INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team dionysos

Dependability, Interoperability and PerfOrmaNce analYsiS of netwOrkS

Rennes - Bretagne-Atlantique

Theme : Networks and Telecommunications

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2. Overall Objectives

2.1. Introduction

The main objectives of the project are the identification, the conception and the selection of the most appropriate network architectures of 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. protocols' test 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 evaluation).

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 mainly 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. As such, it is considered as a part of the standardization process. 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 pricing 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 go from discrete event simulation and Monte Carlo procedures to analytical techniques, and include numerical algorithms as well. Our main mathematical tools are stochastic processes in general and queuing models and Markov chains in particular, optimization techniques, graph theory, combinatorics, etc.

2.2. Highlights

In 2009, we underline the following elements of our activity:

- We edited [79], a book on Rare Event Simulation (editors: G. Rubino and B. Tuffin), in which we co-wrote several chapters: [74], [73], [72], [68], [70], [75].
- Our PSQA technology (see 3.2, 6.10 in this report) has been again awarded. We got an award in the international conference NEM Summit 2009 for the best demonstration (see 7.5). The participants for Dionysos were G. Rubino and K. Singh.
- Bruno Tuffin sent to print a book on Monte Carlo techniques [77].

3. Scientific Foundations

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, since it can be seen as an unifying concept in our activities. Then we briefly describe the specific sub-area of models' evaluation and about the particular multidisciplinary domain of pricing problems.

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, ...), for dependability it also comes through appropriate metrics: reliability, availability, or vulnerability, in the case for instance of WAN (Wide Area Network) topologies, etc.

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

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

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

3.3. Stochastic modeling

The scientific foundations of our modeling activities are composed of stochastic processes theory and, in particular, Markov processes, queuing theory, stochastic graphs theory, etc., either for developing analytical models or for discrete event simulation or Monte Carlo (and Quasi-Monte Carlo) techniques. We are always interested in models' 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, queuing ones) and also at the *burst level*, leading to *fluid models*.

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

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, 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.

4. Application Domains

4.1. Panorama

Our main application domains are those related to network design, at both the transport infrastructure and the service levels. Our expertise currently focuses on IP technology in a variety of contexts (IP QoS, IP QoE, IP mobility, ...), and on analysis and dimensioning tools: telecommunications architecture configuration, bottleneck search, resource allocation policies comparison, etc.

We can start by pointing out the PSQA technology we have been developing in the last years (PSQA stands for Pseudo-Subjective Quality Assessment) that allows an automatic and quantitative evaluation of the quality delivered to the user by a network transporting audio or video content. PSQA is accurate (which means that it provides values close to those that would have been obtained using a panel of human observers) and efficient (which means that it can work, if useful or necessary, in real time). Its main application area is in network monitoring: PSQA allows to deploy an auditing system that can continuously analyze the perceived quality (the QoE) at specific points in the network. The other main application area of PSQA is in network control, exploiting the fact that the quality assessment can been done in real time. The first applications of our technique that are currently being explored are in the monitoring and control of networks transporting video flows, with focus on IPTV applications in the context of P2P infrastructures and, more generally, of CDN (Content Delivery Networks), on networks of mobile terminals, on the properties of the SVC codec and their impact on the QoE.

In the field of traffic engineering and system dimensioning, the technological evolution also raises a number of new performance evaluation problems. Besides these main application domains, other important subjects where quantitative analysis plays a central role are, for example, the analysis of control mechanisms, or the problems posed by pricing, which are of evident interest for operators. In the IP world, extensions such as mobile IP, or cellular IP, are also important application domains for our research work.

The first field in which the team's expertise is requested is the area of IP networks. The usual context is that of an industry member who wishes to develop new techniques, or that of a user who has to set up a new communications system or to upgrade (or more generally, modify) an existing one. This may involve a specific aspect of the system (e.g. the costs model which allows the development of a billing policy), or a particular kind of network (for instance, a home-network), or a family of services (for instance, a security policy).

We can also classify our main application domains per type of services involved. Then, the past and current expertise of the team's members mainly involve the transport of multimedia flows over IP, the various network QoS management aspects, the testing techniques associated with the interoperability of network components, etc. In this context we find, for instance, problems related to the conception of mechanisms well adapted to specific flow types and QoS goals, both at the network access level, and at the intermediary node level.

With regard to analysis and dimensioning, we contribute to the different related methodologies (measurements, simulation, analytical techniques), and also to the development of new mathematical and software tools. We develop models for the collection of specific characteristics of the studied systems (e.g., those related to QoS analysis, or to QoE assessment). We also develop new simulation methodologies, in order to overcome certain limitations of the existing techniques. Finally, it should be noted that networks now offer services with a certain level of redundancy, which leads to problems of reliability. Our team has a long experience in the specific study of this systems' aspect and in related problems such as performability and vulnerability (a notion aiming at quantifying the robustness of a network architecture (topology) without taking into account the reliability of each component).

5. Software

5.1. T3devKit testing toolkit and IPv6 test suites

Participants: Anthony Baire, César Viho, François Lerebours.

We have built a toolkit for easing executing tests written in the standardised TTCN-3 test specification language. This toolkit is made of a C++ library together with a highly customisable 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 fixes 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 publicly released under the name T3DevKit and made available under the CeCILL-C License.
All these tools with associated test suites (for RIPng, DHCPv6 and examples for DNS) are freely available at http://www.irisa.fr/tipi.

5.2. Performance and dependability evaluation

Participants: Gerardo Rubino, Bruno Sericola, Bruno Tuffin.

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

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

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

6. New Results

6.1. Pricing

Participants: Hai Tran Hoang, Hélène Le Cadre, Bruno Tuffin.

Pricing is probably one of the most efficient means to control congestion in a communication network. It is furthermore mandatory for service differentiation and is a way to yield incentives for participation in P2P or ad hoc networks. Our work in the area has focused on two aspects: the design and feasability of pricing schemes first, and more recently, the analysis of the behavior of those pricing schemes in the case of an oligopoly, with providers competing for customers or daling with inter-domain relationships.

We have therefore first looked at different ways to design a pricing schemes. In [21], we have developped several schemes for pricing a RED buffer, where the drop probability (or more exactly the slope of the drop curve of RED) depends on the willingness to pay of the users: the more you pay, the less one of your packets is likely to be dropped. Learning techniques are used to drive the system to an equilibrium. As a general pricing principle, since there is usually no strict guarantee of QoS, we have designed in [26] a technique where a reimbursement is realized in case a QoS threshold is not met. We have compared it with the case without reimbursement and illustrated that it could drive to a higher revenue for a provider (because more users are likely to apply). In [41], we have designed a pricing scheme specifically focusing on WiMAX, taking into account its performance characteristics.

