the research work in general, and specific technical topics in particular. Titles of 2013:
  - Using randomness for solving deterministic problems
  - Internet as a research problem
  - Great challenges in maths: Riemann Hypothesis
  - Great challenges in math/computer science: the “P versus NP” problem

### 9.4. Standardization activities

**Participants:** Anthony Baire, César Viho, Nanxing Chen.

The Dionysos team continues to dedicate a significant effort towards standardization and certification in the telecommunications area. We participate in several working groups of the main telecommunication standardization institutes like the IETF (Internet Engineering Task Force), ETSI (European Telecommunication Standardization Institute), etc. We are also active in the main mailing-lists treating new generation networks and protocols. Several proposals of drafts and contributions to the definition of standards and RFCs (Request For Comments) have been published. This year we continued focusing mainly on Internet of Things and related protocols such as 6LowPAN (IPv6 for Low Power Area Networks) and CoAP (Constrained Application Protocol).

#### 9.4.1. IPv6 Ready Logo Program

**Participants:** Anthony Baire, César Viho.

Dionysos team has also a major role in the world-wide certification process for IPv6 products launched by the IPv6 Forum, the “IPv6 Ready Logo Program”. For details, see <http://www.ipv6ready.org>. This project aims to provide the means needed to test existing IPv6 products to be deployed in the market. Dionysos contributes to the technical part of this Program by defining the certification process itself, specifying required tests, and developing some of the interoperability tests needed. This work is done together with the IPv6 Forum, the ETSI in Europe, the WIDE-project in Japan, the TTA (Telecommunications Technology Association) in Korea and BII in China.

This year, in collaboration with the IPSO alliance and ETSI, we addressed the usage of IPv6 on smart objects based on the IEEE 802.15.4 link layer (for instance, sensor networks). These networks have special constraints (limited power, packet loss, ...) and new protocols are designed at IETF (6LowPAN, CoAP) to allow using IPv6 with these constraints. We participated in the preparation of two Interoperability events for these protocols in June in Berlin (Germany) and in November in Las Vegas (USA).

## 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<sup>o</sup> 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<sup>o</sup> 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<sup>o</sup> 3, pp. 702–713
- [6] H. NABLI, B. SERICOLA. *Performability analysis: a new algorithm*, in "IEEE Transactions on Computers", 1996, vol. 45, n<sup>o</sup> 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<sup>o</sup> 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<sup>o</sup> 4

## Publications of the year

### Doctoral Dissertations and Habilitation Theses

- [10] N. CHEN. , *Passive interoperability testing for communication protocols*, Université Rennes 1, June 2013, <http://hal.inria.fr/tel-00869819>
- [11] W. CHERIF. , *Adaptation de contexte basée sur la Qualité d'Expérience dans les réseaux Internet du Futur*, Université Rennes 1, June 2013, <http://hal.inria.fr/tel-00940287>
- [12] A. KSENTINI. , *Building the bridges between QoS and QoE for network control mechanisms*, Université Rennes 1, July 2013, Habilitation à Diriger des Recherches, <http://hal.inria.fr/tel-00913872>
- [13] S. SAGGADI. , *Simulation d'événements rares par Monte Carlo dans les réseaux hautement fiables*, Université Rennes 1, July 2013, <http://hal.inria.fr/tel-00940140>
- [14] P. SARTOR. , *Propriétés et méthodes de calcul de la fiabilité diamètre-bornée des réseaux*, Université Rennes 1, December 2013, <http://hal.inria.fr/tel-00939946>

