



Project-Team REOP

Réseaux d'opérateurs

Rennes, Brest Activity Report

2014

1 Team

Faculty Members

Xavier Lagrange, Professor (HDR)
Alberto Blanc, Associate Professor
Annie Gravey, Professor
Loutfi Nuaymi, Associate Professor (HDR)
Gwendal Simon, Associate Professor
Géraldine Texier, Associate Professor
Sandrine Vaton, Professor (HDR)

Post-Doctoral Fellows

Tristan Groléat, Post-doc
Jelena Pesic, Post-doc
Santiago Ruano Rincon, Post-doc
Luis Suarez, Post-doc
Ahmed Triki, Post-doc
Bogdan Uscumlic, Post-doc
Feng Yan, Post-doc
Ramon Aparicio-Pardo, Post-doc

PhD students

Nahla Abid, Orange Labs, CIFRE, since October 2009
Hussein Al Haj Hassan, Telecom Bretagne, since October 2012
Hassan Ali Ahmad, Orange Labs, CIFRE, October 2010 - January 2014
Muhammad Moiz Anis, Institut Mines-Telecom, November 2010 - February 2014
Siwar Ben Hadj Said, Orange Labs, CIFRE, since October 2010 (ATNET team from october 2014)
Yang Yang Chen, Telecom-Bretagne, since October 2012
Franck Cornevaux-Juignet, Telecom Bretagne, since October 2014
William David Diego Maza, Orange Labs, CIFRE, since January 2013
Jialong Duan, Telecom Bretagne, since November 2014
Souheir Eido, Telecom Bretagne, since January 2013
Moufida Feknous, Orange Labs, CIFRE, since January 2012
Younes Khadraoui, Telecom Bretagne, since October 2013
Tristan Groleat, Telecom Bretagne, January 2011 - March 2014
Patrice Houze, Orange Labs, CIFRE, since November 2014
Romain Jacquet, Telecom Bretagne, since October 2011
André Lalevée, Telecom Bretagne, since October 2014
Pratibha Mitharwal, Telecom Bretagne, since February 2013
Laudin Molina, Telecom Bretagne, since December 2014

Karine Pires, LIP6 et Telecom Bretagne, since October 2011
Ion Popescu, Telecom Bretagne, since November 2012
Malla Reddy Sama, Orange Labs CIFRE, since October 2012
Dareen Shedhadeh, Telecom Bretagne, since January 2014
Qipeng Song, Telecom Bretagne, since October 2014
Serge Romaric Tembo, Orange Labs CIFRE, since November 2013
Wei You, Orange Labs, CIFRE, October 2010 - January 2014

Administrative assistant

Marie-Pierre Yvenat, Telecom Bretagne
Armelle Lannuzel, Telecom Bretagne

2 Overall Objectives

2.1 Overview

The number of communicating devices connected to the Internet will dramatically grow in the next decade. For instance in a country like France, it will increase from tens of millions of terminals to a few billions. This trend is not only a change in the magnitude of terminals but also in their heterogeneity: some terminals exchange very low traffic but with a high requirement of availability and reliability while other terminals must transfer large amounts of data (video streaming), some terminals can be fixed while others are highly mobile, some have very strict consumption constraints (battery limitation) while others have a source of energy.

During the previous decade, the research community concentrated its effort to increase transmission rates, to provide network access anywhere and anytime, and to define reliable mobility management procedures. These issues will always exist in the next decade, but they become more complex because the network must resist a change of scale and greater diversity of uses while ensuring Quality of Service, a good level of security and low power consumption energy.

Another major change that the Internet has experienced over the past decade is the rise of "over-the-top" operators, which offer services based on the network capacity and create value. By nature these services are deployed on endpoints. However, with the continuous increase of processor performance and memory capacity, integrating the service delivery within the network is now possible. Networks will then not be organized as a set of nodes with an address that convey information but will be conceived to achieve some tasks and to provide resources: this is the concept of Network Centric Information that may be developed in the next years.

The REOP project focuses on the evolutions that operators must do both in access networks and core networks to meet the challenges posed by these new paradigms: the development of the Internet of Things and the necessary migration from "communication between machines" to "information supply". The field of ad-hoc networks and home networks is clearly excluded from this research project. Possible solutions to address these changes concern both the core network, the aggregation network (metro) and the access network.

2.2 Key Issues

In its current state, REOP studies the following key issues. In the core network and aggregation network (metro), the following subjects are studied:

- Network organization based on tasks (Information Centric Networking) and traffic management (traffic engineering)
- Interconnection of core networks (inter-domain routing, intra-domain routing, inter-domain QoS monitoring, multi-criteria path optimization)
- Network and traffic monitoring for security, reliability and quality of service
- Distributed and flat architectures for mobility management.

In most cases, the bottleneck regarding the throughput and more generally the performance is located in the access network. It is then a key issue and REOP works on the following items:

- Cooperation and/or sharing of mobile and fixed access networks to minimize energy consumption while improving the quality of service
- Radio resource management to minimize the energy consumption
- Traffic control in optical access networks, and heterogeneous access networks.

Some subjects are related to both the access network and the core network:

- New metro network architectures (Optical Packet Switching), and new boundaries between access and metro networks (long-reach PON, WDM PON)
- optimization, while taking into account the radio access network, of centralized policy choices operator (in particular QoS) in an open OFDMA environment.

3 Scientific Foundations

3.1 Introduction

Since the objective of a network is to interconnect various types of devices and to share different types of resource (information, storage capacity, computing power), studying network is by nature a multi-disciplinary activity. Furthermore, it requires an holistic approach because the global optimization of network must take into account several criteria (including transmission bit rate, latency, energy) and various types of constraints (*e.g.*, robustness and simplicity of the protocols, and scalability). In many cases, simulations of implementations on test beds are required to analyze performances. However, when the analysis is focused on a particular mechanism, several scientific tools can be used like stochastic analysis, discrete optimization.

3.2 Mathematical methods and models

Keywords: decision theory, estimation theory, classification, data stream mining, queuing systems analysis, large deviation theory, game theory, linear programming.

Traffic is an object of studies in itself and as such it can be analyzed in order to discover interesting properties such as long range dependence, non stationarities, non-gaussianity, heavy tailed distributions, etc... It is necessary to produce accurate traffic models in order to predict, for example, the utilization of resources or the quality of service. Very often traffic models are of stochastic nature. They can be very simple such as a Poisson process or more sophisticated such as Markov modulated models or, for example, fractional Brownian motions. These models are often parametric and their parameters must be estimated by the analysis of traffic captures.