But our activity around pricing has mostly been redirected towards competition issues among providers: the impact of this competition has to be carefully analyzed. In [43], we have studied a pricing game when several WiFi providers compete for customers. In [51], the game is played when customers churn, i.e., migrate between providers, the churn rates depending on the different prices, reputations or QoS levels. In [52], we have analyzed a pricing game between a WiFi and a WiMAX providers, were the WiFi can adapt its transmission range to reach the most adequate part of the population. We have similarly studied in [53] the case where providers own a part of the spectrum but there is a remaining part which can be shared freely. The question we try to solve is: what is the best interest, in terms of social or user welfare, is it to licence or to unlicence the frequency band? What is the best trade-off? Another situation typical of current relationships between providers is the case where there are mobile network operators (MNOs) and virtual mobile network operators (MVNOs). The goal is to determine the best strategy both for MNOs and MVNOs in terms of investment or contract, and what are the regulation procedures that can be imposed to make the system viable [48], [47], [49]. A related work on regulation is [50], where (using repeated game theory), we fix a limit on the interval before being allowed to change prices, in order to prevent collusion among providers.

Another important activity is around interdomain issues, where intermediate domains need some (economic in our case) incentives for forwarding the traffic of other domains. In [80], we have described the problem, provided a state of the art and highlighted the difficulties that must be solved.

All the above models require to understand the behavior of customers facing price offers. In [20], we have proposed a statistical method to represent users' preferences for bundles of offers from providers, in a competitive context. The goal is to propose the most profitable set of possibilities.

6.2. Dependability and extensions

Participants: Gerardo Rubino, Samira Saggadi, Bruno Sericola, Bruno Tuffin.

We maintain a research activity in different areas related to dependability, performability and vulnerability analysis of communication systems. In 2009 our focus has been on evaluation techniques using both the Monte Carlo and the Quasi-Monte Carlo approaches, following the cooperative research action (ARC) RARE we were leading in 2006-2007. Monte Carlo methods often represent the single tool to solve complex problems, and rare event simulation requires a special attention, to accelerate the occurence of the event and get an unbiased estimator with a sufficiently small relative variance. We have published a book on rare event simulation [79]. In this book, we have authored or co-authored several chapters: the introductive one presenting the main issues and the bases of the solution methods [74], the two main techniques that are importance sampling (IS) [73] and splitting [72], as well as the robustness properties of estimators and confidence intervals with respect to rarity in [70]. While applications in physics, queuieing, transport or biology were tackled by colleagues, we have treated dependability problems, both for static [68] and dynamic [75] models.

Another book on Monte Carlo simulation and addressed to graduate students or practitionners, is [77]. It presents all the basic notions from random number generation output analysis, variance reduction techniques and shows how they can be applied to the computation of integrals or sums, and to solve equations or optimization problems. We also presented a tutorial on Monte Carlo methods for rare event analysis, using material from [79], in QEST'09 [59].

Novel results in simulation during year 2009 can be decomposed into two subsets: results on rare event simulation, and those on quasi-Monte Carlo methods. On rare event simulation, we have discussed in [16] the importance of designing estimators that stay efficient as the probability of the considered event decreases to zero. While robustness properties generally look at the second moment only, we discuss in the importance of investigating higher order moments, and define related properties. An efficient application of importance sampling to highly reliable Markovian systems is obtained in [17], where we try to approach the so-called *zero-variance* by using the knowledge of its general form, for which we approach the (unknown in practice) parameters. Two other methods, specific to the evaluation of the probability that a graph is disconnected, are described in [69] and in [38]. Randomized quasi-Monte Carlo (RQMC) methods estimate the expectation of a random variable by the average of n dependent realizations of it. In general, due to the strong dependence used, the estimation error may not obey a central limit theorem. Analysis of RQMC methods have so far focused mostly on the convergence rates of asymptotic worst-case error bounds and variance bounds, when n tends to infinity, but little is known about the limiting distribution of the error. We have analyzed that asymptotic distribution in [46], [45] for the special case of a randomly-shifted lattice rule, when the integrand is smooth. In dimension 1, we show that the limiting distribution is uniform over a bounded interval if the integrand is non-periodic, and has a square root form over a bounded interval if the integrand is periodic. In higher dimensions, for linear functions, the distribution function of the properly standardized error converges to a spline of degree equal to the dimension. An efficient application of RQMC to discrete choice models is also realized in [60].

We started a collaboration with the Inria team-project Ipso on the evaluation of the moments of cumulative reward in Markov models [14]. We studied the convergence of the normalized moments and, based on this convergence, we developed a new algorithm to compute them. We also analyzed these moments and gave a probabilistic interpretation of the quantities arising in the algorithm. We also obtained in [13] an improvement of an algorithm we developed a few years ago for the distribuition computation of the cumulative reward in Markov chains.

Last, in [54] we analyzed some issues related to the way the Mean Up Time of components are estimated and the impact of this estimation when deriving results for the whole system.

6.3. Fast self-stabilization in large scale wireless networks

Participants: Katy Paroux, Bruno Sericola.

In large-scale wireless networks, distributed self-organization is more convenient than centralized planification. Self-stabilization protocols are a useful technique to provide self-organization but their stabilizing time is related to the size of the network. A wide range of problems such as TDMA assignment or clustering may be solved thanks to local coloring on a graph model but with a tradeoff between the coloring time and the stabilization time of the protocol using the coloring. This stabilization time is related to the height of a directed acyclic graph induced by the colors, thus to the longest strictly ascending sequence of colors. In [23], we model this height by the longest increasing contiguous sequence of non-independent uniform random variables. Then using a Markov chain approach, we obtain a theoretical upper bound on the stabilization time. More precisely, our results show the scalability properties of such a protocol, but also that using a large number of colors does not impact its stabilization time.

6.4. Network topology quality using random walks

Participant: Bruno Sericola.

This work is a collaboration with the Inria team-project Asap. We proposed in [42] a fully decentralized algorithm to provide each node with a value reflecting its connectivity quality. Comparing these values between nodes, enables to have a local approximation of a global characteristic of the graph. Our algorithm relies on an anonymous probe visiting the network in a unbiased random fashion. Each node records the time elapsed between visits of the probe which is called the return time of the random walk. Computing the standard deviation of such return times enables to approximate the conductance of the graph. Typically, this information may be used by nodes to assess their position, and therefore the fact that they are critical, in a graph exhibiting low conductance.

6.5. Analytical techniques in queueing models

Participants: Gerardo Rubino, Bruno Sericola.

