UMR IRISA

Activity Report 2017

Team DIONYSOS

Dependability Interoperability and Performance Analysis of Networks

Joint team with Inria Rennes – Bretagne Atlantique

D2 – Networks, Telecommunications and Services

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Creation of the Project-Team: 2009 January 01

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1. Personnel

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2. Overall Objectives

2.1. Overall objectives

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

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

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

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

3. Research Program

3.1. Introduction

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

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

3.2. Quality of Service and Quality of Experience

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

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

Some important aspects of the behavior of modern communication systems have subjective components: the quality of a video stream or an audio signal, *as perceived by the user*, is related to some of the previous mentioned parameters (packet loss, delays, ...) but in an extremely complex way. We are interested in analyzing these types of flows from this user-oriented point of view. We focus on the *user perceived quality*, in short, PQ, 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 technology we have developed allowing to automatically measure this PQ.

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 explore 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.

A specific aspect of network applications and/or services based on video or voice content, is our PSQA technology, able to measure the Perceptual Quality automatically and in real time. PSQA provides a MOS value as close as it makes sense to the value obtained from subjective testing sessions. The technology has been tested in many environments, including one way communications as, for instance, in video streaming, and bi-directional communications as in IP telephony, UDP- or TCP-based systems, etc. It has already served in many collaborative projects as the measuring tool used.

4.2. Stochastic modeling

Many of the techniques developed at Dionysos are related to 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. We develop methods in different areas: numerical analysis of stochastic models, bound computations in the same area, Discrete Event Simulation, or, as just mentioned, rare event analysis.

5. Highlights of the Year

5.1. Awards

BEST PAPER AWARD:

[43]
C. HARDY, E. LE MERRER, B. SERICOLA. *Distributed deep learning on edge-devices: feasibility via adaptive compression*, in "IEEE NCA 2017 - 16th IEEE International Symposium on Network Computing and Applications", Boston, United States, October 2017, This article has received the Best Paper Award, https://hal.inria.fr/hal-01650936

6. New Software and Platforms

6.1. IPv6 Test Toolkit

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

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

- Participants: Annie Floch, Anthony Baire, Ariel Sabiguero, Bruno Deniaud, César Viho and Frédéric Roudaut
- Contact: César Viho

6.2. Passive Test Tool

- Participants: Anthony Baire and César Viho
- Contact: Anthony Baire

6.3. T3DevKit

KEYWORDS: IPv6 - Conformance testing - TTCN-3
SCIENTIFIC DESCRIPTION: We have built a toolkit for easing executing tests written in the standardized TTCN-3 test specification language. This toolkit is made of a C++ library together with a highly customizable CoDec generator that allows fast development of external components (that are required to execute a test suite) such as CoDec (for message Coding/Decoding), System and Platform Adapters. It also provides a framework for representing and manipulating TTCN-3 events so as to ease the production of test reports. The toolkit addresses issues that are not yet covered by ETSI standards while being fully compatible with the existing standard interfaces: TRI (Test Runtime Interfaces) and TCI (Test Control Interfaces), it has been tested with four TTCN-3 environments (IBM, Elvior, Danet and Go4IT) and on three different platforms (Linux, Windows and Cygwin).
FUNCTIONAL DESCRIPTION: T3DevKit is a free open source toolkit to ease the development of test suites in the TTCN-3 environment. It provides:

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

- Participants: Annie Floch, Anthony Baire, Ariel Sabiguero, César Viho and Frédéric Roudaut
- Contact: Federico Sismondi

6.4. ttproto

Testing Tool Prototype
KEYWORDS: Interoperability - Conformance testing - TTCN-3
FUNCTIONAL DESCRIPTION: ttproto is an experimental tool for implementing testing tools, for conformance and interoperability testing.

It was first implemented to explore new features and concepts for the TTCN-3 standard, but we also used it to implement a passive interoperability test suite we provided for the CoAP interoperability event held in Paris in March 2012.

This tool is implemented in python3 and its design was influenced mainly by TTCN-3 (abstract model, templates, snapshots, behaviour trees, communication ports, logging) and by Scapy (syntax, flexibility, customisability)

Its purpose is to facilitate rapid prototyping rather than experimentations (rather than production use). We choosed to maximise its modularity and readability rather than performances and real-time considerations.

Now you should have a look at the Features page: https://www.irisa.fr/tipi/wiki/doku.php/testing_tool_prototype:features

- Contact: Federico Sismondi
- URL: https://www.irisa.fr/tipi/wiki/doku.php/testing_tool_prototype

6.5. CoAP Testing Tool

KEYWORDS: Test - Interoperability - Conformance testing - Plugtests

FUNCTIONAL DESCRIPTION: The software helps developers of the CoAP protocol assessing if their implementations (either CoAP clients or CoAP servers) are conformant to protocol specifications, and interoperable with other implementations. It encompasses:

- Coordination of CoAP interoperability tests
- Analysis of CoAP traces & issuing verdicts
- Automation of open source CoAP implementations for based reference interop testing
- Authors: Federico Sismondi and César Viho
- Contact: Federico Sismondi

6.6. ioppytest

Interoperability testing
KEYWORDS: Interoperability - Conformance testing - CoAP - 6LoWPAN - OneM2M
FUNCTIONAL DESCRIPTION: The software is a framework for developing interoperability tests. The interoperability tests help developers of network protocol assessing if their implementations are conformant to protocol specifications, and interoperable with other implementations.

The software already integrates interoperability tests for CoAP, OneM2M and 6LoWPAN The framework provides the following features to the users:

- Coordination of the interoperability tests (enabling remote testing)
- VPN-like connectivity between users' implementations (enabling remote testing)
- Analysis of exchanged network traces & issuing verdicts
- Automation of open source implementations for based reference interop testing

This framework is the evolution of the CoAP Testing Tool (https://bil.inria.fr/fr/software/view/2937/tab)

- Contact: Federico Sismondi
- URL: https://gitlab.f-interop.eu/f-interop-contributors/ioppytest

6.7. AdaComp

Participants: Corentin Hardy, Bruno Sericola

Our recent works, in collaboration with Technicolor, on deep learning and distributed learning led us to study a kind of data parallelism called the Parameter Server model. This model consists in sharing the learning of a deep neural network between many devices (called the workers) via a centralized Parameter Server (PS). We deployed a platform which allow us to experiment different state-of-the-art algorithms based on the PS model. The platform is composed of a unique powerful machine where many Linux containers (LXC) are running. Each LXC executes a `Tensorflow` session and can be a worker or a PS. The first experimentations were used to validate the correct functioning of the platform, to better understand its limitations and to determine what can be measured in an unbiased way. Others experimentations helped us to understand the role of different parameters of the overall model, mainly those related to the distribution on user-devices, and their impact on the learning (accuracy of the model, number of iterations to learn the model). During these experimentations, we noted that the main bottleneck is the ingress traffic of PS during the learning phase. To reduce this ingress traffic, we chose to compress the messages sent by the workers to the PS. We proposed in [43] a method to reduce up to 2 orders of magnitude this ingress traffic, keeping a good accuracy on the learned model. This new method, called AdaComp, is available in `github` (https://github.com/Hardy-c/AdaComp).

6.8. DNN-withRNL

Participants: Corentin Hardy, Gerardo Rubino, Bruno Sericola

The extension of the AdaComp method, presented in 6.7, to Random Neural Networks started with the introduction of Random Neural Layers, see [65]. Concerning the associated software, see https://github.com/Hardy-c/DNN-with-RNL.

7. New Results

7.1. Performance Evaluation

Participants: Yann Busnel, Yves Mocquard, Bruno Sericola, Gerardo Rubino

Correlation estimation between distributed massive streams. The real time analysis of massive data streams is of utmost importance in data intensive applications that need to detect as fast as possible and as efficiently as possible (in terms of computation and memory space) any correlation between its inputs or any deviance from some expected nominal behavior. The IoT infrastructure can be used for monitoring any events or changes in structural conditions that can compromise safety and increase risk. It is thus a recurrent and crucial issue to determine whether huge data streams, received at monitored devices, are correlated or not as it may reveal the presence of attacks. In [14] we propose a metric, called *Codeviation*, that allows to evaluate the correlation between distributed massive streams. This metric is inspired from classical material in statistics and probability theory, and as such enables to understand how observed quantities change together, and in which proportion. We then propose to estimate the codeviation in the data stream model. In this model, functions are estimated on a huge sequence of data items, in an online fashion, and with a very small amount of memory with respect to both the size of the input stream and the domain from which data items are drawn. We then generalize our approach by presenting a new metric, the *Sketch-☆ metric*, which allows us to define a distance between updatable summaries of large data streams. An important feature of the *Sketch-☆ metric* is that, given a measure on the entire initial data streams, the *Sketch-☆ metric* preserves the axioms of the latter measure on the sketch. We also conducted extensive experiments on both synthetic traces and real data sets allowing us to validate the robustness and accuracy of our metrics.

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

A stream processing application is commonly modeled as a direct acyclic graph where data operators, represented by nodes, are interconnected by streams of tuples containing data to be analyzed, the directed edges (the arcs). Scalability is usually attained at the deployment phase where each data operator can be parallelized using multiple instances, each of which will handle a subset of the tuples conveyed by the operators' ingoing stream. Balancing the load among the instances of a parallel operator is important as it yields to better resource utilization and thus larger throughputs and reduced tuple processing latencies.

Shuffle grouping is a technique used by stream processing frameworks to share input load among parallel instances of stateless operators. With shuffle grouping each tuple of a stream can be assigned to any available operator instance, independently from any previous assignment. A common approach to implement shuffle grouping is to adopt a Round-Robin policy, a simple solution that fares well as long as the tuple execution time is almost the same for all the tuples. However, such an assumption rarely holds in real cases where execution time strongly depends on tuple content. As a consequence, parallel stateless operators within stream processing applications may experience unpredictable unbalance that, in the end, causes undesirable increase in tuple completion times. In [61] we propose Online Shuffle Grouping (OSG), a novel approach to shuffle grouping aimed at reducing the overall tuple completion time. OSG estimates the execution time of each tuple, enabling a proactive and online scheduling of input load to the target operator instances. Sketches are used to efficiently store the otherwise large amount of information required to schedule incoming load. We provide a probabilistic analysis and illustrate, through both simulations and a running prototype, its impact on stream processing applications.

Grand Challenge. Since 2011, the ACM International Conference on Distributed Event-based Systems (DEBS) launched the Grand Challenge series to increase the focus on these systems as well as provide common benchmarks to evaluate and compare them. The ACM DEBS 2017 Grand Challenge focused on (soft) real-time anomaly detection in manufacturing equipment. To handle continuous monitoring, each machine is fitted with a vast array of sensors, either digital or analog. These sensors provide periodic measurements, which are sent to a monitoring base station. The latter receives then a large collection of observations. Analyzing in an efficient and accurate way, this very-high-rate – and potentially massive – stream of events is the core of the Grand Challenge. Although, the analysis of a massive amount of sensor reading requires an on-line analytics pipeline that deals with linked-data, clustering as well as a Markov model training and querying. The FlinkMan system [62] proposes a solution to the 2017 Grand Challenge, making use of a publicly available streaming engine and thus offering a generic solution that is not specially tailored for this or for another challenge. We offer an efficient solution that maximally utilizes available cores, balances the load among the cores, and avoids to the extent possible tasks such as garbage collection that are only indirectly related to the task at hand.

Health big data processing. Sharing and exploiting efficiently Health Big Data (HBD) lead to tackle great challenges: data protection and governance taking into account legal, ethical and deontological aspects which enables a trust, transparent and win-to-win relationship between researchers, citizen and data providers. Lack of interoperability: data are compartmentalized and are so syntactically and semantically heterogeneous. Variable data quality with a great impact on data management and statistical analysis. The objective of the INSHARE project [41] is to explore, through an experimental proof of concept, how recent technologies could overcome such issues. It aims at demonstrating the feasibility and the added value of an IT platform based on CDW, dedicated to collaborative HBD sharing for medical research.