The theory of queuing systems is used in order to predict the performance offered to the applications. It can be used to analyse the cost of mobility management in mobile networks as signalling related to mobility management represents a more and more important part of the total traffic. It is also useful for the analysis of the performance of complex link layer protocols in radio networks.

As traffic is more and more heterogeneous in nature and as the applications have different needs in terms of Quality of Service it is important for operators to monitor and classify the traffic per category of applications. This can be based on port analysis or Deep Packet Inspection (DPI) but these methods have drawbacks, such as the problem of applications that change or use dynamic port numbers and the problem of ciphered traffic. Another approach to the traffic classification problem is to use pattern recognition methods such as Support Vector Machine (SVM) in order to classify flows on the basis of descriptors such as the length of packets.

It is important to detect anomalies in traffic and to be able to do so with a low false alarm rate and a low delay. Sequential decision theory provides a rigorous framework to deal with real-time traffic anomaly detection problems. These methods are useful in the context of, for example, anomaly based Intrusion Detection Systems (IDS). The anomalies that one can discover in the traffic if one works on coarse traffic aggregates such as aggregated volumes of traffic are not useful in the framework of IDS. On the contrary very rich anomalies can be discovered if one observes the traffic at a finer time scale, such as the volumes of traffic per IP address for example. As the cardinality of the state space of IP addresses is very large it is necessary to use specific methods from data stream mining to maintain counts of packets per IP address on high bit rate links in real time.

The economical context that network operators have to face is considered to be very difficult. Indeed, the emergence of bandwidth demanding services are putting operators under pressure since they generate a lot of traffic that consumes capacities deployed by operators. But on the other hand the revenues these services generate revenues for service providers (i.e. OTT) but not for network operators. Economical models must therefore be rethought in order to permit a fair share of the revenues between the different stakeholders. The interactions between the stakeholders in this ecosystem can be analyzed with some tools of game theory.

3.3 Hardware and software traffic processing

Keywords: GPU, multi-core, parallelization, hardware acceleration, FPGA, SDN.

A major challenge for network operators is to be able to process traffic at very high bit rates. They have to face an exponential increase in the traffic because of the deployment of optic fiber based technologies in the access and because of the rise of video traffic demand. On the other hand one has to implement more and more sophisticated treatments in order to optimize bandwidth usage, to offer a good quality of service and to guarantee the security of the network. In order to deal with high bit rate traffic several approaches must be used. One can leverage on the capabilities offered by parallelization on multi-core architectures or even on GPU. A software approach is not always sufficient when one has to process traffic at bit rates higher than Gb/sec. Another solution is to use hardware acceleration in order to speed up some treatments. For example FPGA boards such as NetFPGA or COMBO cards are two platforms available for hardware accelerated treatments of network traffic. Software defined networking (SDN) with OpenFlow is also promising to implement with a software approach various traffic management protocols.

3.4 Discrete Optimization

Keywords: optimization, integer linear programs, approximate algorithms, exact algorithms, heuristics.

Operations research is a scientific area that has developed a special relation with network. The network resource (memory, processing, data rate, radio spectrum) is inherently limited. However, network operators should provide a quality of service (QoS) as good as possible. It is thus common that network scientists formulate optimization problems with an objective function to minimize (or maximize) subject to various constraints.

For example, network design relies on minimizing the cost of the resources requested to support a given traffic matrix. The traffic matrix is based on “busy hour” traffic flow predictions by the operator. Supporting the traffic on the network can often be expressed as a set of linear equations, involving traffic flows and sets of resources. Linear programming is then used to minimize the cost of resources. For small networks, an exact solution can be identified, thanks to mathematical solvers whereas large network design often relies on various heuristics.

Within the vast field of operations research, discrete optimization is one of the most fascinating branch, which still encompasses many open fundamental problems. In particular, the impossibility to develop fast algorithms that computes optimal solutions for discrete problems have conducted network scientists to find trade-offs between performances and computability.

From a scientific standpoint, network scientists are interested in developing fast approximate algorithms, where the performances are bounded with respect to the optimal solution, or exact algorithms that lever some relaxed version of problems. Meta-heuristics have also gained some interests since they allow significant progresses in problem solving at relatively low development costs.

3.5 Protocol Design for Optical Networks

Keywords: Medium Access Control, Label Based Switching, Reservation, Scheduling, GMPLS, SDN.

Introducing optical technologies into network architecture implies designing new protocols for both transfer and control planes. This is mostly true for *transparent* or *translucent* optical technologies, that do not rely at all (or rely only partially) on Optical to Electronic (OE) conversions.

Optical circuits build upon the sets of wavelengths made available by WDM are commonly used in the backbone's transport layer. However, a wavelength granularity may be too coarse in many situations where some small flows have to be supported as e.g. in metro/aggregation networks. In that case, a finer (sub-wavelength) granularity is requested, that can be delivered by Optical Packet Switching (OPS) or Optical Burst Switching (OBS). Both OPS and OBS offer an optical packet-based transfer but differ by the method used to carry control information; in OPS, a header is appended to each data packet on the wavelength uses to carry client data whereas in OBS, a separate wavelength is used to carry control-related information.

Optical transfer plane significantly differs from existing electronic transfer planes. One major difference is the lack of easily implemented buffering facilities in the optical domain, which precludes implementing buffering as the major contention control mechanism. Therefore, contention has to be avoided in other manners, e.g. by designing complex scheduling mechanisms, as in the upstream direction of Passive Optical Networks. Static or dynamic reservation schemes can also be implemented in the control plane in order to avoid contention in the transfer plane. Another difference between electronic and optical networks is that the transfer rate of a given optical channel can be dynamically controlled; this feature is very useful e.g. to activate backup resources in case of failures.

The optical control plane has to be integrated with existing control planes.

This can be done either by designing a new Ethernet transport network (similarly to EPON in an FTTH access network). An alternative is to build a new multi-client optical transport layer that could be integrated in a global GMPLS framework (GMPLS is the current framework used in operators' networks to globally command their networks). This is facilitated by generalizing label switching in technologies used for transport networks. In both cases, SDN can be used to configure the network.

4 Application Domains

4.1 Inter-domain Issues

Participants: Alberto Blanc, Annie Gravey, Géraldine Texier, Sandrine Vaton.