In [25], we expose a clear methodology to analyze maximum level and hitting probabilities in a Markov driven fluid queue for various initial condition scenarios and in both cases of infinite and finite buffers. Step by step we build up our argument that finally leads to matrix differential Riccati equations for which there exists a unique solution. The power of the methodology resides in the simple probabilistic argument used that permits to obtain analytic solutions of these differential equations. We illustrate our results by a comprehensive fluid model that we exactly solve.

In [66], [64] and [30] we presented some preliminary results on two general and basic problems related to queueing systems. In [66] we extended results obtained some years ago, concerning a new queueing paradigm, better adapted to models of nodes in a communication network than standard queueing models. In the paper written some years ago, we basically developed a Mean Value Analysis of a M/GI/1 model when the data occupying the buffers is seen at the bit level. The extension proposed in [66] mainly consists in deriving results about other models (for instance, belonging to the G/M/1 family), and in deriving also analytical expressions for second moments of the metrics of interest. In [64] we discuss the concept of power of a queueing model proposed by Kleinrock in the 80s, we give some new results about it and underline some weaknesses of Kleinrock's definition. These results are extended in [30], where alternative definitions are explored.

6.6. Analytic models of cluster-based distributed systems

Participant: Bruno Sericola.

We started a collaboration with the Inria team-project Adept. It is well-known that peer-to-peer overlays networks can only survive Byzantine attacks if malicious nodes are not able to predict what will be the topology of the network for a given sequence of join and leave operations. In this paper we investigate adversarial strategies by following specific games. Our analysis demonstrates first that an adversary can very quickly subvert DHT-based overlays by simply never triggering leave operations. We then show that when all nodes (honest and malicious ones) are imposed on a limited lifetime, the system eventually reaches a stationary regime where the ratio of polluted clusters is bounded, independently from the initial amount of corruption in the system. These results, obtained by using Markov models, are shown in [32] and [33].

6.7. Interoperability Assessment

Participants: Anthony Baire, François Lerebours, César Viho.

In previous works we have developed a software toolkit named T3DevKit for easing the development of TTCN-3 tests. The original tool was targeted to bit-oriented protocols. This year we have enhanced the codec generator to support text-oriented protocols, thus transforming it into a more general solution (see 5.1). This new version of T3DevKit have been presented as a tutorial twice in 2009 [82].

We have also completely reengineered the logging module of this package, so as to provide a generic framework for representing and processing test events. The goal is to provide a smart interface to let TTCN-3 developers customise the report generator with minimal developments [81].

6.8. Multimedia streaming

Participants: Kamal Singh, Gerardo Rubino, César Viho.

There is a growing demand for efficient multimedia streaming applications over the Internet and next generation mobile networks. The third generation (3G) mobile systems are designed to further enhance the communication by providing high data rates of the order of 2 Mbps. High Speed Downlink Packet Access (HSDPA) is an enhancement to 3G networks that supports data rates of several Mbps, making it suitable for applications like multimedia, in addition to traditional services like voice calls. Services like person-to-person two-way video calls or one-way video calls, aim to improve person-to-person communication. Entertainment services like gaming, video streaming of a movie, movie trailers or video clips are also supported in 3G. Many more of such services are possible due to the augmented data rates supported by the 3G networks and because of the support for Quality of Service (QoS) differentiation in order to efficiently deliver required quality for different types of services.

We studied the provisioning of QoS over High Speed Downlink Packet Access (HSDPA) making it suitable for multimedia applications. The key point of HSDPA is its fast and adaptive packet scheduling. We studied [76] a new QoS aware HSDPA scheduler and compared it with the existing HSDPA schedulers. These schedulers were evaluated with a focus on download centric services in a 3G network. A mixed scenario was considered for evaluating the performance. In terms of the maximum number of users that can be served at one time it was found that QoS aware schedulers performed better. For the low load conditions Best Effort schedulers could satisfy different users, but as the load was increased, only QoS schedulers were able to guarantee a minimum quality to the 90% of the video users. The trade-off was the lower per-user throughput that the BE users were getting in comparison. Nevertheless, the QoS-aware schedulers were still dividing the remaining capacity among the BE users in a fair manner.

In a different area, we continued our work on the design of Peer-to-peer architectures for the implementation of a video Content Delivery Network. In [36] we continued on the description of an open-source P2P system for video streaming applications and in [35] we discussed some performance evaluation issues about that architecture. Related to the area, we started a new collaborative project called VIPEER, where the idea is to explore the use of the boxes of the customers of a provider to help in the distribution of video flows (see 7.8 in this report).

6.9. Multipath video streaming

Participants: Majd Ghareeb, César Viho.

With the aim at keeping a high perceived video quality, video streaming over Internet still faces important challenges. Among other solutions, MultiPath Video Streaming (MPVS) over Video Distribution Network (VDN) comes as a promising solution to overcome the limitations of the classical single path and IP-level video streaming approaches. In [39], we present an adaptive MPVS mechanism to maximize the overall video quality perceived at the client. Overlay path selection is dynamically done based on available bandwidth estimation, while the Quality of Experience (QoE) is subjectively measured using Pseudo-Subjective Quality Assessment (PSQA) tool developed in our team. We present the results on performance evaluation aspects in [40]. They show the ability of our mechanism to adapt automatically and in real-time to the load variation on different paths in order to maximize the overall quality perceived by end-users. See also [31] for a general presentation.

6.10. QoE (Quality of Experience)

Participants: Gerardo Rubino, Kamal Singh.

We continue the development of the PSQA technology (Pseudo-Subjective Quality Assessment) in the area of Quality of Experience (QoE). PSQA is a method to build measuring modules capable of quantifying the quality of a video or an audio sequence, as perceived by the user, when received through an IP network. PSQA provides an accurate and efficiently computed evaluation of the quality. Accuracy means that PSQA gives values close to those than can be obtained from a panel of human observers, under a controlled subjective testing experiment, following an appropriate norm (which depends on the type of sequence or application). Efficiency means that our measuring tool can work in real time, if necessary. Observe that perceived quality is the main component of QoE.

At the heart of the PSQA approach there is the statistical learning process necessary to develop measuring modules. So far we have been using Random Neural Networks as our learning tool, where the specific learning technique was a classical Gradient Descent one. In [10], we explored the use of much more efficient procedures, and in particular, we showed that the Levenberg-Marquardt method, well known in the standard Artificial Neural Network field, can be adapted to also improve significantly the performance of the basic learning algorithms. We also explored one of the most important variations of that algorithm, the so called "adaptive momentum" one, which works with RNN with the same efficiency as with ANN.