### Articles in International Peer-Reviewed Journals

- [15] E. ANCEAUME, F. CASTELLA, R. LUDINARD, B. SERICOLA. *Markov Chains Competing for Transitions: Application to Large-Scale Distributed Systems*, in "Methodology and Computing in Applied Probability", June 2013, vol. 15, n<sup>o</sup> 2, pp. 305–332 [DOI : 10.1007/s11009-011-9239-6], <http://hal.inria.fr/hal-00650081>
- [16] E. ANCEAUME, F. CASTELLA, B. SERICOLA. *Analysis of a large number of Markov chains competing for transitions*, in "International Journal of Systems Science", March 2014, vol. 45, n<sup>o</sup> 3, pp. 232–240 [DOI : 10.1080/00207721.2012.704090], <http://hal.inria.fr/hal-00736916>
- [17] S. BASTERRECH, G. RUBINO. *Real-Time Estimation of Speech Quality through the Internet Using Echo State Networks*, in "Journal of Advances in Computer Networks", 2013, vol. 1, n<sup>o</sup> 3, pp. 183–188 [DOI : 10.7763/JACN.2013.V1.37], <http://hal.inria.fr/hal-00935968>
- [18] Y. BENMOUSSA, J. BOUKHOBZA, E. SENN, D. BENAZZOUEZ, Y. HADJADJ-AOUL. *DyPS: Dynamic Processor Switching for Energy-Aware Video Decoding on Multi-core SoCs*, in "ACM SIGBED Review", January 2014, <http://hal.inria.fr/hal-00931885>
- [19] Z. I. BOTEV, P. L'ÉCUYER, G. RUBINO, R. SIMARD, B. TUFFIN. *Static Network Reliability Estimation Via Generalized Splitting*, in "INFORMS Journal on Computing", 2013, vol. 25, n<sup>o</sup> 1, pp. 56-71 [DOI : 10.1287/IJOC.1110.0493], <http://hal.inria.fr/hal-00789621>
- [20] Z. I. BOTEV, P. L'ÉCUYER, B. TUFFIN. *Markov chain importance sampling with applications to rare event probability estimation*, in "Statistics and Computing", 2013, vol. 23, n<sup>o</sup> 2, pp. 271-285 [DOI : 10.1007/s11222-011-9308-2], <http://hal.inria.fr/hal-00758028>
- [21] E. CANALE, H. CANCELA, F. ROBLEDO, G. RUBINO, P. SARTOR. *On computing the 2-diameter-constrained K-reliability of networks*, in "International Transactions in Operational Research", 2013, vol. 20, n<sup>o</sup> 1, pp. 49-58 [DOI : 10.1111/I.1475-3995.2012.00864.X], <http://hal.inria.fr/hal-00773335>
- [22] V. CARON, A. GUYADER, M. MUNOZ ZUNIGA, B. TUFFIN. *Some recent results in rare event estimation*, in "ESAIM Proceedings", 2014, vol. 44, pp. 239-259 [DOI : 10.1051/PROC/201444015], <http://hal.inria.fr/hal-00908575>
- [23] P. COUCHENEY, P. MAILLÉ, B. TUFFIN. *Impact of Reputation-Sensitive Users and Competition Between ISPs on the Net Neutrality Debate*, in "IEEE Transactions on Network and Service Management", 2013, <http://hal.inria.fr/hal-00681402>
- [24] E. DE SOUZA E SILVA, R. M. LEÃO, R. A. MARIE. *Efficient Transient Analysis of Markovian Models using a Block Reduction Approach*, in "INFORMS Journal on Computing", 2013, vol. 25, n<sup>o</sup> 4, pp. 743-757 [DOI : 10.1287/IJOC.1120.0537], <http://hal.inria.fr/hal-00758039>
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- [26] O. MARCÉ, H.-H. TRAN, B. TUFFIN. *Double-sided auctions applied to vertical handover for mobility management in wireless networks*, in "Journal of Network and Systems Management", 2013, pp. 1-24, <http://hal.inria.fr/hal-00908573>

- [27] R. A. MARIE. *Optimal preventive and corrective maintenance for equipments with Erlangian life-time distribution*, in "International Journal of Logistics Systems and Management", 2013, vol. 15, n<sup>o</sup> 2-3, pp. 260-274 [DOI : 10.1504/IJLSM.2013.053771], <http://hal.inria.fr/hal-00756903>
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- [31] T. TALEB, A. KSENTINI. *Follow Me Cloud: Interworking Distributed Clouds & Distributed Mobile Networks*, in "IEEE Network Magazine", September 2013, <http://hal.inria.fr/hal-00911274>
- [32] T. TALEB, A. KSENTINI. *On Alleviating MTC overload in EPS*, in "Elsevier Adhoc networks", March 2013, <http://hal.inria.fr/hal-00911273>

### Invited Conferences

- [33] A. KRINIK, G. RUBINO. *The Single Server Restart Queueing Model*, in "Proc. AMS Joint Mathematical Meetings", Boston, United States, January 2013, <http://hal.inria.fr/hal-00773324>
- [34] G. RUBINO. *Quality of Monte Carlo rare event analyzers*, in "Proc. AMS Joint Mathematical Meetings", San Diego, United States, 2013, <http://hal.inria.fr/hal-00771631>
- [35] G. RUBINO. *Some fluid models in performance and dependability analysis*, in "APS - INFORMS Applied Probability Society Conference", San José, Costa Rica, INFORMS, July 2013, <http://hal.inria.fr/hal-00938341>
- [36] G. RUBINO. *Techniques for rare event analysis and applications*, in "UQAW - Advances in Uncertainty Quantification Methods, Algorithms and Applications", Tuwal, Saudi Arabia, KAUST - King Abdullah University of Science and Technology, January 2014, <http://hal.inria.fr/hal-00938345>

### International Conferences with Proceedings

- [37] E. ANCEAUME, Y. BUSNEL, B. SERICOLA. *Uniform Node Sampling Service Robust against Collusions of Malicious Nodes*, in "43rd Annual IEEE/IFIP International Conference on Dependable Systems and Networks (DSN 2013)", Budapest, Hungary, June 2013, vol. 43, 249 p. , <http://hal.inria.fr/hal-00804430>
- [38] E. ANCEAUME, E. LE MERRER, R. LUDINARD, B. SERICOLA, G. STRAUB. *A Self-organising Isolated Anomaly Detection Architecture for Large Scale Systems*, in "Nem-Summit", France, October 2013, 12 p. , <http://hal.inria.fr/hal-00907374>
- [39] L. ASPIROT, E. MORDECKI, G. RUBINO. *Fluid Limit for the Machine Repairman Model with Phase-Type Distributions*, in "QEST - 10th International Conference on Quantitative Evaluation of SysTems",

- Buenos Aires, Argentina, 2013, pp. 139-154 [DOI : 10.1007/978-3-642-40196-1\_10], <http://hal.inria.fr/hal-00935981>
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