While the Internet traffic is still increasing, the emergence of new usages with QoS-demanding traffics like multimedia traffic (especially high definition videos), interactive applications (videoconferences, games,...) or the replacement by businesses of their dedicated networks by Internet and VPNs raise important issues on Inter-Domain routing and relationships. Another issue is the modification of the inter-domain routing policies, with Content

Providers or Content Distribution Networks (CDN) becoming major players who directly peer with ISPs to deliver their content over the Internet. A major consequence of this evolution is the question of the durability of the Internet Best Effort model. Indeed, Best Effort resource management is not possible within congested networks. Then the old debate around QoS in the Internet has become a real concern for both engineering and economics. The activities of ReOP on Inter-Domain to offer QoS from end to end address both Inter-Domain Routing problems to be able to find and establish a path with QoS guarantees involving several domains in the Internet [6][5][4][?] and cooperation incentives problems between Network Service Providers like reputation or monetary issues for example by revenue sharing or reimbursement when QoS is not fulfilled.

4.2 Network Monitoring

Participants: Sandrine Vaton, Franck Cornevaux Juignet, Tristan Groléat, André Lalevée, Serge Romaric Tembo, Santiago Ruano Rincon, Géraldine Texier.

Network monitoring refers to the observation of network and traffic by means of sensors of different types and by the analysis of those measurements. The goal is to gain information about the traffic or the state of the network and its equipments.

The applications of network monitoring are varied. A first application is the characterization of network usage i.e. the composition of traffic in terms of categories of applications, as well as a characterization of the categories of applications (bandwidth, variability...) in order to evaluate resource consumptions (bandwidth, spectrum...). The spatial distribution of the traffic over the network (sources/sinks of traffic) results from the combination of the traffic demand and management.

Another application concerns the characterization of the infrastructure that is to say the topology of the network as well as the main characteristics (bandwidth, delay) of its links/paths. The stability of the network should also be assessed by monitoring the routing (in particular BGP announcements) and the exchanges of traffic between Autonomous Systems (AS).

A major application of network monitoring addresses security issues which is a major concern for network operators and their clients. For example, the early detection of attacks distributed through botnets is an application of traffic analysis at the level of different probes in the network. The analysis of traffic at honeypots permits to analyze threats.

As DNS servers are key components of communications over the Internet the Quality of Service that the main DNS servers provide is also under supervision. Other statistics such as those related to the deployment of IPv6 are also necessary to characterize the network.

The demand for reliability, availability, robustness and quality of service conducts to trigger intensive research about autonomic networking. The goal is to automate numerous tedious OAM operations like multiple faults diagnosis and alarms correlation. Detecting, isolating and correcting primary faults related to network connectivity and network performance should be automatized using the tremendous amount of alarms generated by network components and services as a primary source of information on ongoing anomalies.

4.3 Mobility Management

Participants: Xavier Lagrange, Gwendal Simon, Hassan Ali Ahmad.

Data traffic in mobile networks is likely to exceed data traffic in fixed networks in the near future. Mobility management is going to take considerable importance. Today, the principle is to concentrate the traffic from and to mobile devices on a single gateway (which is called an anchor) in the mobile core network. By use of tunnelling mechanisms, the traffic is forwarded to the location of the mobile terminal. Such a mechanism is used in Mobile IP, Proxy Mobile IP and GTP (LTE mobility). This architecture concentrates the traffic in a single entity and merges mobility signaling and data traffic. It is necessary to develop new mechanisms for mobility management that are more distributed and that are activated only when the user or the service really need it.

The activity of REOP includes the definition of mobility management mechanisms that are dynamic and distributed [3]. It is done in collaboration with OCIF. Dynamic Mobility Anchoring (DMA) is a new mobility protocol jointly proposed by OCIF/REOP and Orange Labs^[Ber10] that is based on IPv6. Part of this work has been used in the DMM (Distributed Mobility Management) working group of IETF. The activity of REOP also deals with the performance analysis of these mechanisms through simulations and the use of stochastic models. A new research topic is currently being developed to study how mobility management in the core network can be virtualized. All the mobility management activity is done in cooperation with Orange Labs

4.4 Radio and Optical Technologies for access and metro networks

Participants: Annie Gravey, Xavier Lagrange, Souheir Eido, Moufida Feknous, Younes Khadraoui, Jelena Pesic, Ion Popescu, Lida Sadeghioon, Ahmed Triki, Bogdan Uscumlic.

High Bandwidth access is now available for residential users, and at moderate tariffs, both in fixed and mobile networks. This has led to major modifications in traffic profiles as the traffic generated by residential users is now dominant, compared to the traffic generated by enterprises; video and more generally real-time entertainment drive traffic increase.

It is therefore necessary to revisit both network architectures and traffic engineering methods for access and aggregation (metro) networks. Different technologies are replacing the existing access technologies for fixed (xDSL) and mobile (3G) networks. Optical fiber is being deployed in order to support *Optics in the First Mile* fixed access such as Passive Optical Networks (PONs) of various types. 4G and LTE also promise to significantly increase the radio access rate. The huge increase in access rates also implies revisiting the current *aggregation* networks architectures that cannot gracefully evolve as traffic volumes increase; in particular, transparent optical networking is considered in order to increase metro network capacity while limiting energy consumption. The delineation between a simple Layer 2 aggregation network and a Layer 3 core network that takes care of all intelligent decisions relative to security and

[Ber10] P. BERTIN, *Gestion de la mobilité dans une architecture d'accès multi-technologies*, PdD Thesis, RSM - Dépt. Réseaux, Sécurité et Multimédia (Institut Mines-Télécom-Télécom Bretagne-UEB), UR1 - Université de Rennes 1, UEB - Université Européenne de Bretagne (UEB), 2010.

routing is also becoming blurred with more intelligence being pushed in the aggregation network. Fixed-Mobile Convergence (FMC) is considered in order to mutualize the aggregation network and thus traffic control functions.

Taking into account technological evolutions, traffic increase and the need to mutualize traffic control functions requires innovative proposals in terms of network architecture and traffic engineering.

4.5 Radio Resource Management and Energy Efficiency

Participants: Loutfi Nuaymi, Xavier Lagrange, Hussein Al Haj Hassan, Muhammad Moiz Anis, Luis Suarez.

The use of mobile networks has significantly increased for the last decade and a large amount of data is transmitted every day on radio channels. The radio spectrum is limited and shared by the different systems (Cellular, Television,...), operators and by different users in a given system. Radio resource management is then a key issue as it determines the quality of service, the capacity of the network and the energy consumption of the terminals and the network.

A radio resource can be defined as a portion of the radio spectrum for a given duration associated to a power. In order to conserve the radio spectrum the same radio resource is used at different locations of the network, which then generates interference. A cross-layer approach is then necessary to optimize the usage of the radio resource : radio resource management should be jointly considered in the power control mechanisms, the medium access control, the link layer protocols, the scheduling procedures. While keeping this global approach, REOP team considers more specifically how to improve the link layer protocols and power controls algorithms.