In [34] we followed the PSQA approach in the case of voice flows, but instead of learning from humans, we used as our reference the values given by PESQ to the sequences. PESQ is an automatic perceptual quality tool, belonging to the full reference family. In other words, PESQ computes a sort of distance between the original and the received sequences. It gives pretty good results but it can not work in real time, by definition. Our paper [34] is thus a first attempt to have a PESQ-like measuring tool working with no need to any reference, with promising results.

Since PSQA provides feedback in real time, one of the first applications area that come in mind is control. If we have a device capable of sending back to some deciding point a numerical evaluation of the perceived quality of a video or audio (or video and audio) communication, and if there is some action we can take to modify the system's state and thus, to possibly modify the quality, then there is an open way to optimize *the ultimate target*, the perception users have about the application / service they are using. This issues were the object of [28] where the main characteristics of PSQA for controlling purposes were discussed. See also 6.14 and 7.5 in this report.

In [29] (see also http://drops.dagstuhl.de/portals/index.php?semnr=09192) the present characteristics and performance of PSQA were described. In [63], [27], [65], global presentations of our technology were given at different forums.

6.11. Optical networks

Participants: Nizar Bouabdallah, Gerardo Rubino.

Typical optical-based backbones are in general underutilized. This is not due to the lack of transmission needs, but to other factors, among which we underline two: the bottleneck effects at access networks, and the somehow rigid and inefficient way of using the optical infrastructure as nowadays available in the current technology. In the team, we work for providing new techniques in order to utilize efficiently the tremendous transmission capacity offered by the optical equipments. To achieve this, we propose intelligent traffic aggregation mechanisms and efficient routing algorithms [9].

Optical technology has increased significantly the transmission capacity of today's transport networks, and it is playing important roles in supporting the rapidly increasing data traffic. Meanwhile, congestion issues are definitively relieved in such core networks. Nonetheless, the rigid and large routing granularity (i.e. wavelength) entailed by such an approach could lead to bandwidth waste [67]. In this regard, increasing research interest is now focusing on the development of new concept of traffic aggregation in optical networks. The main objective of our work is therefore eliminating both the bandwidth underutilization and the scalability concerns that are typical of all-optical wavelength-routed networks.

Specifically, we propose using multiple-access lightpaths (i.e., optical circuits) instead of the traditional point-to-point lightpaths. By doing so, we aim at increasing the lightpath utilization since its capacity is shared by multiple connections instead of a single end-to-end connection. To achieve this and a first main contribution of our work, we conceived new medium access and sharing mechanisms adapted to such very high speed networks. Such mechanisms lead to significant cost savings.

We also provide new sharing policy techniques to ensure QoS-aware protection schemes. The main objective is to give multiple grades of service for different clients, with various availability requirements, sharing the same protection paths. Indeed the resulting network reliability depends mainly on the deployed redundancy capacity and how such capacity is shared among the different classes of service. In view of this, we aim at proposing new priority-enabled shared-protection mechanisms as well as new models to evaluate their effectiveness. To do so, we elaborate new analytical models for the proposed priority-enabled schemes [9].

In the design of an optical backbone, a commonly applied requirement is to ensure the existence of at least two node-disjoint-paths between pairs of distinguished nodes. The problem of finding a topology verifying this restriction is known as the Steiner Two-Node-Survivable Network Problem (denoted by STNSNP), an NP-hard problem. In [24] we introduce a Greedy Randomised Adaptive Search Procedure (GRASP) for designing low-cost topologies for the STNSNP model. The heuristic was tested over a large problem set containing heterogeneous topologies with different characteristics, including instances with hundreds of nodes. The numerical results were highly satisfactory, accomplishing in all cases good quality local-optimal solutions.

6.12. Wireless networks

Participants: Bruno Sericola, Nizar Bouabdallah.

Efficient mobility management is one of the major challenges for next-generation mobile systems. Indeed, a mobile node (MN) within an access network may cause excessive signaling traffic and service disruption due to frequent handoffs. The two latter effects need to be minimized to support quality of service (QoS) requirements of emerging multimedia applications. In our work, we propose a new adaptive micro-mobility management scheme designed to track efficiently the mobility of nodes so as to minimize both handoff latency and total signaling cost while ensuring the MNÕs QoS requirements [19]. We introduce the concept of residing area. Accordingly, the micro-mobility domain is divided into virtual residing areas where the MN limits its signaling exchanges within this local region instead of communicating with the relatively far away root of the domain at each handoff occurrence. A key distinguishing feature of our solution is its adaptive nature since the virtual residing areas are constructed according to the current network state and the QoS constraints. To evaluate the efficiency of our proposal, we compared our scheme with existing solutions using both analytical and simulation approaches. Numerical and simulation results show that our proposed scheme can significantly reduce registration updates and link usage costs and provide low handoff latency and packet loss rate under various scenarios.

One of the major concerns in multi-hop wireless networks, called also wireless mesh networks (WMNs), is the radio resource utilization efficiency, which can be enhanced by managing efficiently the mobility of users as well as the interference effect among neighboring links. Our main objective is therefore to route efficiently the traffic generated by mobile nodes including the signaling messages in order to optimize network radio resource utilization. In other words, we aim at minimizing the total signaling cost by controlling the number of registration updates with the root of the domain. To achieve this, we propose new micro-mobility management schemes based on clustering techniques to track efficiently the mobility of nodes within the network. These mechanisms are conceived to minimize the total signaling cost of exchanged messages needed to manage the mobility of nodes as well as to optimize the link usage cost of the data traffic generated by each mobile user [18].

Specifically, we proposed a new interference-aware routing metric as well as two mobility-aware clustering algorithms that take into consideration the mobility properties of users in order to improve the WMN performance. We prove that both clustering schemes can achieve significant gains in terms of radio resource utilization and load balancing, especially when using our interference-aware routing metric. Hence, and as a

main contribution, we show that by taking into account the interference effect between links, we can improve the performance of our clustering algorithms and increase the gain initially observed with the conventional hop-count metric.

As a second alternative to increase the capacity of wireless mesh networks, we propose using the cognitive radio (CR) capabilities. The capacity of a WMN is indeed dependent on the spectrum resources it has, and the efficiency with which it uses them.

Most current WMNs rely on existing technologies such as IEEE 802.11, and operate using unlicensed spectrum. This has contributed to the rapid growth of the technology, as WMNs have been deployed across campuses, rural regions, and even entire cities. However, the bandwidth-intensive nature of WMNs - the result of using multi-hop communication in a shared medium - creates difficulties for delivering satisfactory quality-of-service (QoS), particularly for networks sharing spectrum with other networks and technologies

In our work, we considered the use of cognitive radio to improve this efficiency, by allowing networks belonging to different service providers to share both spectrum and infrastructure resources according to several different models. Using an ILP based problem formulation, this approach is demonstrated to yield significant benefits to the networks, by increasing QoS or allowing the networks to decrease their spectrum requirements.