The consortium includes 6 data providers: 2 academic hospitals, the SNIIRAM (the French national reimbursement database) and 3 national or regional registries. The platform is designed following a three steps approach: (1) to analyze use cases, needs and requirements, (2) to define data sharing governance and secure access to the platform, (3) to define the platform specifications. Three use cases (healthcare trajectory analysis, epidemiological registry enrichment, signal detection) were analyzed to design the platform corresponding to five studies and using eleven data sources. The governance was derived from the SCANNER model and adapted to data sharing. As a result, the platform architecture integrates the following tools and services: data repository and hosting, semantic integration services, data processing, aggregate computing, data quality and integrity monitoring, id linking, multi-source query builder, visualization and data export services, data governance, study management service and security including data watermarking.

Throughput prediction in cellular networks. Downlink data rates can vary significantly in cellular networks, with a potentially non-negligible effect on the user experience. Content providers address this problem by using different representations (*e.g.*, picture resolution, video resolution and rate) of the same content and by switching among these based on measurements collected during the connection. If it were possible to know the achievable data rate before the connection establishment, content providers could choose the most appropriate representation from the very beginning. We have conducted a measurement campaign involving 60 users connected to a production network in France, to determine whether it is possible to predict the achievable data rate using measurements collected, before establishing the connection to the content provider, on the operator's network and on the mobile node. We show that it is indeed possible to exploit these measurements to predict, with a reasonable accuracy, the achievable data rate [53].

Population protocol model. We consider in [50] a large system populated by n anonymous nodes that communicate through asynchronous and pairwise interactions. The aim of these interactions is, for each node, to converge toward a global property of the system that depends on the initial state of the nodes. We focus on both the counting and proportion problems. We show that for any $\delta \in (0, 1)$, the number of interactions needed per node to converge is $O(\ln(n/\delta))$ with probability at least $1 - \delta$. We also prove that each node can determine, with any high probability, the proportion of nodes that initially started in a given state without knowing the number of nodes in the system. This work provides a precise analysis of the convergence bounds, and shows that using the 4-norm is very effective to derive useful bounds.

The context of [71] is the well studied dissemination of information in large scale distributed networks through pairwise interactions. This problem, originally called *rumor mongering*, and then *rumor spreading* has mainly been investigated in the synchronous model, which relies on the assumption that all the nodes of the network act in synchrony, that is, at each round of the protocol, each node is allowed to contact a random neighbor. In this paper, we drop this assumption under the argument that it is not realistic in large scale systems. We thus consider the asynchronous variant, where, at random times, nodes successively interact by pairs exchanging their information on the rumor. In a previous paper, we performed a study of the total number of interactions needed for all the nodes of the network to discover the rumor. While most of the existing results involve huge constants that do not allow us to compare different protocols, we provided a thorough analysis of the distribution of this total number of interactions together with its asymptotic behavior. In this paper we extend this discrete-time analysis by solving a conjecture proposed previously and we consider the continuous-time case, where a Poisson process is associated with each node to determine the instants at which interactions occur. The rumor spreading time is thus more realistic since it is the time needed for all the nodes of the network to discover the rumor. Once again, as most of the existing results involve huge constants, we provide a tight bound and equivalent of the complementary distribution of the rumor spreading time. We also give the exact asymptotic behavior of the complementary distribution of the rumor spreading time around its expected value when the number of nodes tends to infinity.

Transient analysis. Last, in two keynotes ([35] and [34]), we described part of our previous analytical results concerning the transient behavior of well-structured Markov processes, mainly on performance models (queueing systems), and we presented recent new results that extend those initial findings. The heart of the novelties lie on an extension of the concept of duality proposed by Anderson in [73] that we call pseudo-dual. The dual of a stochastic process needs strong monotonicity conditions to exist. Our proposed pseudo-dual always exist, and is directly defined on a linear system of differential equations with constant coefficients, that can be, in particular, the system of Chapman-Kolmogorov equations corresponding to a Markov process, but not necessarily. This allows, for instance, to prove the validity of closed-forms expressions of the transient distribution of a Markov process in cases where the dual doesn't exist. The keynote [35] was presented to a public oriented toward differential equations and dynamical systems; [34] has a more modeling flavour. A paper is under preparation with the technical details.

7.2. Distributed deep learning on edge-devices

Participants: Corentin Hardy, Gerardo Rubino, Bruno Sericola

A large portion of data mining and analytic services use modern machine learning techniques, such as deep learning. The state-of-the-art results related to deep learning come at the price of an intensive use of computing resources. The leading frameworks (*e.g.*, TensorFlow) are executed on GPUs or on high-end servers in data centers. On the other end, there is a proliferation of personal devices with possibly free CPU cycles; this can enable services to run in users' homes, embedding machine learning operations. In [66] and [43], we ask the following question: *Is distributed deep learning computation on WAN connected devices feasible, in spite of the traffic caused by learning tasks*? We show that such a setup rises some important challenges, most notably the ingress traffic that the servers hosting the up-to-date model have to sustain. In order to reduce this stress, we propose *AdaComp*, a novel algorithm for compressing worker updates to the model on the server. Applicable to stochastic gradient descent based approaches, it combines efficient gradient selection and learning rate modulation. We experiment and measure the impact of compression, device heterogeneity and reliability on the accuracy of learned models, with an emulator platform that embeds TensorFlow into Linux containers. We report a reduction of the total amount of data sent by workers to the server by two order of magnitude (*e.g.*, 191-fold reduction for a convolutional network on the MNIST dataset), when compared to a standard asynchronous stochastic gradient descent, while preserving model accuracy. The extension of the AdaComp algorithm to Random Neural Networks started with the introduction of Random Neural Layers, see [65].

7.3. Network Economics

Participants: Bruno Tuffin, Patrick Maillé, Pierre L'Ecuyer

The general field of network economics, analyzing the relationships between all acts of the digital economy, has been an important subject for years in the team. The whole problem of network economics, from theory to practice, describing all issues and challenges, is described in our book [7].

Roaming. In October 2015, the European parliament has decided to forbid roaming charges among EU mobile phone users, starting June 2017, as a first step toward the unification of the European digital market. We have investigated the consequences of such a measure from an economic perspective. In [47], we analyze the effect of the willingness-to-pay heterogeneity among users (also due to wealth heterogeneity), and the fact that the roaming behavior is positively correlated with wealth. Our analysis suggests that imposing free roaming degrades the revenues of the operator but can also deter some users from subscribing; hence we conclude that such (apparently beneficial) regulatory decisions must be taken with care. In [47], we particularly focus on the strategies on transit payments between ISPs in different countries. We highlight that scrutiny is also required since, depending on parameters, consumer surplus or subscription penetration are not necessarily maximized if free roaming is enforced.

Network neutrality. Most of our activity has been devoted to the vivid network neutrality debate, going beyond the traditional for or against neutrality, and trying to tackle it from different angles.

Network neutrality has been a very sensitive topic of discussion all over the world. In the keynote talk [59], we first introduce the elements of the debate and how the problem can be modeled and analyzed through game theory. With an Internet ecosystem much more complex now than the simple delivery chain Content-ISP-User, we highlight, in a second step, how neutrality principles can be bypassed in various ways without violating the rules currently evoked in the debate, for example via Content Delivery Networks (CDNs), or via search engines which can affect the visibility and accessibility of content. We describe some other grey zones requiring to be dealt with and spend some time on discussing the (potential) implications for clouds.

The impact of CDNs on the debate has been detailed in [18]. Content Delivery Networks (CDN) have become key telecommunication actors. They contribute to improve significantly the quality of services delivering content to end users. However, their impact on the ecosystem raises concerns about their fairness, and therefore the question of their inclusion in the neutrality debates becomes relevant. We analyze the impact of a revenue-maximizing CDN on some other major actors, namely, the end-users, the network operators and the content providers, at comparing the outcome with that of a fair behavior, and at providing tools to investigate whether some regulation should be introduced.We present a mathematical model and show that there exists a unique optimal revenue-maximizing policy for a CDN actor, in terms of dimensioning and allocation of its storage capacity, and depending on parameters such as prices for service/transport/storage. Numerical experiments are then performed with both synthetic data and real traces obtained from a major Video-on-Demand provider. In addition, using the real traces, we compare the revenue-based policy with policies based on several fairness criteria.

Network neutrality is often advocated by content providers, stressing that side payments to Internet Service Providers would hinder innovation. However, we also observe some content providers actually paying those fees. In [24], we intend to explain such behaviors through economic modeling, illustrating how side payments can be a way for an incumbent content provider to prevent new competitors from entering the market. We investigate the conditions under which the incumbent can benefit from such a barrier-to-entry, and the consequences of that strategic behavior on the other actors: content providers, users, and the Internet Service Provider. We also describe how the Nash bargaining solution concept can be used to determine the side payment.

Similarly, major content/service providers are publishing grades they give to ISPs about the quality of delivery of their content. The goal is to inform customers about the “best” ISPs. But this could be an incentive for, or even a pressure on, ISPs to differentiate service and provide a better quality to those big content providers in order to be more attractive. Instead of the traditional vision of ISPs pressing content providers, we face here the opposite situation, still possibly at the expense of small content providers though. We design in [48] a model describing the various actors and their strategies, analyzes it using non-cooperative game theory tools, and quantifies the impact of those advertised grades with respect to the situation where no grade is published. We illustrate that a non-neutral behavior, differentiating traffic, is not leading to a desirable situation.

Sponsored data. With wireless sponsored data, a third party, content or service provider, can pay for some of your data traffic so that it is not counted in your plan's monthly cap. This type of behavior is currently under scrutiny, with telecommunication regulators wondering if it could be applied to prevent competitors from entering the market, and what the impact on all telecommunication actors can be. To answer those questions, we design and analyze in [69] a model where a Content Provider (CP) can choose the proportion of data to sponsor and a level of advertisement to get a return on investment, and several Internet Service Providers (ISPs) in competition. We distinguish three scenarios: no sponsoring, the same sponsoring to all users, and a different sponsoring depending on the ISP you have subscribed to. This last possibility may particularly be considered an infringement of the network neutrality principle. We see that sponsoring can be beneficial to users and ISPs, especially with identical sponsoring. We also discuss the impact of zero-rating where an ISP offers free data to a CP to attract more customers, of and vertical integration where a CP and an ISP are the same company.

Online platforms and search engines. The search neutrality debate is about whether search engines should or should not be allowed to uprank certain results among the organic content matching a query. This debate is related to that of network neutrality, which focuses on whether all bytes being transmitted through the Internet should be treated equally. In a previous paper, we had formulated a model that formalizes this question and characterized an optimal ranking policy for a search engine. The model relies on the trade-off between short-term revenues, captured by the benefits of highly-paying results, and long-term revenues which can increase by providing users with more relevant results to minimize churn. In [21], we apply that model to investigate the relations between search neutrality and innovation. We illustrate through a simple setting and computer simulations that a revenue-maximizing search engine may indeed deter innovation at the content level. Our simple setting obviously simplifies reality, but this has the advantage of providing better insights on how optimization by some actors impacts other actors.

Sponsored auctions. Advertisement in dedicated webpage spaces or in search engines sponsored slots is usually sold using auctions, with a payment rule that is either per impression or per click. But advertisers can be both sensitive to being viewed (brand awareness effect) and being clicked (conversion into sales). In [23], we generalize the auction mechanism by including both pricing components: the advertisers are charged when their ad is displayed, and pay an additional price if the ad is clicked. Applying the results for Vickrey-Clarke-Groves (VCG) auctions, we show how to compute payments to ensure incentive compatibility from advertisers as well as maximize the total value extracted from the advertisement slot(s). We provide tight upper bounds for the loss of efficiency due to applying only pay-per-click (or pay-per-view) pricing instead of our scheme. Those bounds depend on the joint distribution of advertisement visibility and population likelihood to click on ads, and can help identify situations where our mechanism yields significant improvements. We also describe how the commonly used generalized second price (GSP) auction can be extended to this context.