An important research work has already been done for Radio Resource Management in wireless and cellular networks in the last decades. Yet, some new and specific issues still need to be addressed. One of them is the urgent need to decrease energy consumption (for GHG, GreenHouse Gases emissions, for energy bill, health issues, etc.). Different approaches have been proposed for that objective: electronics and antennas, cognitive radio, cell configuration change (cell size, femtocells, relays), dedicated radio resource management algorithms. For the moment, we work on cell configuration change and intend to work soon on cognitive radio. Among the questions to answer are : which cells to deactivate? how to redistribute remaining traffic after deactivation? how long are they going to be deactivated?

In the context of open LTE and OFDMA networks, we also study centralized QoS policy choices and associated Radio Resource Management algorithms, these latter being distributed over thousands of base stations. Several criterions can be considered for these studies: radio resource use efficiency, user received quality, operator revenue and also others.

5 Software

5.1 Wi2me

Participants: Alberto Blanc, Xavier Lagrange¹.

The WiFi technology becomes more and more popular and the the density of access points is very high in urban areas. Several community networks, which are based on sharing WiFi residential access points, are now available. They can provide locally a wireless access at a high speed rate but show uncontrolled performance. In this scenario, the goal for a user is to have multiple interfaces, and exploit them the best he/she can, by always selecting the best matching between flows and interfaces. In order to have real traces and to evaluate the performance, the availability and the potentiality of these networks, OCIF team have developed a new mobile sensing tool, called Wi2Me Traces Explorer. It is an Android-based application that performs network discovery, automatic authentication and TCP traffic generation through WiFi and 3G.

REOP team is involved in Wi2me project. It studies in cooperation with OCIF how to analyse the gross results given by the platform in order to characterize the performance and the quality of service of the community networks. REOP team is also currently working on how to integrate in the Wi2Me database measurement results given by monitoring 3G terminals and the VIGIE tool (for further information, see http://perso.telecom-bretagne.eu/xavierlagrange/logiciels_pedagogiques/vigie/).

5.2 Blockmon

Participants: Tristan Groléat, Sandrine Vaton.

Blockmon is a software allowing construction of flexible and high performance (rates in the 10Gbps range) monitoring and data analysis nodes, where a node can be for example a hardware probe or a PC. Blockmon is based around the notion of blocks, which are small units of processing (e.g., packet counting). Blocks are connected and communicate via gates, and the set of inter-connected blocks represents a composition, where compositions are expressed in terms of an XML file.

Blockmon was developed in the framework of FP7 European project DEMONS (see See also : <http://fp7-demons.eu/>). Several partners are co-authors of the software: Andrea di Pietro (University of Pisa), Felipe Huici (NEC Europe), Nicola Bonelli (University of Pisa), Brian Trammell (ETH Zurich), Peter Kastovsky (INVEA-TECH), Tristan Groléat (Télécom Bretagne), Sandrine Vaton (Télécom Bretagne), Maurizio Dusi (NEC Europe). The Blockmon distribution is available under a BSD-style license at <http://blockmon.github.com/blockmon>.

5.3 High performance open source traffic generator

Participants: Tristan Groléat, Sandrine Vaton.

¹Only participants in REOP are listed.

Traffic generators that support tens of Gb/sec are necessary in order to test hardware accelerated traffic monitoring probes. But commercial traffic generators that support such bit rate are very expensive. For that reason we have developed our own easily configurable, extendable, affordable and open source traffic generator. The open-source traffic generator is available at <https://github.com/tristan-TB/hardware-traffic-generator>.

The architecture of the traffic generator is very flexible. Parameters of the traffic such as data rate, packet size, inter-packet delay, packet header and payload can be easily configured through a GUI. The architecture of the traffic generator is modular and each module can be configured without FPGA reconfiguration. The creation of new modules modifying the generated traffic is also possible.

The traffic generator is able to generate traffic accurately at any rate up to 20 Gb/sec, even when sending small packets, which are the most challenging to handle. The generator respects the configured data rate with a very good accuracy.

6 New Results

6.1 Inter-domain issues

Participants: Sandrine Vaton, Romain Jacquet, Géraldine Texier, Alberto Blanc.

In [19] we consider a problem related to possible feedback from the monitoring plane to the business plane. The latest results of the PhD of Maria Isabel Amigo, defended in 2013 and co-advised by the University of the Republic (Montevideo, Uruguay), are published in this article. The PhD was performed in the framework of the European Integrated Project ETICS. The research context concerns the pricing of quality assured services in Network Service Providers (NSPs) alliances. We consider a situation in which the service is sold through first price auctions and a percentage q of the price paid for is reimbursed in case the quality is not satisfied. In a previous article we have proven that the percentage of reimbursement that maximizes the seller's revenue is $q = 100\%$ in case of symmetric buyers. In particular this value prevents problems such as the market for lemons which would arise if no reimbursement takes place. In this article we present a simulator that can be used in order to determine the optimal percentage of reimbursement in case of asymmetric buyers (with different willingness to pay). We demonstrate by performing numerous simulations that once again the optimal percentage is $q = 100\%$.

In [27], we address the computation of end-to-end QoS paths in a graph representing the Internet that comprises alliances and ASes, where both ASes and alliances publish a list of offers describing the QoS guarantees that they can offer between their entry and exit points. Value added services like VoIP, videoconferencing and IPTV need end-to-end Quality of Service (QoS) guarantees in order to work correctly. As the Internet is a collection of Autonomous Systems (AS), most of the time the communication endpoints belong to different ASes, so that all the ASes traversed by the communication must cooperate in order to offer end-to-end guarantees. Yet each AS is usually unwilling to disclose any detail about its internal network. To address this confidentiality issue we propose in [27] a system where each AS publishes a list of offers, specifying the QoS guarantees between its entry and exit points, without specifying

anything else about its internal network. As proposed in several works, it is also possible for ASes to form alliances, which can be seen as “macro ASes” that publish the available offers between the entry and exit points of the alliance. We propose ACQA, an algorithm that can find end-to-end paths satisfying given QoS constraints by combining the offers of several alliances and/or ASes.

6.2 Large scale delivery of live video streams

Participants: Gwendal Simon, Alberto Blanc, Géraldine Texier, Karine Pires.

The delivery of multimedia applications have become a major concern for network operators because these applications have stringent requirements, which are sometimes difficult to accommodate with the underlying protocols and infrastructure of Internet.