In terms of virtual wireless networks (VWNs), despite having no dedicated spectrum resources, the feasibility of supporting QoS is demonstrated. These VWNs benefit from having multiple primary networks from which they can borrow resources. The VWN supports additional users, and considerably increases the utilization of channel resources. The successful operation of the VWN shows that the previously wasted spectrum resources of the primary networks have significant value.

Finally, in large scale multi-hop wireless networks, flat architectures are typically not scalable. Clustering was introduced to support self-organization and enable hierarchical routing. When dealing with multi-hop wireless networks, robustness is a crucial issue due to the dynamism of such networks. Several algorithms have been designed for clustering. In [22], we show that a clustering algorithm that previously exhibited good robustness properties, is actually self-stabilizing. We propose several enhancements to the scheme to reduce the stabilization time and thus improve stability in a dynamic environment. The key technique to these enhancements is a localized self-stabilizing algorithm for Directed Acyclic Graph (DAG) construction. We provide extensive studies (both theoretical and experimental) that show that our approach enables efficient yet adaptive clustering in wireless multi-hop networks.

6.13. Wireless sensor networks

Participants: Nizar Bouabdallah, Fatma Bouabdallah-Othman, Mario Rivero, Bruno Sericola.

Wireless sensor networks (WSNs) can be viewed as a particular case of wireless mesh networks (WMNs), where designers have to cope with the limited power, buffering and processing capacities of the sensor nodes. Despite these limitations, the growing capabilities of these tiny motes, which consist of sensing, data processing, and communicating, enables the deployment of reliable WSNs based on the cooperative effort of a large number of sensor nodes.

In contrast to the traditional networks aim to achieve high QoS levels, sensor network protocols focus primarily on power conservation, because of the limited capacity of the sensor nodes' batteries. However, this should be accomplished while respecting certain constraints on the information reliability and reporting delays. The physical phenomenon should be indeed reliably detected and estimated from the collective information provided by sensor nodes, in order to be able to initiate right actions.

Achieving these two opposite requirements, i.e., the trade-off between energy conservation and information reliability, is the key driver of our work on WSNs [9].

To reduce the transmission of redundant information while respecting the QoS application requirements, we proposed to profit from the natural temporal and spatial correlation among the observations of the densely deployed sensor nodes.

For instance, continuous monitoring applications require periodic refreshed data information at the sink from the sensor nodes. Profiting from spatial correlation to asleep redundant nodes or using data aggregation is usually not desired with such applications, where the network is designed to provide a continuous tracking of the individual sensor nodes' measurements. The sink node is usually interested in the separate measurements of sensor nodes, which may be used to control or test the behavior of different components of a new product. To date, this entails the need of the sensor nodes to transmit continuously in a periodic fashion to the sink, which may lead to excessive energy consumption.

To reduce the transmission of redundant information without affecting the application requirements, we proposed to profit from the natural temporal correlation among the successive observations of each sensor node. Specifically, we proposed to perform smarter data reporting by avoiding the transmission of non relevant data information [11]. By relevant data we refer to data that contains different information from the previous data transmitted by the same sensor.

It has been verified that our scheme can allow for an improvement in the network lifetime while ensuring the continuous monitoring task. The gain greatly depends on the rate of variation of the phenomenon that the sensors are monitoring [58].

Considering continuous monitoring applications, we also proposed to further improve the network lifetime by balancing efficiently the energy consumption within the WSN.

The routing protocols should indeed avoid the energy depletion of nodes with naturally higher load, a typical issue in conventional routing schemes such as with MTE (minimum total energy) routing. The MTE routing consists in finding the route that minimizes the total consumed energy between any pair of source and destination nodes. Nevertheless, routing always through the path with the minimum energy consumption, will deplete quickly the energy of the sensor nodes contained therein, causing thus a premature death of the WSN.

A perfect routing protocol would hence drain energy slowly and uniformly among nodes, leading to the death of all the sensors nearly at the same time. Typically, an ideal routing protocol would spread efficiently the traffic inside the network and avoid the fast drain of sensor nodes with natural high energy consumption.

To achieve this, we proposed balancing the energy consumption throughout the network by sending the traffic generated by each sensor node through multiple paths instead of forwarding always through the same path [12]. The problem consists then in determining the set of routes to be used by each sensor node and the associated weights (i.e., the routing configuration) that maximize the network lifetime. As a main contribution of this work, we showed that by efficiently balancing the traffic inside the network, significant energy savings up to 15 % can be achieved compared to the basic routing protocols.

So far, we have described different solutions to reduce the energy consumption in WSNs at different layers: physical (transmission range adjustment), MAC (sleep schedule, correlation-based schemes) and network layers (load balancing). While these protocols may achieve very high performance; in essence, they have not been jointly designed to maximize the overall network performance, specifically to minimize the energy expenditure. The main threat is that the gain achieved at one layer can be ruined at the other layers. The cross-layer design stands out thus as an attractive solution to enable further energy conservation and to cope with the relative inefficiency of traditional layered protocol architectures.

In view of this, we considered a cross layer optimization of the routing and the link layers. To do so, we extended the load balancing routing strategy to work jointly with a MAC level optimization strategy [37].

6.14. QoS support and QoE-based ressource management in wireless networks

Participants: Kandaraj Piamrat, Adlen Ksentini, César Viho.

Supporting QoS in wireless networks is an important challenge due to the probabilistic nature of the employed MAC protocol, the well-known Carrier Sense with Multiple Access (CSMA/CA). Among the proposed solutions to sustain QoS in IEEE 802.11, we have the restriction of the accepted traffics through admission control algorithms. This protects and maintains service quality for the admitted traffic. However, if there are no restrictions to limit the traffic volume being introduced to the service set, performance degradation will result due to higher backoff time and collision rate. In [71], we presented a delay-based admission control algorithm in IEEE 802.11. We presented an accurate delay estimation model to adjust the contention window size in real-time basis by considering key network factors, MAC queue dynamics, and application-level QoS requirements. Based on the abovementioned delay-based CW size we introduced a fully distributed admission control protocol to guarantee QoS.

Another way to guarantee QoS in IEEE 802.11 for multimedia applications is to consider cross-layer solutions that involve the application and MAC layers. In [44], we presented a cross-layer solution to enhance VoIP in 802.11 (known also as VoWLAN). According to the MAC layer information that represent the network load as well as the wireless channel quality (in term of BER), the application layer (here the voice coder) adapts the encoding voice rate. Thus, the application layer can adapt its rate accroding to the wireless network characteristics in term of network load and physical rate.