7.4. Monte Carlo

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

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. We have published an introduction to Monte Carlo methods on Insterstices, including animations https://interstices.info/jcms/int_69164/la-simulation-de-monte-carlo.

Rare event simulation. The mean time to failure (MTTF) of a stochastic system is often estimated by simulation. One natural estimator, which we call the direct estimator, simply averages independent and identically distributed copies of simulated times to failure. When the system is regenerative, an alternative approach is based on a ratio representation of the MTTF. The purpose of [42] is to compare the two estimators. We first analyze them in the setting of crude simulation (i.e., no importance sampling), showing that they are actually asymptotically identical in a rare-event context. The two crude estimators are inefficient in different but closely related ways: the direct estimator requires a large computational time because times to failure often include many transitions, whereas the ratio estimator entails estimating a rare-event probability. We then

discuss the two approaches when employing importance sampling; for highly reliable Markovian systems, we show that using a ratio estimator is advised.

Another problem studied in [40] is the estimation of the tail of the distribution of the sum of correlated log-normal random variables. While a number of theoretically efficient estimators have been proposed for this setting, using a few numerical examples we illustrate that these published proposals may not always be useful in practical simulations. As a remedy to this defect, we propose a new estimator and we demonstrate that, not only is our novel estimator theoretically efficient, but, more importantly, its practical performance is significantly better than that of its competitors.

Random variable generation. Random number generators were invented before there were symbols for writing numbers, and long before mechanical and electronic computers. All major civilizations through the ages found the urge to make random selections, for various reasons. Today, random number generators, particularly on computers, are an important (although often hidden) ingredient in human activity. In the invited paper [32], we give a historical account on the design, implementation, and testing of uniform random number generators used for simulation.

We study in [68] the lattice structure of random number generators of the specific MIXMAX family, a class of matrix linear congruential generators that produce a vector of random numbers at each step. These generators were initially proposed and justified as close approximations to certain ergodic dynamical systems having the Kolmogorov K-mixing property, which implies a chaotic (fast-mixing) behavior. But for a K-mixing system, the matrix must have irrational entries, whereas for the MIXMAX it has only integer entries. As a result, the MIXMAX has a lattice structure just like linear congruential and multiple recursive generators. We study this lattice structure for vectors of successive and non-successive output values in various dimensions. We show in particular that for coordinates at specific lags not too far apart, in three dimensions, all the nonzero points lie in only two hyperplanes. This is reminiscent of the behavior of lagged-Fibonacci and AWC/SWB generators. And even if we skip the output coordinates involved in this bad structure, other highly structured projections often remain, depending on the choice of parameters.

Quasi-Monte Carlo (QMC). In [5], which appeared in 2017, we survey basic ideas and results on randomized quasi-Monte Carlo (RQMC) methods, discuss their practical aspects, and give numerical illustrations. RQMC can improve accuracy compared with standard Monte Carlo (MC) when estimating an integral interpreted as a mathematical expectation. RQMC estimators are unbiased and their variance converges at a faster rate (under certain conditions) than MC estimators, as a function of the sample size. Variants of RQMC also work for the simulation of Markov chains, for function approximation and optimization, for solving partial differential equations, etc. In this introductory survey, we look at how RQMC point sets and sequences are constructed, how we measure their uniformity, why they can work for high-dimensional integrals, and how can they work when simulating Markov chains over a large number of steps.

General presentations. Finally, in two general presentations, we described state-of-the-art technologies available to deal with rare events by means of Monte Carlo techniques, including several methods produced inside Dionysos. In the tutorial [33], we gave an overview of the field, with a focus on dependability analysis applications. The keynote [36] described specific procedures taken from our monograph [72], that were adapted to the needs of the micro-simulation community.

7.5. Wireless Networks

Participants: Yue Li, Imad Alawe, Quang Pham, Patrick Maillé, Yassine Hadjadj-Aoul, César Viho, Gerardo Rubino

Mobile wireless networks' improvements. Software Defined Networking (SDN) is one of the key enablers for evolving mobile network architecture towards 5G. SDN involves the separation of control and data plane functions, which leads, in the context of 5G, to consider the separation of the control and data plane functions of the different gateways of the Evolved Packet Core (EPC), namely Serving and Packet data Gateways (S and P-GW). Indeed, the envisioned solutions propose to separate the S/P-GW into two entities: the S/P-GW-C, which integrates the control plane functions and the S/P-GW-U that handles the User Equipment (UE)

data plane traffic. There are two major approaches to create and update user plane forwarding rules for such a partition: (i) considering an SDN controller for the S/P-GW-C (SDNEPC) or (ii) using a direct specific interface to control the S/P-GW-U (enhancedEPC). In [38], we evaluate, using a testbed, those two visions against the classical virtual EPC (vEPC), where all the elements of the EPC are virtualized. Besides evaluating the capacity of the vEPC to manage and scale to UE requests, we compare the performances of the solutions in terms of the time needed to create the user data plane. The obtained results allow drawing several remarks, which may help to dimension the vEPC's components as well as to improve the S/P-GW-U management procedure.

One of the requirements of 5G is to support a massive number of connected devices, considering many use-cases such as IoT and massive Machine Type Communication (MTC). While this represents an interesting opportunity for operators to grow their business, it will need new mechanisms to scale and manage the envisioned high number of devices and their generated traffic. Particularity, the signaling traffic, which will overload the 5G core Network Function (NF) in charge of authentication and mobility, namely Access and Mobility Management Function (AMF). The objective of [37] is to provide an algorithm based on Control Theory allowing: (i) to equilibrate the load on the AMF instances in order to maintain an optimal response time with limited computing latency; (ii) to scale out or in the AMF instance (using NFV techniques) depending on the network load to save energy and avoid wasting resources. Obtained results indicate the superiority of our algorithm in ensuring fair load balancing while scaling dynamically with the traffic load. In [64] we are going further by using new advances on machine learning, and more specifically Recurrent Neural Networks (RNN), to predict accurately the arrival traffic pattern of devices. The main objective of the proposed approach is to early react to congestion by pro-actively scaling the AMF VNF in a way to absorb such congestion while respecting the traffic constraints.

Energy consumption improvements. Recently in cellular networks, the focus has been moved to seeking ways to increase the energy efficiency by better adapting to the existing users behaviors. In [17], we are going a step further in studying a new type of disruptive service by trying to answer the question "What are the potential energy efficiency gains if some of the users are willing to tolerate delays?". We present an analytical model of the energy usage of LTE base stations, which provides lower bounds of the possible energy gains under a decentralized, noncooperative setup. The model is analyzed in six different scenarios (such as micro-macro cell interaction and coverage redundancy) for varying traffic and user-tolerable delays. We show that it is possible to reduce the power consumption by up to 30%.

Computation offloading in mobile network. Mobile edge computing (MEC) emerges as a promising paradigm that extends the cloud computing to the edge of pervasive radio access networks, in near vicinity to mobile users, reducing drastically the latency of end-to-end access to computing resources. Moreover, MEC enables the access to up-to-date information on users' network quality via the radio network information service (RNIS) application programming interface (API), allowing to build novel applications tailored to users' context. In [25] and [49], we present a novel framework for offloading computation tasks, from a user device to a server hosted in the mobile edge (ME) with highest CPU availability. Besides taking advantage of the proximity of the MEC server, the main innovation of the proposed solution is to rely on the RNIS API to drive the user equipment (UE) decision to offload or not computing tasks for a given application. The contributions are twofold. First, we propose the design of an application hosted in the ME, which estimates the current value of the round trip time (RTT) between the UE and the ME, according to radio quality indicators available through RNIS API, and provides it to the UE. Second, we present a novel computation algorithm which, based on the estimated RTT coupled with other parameters (e.g., energy consumption), decide when to offload UE's applications computing tasks to the MEC server. The effectiveness of the proposed framework is demonstrated via testbed experiments featuring a face recognition application.

Services improvement in wireless heterogeneous networks. With the rapid growth of HTTP-based Adaptive Streaming (HAS) multimedia video services on the Internet, improving the Quality of Experience (QoE) of video delivery will be highly requested in wireless heterogeneous networks. Various access technologies such as 3G/LTE and Wi-Fi with overlapping coverage is the main characteristic of network heterogeneity. Since contemporary mobile devices are usually equipped with multiple radio interfaces, mobile users are enabled to

utilize multiple access links simultaneously for additional capacity or reliability. However, network and video quality selection can have notable impact on the QoE of DASH clients facing the video service's requirements, the wireless channel profiles and the costs of the different links. In this context, the emerging Multi-access Edge Computing (MEC) standard gives new opportunities to improve DASH performance, by moving IT and cloud computing capabilities down to the edge of the mobile network. In [45], we propose a MEC-assisted architecture for improving the performance of DASH-based streaming, a standard implementation of a HAS framework in wireless heterogeneous networks. With the proposed algorithm running as a MEC service, the overall QoE and fairness of DASH clients are improved in a real time manner in case of network congestion.

QoE aware routing in wireless networks. This year we continued our research on QoE-based optimization routing for wireless mesh networks. The difficulties of the problem are analyzed and centralized and decentralized algorithms are proposed. The quality of the solution, the computational complexity of the proposed algorithm, and the fairness are our main concerns. Several centralized approximation algorithms have been already proposed in order to address the complexity and the quality of possible solutions. This year, we focused mainly on distributed algorithm to complement of the existing centralized algorithms. We propose decentralized heuristic algorithms based on the well-known Optimized Link-State Routing (OLSR) protocol. Control packets of OLSR are modified so as to be able to convey QoE-related information. The routing algorithm chooses the paths heuristically. After that, we studied message passing algorithms in order to find near optimal routing solutions in cooperative distributed networks. These algorithms have been published in [27], [13].

Sensors networks. In the literature, it is common to consider that sensor nodes in a clustered-based event-driven Wireless Sensor Network (WSN) use a Carrier Sense Multiple Access (CSMA) protocol with a fixed transmission probability to control data transmission. However, due to the highly variable environment in these networks, a fixed transmission probability may lead to a significant amount of extra energy consumption. In view of this, three different transmission probability strategies for event-driven WSNs were studied in [51]: the optimal one, the "fixed" approach and a third "adaptive" method. As expected, the optimum strategy achieves the best results in terms of energy consumption but its implementation in a practical system is not feasible. The commonly used fixed transmission strategy (the probability for any node to attempt transmission is a constant) is the simplest approach but it does not adapt to changes in the system's conditions and achieves the worst performance. In the paper, we find that our proposed adaptive transmission strategy, where that probability is changed depending on specific conditions and in a very precise way, is pretty easy to implement and achieves results very close to the optimal method. The three strategies are analyzed in terms of energy consumption but also regarding the cluster formation latency. In [28], we also investigate cluster head selection schemes. Specifically, we consider two intelligent schemes based on the fuzzy C-means and k-medoids algorithms, and a random selection with no intelligence. We show that the use of intelligent schemes greatly improves the performance of the system, but their use entails higher complexity and some selection delay. The main performance metrics considered in this work are energy consumption, successful transmission probability and cluster formation latency. As an additional feature of this work, we study the effect of errors in the wireless channel and the impact on the performance of the system under the different considered transmission probability schemes.

Transmission delay, throughput and energy are also important criteria to consider in wireless sensor networks (WSNs). The IEEE 802.15.4 standard was conceived with the objective of reducing resource's consumption in both WSNs and Personal Area Networks (WPANs). In such networks, the slotted CSMA/CA still occupies a prominent place as a channel control access mechanism with its inherent simplicity and reduced complexity. In [26], we propose to introduce a network allocation vector (NAV) to reduce energy consumption and collisions in IEEE 802.15.4 networks. A Markov chain-based analytical model of the fragmentation mechanism, in a saturated traffic, is given as well as a model of the energy consumption using the NAV mechanism. The obtained results show that the fragmentation technique improves at the same time the throughput, the access delay and the bandwidth occupation. They also show that using the NAV allows reducing significantly the energy consumption when applying the fragmentation technique in slotted CSMA/CA under saturated traffic conditions.