We have worked on live streaming for Content Delivery Networks (CDNs). The demand for large-scale delivery of live video grows tremendously. New solutions are expected. Our main goal has been to find a trade-off between the Quality of Experience (QoE) and the infrastructure cost. We have proposed several solutions based on dynamic adaptive streaming technologies, where one video stream is offered from several video representations. The main idea is to determine the best representations so that both end-users are satisfied and the overall volume of data to deliver within the CDN infrastructure is limited. One of our solutions is to not send all representations to all edge-servers [16]. Another idea is to modify the encoding parameters of the representations [41]. In the specific case of cellular network, we have studied an optimization framework for uploading live videos from the smartphones to the base station [35]. Finally, another solution consists in selecting the live streams that actually benefits from a delivery with adaptive streaming [36].

We have also started to study the CDN from an economic point of view [33]. The growing importance of CDNs in the value chain of content delivery raises concerns about the “neutrality” of these players. We have proposed a model to analyze the impact of revenue-oriented CDN management policies on the fairness of the competition among two content providers that use CDN services to deliver contents. We have showed that there exists a unique optimal revenue-maximizing policy for a CDN actor, which depends on prices for service/transport/storage, and on the distribution of content popularity.

Finally, we have studied some new architectures for large-scale delivery actors. One of these architectures targets the cloud gaming applications [9]. In this case, the live stream is generated by the game engine, which is hosted in the cloud. The need for interactivity requires the development of specific solutions, based on CDN. We have also studied caching approaches in the context of Information-Centric Network (ICN) [14]. The idea behind ICN is to cache the content directly into the routers, which brings many opportunities. Finally, another approach is to leverage Peer-to-Peer (P2P) technologies to assist the delivery. Our goal is not to develop new P2P solutions, but rather to optimize the use of resources when several P2P overlays compete [15].

6.3 Network Monitoring

Participants: Franck Cornevaux, André Lalevée, Tristan Groléat, Santiago Ruano Rincon,

Sandrine Vaton.

The PhD of Tristan Groléat [4] has been defended in march 2014. This PhD has been dedicated to high performance traffic monitoring for network security and network management. The PhD was performed in the framework of the European Integrated Project DEMONS, and in collaboration with the UMR Lab-STICC. The goal was to investigate possible solutions to design monitoring probes that support high data rates (dozens of Gb/sec). We have worked on software (CPU, GPU) and hardware (FPGA) acceleration of algorithms. Platforms such as NetFPGA 4G and 40G cards and INVEA-TECH COMBO 20G have been used for the experiments. Different use cases have been considered, among which traffic classification with SVM, high speed traffic generation for stress tests, and the detection of some flooding attacks (Distributed Denial of Service, DDoS). These optimized applications all work over 10 Gb/s and could support more, proving the feasibility of advanced high-speed network monitoring tools. Our latest developments in this line of work have been published in two journal papers [13] [12]. Two PhD have started in fall 2014 to continue research in this direction (André Lalevée, Franck Cornevaux Juignet).

6.4 Mobility Management

Participants: Hassan Ali-Ahmad, Xavier Lagrange, Gwendal Simon.

Current network architectures, as well as mobility management protocols, are generally deployed in a centralized manner. All the data traffic passes through a single centralized entity, and all the users' bindings are managed at this entity as well. As the number of mobile users and the volume of their traffic increase, such centralized architectures are expected to encounter scalability issues as well as performance issues. Moreover, these protocols are designed to be always activated, managing all the services and all the traffic in the same way. They do not take into consideration that a given mobile user may not move during the use of a service or that a service may not require mobility functions at all. Such approaches may thus lead to non-optimal routing and large overhead due to tunneling mechanisms.

Recently, mobile network operators are experiencing a rapid increase in mobile data traffic. In order to cope with this, a new trend is to flatten networks architectures and hence IP mobility management protocols need to be adapted for such evolution. Therefore, there is a need to define novel mobility management mechanisms that are both distributed and offered dynamically. They should be distributed in order to avoid any network bottleneck or single point of failure, and to provide better reliability. They should be activated and deactivated dynamically as needed, in order to globally reduce the network resources consumption and to increase the achieved performances. In order to cope with this context, the thesis of Hassan Ali-Ahmad [1] concerns designing, analyzing, and evaluating novel IPv6 network architectures and mobility protocols that are distributed and dynamic, and in particular distributed mobility management (DMM). We proposed a new distributed dynamic mobility management scheme. The proposed scheme is mainly based on the mobile IPv6 (MIPv6) protocol, with an optional extension for the joint use with the session initiation protocol (SIP). The proposed scheme operations are detailed in different scenarios. In order to evaluate the proposed scheme, we carry out a qualitative analysis as well as a quantitative analysis in terms of mobility costs,

handover, and quality-of-service [7]. After assuring the benefits of the proposed scheme, we study its impacts on other aspects such as security considerations and location management, proposing a solution track for each. The quantitative analysis was extended in [17] to take into account the number of contexts that should be maintained by the different entities of the network with a distributed approach.

6.5 Radio and Optical Technologies for access and metro networks

Participants: Annie Gravey, Xavier Lagrange, Souheir Eido, Moufida Feknous, Younes Khadraoui, Jelena Pesic, Ion Popescu, Lida Sadeghioon, Ahmed Triki, Bogdan Uscumlic.

In 2014, we² have mostly focused on optical metro networks that support sub-wavelength granularity. A WDM link may carry as much as 40 or 80 separate data channels (each data channel corresponds to a single wavelength). Two OBS technologies are considered:

- Packet Optical Add-Drop Multiplexer (POADM) ring networks, which relies on multiple synchronized data channels that are shared between nodes. A node inserts at most one optical packet per slot whenever possible (opportunistic access);
- Time-Domain Wavelength Interleaved Network (TWIN) mesh networks which operates as the superposition of several multipoint-to-point trees. Each tree corresponds to a given wavelength, that is dedicated to a given destination. A node can send at most one packet per slot, and a scheduler is used to avoid contention in intermediate nodes and at destination.

In the framework of the SASER project, we have continued working on TWIN networks, and more particularly on resource allocation for a given traffic matrix. This involves the computation of the scheduler that is used to avoid contention in all nodes (source, intermediate, destination). This study has been partly carried out with colleagues from Orange Labs, who also participate to SASER. A large part of the obtained results are related to dimensioning techniques implementing on Routing and Wavelength Assignment (RWA) problems, and relying on ILP techniques. Our current results have then been obtained for small networks. We have focused on several aspects:

- relationship between scheduler optimization, requested QoS (in terms of latency) and network performance [26];
- introduction of scheduling policies that are robust to single link failures [38, 39]; both dedicated and shared protection schemes have been considered;
- comparison between dynamic scheduling performed by the control plane and static scheduling performed by the management plane [5, 42].