QoS technical parameters fail to highlight user satisfaction, also called Quality of (User) Experience (QoE). Therefore, many techniques have been developed in order to assess as accurately as possible this perceptual quality. To investigate QoE measurement, we consider three approaches, namely the subjective approach, the objective one, and the hybrid method developed in the team, PSQA (see 6.10). In [57], we studied loss pattern in wireless network and then measured how loss distribution has affected quality perception seen by user. We demonstrate that PSQA provides good estimations comparing to the well-known objective metric called Peak Signal to Noise Ratio (PSNR). We also observe that PSQA gives similar result compared with subjective tests (that is, with human evaluations) in most of the cases. One of the objectives of this evaluation is to validate PSQA the use of QoE as a metric for resource management in the future. For that, we give some possible directions allowing us to manage network resources using this metric. This study of QoE behavior has been conducted on a real platform in collaboration with VTT Technical Research Centre of Finland.

Recently, mobile networking has empowered our lifestyle in many ways. Wireless multicasting is one of them; it is spreading because of various applications such as mobile auction, entertainment services, etc. However, wireless multicast has some drawbacks. In order to reach farther stations and to minimize disturbance and interference, the transmission rate has been set to the lowest rate. This is a crucial point for a network operator who wants to manage valuable bandwidth and to waste as the smallest possible amount of it. We propose to adapt the transmission rate of access points (AP) according to the QoE of multicast client encountering the worst quality. If a client has a degrading QoE (less than a preferable threshold), then we lower the transmission rate. If all clients are satisfied, AP tries to increase the transmission rate in order to get more throughput. This strategy has been presented in [55]. Furthermore, this mechanism has been improved in order to adapt not only to QoE but also to varying network condition; hence the proposition of dynamic adaptation mechanism in [56]. The strategy consists in incrementing the waiting (backoff) time in binary exponential manner after each failed attempt of rate increase. This implies that the AP will have to wait longer before switching to higher rate after each failure of rate increase.

7. Contracts and Grants with Industry

7.1. ADR Selfnets

Participants: Hai Tran Hoang, Bruno Tuffin.

We participate to the common lab ALU-INRIA within the “Action de Recherche" SELFNETS, on pricing issues in inter-domain. The goal is to produce economic incentives for intermediate autonomous systems to forward the traffic of concurrent providers.

7.2. Cifre contract on pricing problems

Participant: Bruno Tuffin.

Cifre contract (PhD thesis supervision) on pricing and revenue and resource management for an integrated telecommunication provider in the context of competition and convergence of services.

7.3. Région Bretagne contract on simulation

Participant: Bruno Tuffin.

ARED contract (with Région Bretagne) for the PhD thesis of Saggadi Samira on rare event simulation with applications in telecommunications.

7.4. CELAR contract on interoperability assessment

Participants: César Viho, François Lerebours, Arnaud Houdelette.

In the context of our work on interoperability assessment, we continue the cooperation with the CELAR (*Centre d'Électronique de l'Armement*), a research laboratory of the French Army. Our work is to provide new framework for interoperability testing with application to routing protocols such as OSPFv3 and MTR (Multi-Topology Routing). The project started in December 2007 for 30 months.

7.5. P2Pim@ges

Participants: Gerardo Rubino, Adlen Ksentini, Kamal Singh.

We worked in the 2-years (October 2008 – October 2010) DGE Project P2Pim@ges devoted to P2P architectures for video distribution. Our contribution mainly focuses on evaluating the QoE of P2P applications. We also developed performance evaluation analysis of P2P solutions, in the context of a managed network (for instance, the network of a telecommunications operator). The project is leaded by Thomson, wit the participation of Orange, TMG, Devoteam, IPdiva, and the academics Telecom Bretagne, M@rsouin, University of Rennes 1, and 3 teams of INRIA, including Dionysos.

One of the prototypes developed in the project for the demonstrations part of the obtained results got the special prize of the NEM Summit 2009 Best Exhibition Award. It was developed by Devoteam, Telecom Bretagne and our team. In the prototype, our PSQA technology (see 6.10) was used to evaluate the perceived quality distributed by a P2P network and to provide feedback for controlling purposes. The demonstration allows to see the network adapting its structure as a function of the QoE delivered, in order to optimize that QoE, thanks to our PSQA module.

7.6. QoSmobile

Participants: Gerardo Rubino, Kamal Singh.

We worked in the 30-months (October 2007 – March 2010) DGE Project QoSmobile on the supervision (monitoring and control) of TV distribution systems over mobile terminals. Our contribution focused on evaluating the QoE of such an infrastructure. QoSmobile is leaded by ENENSYS, and the partners are Expway, Alcatel-Lucent, Siradel and our team.

7.7. SVC4QoE

Participants: Adlen Ksentini, Baptiste Marienval, Kamal Singh, Gerardo Rubino.

We are working in the 2-years (October 2009 – October 2011) DGE Project SVC4QoE, where the main focus is the SVC video coding standard and its impacts on QoE, in the context of DVB-T2 video broadcast. Our contribution focuses on evaluating through simulations and analytical models the SVC video transmission over a DVB-T2 broadcast network. SVC4QoE is leaded by TEAMCAST, and the partners are Thomson Grass Valley, TDF, Neotilus, IRCCYN, AccepTV, Telecom Bretagne, and our team.

7.8. ANR project VIPEER

Participants: Yassine Hadjadj Aoul, Gerardo Rubino, Kamal Singh.

We started a 3-year ANR project (end 2009-end 2012) called VIPEER: Video Traffic Engineering in an Intra-Domain Context using Peer-to-Peer Paradigms. The VIPEER project proposes to develop a distributed Content Delivery Network (dCDN) that combines classic CDN technologies with P2P concepts; our main application in the project is IPTV. Dionysos will mainly cover the QoE assessments in the project. Our partners are Télécom Bretagne, Eurecom, Envivio, Orange Labs and NDS Technologies.

8. Other Grants and Activities

8.1. National initiatives

8.1.1. ANR Télécommnucation WINEM

Participant: Bruno Tuffin.

We are part of the ANR telecommnucation project WINEM: "WIMAX Network Engineering and Multihoming". The project goes in the period 2007- June 2010. It is done in cooperation with Motorola, the GET (INT and Telecom Bretagne), MAESTRO project-team at INRIA Sophia-Antipolis, the University of Avignon, the Eurecom institute and Orange Labs.