7.6. Optical Networks

Participants: Nicolás Jara, Gerardo Rubino

The rapid increase in demand for bandwidth in communication networks has caused a growth in the use of technologies based on WDM optical infrastructures. Nevertheless, in this last decade many researchers have recognized a "Capacity Crunch" associated with this technology, a transmission capacity limit on optical fibers, that is close to be reached pretty soon. This situation claims for an evolution on the currently used WDM optical architectures, in order to satisfy this relentless exponential growth in bandwidth demand. Following this trend, research started to examine in some detail specific aspects of the present functioning, and in particular, the way these networks are operated. Currently, optical networks are operated statically, but this is known to be inefficient in the usage of network resources, and with the previously mentioned upcoming risk of capacity collapse, it is of pressing matter to upgrade it. To this purpose, several proposals have been addressed and researched so far. Among these solutions, dynamic optical networks is the one closest to be implemented, but it has not been considered yet since the network cost savings are not enough to convince enterprises. This has been the focus of our research effort in the area.

The design of dynamic optical networks decomposes into different tasks, where the engineers must basically organize the way the main system's resources are used, minimizing the design and operation costs and respecting critical performance constraints. These tasks must guarantee certain level of quality of service (QoS) pre-established in the Service Level Agreement. In order to provide a proper quality of service measurement, we propose a new fast and accurate analytical method to evaluate the blocking probability that is at the heart of the path toward solving all the mentioned design problems. Blocking probability is the main QoS metric considered in the field. This work has been done in [20], where an analytical procedure has been proposed that combines efficiency and accuracy.

Next, the different tasks that must be addressed to find a good global design have been addressed in [19]. These are: which wavelength is going to be used by each user (the Wavelength Assignment Problem), how many wavelengths will be needed on each network link (the Wavelength Dimensioning Problem), and which set of paths enabling each network user to transmit (known as the Routing Problem) are to be established in order to minimize costs and to deal with link failures when the network is operating (this is the Fault Tolerance Problem). Two types of innovations and presented in this last paper. First, each of the problems receives a solution shown to be highly efficient. Second, and this is also new, we solve all the design problems simultaneously, using a single global algorithm (the usual way is to isolate them and to solve them one at a time, in a specific order). This work may provide a strategy to finally achieve sufficient cost savings, and thus, to contribute to make the decision to migrate from static to dynamic resource allocation easier. A preliminary version of a part of these results was presented previously in [44].

7.7. Future networks and architectures

Participants: Jean-Michel Sanner, Hamza Ben Ammar, Louiza Yala, Yassine Hadjadj-Aoul, Gerardo Rubino

SDN and NFV placement. Mastering the increasing complexity of current and future networks, while reducing the operational and investments costs, is one of the major challenges faced by network operators (NOs). This explains in large part the recent enthusiasm of NOs towards Software Defined Networking (SDN) and Network Function Virtualization (NFV). Indeed, on the one hand, SDN makes it possible to get rid of the control plane distribution complexity, by centralizing it logically, while allowing its programmability. On the other hand, the NFV allows virtualizing the network functions, which considerably facilitates the deployment and the orchestration of the network resources. Providing a carrier grade network involves, however, several requirements such as providing a robust network meeting the constraints of the supported services. In order to achieve this objective, it is clearly necessary to scale network functions while placing them strategically in a way to guarantee the system's responsiveness.

The placement in TelCo networks are generally multi-objective and multi-constrained problems. The solutions proposed in the literature usually model the placement problem by providing a mixed integer linear program (MILP). Their performances are, however, quickly limited for large sized networks, due to the significant increase in the computational delays. In order to avoid the inherent complexity of optimal approaches and the

lack of flexibility of heuristics, we propose in [54] a genetic algorithm designed from the NSGA II framework that aims to deal with the controller placement problem. Genetic algorithms can be both multi-objective, multi-constraints and can be designed to be implemented in parallel. They constitute a real opportunity to find good solutions to this category of problems. Furthermore, the proposed algorithm can be easily adapted to manage dynamic placements scenarios. In [55], our main focus were devoted to maximize the clusters average connectivity and to balance the control's load between clusters, in a way to improve the networks' reliability.

We focus, in [60], on the problem of optimal computing resource allocation and placement for the provision of a virtualized Content Delivery Network (CDN) service over a telecom operator's Network Functions Virtualization (NFV) infrastructure. Starting from a Quality of Experience (QoE)-driven decision on the necessary amount of CPU resources to allocate in order to satisfy a virtual CDN deployment request with QoE guarantees, we address the problem of distributing these resources to virtual machines and placing the latter to physical hosts, optimizing for the conflicting objectives of management cost and service availability, while respecting physical capacity, availability and cost constraints. We present a multi-objective optimization problem formulation, and provide efficient algorithms to solve it by relaxing some of the original problem's assumptions. Numerical results demonstrate how our solutions address the trade-off between service availability and cost, and show the benefits of our approach compared with resource placement algorithms which do not take this trade-off into account.

Real-time NFV placement in edge cloud. Sometimes, the placement of NFV can not be planned in advance and therefore requires real-time placement as requests arrive. The placement is particularly challenging with the recent development of geographically distributed mini data centers, also referred to as cloudlets, at the edge of the network (i.e., typically at Points of Presence (PoPs) level). These edge data centers have rather small capacities in terms of storage, computing and networking resources, when compared with the huge centralized data centers deployed today.

All these radical changes in NOs' infrastructures raise many new issues (especially in terms of resource allocation), which so far have not been considered in the cloud literature. Traditionally, resources in cloud platforms are considered as to be infinite and request blocking is most of the time ignored when evaluating resources' allocation algorithms, precisely because of this infinite capacity assumption. However, if we assume that the NO's infrastructure will very likely be composed of small data centers with limited capacities, and deployed at the edge of network, the congestion of such a system may occur, notably if the demand is sufficiently high and exceeds what the infrastructure can handle at a given time.

We proposed in [57] an analytical model for the blocking analysis in a multidimensional cloud system, which was validated using discrete events' simulations. Besides, we conducted a comparative analysis of the most popular placement's strategies. The proposed model, as well as the comparative study, reveal practical insights into the performance evaluation of resource allocation and capacity planning for distributed edge cloud with limited capacities.

In [58] we set design principles of future distributed edge clouds in order to meet application requirements. We precisely introduce a costless distributed resource allocation algorithm, named *CLOSE*, which considers local information only. We compare via simulations the performance of *CLOSE* against those obtained by using mechanisms proposed in the literature, notably the Tricircle project within OpenStack. It turns out that the proposed distributed algorithm yields better performance while requiring less overhead.

In the context of the Open Network Automation Platform (ONAP), we develop in [56] a resource allocation strategy for deploying Virtualized Network Functions (VNFs) on distributed data centers. For this purpose, we rely on a three-level data center hierarchy exploiting co-location facilities available within Main and Core Central Offices. We precisely propose an active VNFs' placement strategy, which dynamically offloads requests on the basis of the load observed within a data center. We compare via simulations the performance of the proposed solution against mechanisms so far proposed in the literature, notably the centralized approach of the multi-site project within OpenStack, currently adopted by ONAP. Our algorithm yields better performance in terms of both data center occupancy and overhead. Furthermore, it allows extending the applicability of ONAP in the context of distributed cloud, without requiring any modification.

Content Centric Networking. Content-Centric Networking (CCN) has been proposed to address the challenges raised by the Internet usage evolution over the last years. One key feature provided by CCN to improve the efficiency of content delivery is the in-network caching, which has major impact on the system performance. In order to improve caching effectiveness in such systems, the study of the functioning of CCN in-network storage must go deeper. In [39], we propose MACS, a Markov chain-based Approximation of CCN caching Systems. We start initially by modeling a single cache node. Then, we extend our model to the case of multiple nodes. A closed-form expression is then derived to define the cache hit probability of each content in the caching system. We compare the results of MACS to those obtained with simulations. The conducted experiments show clearly the accuracy of our model in estimating the cache hit performance of the system.

In [16], we present the design and implementation of a Content-Delivery-Network-as-a-Service (CDNaaS) architecture, which allows a telecom operator to open up its cloud infrastructure for content providers to deploy virtual CDN instances on demand, at regions where the operator has presence. Using northbound REST APIs, content providers can express performance requirements and demand specifications, which are translated into an appropriate service placement on the underlying cloud substrate. Our architecture is extensible, supporting various different CDN flavors, and, in turn, different schemes for cloud resource allocation and management. In order to decide on the latter in an optimal manner from an infrastructure cost and a service quality perspective, knowledge of the performance capabilities of the underlying technologies and computing resources is critical. Therefore, to gain insight which can be applied to the design of such mechanisms, but also with further implications on service pricing and SLA design, we carry out a measurement campaign to evaluate the capabilities of key enabling technologies for CDNaaS provision. In particular, we focus on virtualization and containerization technologies for implementing virtual CDN functions to deliver a generic HTTP service, as well as an HTTP video streaming one, empirically capturing the relationship between performance and service workload, both from a system operator and a user-centric viewpoints.

New tools for network design. In the efforts for designing future networks' topologies, the inclusion of dependability aspects has been recently enriched with finer criteria, and one relatively new family of metrics consider diameter-constrained parameters that capture more accurately reliability aspects of communication infrastructures. This is done by taking into account not only connectivity properties but also delays when nodes are connected. Paper [15] deals with factorization theory in diameter-constrained reliability, when terminal nodes are further required to be connected by d hops or fewer (d is a given strictly positive parameter of the metric, called its diameter). This metric was defined in 2001, inspired by delay-sensitive applications in telecommunications. Factorization theory is fundamental for classical network reliability evaluation, and today it is a mature area. However, its extension to the diameter-constrained context requires at least the recognition of irrelevant links, which is an open problem. In this paper, irrelevant links are efficiently determined in the most used case, where we consider the communication between a given pair of nodes in the network. The article also proposes a Factoring algorithm that includes the way series-parallels substructures can be handled.

Quality of Experience activities. We continue to develop tools for Quality of Experience assessment, and applications of this quantitative evaluation.

Predicting time series. For the future of the PSQA project, we intend to integrate the capability of *predicting* the Perceptual Quality and not only evaluating its current value. With this goal in mind, we explored this year the idea of combining a Reservoir Computing architecture (whose good performances have been reported many times, when used to predict sequences of numbers or of vectors) with Recurrent Random Neural Networks, that belong to a class of Neural Networks that have some nice properties. Both have been very successful in many applications. In [29] we propose a new model belonging to the first class, taking the structure of the second for its dynamics. The new model is called Echo State Queuing Network. The paper positions the model in the global Machine Learning area, and provides examples of its use and performances. We show on largely used benchmarks that it is a very accurate tool, and we illustrate how it compares with standard Reservoir Computing models. In [31] we presented some preliminary results to the Random Neural Network community.

QoE and P2P design. In [30] we describe a Peer-to-Peer (P2P) network that was designed to support Video on Demand (VoD) services. The network is based on a video-file sharing mechanism that classifies peers

according to the window (segment of the file) that they are downloading. This classification easily allows identifying peers that are able to share windows among them, so one of our major contributions is the definition of a mechanism that could be implemented to efficiently distribute video content in future 5G networks. Considering that cooperation among peers can be insufficient to guarantee an appropriate system performance, we also propose that this network must be assisted by upload bandwidth coming from servers; since these resources represent an extra cost to the service provider, especially in mobile networks, we complement our work by defining a scheme that efficiently allocates them only to those peers that are in windows with resources scarcity (we called it *prioritized windows distribution scheme*). On the basis of a fluid model and a Markov chain, we also develop a methodology that allows us to select the system parameters values (e.g., windows sizes or minimum servers upload bandwidth) that satisfy a set of Quality of Experience (QoE) parameters.