Moreover, we have provided several comparative studies of the two competing technologies (POADM and TWIN) supporting sub-wavelength granularity [38, 37]. In general, the data channel related cost is higher for TWIN as in TWIN each destination is allocated one or several

²Only REOP participants are cited in the list of participants

wavelengths in POADM, a single wavelength can carry packets for several destinations. On the other hand, the node related cost is higher for POADM as packets are handled optically in each transit node.

We have finalized our work regarding the design of a MAC for POADM networks by a presentation during OFC'2014 [25] which was expanded into an invited paper to be published in 2015. We have specified a MAC structure for multiring POADM networks, which can support multiprotocol encapsulation and provides the support of differentiated quality of service (QoS) and differentiated protection on a per-flow basis. Unicast and multicast flows are efficiently transported between stations, with a lightweight control within each station. An opportunistic insertion process associated with an appropriate scheduling process is shown to ensure transport network QoS levels. Simple models are provided to assess the transfer performance on the POADM ring. Per-flow protection mechanisms are proposed, and their efficiency is assessed. Using label controlled mapping and switching provides POADM networks with a clean separation between data and control planes. The data plane is controlled by various local tables that can be static (as in the current Metro networks), periodically distributed by a centralized control plane (as in a SDN framework), or locally computed thanks to some distributed procedures (as in a GMPLS framework). It is thus shown that POADM rings can be used to directly support metro Ethernet services and allow collapsing the stack of transport network layers.

Today, customers can access services via fixed line networks or via radio access networks (RAN). Controlling these access networks consists in both performing control of each access network, and allowing concurrent access to several such networks. Up to now, fixed and mobile access networks have been optimized and evolved independently, with partly contradicting trends (e.g. centralization of fixed networks, decentralization of mobile networks). Currently, there is a complete functional and physical separation of fixed line access/aggregation networks and mobile networks. In the framework of the COMBO project, we study Fixed Mobile Convergence (FMC) at network level. We contribute to the specification of different convergent architectures in [24]. The team first focuses on the design of procedures enabling the users to dynamically select one access network (or possibly several) for a given service, and enabling network operators to effectively share deployed resources (links and equipment) between fixed and mobile accesses. In [28], we consider the different cooperation schemes between cellular networks and Wi-Fi-based accesses in order to offload cellular networks. We proposed in [31] a very tight coupling between LTE and Wi-Fi, which can be used to enhance the offloading procedures. In this architecture PDCP (Packet Data Convergence Protocol) is used as the common layer between LTE and Wi-Fi and the security procedures defined for LTE are reused for Wi-Fi transmission. It is thus possible to use Wi-Fi transmissions even when a terminal is covered by a Wi-Fi access point for a short period. In [29], we study how residential gateways that includes Wi-Fi access points can be virtualized.

The global network architecture should also be revisited by taking advantage of the new optical access technologies. This is reported in [11], which shows that the current aggregation architecture based on primary and secondary aggregation rings should be reconsidered to limit potential bottlenecks and to take account of both infrastructure costs and potential energy savings. The paper then presents alternative architectures to revise and move the boundaries existing today between access and aggregation networks. A first alternative architecture is

fully centralized and performs traffic aggregation in a central location. The second alternative architecture proposes to locate the first aggregation points (called "Next Generation Points of Presence") on the primary aggregation ring and to centralize control functions.

Lastly, as the current LTE architecture is challenged by a rapid increase of mobile data traffic, different offloading scenarios are considered, which help operators controlling the ever increasing of mobile data volumes over the femto and the macro cellular networks. In [23], we consider the Selected IP traffic offload (SIPTO) approach in order to selectively offload mobile IP traffic in order to use servers deployed within the metro network "at/above the RAN". A quantitative study is carried out to estimate the potential gains of bandwidth due to mobile traffic offload, both in the core and the metro networks, depending on the location of the servers accessed thanks to the offloading strategy. It is shown that up to 30% of core network capacity can be spared by implementing this approach and by geographically distributing video servers and data centres. These extensive offload techniques rely on advanced network interface selection and advanced route controls, which in turn implement network interface selection mechanisms supported in existing mobility and multihoming protocols; [34] provides a survey of these network interface selection mechanisms.

6.6 Radio Resource Management and Energy Efficiency

Participants: Loutfi Nuaymi, Xavier Lagrange, Hussein Al Haj Hassan, Muhammad Moiz Anis, Luis Suarez.

Energy-efficient cell breathing is a mechanism that consists of adapting the cell sizes and the number of active Base Stations (BS) to the distribution and current levels of traffic. In [40] we analyse the effect of this technique on the electromagnetic (EM) radiation levels for mobile phone devices. Although there exist large details in the literature of cell-breathing on energy-efficiency related to the Radio Resource Management (RRM) aspects, to the best of our knowledge there is still a lack of work on analysing the consequences of cell-breathing and BS switching-off schemes on the EM exposure issues related to the mobile terminal. In such approaches during low-traffic periods (whereas there are some BSs being switched-off) there are some other BSs that must remain active expanding their cell sizes to guarantee coverage. This requires a transmission power increase for both downlink and uplink side, which implies for mobile devices an increase of the specific absorption rate (SAR) [W/kg] on the mobile user. To conduct our study, we use one of our previously proposed techniques on cell-breathing to analyse the impact of uplink transmission power increase on resulting SAR levels. Here, different BS switching-off aggressiveness levels are considered to observe the resulting exposure levels using a 3G/CDMA scenario. The results show how SAR maximum levels increase as more aggressive switching-off schemes take place as well as the uplink interference rises due to a progressive increase of network load.

In [20], we study the problem of wireless schedulers for cloud-based wireless gaming systems, with focus on energy efficiency issues. While green communications and networks have been widely studied in recent years, the rise of gaming based on wireless clouds introduces many specific aspects allowing important savings and improvements. We try to minimize the power consumption of this type of networks in a hybrid WiFi/LTE radio access network (RAN) by

proposing a novel Wireless Cloud Scheduler (WCS) mechanism and applying different power utility functions. We find that it is possible to reduce the power consumption, increase the maximum attainable capacity of the network in terms of number of served UEs and minimize the costs of cloud resources usage, while maintaining a good level of QoS.

Recently, renewable energy (RE) has been introduced as a promising solution to reduce the "non-green" energy consumption of cellular networks. In [18], we study the electric bill reduction of a cellular network powered by both RE sources and the power grid in a variable electricity price environment. We decompose the problem of electric bill reduction into three sub-problems: RE allocation, energy consumption minimization and radio resource allocation (RRA). In this context, we propose a new algorithm that adjusts the network configuration to increase the utilization of RE. Results show the efficiency of our proposed algorithm, where it achieves 30 percent reduction of energy consumption and outperforms a benchmark algorithm with a gain of up to 20 percentage points in terms of electric bill reduction.