It is dedicated to the IEEE 802.16e standard for Broadband Wireless Metropolitan Access (see http://www.lia.univ-avignon.fr/WiNEM/). This project has been extended for six months up to June 2010.

8.1.2. ANR Verso CAPTURES

Participant: Bruno Tuffin.

We coordinate the ANR Verso CAPTURES: Competition Among Providers for Telecommunication Users: Rivalry and Earning Stakes", in the period Dec. 2008 – Nov. 2012, in cooperation with Telecom Bretagne and Orange Labs.

The goal of this project is to deal with competition among providers in telecommunications. We need to study the distribution of customers among providers as a first level of game, and then to focus on a second higher level, the price and QoS war. See http://captures.inria.fr/ for details.

8.2. European initiatives

8.2.1. NoE EuroNF

Participants: Gerardo Rubino, Bruno Tuffin.

EuroNF Euro-NF is a Network of Excellence on the Network of the Future, formed by 35 institutions (from the academia and industry) from 16 countries. Its main target is to integrate the research effort of the partners to be a source of innovation and a think tank on possible scientific, technological and socio-economic trajectories towards the network of the future. It has started in January 2008 and is ending in December 2010 (see http://euronf.enst.fr/en_accueil.html for details).

Bruno Tuffin is the INRIA team leader in this project.

The group is contributing to the following working packages (Joint Research Activities):

- WP.JRA.2.2: Traffic Engineering, Mechanisms and Protocols for Controlled Bandwidth Sharing;
- WP.JRA.2.4: Routing and Traffic Management in a Multi-Provider Context;
- WP.JRA.2.5: Design of Optimal Highly Dependable Networks;
- WP.JRA.3.2: SLAs, Pricing, Quality of Experience;
- WP.JRA.3.3: Cost Models.

G. Rubino is the leader of the WP SEA 7.1, on Industrial Cooperation between EuroNF and the European industry.

8.2.2. PRECO project

Participant: Bruno Tuffin.

We are members of the PRECO project (Pricing and Regulation in COmpetitive telecommunication networks) within EuroNF NoE, funded for a period of one year Sept. 2008 and Sept. 2009, in collaboration with TELECOM Bretagne and the University of Rome 2.

8.2.3. AMESA project

Participant: Bruno Tuffin.

We are members of the AMESA project (Analysis of MEchanisms for Sponsored search Auctions) within EuroNF NoE, funded for a period of about one year Oct. 2008 and Dec. 2009, in collaboration with Athens University of Economics and Business, the CWI, TELECOM Bretagne and the University of Rome 2.

8.2.4. COST initiative ECON@TEL

Participant: Bruno Tuffin.

Bruno Tuffin is the French national delegate and project coordinator for the EU COST Activity IS0605. The goal of ECONTEL is to develop a strategic research and training network linking key individuals and organizations in order to enhance Europe's competence in the field of telecommunications economics, to support related R&D-initiatives, and to provide guidelines and recommendations to European players (end-users, enterprises, operators, regulators, policy makers, content providers) concerning the provision to citizens and enterprises of new converged broadband and wireless content delivery networks (see http://www.cost605.org/).

8.2.5. Other European collaborations

Participants: Bruno Sericola, Bruno Tuffin, Nizar Bouabdallah, Gerardo Rubino.

- We work with Ad Ridder, from the University of Twente, The Netherlands, on rare event simulation.
- We work with Peter Reichl (FTW, Vienna, Austria) on pricing and security issues.
- We are currently working with Marie-Ange Remiche from the university of Brussels (ULB) on the analysis of stationary fluid queues [25].
- We also work on fluid queues and on memory constrained queus with Miklos Telek (Technical University of Budapest, Hungary).
- We work with Hamid Nafaa from the University College Dublin (UCD) on the analysis of Video on Demand multi-source streaming architectures.

8.3. International initiatives

8.3.1. Associated team "MOCQUASIN" (Monte Carlo and Quasi-Monte Carlo for rare event simulation)

Participants: Pierre L'Ecuyer (Montreal, responsible for Canada), Katy Paroux, Gerardo Rubino, Bruno Tuffin (responsible for France), Samira Saggadi, Fabian Bastin, David Munger.

The goal of this team is to develop efficient Monte Carlo methods to compute integrals, sums or to solve equations or optimization problems. They are unavoidable tools in areas such as finance, electronics, sismology, computer science, engineering, physics, transport, biloy, social sciences... Nonetheless, the numerical methods available to tackle these problems have the reputation of being slow: they usually require a large computational time to reach a given precision. The goal of the project is to work on acceleration techniques, meaning to reach faster the targeted precision. The typical framework is that of rare event simulation for which getting even only one occurence of the event could require a very long time. There are two main acceleration techniques: importance sampling and splitting on which we work. A combination with the faster randomized quasi-Monte Carlo methods is also a challenge we address in the joint team.

(see http://www.irisa.fr/dionysos/pages_perso/tuffin/MOCQUASIN/).

8.3.2. Associated team "OCERC" (Optimization of the energy consumption in wireless sensor networks)

Participants: Raouf Boutaba (Waterloo, responsible for Canada), Nizar Bouabdallah (responsible for France), Fatma Bouabdallah-Othman, Adlen Ksentini, Mario Rivero, Bruno Sericola.

OCERC is an associated team between DIONYSOS team from INRIA and the team of Professor Boutaba of the University of Waterloo. OCERC stands for "Optimization of the energy consumption in wireless sensor networks". The collaboration aims at proposing new solutions to reduce the energy consumption in wireless sensor networks.

8.3.3. ECOS project "Mesh wireless networks and P2P multimedia applications: tools for guaranteeing Quality of Experience"

Participants: Adlen Ksentini, Gerardo Rubino.

This is a 3-year project (2009 – 2011) between France and Uruguay. The Uruguayan partner is the Engineering School of the University of the Republic, at Montevideo. The project concerns the study of tools allowing to reach good levels in the Quality of Experience in P2P networks for multimedia purposes, when the transport infrastructure is a mesh wireless network. The French coordinator of the project is G. Rubino.

8.3.4. STIC AmSud project "Performance evaluation and design of optical and wireless networks"

Participants: Nizar Bouabdallah, Gerardo Rubino.

This is a 2-year project (2009–2010) between Chile, France and Uruguay. The goal is the development of models and model analysis tools for the study of performance aspects in networks, mainly for optical and for wireless structures. The partners are: U. Técnica "Federico Santa María" and U. Adolfo Ibañez in Chile, U. de la República en Uruguay, U. Joseph Fourier, U. de Pau et des Pays de l'Adour and INRIA in France. The global coordinator of the project is G. Rubino (Dionysos, INRIA).