8. Bilateral Contracts and Grants with Industry

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

Participants: Corentin Hardy, Bruno Sericola

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

8.2. Cifre contract on Throughput Prediction in Mobile Networks

Participants: Yann Busnel

This is a Cifre contract (2015-2018) including a PhD thesis supervision (PhD of Alassane Samba), done with Orange, on cooperation in statistical approaches for the prediction of throughput without history. Throughput has a strong impact on user experience in cellular networks. The ability to predict the throughput of a connection, before it starts, brings new possibilities, particularly to Internet service providers. They could adapt contents to the quality of service really reachable by users, in order to enhance their experience.

8.3. Cifre contract on Mobile SDN architecture

Participants: Yassine Hadjadj-Aoul, César Viho

This is a Cifre contract (2015-2018) including a PhD thesis supervision (PhD of Imad Alawe), done with TDF, on the proposition of a scalable SDN-based mobile network architectures for the future 5G network.

8.4. Cifre contract on Personalization for Cognitive Autonomic Networks in 5G

Participants: César Viho

This is a Cifre contract (2017-2019) including a PhD thesis supervision (PhD of Illyyne Saffar), done with Nokia, on the proposition to use machine learning and data analytics to transform user and network data into actionable knowledge which in turn can be automatically exploited by Autonomic Networking approaches for cognitive self management of the 5G network.

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

Participants: Bruno Tuffin, Gerardo Rubino

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

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

8.6. Bilateral Contract with Industry: ADR Nokia Bell Labs

Participants: Yassine Hadjadj-Aoul, Gerardo Rubino

Gerardo Rubino is the coordinator of the reasearch action, named "Analytics and machine learning", with Nokia Bell Labs.

The objective is to carry out common research on an integrated framework for 5G, programmable networks, IoT and clouds that aims at statically and dynamically managing and optimizing the 5G infrastructure using, in particular, machine learning techniques.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

- Sofiène Jelassi is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Yassine Hadjadj-Aoul is participating at 20% of his time to the IRT BCOM granted by the ANR.
- Yann Busnel is a member of the three following projects: SocioPlug granted by the ANR (ANR-13-INFR-0003), INSHARE granted by the ANR (ANR-15-CE19-0024) and BigClin granted by the LabEx CominLabs (ANR-10-LABX-07-01).

9.1.2. IPL (Inria Project Lab) BetterNet

Yassine Hadjadj-Aoul, Gerardo Rubino and Bruno Tuffin are members of the IPL (Inria Project Lab) BetterNet: An Observatory to Measure and Improve Internet Service Access from User Experience, 2016-2020.

BetterNet aims at building and delivering a scientific and technical collaborative observatory to measure and improve the Internet service access as perceived by users. In this Inria Project Lab, we will propose new original user-centered measurement methods, which will associate social sciences to better understand Internet usage and the quality of services and networks. Our observatory can be defined as a vantage point, where: 1) tools, models and algorithms/heuristics will be provided to collect data, 2) acquired data will be analyzed, and shared appropriately with scientists, stakeholders and civil society, and 3) new value-added services will be proposed to end-users.

9.2. European Initiatives

9.2.1. Eurostars Camion Project

Participants: Yassine Hadjadj-Aoul

We were involved in a 30 months Eurostars European Project named Camion, which started on October 2014, aiming at offering cost-efficient, QoE-optimized content delivery, allowing for faster content access, as well as offline operation, while improving wireless network capacity and coverage. Camion is leaded by JCP-Connect, and the partners are a SME (FON) and our team. The project ended by June 2017.

9.2.2. Collaborations in European Programs

9.2.2.1. FINTEROP

Program: H2020-ICT-12-2015

Project acronym: F-Interop

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

Duration: November 2015 – October 2018

Coordinator: UPMC-LIP6

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

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

9.2.3. Collaborations with Major European Organizations

Partner 1: Sapienza University of Rome, Italy.

We work with Nicoló Rivetti and Leonardo Querzoni on the analysis of stream processing systems.

9.3. International Initiatives

9.3.1. Inria International Partners

9.3.1.1. Informal International Partners

- We maintain a strong line of collaborations with the Technical University Federico Santa María (UTFSM), Valparaíso, Chile. Over the years, this has taken different forms (associated team Manap, Stic AmSud project "AMMA", Stic AmSud project "DAT"). In 2017, we had a joint PhD work running (PhD of Nicolás Jara, to be defended at the beginning of next year), and a new joint PhD to be started in 2018 (PhD of Jonathan Olavarría). The first one is on optical network analysis and design, the second one on modeling evaluation techniques, with focus on Stochastic Activity Networks.
- We started a collaboration with the Faculty of Sciences of the university of the Republic, in Uruguay, on the application of mathematical modeling tools to a better understanding of a cognitive disease called semantic dementia. This involves Prof. Eduardo Mizraji and Jorge Graneri, PhD student, whose co-advisors are Prof. Mizraji and G. Rubino from Dionysos. Our contribution to this project is around the use of mathematical models, in particular around neural structures.

9.3.2. Participation in Other International Programs

9.3.2.1. International Initiatives

SM-HCD-HDD

Title: Statistical methods for highly complex and/or high dimensional data

International Partner (Institution - Laboratory - Researcher):

Universidad de la Republica Uruguay (Uruguay), Faculty of Sciences; Resp.: Ricardo Fraiman, Department of Mathematics

CNRS (France); Resp.: Catherine Aaron

Universidad Nacional del Litoral (Argentina); Resp.: Liliana Forzani

Duration: 3 years

Start year: 2016

In this project we work on specific statistical tools, mainly concerning predicting the behavior of time series. Our goal is to improve our tools for Perceptual Quality evaluation.

9.3.2.2. International Initiatives

MOCQUASIN

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

International Partner (Institution - Laboratory - Researcher):

Université de Montréal (Canada) - DIRO - Pierre L'Ecuyer

Duration: 3 years

Start year: 2013

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

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

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Pierre L'Ecuyer holds an Inria International Chair, Nov. 2013- Oct. 2018.
- Marvin Nakayama (New Jersey Institute of Technology, NJ, USA) visited us 3 days in October to work on the estimation of quantiles in the case of rare events.
- Jonathan Olavarría, from UTFSM, Chile, from January to March (for two months), to work on stochastic models.
- Prof. Leslie Murray, from University of Rosario, Argentina (one month, February) to work on Monte Carlo techniques for rare event analysis.
- Jorge Graneri, from UDELAR, Uruguay (two months in the last quarter of the year, to work on biological applications).
- Prof. Claudio Risso, from UDELAR, Uruguay (two weeks in the last quarter of the year, to work on time series predictions).
- Prof. Gustavo Guerberoff, from UDELAR, Uruguay (two weeks in the last quarter of the year, to work on time series predictions).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. Member of the Organizing Committees

Pierre L'Ecuyer is member of the Steering Committee of MCQMC.

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

Y. Hadjadj-Aoul is co-chairing the Steering Committee of the International Conference on Information and Communication Technologies for Disaster Management (ICT-DM) from December 2016 and member of the steering committee since 2016.

Y. Hadjadj-Aoul is co-charing **ISNCC'2018**, "*The 5th International Symposium on Networks, Computers and Communications*" (Co-sponsored by IEEE), Roma, Italy (May 2018)

Yann Busnel has been member of the Organization Committee of AlgoTel 2017 (19èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications), which held in Quiberon in June 2017.

10.1.2. Scientific Events Selection

10.1.2.1. Chair of Conference Program Committees

- Patrick Maillé and Bruno Tuffin were co-chairs of the International Workshop on Advanced Internet Charging and QoS technologies (ICQT'17), Tokyo, Japan, in November 2017
- Yassine Hadjadj-Aoul was co-chair of ISNCC'2017, "*The 4th International Symposium on Networks, Computers and Communications*" (Co-sponsored by IEEE), Marrakech, Morocco (May 2017)

10.1.2.2. Member of the Conference Program Committees

Yann Busnel was a member of the Program Committee of the following events:

- NCA 2017: 16th IEEE International Symposium on Network Computing and Applications, Boston, USA, October 2017.
- CoRes 2017: 2èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication, Quiberon, France, May 2017.

Pierre L'Ecuyer was a member of the Program Committee of the following events:

- MCM'2017: Eleventh International Conference on Monte Carlo Methods and its Applications, Montreal, Canada, July 2017.
- ICORES 2017: International Conference on Operations Research and Enterprise Systems, Porto, Portugal, Feb. 2017.

Patrick Maillé was a member of the Program Committee of the following events:

- 15th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks, Telecom ParisTech, Paris, France, 15th - 19th May, 2017.
- NetEcon 2017: the 12th Workshop on the Economics of Networks, Systems and Computation, Cambridge, MA, USA, June 2017.

Bruno Sericola was a member of the Program Committee of the following event:

- ASMTA 2017: International Conference on Analytical and Stochastic Modelling Techniques and Applications, Newcastle-upon-Tyne, United Kingdom, 10-12 July 2017.

Gerardo Rubino was a member of the Program Committee of the following events:

- 11th International Conference on Monte Carlo Methods and Applications (MCM 2017), Montreal, Canada, July 3-7, 2017.
- XLIII Latin-American Conference in Computer Science (CLEI 2017), Córdoba, Argentina, September 4-8, 2017.
- IX International Congress of Computer Science and Telecommunications (COMTEL 2017), Lima, Peru, October 11-13, 2017.

Bruno Tuffin was a member of the Program Committee of the following events:

- 6th Workshop on Smart Data Pricing (SDP 2017), Workshop of IEEE INFOCOM 2017, Atlanta, GA, USA, May 2017.
- The Third International Symposium on Ubiquitous Networking (UNET 2017), Casablanca, Morocco, May 10-12, 2017.
- NetEcon 2017: the 12th Workshop on the Economics of Networks, Systems and Computation, Cambridge, MA, USA, June 2017.
- 11th International Conference on Monte Carlo Methods and Applications (MCM 2017), Montreal, Canada, July 3-7, 2017.
- 7th International Conference on Simulation and Modeling Methodologies, Technologies and Applications (SIMULTECH), Madrid, Spain, 29-31 July 2017.
- 14th International Conference on Economics of Grids, Clouds, Systems & Services (GECON'2017), Biarritz-Anglet-Bayonne, France, Sept. 19-21, 2017.
- The International Conference on Wireless Networks and Mobile Communications (WINCOM'17). Rabbat, Morocco, November 1-4, 2017.
- IEEE Globecom 2017, Singapore, Dec. 4-8, 2017
- 11th EAI International Conference on Performance Evaluation Methodologies and Tools (ValueTools 2017), Venice, Italy, December 5-7, 2017

Yassine Hadjadj-Aoul was a member of the Program Committee of the following events:

- IEEE Globecom 2017, Singapore, Dec. 4-8, 2017
- IEEE ICC 2017, Paris, France, May. 21-25, 2017
- IEEE WCNC 2017, San Francisco, USA, March 19-22
- IEEE Symposium on Computers and Communications (ISCC 2017), Heraklion, Crete, Greece, July 3-6, 2017
- IEEE International Symposium on Networks, Computers and Communications (ISNCC 2017), Marrakech, Morroco, May 16-18, 2017

10.1.2.3. Reviewer

Yann Busnel served as a reviewer for several major international conferences, such as DaWak 2017 (19th International Conference on Big Data Analytics and Knowledge Discovery).

Bruno Sericola served as a reviewer for several major international conferences.

Yassine Hadjadj-Aoul served as a reviewer for several major international conferences.

Gerardo Rubino served as a reviewer for several major international conferences, including those at which he served as a member of the Committee Program.

10.1.3. Journal

10.1.3.1. Member of the Editorial Boards

Bruno Tuffin is the Simulation Area Editor for *Informs Journal on Computing*.

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

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

Bruno Tuffin is an associate editor for the following journal:

- ACM Transactions on Modeling and Computer Simulation, since November 2008.