Nowadays, smartphones are used to download files such as movies, music, etc. These files present some flexibility in delivery time; we exploit this feature to reduce network overload peaks. If the network is overloaded, downloads are postponed, thus reducing the traffic load during rush hours. In [8] we proposed an architecture that enables the network to determine the best time to trigger a download that is queued. This architecture is based on a specific server in the network and a mobile application. By reducing the peak load, over-dimensioning the radio resource (transmission power, number of radio channels) is then avoided. This is thus a way of improving the energy efficiency.

Using a relay approach can be also a way to improve the efficiency and the capacity of wireless and cellular networks. We propose a simple adaptation of the Wi-Fi medium access control in [32] to allow any Wi-Fi terminal to act as a relay. In [21] and [22], we study how mobile relays can be used in the context of public transportation and analyse the increase of capacity that can be expected with mobile relays.

For massive distribution of the same content (video, audio, text,...) broadcast technologies are the most efficient ones. However, the link budget of the new broadcast radio interface DVB-T2 (Digital Video Broadcasting - Second Generation Terrestrial) cannot guarantee a good coverage level to handheld terminals. We then propose a novel cooperation scheme between broadcast systems and cellular networks: the LTE network helps in resolving the DVB handheld outage by retransmitting the missing DVB sequences to the handheld receivers. In [2], we analyzed the coverage for handheld receivers in a single frequency broadcast network. We specifically considered several outdoor and indoor scenarios in a DVB-T2 network. We analyzed how a data flow is processed in DVB-T2 and proposed a scheme for the identification of packets in the DVB transmission. The core contribution of the work is the proposition of a Real-time Flow Repair (RFR) Service based on cellular network, which repairs any multimedia data-flow to the handheld receivers in real-time. The proposed RFR service is based on a light client-server application protocol, namely Constrained Application Protocol (CoAP). The RFR proposal is also supported by the analysis of the load generated in LTE Radio access network due to RFR service.

7 Contracts and Grants with Industry

7.1 Orange Labs contract on net neutrality and delivery through CDN

Participants: Gwendal Simon.

This contract aims at studying from an economic perspective the net neutrality debate regarding large-scale delivery of video streams. Today's, the net neutrality debate focuses on network operators and on the management of packets at the router level. We would like to study the debate from a broader perspective by analyzing the full value chain and the interplay between various actors.

7.2 Orange Labs CIFRE on detection and correction of faults in networks

Participants: Sandrine Vaton, Serge Romaric Tembo.

We have a 3 year (2013-2016) bilateral CIFRE project with Orange Labs on the application of swarm intelligence to the detection, isolation and correcting of multiple faults in telecommunication networks. The PhD of Serge Romaric Tembo is performed in the framework of this collaboration. _____

7.3 Orange Labs CIFRE contracts on mobility management

Participants: Xavier Lagrange, Gwendal Simon, Nahla Abid, Hassan Ali Ahmad, Siwar Ben Hadj Said, Malla Reddy Sama.

We have four 3-year CIFRE projects with Orange Labs on mobility management. Mobility management may generate a large amount of signalling that can be in some cases concentrated on a single node. That node can be a single point of failure. Furthermore, in a mobile network by essence any user may access the network on any location. Mobility and security should then be jointly considered. The CIFRE theses with Orange Labs address these different issues. They are supervised with Jean-Marie Bonnin from OCIF team. Regular internal progress meetings that gather all supervisors and all PhD students are organized to stimulate cross-fertilization. The subjects of the theses are

- Naming, Address and Mobility in Future Internet (Nahla Abid)
- Distributed and Dynamic Mobility Management in Future Internet (Hassan Ali Ahmad)
- Contextual Connectivity in Access Networks in Future Internet (Siwar Ben Hadj Said)
- Virtualized EPC - Benefits and Limits (Malla Reddy Sama)

7.4 Orange Labs CIFRE contract on IP-centric QoS management in mobile networks

Participants: Xavier Lagrange, William David Diego Maza.

We have a 3-year CIFRE projects with Orange Labs on traffic engineering in mobiles networks. This contract funds William Diego Maza's thesis. Mobile networks are currently facing a data traffic explosion. Consequently, congestion may appear soon, thus degrading the customer experience. QoS mechanisms are then required to preserve the most sensitive and/or valuable flows. 3GPP proposes a model capable of supporting several levels of QoS. However, this model was inherited from connection-oriented legacy networks and raises issues in terms of scalability, efficiency, performances and flexibility when used in the context of the foreseen mobile Internet. The objective of the work is to study IP-centric mechanisms that can be both simple and cheap to deploy and efficient enough to provide several levels of QoS. This project has been started in 2013.

7.5 Orange Labs CIFRE contract on access and metro networks

Participants: Annie Gravey, Moufida Feknous.

We have a 3-year CIFRE projects with Orange Labs on traffic engineering in optical access networks. This contract funds Moufida Feknous's thesis, and is part of a long standing cooperation between Orange Labs and Telecom Bretagne on optical networking. While the thesis funded by this contract focuses on traffic management issues in Optical access and aggregation networks, we shall also collaborate on the FP7 COMBO project that starts in 2013.

7.6 SYSTUF

Participants: Xavier Lagrange, Yang Yang Chen.

- Title: SYStèmes télécoms pour les Transports Urbains du Futur
- Framework: Fonds national pour la Société Numérique - Usages, services et contenus numériques innovants, Consultation AAP Systèmes de Transport Intelligents
- Duration: 2012-2015
- Partners : IFSTTAR (formerly INRETS), Eurecom, MERCE (Mitsubishi Electric), Alcatel-Lucent, RATP, ALSTOM
- Abstract: the objective of SYSTUF is to define and implement a new broadband multiservice wireless communication system for public transportation systems (bus, tram, metro). The technology is based on (LTE, Long Term Evolution) and more specifically on LTE mobile relays. On major constraint is to use the same system for critical communications (Communication Based Transport Control), Video transmission (CCTV), passenger information and infotainment. Reop is involved in the performance analysis of the gain provided by mobile relays and the protocols to develop to optimize mobility management.
- See also : <http://systuf.ifsttar.fr/>

7.7 CELTIC SASER-SAVENET

Participants: Annie Gravey, Bogdan Uscumlic.