8.3.5. Other international activities

- We work with Hector Cancela (Montevideo, Uruguay) on simulation issues.
- We work with the University of Waterloo (Canada) on wireless mesh and sensor networks.
- In the STIC INRIA - DGRSRT (Universities of Tunisia) program, Nizar Bouabdallah works with SUP'COM (Tunisia) on "QoS in WiMAX mobile networks".

8.4. Visiting researchers

- Peter Reichl (FTW, Vienna, Austria) was our guest for 6 weeks during summer, to work on socio-economic aspects of next generation networks.
- Ad Ridder (University of Twente, Netherlands) was our guest for 1 week in December to work on Monte Carlo techniques for rare event simulation.

9. Dissemination

9.1. Animation of research activities

9.1.1. International memberships

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

9.1.2. Organization of conferences

- Nizar Bouabdallah served as a TPC Co-Chair for the IEEE GLOBECOM 2009 Ad Hoc and Sensor Networks Symposium, Honolulu, Hawaii, USA.
- Bruno Tuffin was co-chair for the sixth International Workshop on Advanced Internet Charging and QoS technologies (ICQT'09), Aachen, Germany, May 2009.
- G. Rubino is a member of the Steering Committee of the international conference QEST (Quantitative Evaluation of SysTems).

9.1.3. Program committees

Nizar Bouabdallah served/serves in the Program Committee of the following conferences:

- IEEE ICC 2009, Ad-Hoc and Sensor Networking Symposium, June 2009, Dresden, Germany;
- IEEE ICC 2010, Ad Hoc, Sensor and Mesh Networking Symposium, May 2010, Cape Town, South Africa;
- IEEE GLOBECOM 2010 Ad Hoc, Sensor and Mesh Networking Symposium, December 2010, Miami, Florida, USA

Gerardo Rubino served/serves in the Program Committee of the following conferences:

- IEEE INFOCOM 2009 (The 28th Conference on Computer Communications), Rio de Janeiro, Brazil, April 2009.
- IFIP/ACM (SIGCOMM) LANC'09 (5th Latin America Networking Conference 2009, Pelotas, Brazil, September 2009.
- 10th International Workshop on Computational Stochastics, Amsterdam, The Netherlands, May-June 2010.

Bruno Sericola served/serves in the Program Committee of the following conferences

- ASMTA'09, 16th International Conference on Analytical and Stochastic Modelling Techniques and Applications, Madrid, Spain, 9-12 June 2009.
- SMCTools'09, 4th International Workshop on Tools for Solving Structured Markov Chains. Pisa, Italy, October 20-22, 2009.
- CFIP'09, 14me Colloque francophone sur l'ingnierie des protocoles, Strasbourg, France, 12-15 octobre 2009.

Bruno Tuffin served/serves in the Program Committee of the following conferences

- 2nd IFAC Workshop on Dependable Control of Discrete Systems (DCDS'09), June 10-12, 2009, Bari, Italy.
- 5th EURO-NGI Conference on Next Generation Internet (NGI 2009). Aveiro, Portugal, June 22-24, 2009.
- The 6th International Workshop on Grid Economics and Business Models (GECON 2009), August 24, 2009, Delft, The Netherlands.
- 6th International Conference on the Quantitative Evaluation of SysTems (QEST) 2009, September 2009, Budapest, Hungary.
- 21st International Teletraffic Congress (ITC 21), September 15,17, 2009, Paris, France.

Adlen Ksentini served/serves in the Program Comittee of the following conferences

- IEEE GLOBECOM 2009 Wireless Network Symposium, December 2009, Hononulu, Hawai, USA
- IEEE GLOBECOM 2010 Wireless Network Symposium, December 2010, Miami, Florida, USA
- EEE ICC 2010, Wireless Communication Symposium, May 2010, Cape Town, South Africa;

9.1.4. Managing research activities

- Bruno Tuffin was a member of the "Comité des actions incitatives" for the "Conseil d'Orientation Scientifique et Technologique de l'INRIA" (COST).
- Cesar VIHO is a member of the "Conseil de laboratoire" and of the "Conseil d'Orientations scientifiques (COS)" de l'Irisa.
- Gerardo Rubino was a member of the Visiting Committee of the Computer Science Department of the University Paris Descartes.
- Gerardo Rubino is a member of the CSV (Selection and Validation Committee) of the "Images et Réseaux" (Images and networks) cluster in the French Brittany Region. The cluster groups most companies and academic institutions working in networking and on image-based applications in Western France.
- Gerardo Rubino is the INRIA representative at the GIS SISCOM, an association composed of the four main academic institutions in Western France in the area of information and communication sciences: the European University of Brittany-UEB, the Institut TELECOM, the CNRS and INRIA, to promote the excellence of the ICT research in Brittany.

9.2. Teaching

9.2.1. Local teaching activities

The team's members have a variety of responsibilities concerning teaching in the local environment (Ifsic, Telecom Bretagne, Rennes Mathematics Institute). At the Bac+5 level, N. Bouabdallah, R. Marie, G. Rubino, B. Sericola, A. Ksentini, B. Tuffin, C. Viho, give different courses in two Masters (in Probability and in Computer science), in the 3rd year of DIIC (Engineering School) at U. of Rennes 1, at Telecom Bretagne at Supelec. The main subjects are networking, protocols, dimensioning problems, dependability analysis, etc. A. Ksentini is in charge of the 2nd year of the Master in Computer Science at the university of Rennes 1.

9.3. Editorial activities

9.3.1. Editorial activity

- Bruno Tuffin is associate Editor for INFORMS Journal on Computing.
- Bruno Tuffin is associate Editor for Mathematical Methods of Operations Research.
- Bruno Tuffin is associate Editor for ACM Transactions on Modeling and Computer Simulation.
- Nizar Bouabdallah Associate Editor for the Wireless Communications and Mobile Computing journal, Wiley InterScience, since February 2009.
- Bruno Sericola is a member of the Editorial Advisory Board of TheOpen Operational Research Journal.

9.4. Standardization activities

Participants: Anthony Baire, François Lerebours, César Viho.

The Dionysos team dedicates a significant effort towards standardization and certification in the telecommunications area. We participate in several working groups of the main telecommunication standardization institutes like the IETF (Internet Engineering Task Force), ETSI (European Telecommunication Standardization Institute), etc. We are also active in the main mailing-lists treating new generation networks and protocols. Several proposals of drafts and contributions to the definition of standards and RFCs (Request For Comments) have been published. Our contributions focus today mainly on IPv6 and related protocols such as IPv6 mobility.

9.4.1. IPv6 Ready Logo Program

Participants: Anthony Baire, François Lerebours, César Viho.

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

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