Bruno Sericola is an associate editor for the following journals:

- International Journal of Stochastic Analysis, since April 2010.
- Performance Evaluation, since April 2015.

Bruno Sericola is Editor in Chief of the books series "Stochastic Models in Computer Science and Telecommunications Networks", ISTE/WILEY, since March 2015.

10.1.3.2. Reviewer - Reviewing Activities

Yann Busnel served as a reviewer for several major international journals, such as TPDS (IEEE Transactions on Parallel and Distributed Systems).

In addition to the reports done during his associate editor and conference TPC member duties, Bruno Tuffin has reviewed papers in 2017 for IEEE JSAC, ACM TOIT, Telecom Policy, IEEE/ACM TON.

Bruno Sericola served as a reviewer for several major international journals.

Yassine Hadjadj-Aoul served as a reviewer for several major international journals, such as TVT (IEEE Transaction on Vehicular Technology) and IEEE JSAC.

César Viho reviewed papers for the journals IEEE Transaction on Wireless Communication, IEEE Transactions on Vehicular Communications, IEEE Communications Magazine, and for the following international conferences: IWCNC, Globecom, and CCNC.

Gerardo Rubino served as a reviewer for several major international journals.

10.1.4. Invited Talks

Yann Busnel made several invited and keynote talks in 2017:

- *Analyse et traitement de flux de données à large échelle*, Invited talk at Journées non thématiques RESCOM 2017, Nice, France, January 2017.
- *Analyse et traitement de flux de données à large échelle* Invited talk at Journées ARC du GRD MACS 2017, Paris, France, May 2017.
- *Ordonnancement dynamique pour un équilibrage de charge quasi-optimal dans les systèmes de traitement de flux*, Plenary talk at AlgoTel 2017, Quiberon, France, June 2017.
- *Comment créer un cloud social sécurisé pour ses données ? Le projet SocioPlug !* invited talk at 23ème Technoférence du Pôle Images & Réseaux, Nantes, France, December 2017.

B. Tuffin gave a keynote talk "Network Neutrality: Modeling, Challenges, and its Impact on Clouds" at the 14th International Conference on Economics of Grids, Clouds, Systems & Services (GECON 2017), Keynote talk, Bayonne Anglet, France, September 19-21, 2017.

B. Tuffin gave the following seminar presentation:

- B. Tuffin. Neutralité du Net: introduction, modélisation et défis. ENS Rennes, Feb. 7, 2017.
- B. Tuffin. La fausse neutralité du net ? ENS-ENSSIB, Lyon, Mars 2017.

Yassine Hadjadj-Aoul led a panel on "Intelligence defined network for future smart cities" during the 4th International Symposium on Networks, Computers and Communications (ISNCC 2017).

Raymond Marie gave a seminar at the Polytechnic University of Hong Kong during a two-week stay as a guest.

G. Rubino made several invited and keynote talks in 2017. Two around Monte Carlo techniques:

- "Rare events in simulation: issues and techniques", plenary talk, for the micro-simulation community (see [36]).
- "Dependability Analysis through Monte Carlo Methods: The Case of Rare Events", a tutorial (see [33]).

and two around transient analysis of Markovian processes:

- "On the derivation of closed-form expressions of the solutions to (possibly infinite) some simple linear systems of ODEs", keynote for researchers in dynamical systems and differential equations (see [35]).
- "New results on the transient analysis of some fundamental queuing systems", keynote oriented to modeling (see [34]).

10.1.5. Leadership within the Scientific Community

Yann Busnel is a member of the CSV (the technical committee) of the Images and Networks Cluster of Brittany, France.

Yann Busnel is a member of the Steering Committee of the RESCOM research group at GDR CNRS RSD.

Yassine Hadjadj-Aoul is a founding member of Special Interests Group "IEEE Sig on Big Data with Computational Intelligence", under the IEEE COMSOC Big Data TC (since June 2017).

Yassine Hadjadj-Aoul is a member of the GT ARC (Automatique et Réseaux de Communication) scientific committee (since Nov. 2017)

Gerardo Rubino is one of the three French representatives at the Scientific Committee of the IFCAM (Indo-French Centre for Applied Mathematics), managing the cooperation in mathematics of the two countries, and federating at the French side, among several other participants, Inria and CNRS.

Gerardo Rubino is a member of the CSV (the technical committee) of the Images and Networks Cluster of Brittany, France.

10.1.6. Scientific Expertise

César Viho has reviewed project proposals for the ANR and for CIFRE contracts for the ANRT.

Gerardo Rubino has participated as an expert for several institutions abroad, and for different tasks (recruitments, promotions, prizes): the University of Vienna, Austria, the University of New South Wales, Australia, the UTFSM, Chile.

10.1.7. Research Administration

- Bruno Tuffin is the co-director of the common lab ALSTOM-Inria since 2014.
- Bruno Tuffin was a member of Inria-MITACS selection committee.
- Bruno Tuffin was a member of Inria Rennes' "Inria delegation" selection committee.
- Bruno Tuffin was a member of Inria Rennes' post-doc selection committee.
- Yann Busnel is head of "Network System, Cybersecurity and Digital law" Research Department at IMT Atlantique.
- Yann Busnel is member of Development Council of Computer Sciences Master at University of Nantes.
- Bruno Sericola is responsible for the Inria Rennes-Bretagne Atlantique budget.
- 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.
- César Viho is director of the MathSTIC (Mathematics, Electronics and Computer Sciences) doctoral school in charge of managing the recruitment of around 1100 PhD students and their activities during their doctorate, in all the concerned areas of the UBL (Université Bretagne Loire).

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Master: Bruno Tuffin, MEPS (performance evaluation), 35h, M1, Univ Rennes, France

Master: Bruno Tuffin, GTA (Game Theory and Applications), 15h, M2, Univ Rennes, France

Master: Patrick Maillé, GTA (Game Theory and Applications), 15h, M2, Univ Rennes, France

Master: Patrick Maillé, Simulation and queuing theory, 25h, M2, IMT Atlantique, France

Licence: Patrick Maillé, Techniques and models in networks, 20h, L3, IMT Atlantique, France

Master: Patrick Maillé, Performance Evaluation, 30h, M1, IMT Atlantique, France

Licence: Yann Busnel, Introduction to Network, 15h, 1st year ENS Rennes, France

Master: Yann Busnel, Big Data and Stream Processing, 9h, IMT Atlantique, Rennes, France

Master: Bruno Sericola, Mathematics, 12h, M2, Istic/University of Rennes 1, France.

Master: Bruno Sericola, Logistic and performance, 12h, M2, Faculté de sciences économiques, Univ of Rennes 1, France

Master: Bruno Sericola, MEPS (performance evaluation), 36h, M1, Univ Rennes, France

Master pro 2nd year: Yassine Hadjadj-Aoul, Multimedia streaming over IP (MMR), 48 hours, Esir/University of Rennes 1, France

Master pro 2nd year: Yassine Hadjadj-Aoul, Multimedia services in IP networks (RSM), 29 hours, Esir/University of Rennes 1, France

Master pro 2nd year: Yassine Hadjadj-Aoul, Software Defined Networks, 6 hours, Istic/University of Rennes 1, France

Master 2nd year: Yassine Hadjadj-Aoul, Video streaming over IP, 8 hours, Istic/University of Rennes 1, France

Master: Yassine Hadjadj-Aoul, Introduction to networking (IR), 26 hours, Esir/University of Rennes 1, France

Master: Yassine Hadjadj-Aoul, Mobile and wireless networking (RMOB), 20 hours, Esir/University of Rennes 1, France

Master 2nd year: Yassine Hadjadj-Aoul, Overview of IoT technologies: focus on LPWAN, 2 hours, INSA, France

Master pro 2nd year: Sofiéne Jelassi, Supervision of heterogeneous networks, 32 hours, Istic/University of Rennes 1, France

Master pro 2nd year: Sofiéne Jelassi, Cloud & SDN virtualization, 32 hours, Istic/University of Rennes 1, France

Master pro 2nd year: Sofiéne Jelassi, Multimedia networks, 32 hours, Istic/University of Rennes 1, France

Master 2nd year: Sofiéne Jelassi, Software defined networking, 6 hours, Istic/University of Rennes 1, France

Master M1: César Viho, Networks: from Services to protocols, 36 hours, Istic/University of Rennes 1, France

Master M2: César Viho, Algorithms on graphs, 40 hours, Istic/University of Rennes 1, France

Bachelor L2: César Viho, Network architecture and components, 16 hours, Istic/University of Rennes 1, France

Supelec Rennes 3rd year: Gerardo Rubino, Dependability Analysis, 15 hours.

UDELAR, Uruguay: Gerardo Rubino, post-graduate course on dependability, 21 hours.

10.2.2. Supervision

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

Joshua Peignier, Estelle Varloot. “Game-theoretic tools to analyze classical vs collaborative economies”, Project Master R&I, 2016-2017. Advisors: P. Maillé and B. Tuffin.

PhD in progress: Alassane Samba, “Technologies Big Data et modèles prédictifs pour la QoS des réseaux”, IMT Atlantique. Advisors: Y. Busnel, G. Simon and P. Dooze (Inria). Defense in 2018.

PhD in progress: Richard Westerlynck, “Analyse répartie et extraction de tendances à grande échelle pour les données massives en santé”, IMT Atlantique. Advisors: Y. Busnel and M. Cuggia (PUPH, CHU Rennes). Defense in 2020.

PhD in progress: Vasile Cazacu, “Calcul distribué pour la fouille de données cliniques”, IMT Atlantique. Advisors: E. Anceaume (CNRS Rennes), Y. Busnel and M. Cuggia (PUPH, CHU Rennes). Defense in 2020.

PhD in progress: Corentin Hardy, “Device-Assisted Distributed Machine-Learning on Many Cores”, started in April 2016; advisors: Bruno Sericola and Erwan Le Merrer from Technicolor, University Rennes 1.

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

PhD in progress: Ali Hodroj, “Enhancing content delivery to multi-homed users in broadband mobile networks”, started in November 2015; advisors: Bruno Sericola, Marc Ibrahim and Yassine Hadjadj-Aoul, University Rennes 1 and St Joseph University of Beyrouth.

PhD in progress: Jean-Michel Sanner; Cifre Grant, Orange Labs, “SDN technologies for network services performances adaptation of carriers networks”; started on January 2013;

PhD in progress: Hamza Ben Ammar, “Socially-aware network and cache resources optimization for efficient media content delivery in Content Centric Networks”, started in October 2015; advisors: Yassine Hadjadj-Aoul, Adlen Ksentini and Soraya Ait Chellouche, University Rennes 1.

PhD in progress: Imad Alawe, “Mobile SDN architecture”, started in October 2015; advisors: César Viho, Yassine Hadjadj-Aoul, University Rennes 1, Philippe Bertin, B-COM and Davy Darche, TDF.

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

PhD in progress: Imane Taibi, “Big data analysis for network monitoring and troubleshooting”; started on Nov. 2017; Advisors: G. Rubino, Inria, and Yassine Hadjadj-Aoul, University Rennes 1, and Chadi Ibrahim, Inria.

PhD in progress: Mohamed Rahali, “Machine learning-based monitoring and management for hybride SDN networks”; started on Oct. 2017; Advisors: G. Rubino, Inria, and Sofiène Jelassi, University of Rennes 1.

PhD in progress: Nicolás Jara, “Fault tolerant design of dynamic WDM optical networks”, Technical University Federico Santa María (UTFSM) and university of Rennes 1, France. Advisors: R. Vallejos (Chile) and G. Rubino (France). Defense in 2018.

PhD in progress: Laura Aspirot, “Fluid Approximations for Stochastic Telecommunication Models”, University of the Republic, Uruguay. Advisors: E. Mordecki (Uruguay) and G. Rubino (France). Defense in 2018.

PhD in progress: Jorge Graneri, “Mathematical Models for Semantic Memory”, University of the Republic, Uruguay. Advisors: E. Mizraji (Uruguay) and G. Rubino (France). Started end 2016.

10.2.3. Juries

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

- Kodjo Séna Apeke. Modélisation ubiquiste pour l’interaction d’échelles. Application à la prédiction de la réponse d’une tumeur sous traitement en radiothérapie. Université de Bretagne Occidentale, 2017.

Bruno Sericola was member of the final selecting board for the recruitment of CNRS researchers in 2017.

Yassine Hadjadj-Aoul was a member of the PhD defense committee of Souheir Eido, IMT Atlantique, Brest (2017)

Yassine Hadjadj-Aoul and Gerardo Rubino were members of the PhD jury of Yue Li. Title: “Elaboration d’une architecture réseau unifiée, ouverte et flexible”. Defense: September 29, 2017.

César Viho was a member of the following juries:

- Recruitment of young graduate scientists and senior researchers at Inria.
- Recruitment of young Associate Professors and senior Professors at ISTIC-Université Rennes 1.

10.3. Popularization

- B. Tuffin. La simulation de Monte-Carlo. Interstices. 2017. https://interstices.info/jcms/int_69164/la-simulation-de-monte-carlo
- G. Rubino makes regular presentations to high school students about the research work in general, and specific technical topics in particular. Current talks:
  - Randomness as a tool
  - Internet as a research problem
  - Great challenges in maths: the Riemann Hypothesis
  - Great challenges in math/computer science: the “P versus NP” problem

11. Bibliography

Major publications by the team in recent years

[1] G. RUBINO, B. TUFFIN (editors). *Rare Event Simulation using Monte Carlo Methods*, John Wiley & Sons, 2009

[2] N. BOUABDALLAH, A.-L. BEYLOT, E. DOTARO, G. PUJOLLE. *Resolving the Fairness Issues in Bus-Based Optical Access Networks*, in "IEEE Journal on Selected Areas in Communications", 2005, vol. 23, n^{o} 8, pp. 1444–1457

[3] Y. HADJADJ-AOUL, T. TALEB. *An adaptive fuzzy-based CAC scheme for uplink and downlink congestion control in converged IP and DVB-S2 networks*, in "IEEE Transactions on Wireless Communications", Feb. 2009, vol. 8, n^{o} 2, pp. 816–825

[4] Y. HAYEL, D. ROS, B. TUFFIN. *Less-than-Best-Effort Services: Pricing and Scheduling*, in "23rd IEEE Infocom Conference", Hong-Kong, China, March 2004

[5] P. L’ECUYER. *Randomized Quasi-Monte Carlo: An Introduction for Practitioners*, in "12th International Conference on Monte Carlo and Quasi-Monte Carlo Methods in Scientific Computing (MCQMC 2016)", Stanford, United States, August 2016, https://hal.inria.fr/hal-01561550

[6] P. LEGUESDRON, J. PELLAUMAIL, G. RUBINO, B. SERICOLA. *Transient analysis of the M/M/1 queue*, in "Advances in Applied Probability", September 1993, vol. 25, n^{o} 3, pp. 702–713

[7] P. MAILLÉ, B. TUFFIN. *Telecommunication Network Economics: From Theory to Applications*, Cambridge University Press, 2014, 288 p. , https://hal.inria.fr/hal-00908598

[8] H. NABLI, B. SERICOLA. *Performability analysis: a new algorithm*, in "IEEE Transactions on Computers", 1996, vol. 45, n° 4, pp. 491–494

[9] 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° 8, pp. 1020–1033

[10] 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

[11] B. TUFFIN. *Bounded Normal Approximation in Highly Reliable Markovian Systems*, in "Journal of Applied Probability", 1999, vol. 36, n° 4

Publications of the year

Doctoral Dissertations and Habilitation Theses

[12] Y. LI. *Edge computing-based access network selection for heterogeneous wireless networks*, Université Rennes 1, September 2017, https://tel.archives-ouvertes.fr/tel-01661436

[13] Q. PHAM TRAN ANH. *Algorithms and optimization for quality of experience aware routing in wireless networks : from centralized solutions*, Université Rennes 1, January 2017, https://tel.archives-ouvertes.fr/tel-01488283

Articles in International Peer-Reviewed Journals

[14] E. ANCEAUME, Y. BUSNEL. *Lightweight Metric Computation for Distributed Massive Data Streams*, in "Transactions on Large-Scale Data- and Knowledge-Centered Systems", April 2017, vol. 10430, n° 33, pp. 1–39 [*DOI :* 10.1007/978-3-662-55696-2_1], https://hal.archives-ouvertes.fr/hal-01634353

[15] E. CANALE, P. ROMERO, G. RUBINO. *Factorization and Exact Evaluation of the Source-Terminal Diameter-Constrained Reliability*, in "Networks", 2017, vol. 70, n° 4, pp. 283-291 [*DOI :* 10.1002/NET.21780], https://hal.inria.fr/hal-01663508

[16] P. FRANGOUDIS, L. YALA, A. KSENTINI. *CDN-as-a-Service Provision over a Telecom Operator's Cloud*, in "IEEE Transactions on Network and Service Management (TNSM)", June 2017, vol. 14, n° 3, pp. 702-716 [*DOI :* 10.1109/TNSM.2017.2710300], https://hal.inria.fr/hal-01659931

[17] S. GAMBOA, A. PELOV, P. MAILLÉ, X. LAGRANGE, N. MONTAVONT. *Reducing the energy footprint of cellular networks with delay-tolerant users*, in "IEEE Systems Journal", June 2017, vol. 11, n° 2, pp. 729 - 739 [*DOI :* 10.1109/JSYST.2015.2476376], https://hal.archives-ouvertes.fr/hal-01611343

[18] E. GOURDIN, P. MAILLÉ, G. SIMON, B. TUFFIN. *The Economics of CDNs and Their Impact on on Service Fairness*, in "IEEE Transactions on Network and Service Management", 2017, vol. 14, n° 1, pp. 22-33, https://hal.inria.fr/hal-01398923

[19] N. JARA, R. VALLEJOS, G. RUBINO. *A Method for Joint Routing, Wavelength Dimensioning and Fault Tolerance for any set of simultaneous failures on Dynamic WDM Optical Networks*, in "Optical Fiber Technology", 2017, vol. 38, n° Supplement C, pp. 30-40 [*DOI :* 10.1016/J.YOFTE.2017.08.001], https://hal.inria.fr/hal-01663501

[20] N. JARA, R. VALLEJOS, G. RUBINO. *Blocking Evaluation and Wavelength Dimensioning of Dynamic WDM Networks without Wavelength Conversion*, in "Journal of optical communications and networking", August 2017, vol. 9, n° 8, pp. 625-634 [*DOI :* 10.1364/JOCN.9.000625], https://hal.inria.fr/hal-01663506

[21] P. L'ECUYER, P. MAILLÉ, N. STIER-MOSES, B. TUFFIN. *Non-Neutrality of Search Engines and its Impact on Innovation*, in "Internet Technology Letters", 2017, https://hal.inria.fr/hal-01634370

[22] P. L'ECUYER, D. MUNGER, B. ORESHKIN, R. SIMARD. *Random Numbers for Parallel Computers: Requirements and Methods*, in "Mathematics and Computers in Simulation", 2017, vol. 135, pp. 3-17, https://hal.inria.fr/hal-01399537

[23] P. MAILLÉ, B. TUFFIN. *Auctions for online ad space among advertisers sensitive to both views and clicks*, in "Electronic Commerce Research", 2017, https://hal.inria.fr/hal-01241308

[24] P. MAILLÉ, B. TUFFIN. *Preventing competition using side payments: when non-neutrality creates barriers to entry*, in "Netnomics", 2017, vol. 18, n° 1, pp. 3-22 [*DOI :* 10.1007/s11066-016-9110-6], https://hal.inria.fr/hal-01398913

[25] F. MESSAOUDI, A. KSENTINI, G. SIMON, P. BERTIN. *On using Edge Computing for computation offloading in mobile network*, in "ACM Transactions on Multimedia Computing, Communications and Applications", October 2017, vol. 13, n° 4, pp. 1 - 28 [*DOI :* 10.1145/3115934], https://hal.inria.fr/hal-01661889

[26] A. MOULOUD, D. AISSANI, Y. HADJADJ-AOUL. *Towards Bandwidth and Energy Optimization in IEEE 802.15.4 Wireless Sensor Networks*, in "Springer Computing", October 2017, pp. 1-24 [*DOI :* 10.1007/s00607-017-0583-4], https://hal.inria.fr/hal-01657663

[27] Q. PHAM TRAN ANH, K. PIAMRAT, K. D. SINGH, C. VIHO. *Video Streaming over Ad-hoc Networks: a QoE-based Optimal Routing Solution*, in "IEEE Transactions on Vehicular Technology", February 2017, vol. 66, n° 2 [*DOI :* 10.1109/TVT.2016.2552041], https://hal.archives-ouvertes.fr/hal-01340989

[28] E. ROMO MONTIEL, M. RIVERO-ANGELES, G. RUBINO, H. MOLINA-LOZANO, R. MENCHACA-MÉNDEZ, R. MENCHACA-MÉNDEZ. *Performance Analysis of Cluster Formation in Wireless Sensor Networks*, in "Sensors", December 2017, vol. 17, n° 12, pp. 1-49 [*DOI :* 10.3390/s17122902], https://hal.inria.fr/hal-01665857

[29] G. RUBINO, S. BASTERRECH. *Echo State Queueing Networks: a combination of Reservoir Computing and Random Neural Networks*, in "Probability in the Engineering and Informational Sciences", 2017, vol. 31, n° 4, pp. 457-476 [*DOI :* 10.1017/S0269964817000110], https://hal.inria.fr/hal-01663499

[30] N. TORRES-CRUZ, M. RIVERO-ANGELES, G. RUBINO, R. MENCHACA-MÉNDEZ, R. MENCHACA-MÉNDEZ. *A window-based, server-assisted P2P network for VoD services with QoE guarantees*, in "Mobile Information Systems", March 2017, vol. 2017, n° Article ID 2084684, pp. 1-16 [*DOI :* 10.1155/2017/2084684], https://hal.inria.fr/hal-01665853

Invited Conferences

[31] S. BASTERRECH, G. RUBINO. *A G-Network as a Reservoir Computing Model*, in "First G-Networks Workshop", Nice, France, January 2017, https://hal.inria.fr/hal-01658101

[32] P. L'ECUYER. *History of uniform random number generation*, in "WSC 2017 - Winter Simulation Conference", Las Vegas, United States, December 2017, https://hal.inria.fr/hal-01561551

[33] G. RUBINO. *Dependability Analysis through Monte Carlo Methods: The Case of Rare Events - Tutorial*, in "ICDT 2017 - The 12th International Conference on Digital Telecommunications", Venezia, Italy, April 2017, https://hal.inria.fr/hal-01658088

[34] G. RUBINO. *New results on the transient analysis of some fundamental queuing systems - Keynote presentation*, in "ACMPT 2017 - Analytical and Computational Methods in Probability Theory and its Applications", Moscow, Russia, A. LEBEDEV (editor), Analytical and Computational Methods in Probability Theory, Lomonosov Moscow State University (MSU), October 2017, https://hal.inria.fr/hal-01657448

[35] G. RUBINO. *On the derivation of closed-form expressions of the solutions to (possibly infinite) some simple linear systems of ODEs - Keynote presentation*, in "CDEDS 2017 - Conference on Differential Equations and Dynamical Systems", Suzhou, China, September 2017, https://hal.inria.fr/hal-01658064

[36] G. RUBINO. *Rare events in simulation: issues and techniques - Plenary speaker*, in "IMA 2017 - the 6th World Congress of the Microsimulation Association", Torino, Italy, June 2017, https://hal.inria.fr/hal-01658082

International Conferences with Proceedings

[37] I. ALAWE, Y. HADJADJ-AOUL, A. KSENTINI, P. BERTIN, D. DARCHE. *On the scalability of 5G Core network: the AMF case*, in "CCNC 2018 - IEEE Consumer Communications and Networking Conference", Las Vegas, United States, January 2018, pp. 1-6, https://hal.inria.fr/hal-01657667

[38] I. ALAWE, A. KSENTINI, Y. HADJADJ-AOUL, P. BERTIN, A. KERBELLEC. *On Evaluating Different Trends for Virtualized and SDN-ready Mobile Network*, in "CloudNet 2017 - 6th IEEE International Conference on Cloud Networking", Prague, Czech Republic, Cloud Networking (CloudNet), 2017 IEEE 6th International Conference on, IEEE, September 2017, pp. 1-6 [*DOI :* 10.1109/CLOUDNET.2017.8071534], https://hal.inria.fr/hal-01657671

[39] H. B. AMMAR, S. A. CHELLOUCHE, Y. HADJADJ-AOUL. *A Markov Chain-based Approximation of CCN Caching Systems*, in "ISCC 2017 - IEEE Symposium on Computers and Communications", Heraklion, Greece, IEEE, July 2017, pp. 1-6 [*DOI :* 10.1109/ISCC.2017.8024551], https://hal.inria.fr/hal-01657679

[40] Z. BOTEV, P. L'ECUYER. *Accurate computation of the right tail of the sum of dependent log-normal variates*, in "WSC 2017 - Winter Simulation Conference", Las Vegas, United States, December 2017, https://hal.inria.fr/hal-01561552

[41] G. BOUZILLÉ, R. WESTERLYNCK, G. DEFOSSEZ, D. BOUSLIMI, S. BAYAT, C. RIOU, Y. BUSNEL, C. LE GUILLOU, J.-M. CAUVIN, C. JACQUELINET, P. PLADYS, E. OGER, E. STINDEL, P. INGRAND, G. COATRIEUX, M. CUGGIA. *Sharing health big data for research - A design by use cases: the INSHARE platform approach*, in "The 16th World Congress on Medical and Health Informatics (MedInfo2017)", Hangzhou, China, The 16th World Congress on Medical and Health Informatics (MedInfo2017), August 2017, https://hal.archives-ouvertes.fr/hal-01535703

[42] P. W. GLYNN, M. K. NAKAYAMA, B. TUFFIN. *On the estimation of the mean time to failure by simulation*, in "2017 Winter Simulation Conference", Las Vegas, United States, December 2017, https://hal.inria.fr/hal-01551078

[43] *Best Paper*
C. HARDY, E. LE MERRER, B. SERICOLA. *Distributed deep learning on edge-devices: feasibility via adaptive compression*, in "IEEE NCA 2017 - 16th IEEE International Symposium on Network Computing and Applications", Boston, United States, October 2017, This article has received the Best Paper Award, https://hal.inria.fr/hal-01650936.

[44] N. JARA, R. VALLEJOS, G. RUBINO. *Alternate Paths for Multiple Fault Tolerance on Dynamic WDM Optical Networks*, in "HPSR 2017 - 18th IEEE International Conference on High Performance Switching and Routing", Campinas, Brazil, IEEE, June 2017, pp. 1-6 [*DOI :* 10.1109/HPSR.2017.7968674], https://hal.inria.fr/hal-01663507

[45] Y. LI, P. FRANGOUDIS, Y. HADJADJ-AOUL, P. BERTIN. *A Mobile Edge Computing-Assisted Video Delivery Architecture for Wireless Heterogeneous Networks*, in "ISCC 2017 - IEEE Symposium on Computers and Communications", Heraklion, Greece, IEEE, July 2017, pp. 1-6 [*DOI :* 10.1109/ISCC.2017.8024583], https://hal.inria.fr/hal-01657678

[46] P. MAILLÉ, B. TUFFIN. *Enforcing free roaming among UE countries: an economic analysis*, in "13th International Conference on Network and Service Management (CNSM)", Tokyo, Japan, November 2017, https://hal.inria.fr/hal-01428920

[47] P. MAILLÉ, B. TUFFIN. *How does imposing free roaming in EU impact users and ISPs' relations?*, in "8th International Conference Network of the Future", London, United Kingdom, November 2017, https://hal.inria.fr/hal-01493911

[48] P. MAILLÉ, B. TUFFIN. *Non-Neutrality Pushed by Big Content Providers*, in "14th International Conference on Economics of Grids, Clouds, Systems, and Services (GE- CON'2017)", Biarritz, France, September 2017, https://hal.inria.fr/hal-01398926

[49] F. MESSAOUDI, A. KSENTINI, P. BERTIN. *On using Edge Computing for computation offloading in mobile network*, in "Globecom 2017 - IEEE Global Communications Conference", Singapore, Singapore, December 2017, https://hal.inria.fr/hal-01661885

[50] Y. MOCQUARD, B. SERICOLA, E. ANCEAUME. *Probabilistic Analysis of Counting Protocols in Large-scale Asynchronous and Anonymous Systems*, in "Proceedings of the 16th IEEE International Conference on Network Computing and Applications", Boston, United States, October 2017, https://hal.archives-ouvertes.fr/hal-01580275

[51] M. RIVERO-ANGELES, G. RUBINO. *Transmission Probability Strategies for Cluster-based Event-Driven Wireless Sensor Networks*, in "CyberC 2017 - International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery", Nanjing, China, October 2017, pp. 1-4, https://hal.inria.fr/hal-01665855

[52] N. RIVETTI, Y. BUSNEL, L. QUERZONI. *Délestage avisé dans les systèmes de traitement de flux*, in "ALGOTEL 2017 - 19èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Quiberon, France, May 2017, https://hal.archives-ouvertes.fr/hal-01519427

[53] A. SAMBA, Y. BUSNEL, A. BLANC, P. DOOZE, G. SIMON. *Instantaneous Throughput Prediction in Cellular Networks: Which Information Is Needed?*, in "2017 IFIP/IEEE International Symposium on Integrated Network Management (IM)", Lisbonne, Portugal, 2017 IFIP/IEEE International Symposium on Integrated Network Management (IM), IEEE, May 2017, https://hal.archives-ouvertes.fr/hal-01535696

[54] J.-M. SANNER, Y. HADJADJ-AOUL, M. OUZZIF, G. RUBINO. *An evolutionary controllers' placement algorithm for reliable SDN networks*, in "ManSDN/NF 2017 - 4th International Workshop on Management of SDN and NFV Systems", Tokyo, Japan, November 2017, pp. 1-6, https://hal.inria.fr/hal-01657698

[55] J.-M. SANNER, M. OUZZIF, Y. HADJADJ-AOUL. *Multi-objective evolutionary algorithms for optimized placements of SDN controllers, VNFs and VNFs chains in new Telecom infrastructures*, in "SDN Day 2017 - Software Defined Networks", Paris, France, November 2017, https://hal.inria.fr/hal-01657689

[56] F. SLIM, F. GUILLEMIN, A. GRAVEY, Y. HADJADJ-AOUL. *Towards a Dynamic Adaptive Placement of Virtual Network Functions under ONAP*, in "Third International NFV-SDN'17-O4SDI - Workshop on Orchestration for Software-Defined Infrastructures)", Berlin, Germany, November 2017, pp. 1-6, https://hal.inria.fr/hal-01657705

[57] F. SLIM, F. GUILLEMIN, Y. HADJADJ-AOUL. *On Virtual Network Functions' Placement in Future Distributed Edge Cloud*, in "CloudNet 2017 - IEEE 6th International Conference on Cloud Networking", Prague, Czech Republic, Cloud Networking (CloudNet), 2017 IEEE 6th International Conference on, IEEE, September 2017, pp. 1-4 [*DOI :* 10.1109/CLOUDNET.2017.8071524], https://hal.inria.fr/hal-01657676

[58] F. SLIM, F. GUILLEMIN, Y. HADJADJ-AOUL. *CLOSE: A Costless Service Offloading Strategy for Distributed Edge Cloud*, in "GTCC 2017 - IEEE Workshop on Game Theory in Computer Communications", Las Vegas, United States, January 2018, https://hal.inria.fr/hal-01661624

[59] B. TUFFIN. *Network Neutrality: Modeling and Challenges and its Impact on Clouds: Keynote Talk*, in "GECON 2017 - 14th International Conference on Economics of Grids, Clouds, Systems & Services", Biarritz, France, September 2017, https://hal.inria.fr/hal-01634382

[60] L. YALA, P. FRANGOUDIS, G. LUCARELLI, A. KSENTINI. *Balancing between cost and availability for CDNaaS resource placement*, in "IEEE Global Communications Conference (GLOBECOM 2017)", Singapore, Singapore, December 2017, https://hal.inria.fr/hal-01590885

National Conferences with Proceedings

[61] N. RIVETTI, E. ANCEAUME, Y. BUSNEL, L. QUERZONI, B. SERICOLA. *Ordonnancement dynamique pour un équilibrage de charge quasi-optimal dans les systèmes de traitement de flux*, in "ALGOTEL 2017 - 19èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Quiberon, France, May 2017, https://hal.archives-ouvertes.fr/hal-01519432

Conferences without Proceedings

[62] Y. BUSNEL, N. RIVEEI, A. GAL. *FlinkMan : Anomaly Detection in Manufacturing Equipment with Apache Flink : Grand Challenge*, in "DEBS '17 - 11th ACM International Conference on Distributed and Event-based Systems", Barcelone, Spain, June 2017, pp. 274-279 [*DOI :* 10.1145/3093742.3095099], https://hal.archives-ouvertes.fr/hal-01644417

Scientific Popularization

[63] B. TUFFIN. *La simulation de Monte-Carlo*, in "Interstices", April 2017, https://hal.inria.fr/hal-01533686

Other Publications

[64] I. ALAWE, Y. HADJADJ-AOUL, P. BERTIN, A. KSENTINI, D. DARCHE. *RNN-based traffic prediction for pro-active scaling of the AMF*, November 2017, 1 p. , SDN Day 2017 - Software Defined Networks Day, Poster, https://hal.inria.fr/hal-01657683

[65] C. HARDY, E. LE MERRER, G. RUBINO, B. SERICOLA. *Evaluation of Random Neural Layers in Deep Neural Networks*, December 2017, 1 p. , NIPS 2017 - workshop Deep Learning: Bridging Theory and Practice, Poster, https://hal.inria.fr/hal-01657644

[66] C. HARDY, E. LE MERRER, B. SERICOLA. *Distributed deep learning on edge-devices in the Parameter Server Model*, September 2017, 1 p. , Workshop on Decentralized Machine Learning, Optimization and Privacy, Poster, https://hal.inria.fr/hal-01651145

[67] C. HARDY, E. LE MERRER, B. SERICOLA. *Distributed deep learning on edge-devices: feasibility via adaptive compression*, October 2017, working paper or preprint, https://hal.inria.fr/hal-01622580

[68] P. L'ECUYER, P. WAMBERGUE, E. BOURCERET. *Spectral Analysis of the MIXMAX Random Number Generators*, 2017, working paper or preprint, https://hal.inria.fr/hal-01634350

[69] P. MAILLÉ, B. TUFFIN. *Analysis of Sponsored Data in the Case of Competing Wireless Service Providers*, 2017, working paper or preprint, https://hal.inria.fr/hal-01670139

[70] P. MAILLÉ, B. TUFFIN. *La fin des frais d'itinérance dans l'Union européenne en 2017, est-ce la panacée ?*, 2017, working paper or preprint, https://hal.inria.fr/hal-01671481

[71] Y. MOCQUARD, B. SERICOLA, E. ANCEAUME. *Probabilistic Analysis of Rumor Spreading Time*, November 2017, working paper or preprint, https://hal.archives-ouvertes.fr/hal-01652777

References in notes

[72] G. RUBINO, B. TUFFIN (editors). *Rare Event Simulation using Monte Carlo Methods*, John Wiley & Sons, 2009

[73] W. J. ANDERSON. *Continuous-Time Markov Chains*, Springer, 1991