- Title: Safe and Secure European Routing
- Framework: CELTIC project
- Duration: 2012-2015
- Partners : Alcatel-Lucent, Nokia Siemens Networks, ADVA Optical Networking, Deutsche Telekom, Orange Labs, INRIA, Telecom Bretagne³
- Abstract: The Internet has become an indispensable part of the infrastructure for most of the aspects of daily life and has developed to a fundamental infrastructure for Europe. The uninterrupted, reliable and secure access to the Internet is seen as a basic right for all citizens and a significant economical factor. The number of attacks on Internet-connected systems are growing and the attacks have become more serious and more technically complex than in the past and can affect an increasing number of sensitive applications, e.g. e-government or e-commerce. It is then critical to ensure security and privacy, service quality and reliability, instantaneous and protected access, scalability. The goal of the SASER research programme is to provide the scientific, technical, and technological concepts and solutions for secure transport networks in the 2020 time frame. A European solution envisaged by SASER is based on the strengths and expertise in security and high-speed optical transport networks to overcome the bottlenecks and vulnerabilities of today's electronic all-IP based infrastructure.
- See also : <http://www.celtic-initiative.org/Projects/Celtic-Plus-Projects/2011/SASER/saser-default.asp>

7.8 CELTIC Opera Net 2

Participants: Loutfi Nuaymi, Hussein Al Haj Hassan.

This project also includes some researcher from the "Micro Ondes" Department of Telecom Bretagne: Francois Le Penec, Christian Person and Vu La Tran.

- Title: Optimising Power Efficiency in Mobile RAdio Networks 2
- Framework: Celtic (European) Projects
- Duration: dec 2011 - may 2015
- Partners : In addition to Telecom Bretagne, the other partners are: Orange, Alcatel Lucent, Thompson Broadcast, Université de Caen, Nheolis (From France), Nokia Siemens Networks, VTT, Efore (from Finland), University of Cardiff (from UK), Mitra Innovation (from Belgium)

³In the list of participants above, only REOP participants are cited.

- Abstract: Reducing the overall environmental impact of mobile radio networks is a central factor in achieving improved mobile services and enabling a growing telecommunications industry in emerging markets. The OPERA-Net-2 (Optimising Power Efficiency in Mobile Radio Networks 2) project concentrates on this challenge, addressing both energy and material efficiencies of 3G, 4G and heterogeneous networks, while also considering the use of renewable energy sources.
- See also : <http://projects.celticplus.eu/opera-net2/>

7.9 FP7 COMBO

Participants: Annie Gravey, Xavier Lagrange, Souheir Eido, Moufida Feknous, Younes Khadraoui.

- Title: CONvergence of fixed and Mobile BrOadband access/aggregation networks (COMBO)
- Framework: EU FP7
- Duration: january 2013 – december 2015 (36 months)
- Partners : In addition to Telecom Bretagne⁴, the other partners are: JCP-connect, Deutsche Telekom AG, Orange, Telefonica, FON Wireless Ltd, Argela, Ericsson, Alcatel Lucent, ADVA Optical Networking Ltd, Telnet, Aitia, Centre Tecnologic de Telecomunicacions de Catalunya, Politecnico di Milano, Lund University.
- Abstract: COMBO will propose and investigate new integrated approaches for Fixed / Mobile Converged (FMC) broadband access / aggregation networks for different scenarios (dense urban, urban, rural).
- See also : <http://www.ict-combo.eu/>

8 Other Grants and Activities

8.1 International Collaborations

Visiting researchers

- Juan Pedro Munoz-Gea from Universidad Politecnica de Cartagena (Spain) spent four months in the ReOP team to study more specifically video uploading in heterogeneous networks. His visit has led to the publication of one article [35].

⁴In the above list of participants, only REOP participants are cited

9 Dissemination

9.1 Organization of conferences

20th Eunice Open European Summer School and Conference

The EUNICE network (see <http://www.eunice-forum.org>) has been created to foster the mobility of students, faculty members and research scientists working in the field of information and communication technologies and to promote educational and research cooperation between its member institutions.

The main goal of the EUNICE Summer School is to give researchers and particularly Ph.D. students the opportunity to present their work at an international level. The 20th EUNICE summer school was held in Rennes on September 1-5, 2014 and was hosted by Telecom Bretagne. It was co-chaired by Jean-Marie Bonnin, Annie Gravey and Yvon Kermarrec.

9.2 Program committees

Annie Gravey is editor for the Journal of Communications and Networks, an international English-language journal published by the Korea Information and Communications Society. In 2014, she served in the Program Committee of the following conferences:

- CAMAD 2014, 19th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks
- WCNC 2014, IEEE Wireless Communications and Networking Conference
- Wimob 2014, 9th International Conference on Wireless and Mobile Computing, Networking and Communications
- ICACCI 2014, IEEE Second International Conference on Advances in Computing, Communications and Informatics
- Globecom 2014, IEEE Global Communications Conference
- ONDM 2014, 17th International Conference on Optical Networking Design and Modeling
- Eunice 2014, 20th Conference on Information and Communications Technologies
- WCSP'14, 2014 6th International Conference on Wireless Communications and Signal Processing
- Networks 2014 - 16th International Telecommunications Network Strategy and Planning Symposium
- ITC'2014 - 26th International Teletraffic Congress (ITC 26)
- ICC'14 CQRM (IEEE ICC 2014 - Communication QoS, Reliability and Modeling Symposium)

Xavier Lagrange is member of the scientific committee of Annals Of Telecommunications published by Springer.

Loutfi Nuaymi is regular reviewer for Wiley Editions books proposals. He also served or serves in the Program Committee of the following conferences:

- WCNC 2014, IEEE Wireless Communications and Networking Conference
- ICC'14 CRN (IEEE ICC 2014 - Cognitive Radio and Networks Symposium)
- VTC 2014 Fall, Vehicular Technology Conference Fall 2014

Gwendal Simon is in the editorial board of the IEEE MMTC R-letters related to Multimedia ACM SIG chapter. He also serves in the Program Committee of the following conferences:

- ACM Multimedia 2014, ACM flagship conference on Multimedia
- IEEE ICC 2014, IEEE International Conference on Communications
- IEEE Globecom 2014, IEEE Global Communications Conference
- Packet Video 2014, 21th IEEE International Packet Video Workshop
- ACM Netgames 2014, 12th ACM Workshop on Network and Systems Support for Games
- ACM Nossdav 2014, 24th ACM workshop on Network and Operating System Support for Digital Audio and Video

Sandrine Vaton serves in the Program Committee of the following conferences:

- TRAC 2014, 5th International Workshop on TRaffic Analysis and Characterization (TPC co-chair)
- IFIP Networking 2014 Conference

10 Bibliography

Major publications by the team in recent years

- [1] M. I. AMIGO, P. BELZARENA, F. LARROCA, S. VATON, "Network bandwidth allocation with end-to-end QoS constraints and revenue sharing in multi-domain federations", *in: ICQT'11: 7th International ICQT Workshop on Advanced Internet Charging and QoS Technology*, S. Verlag (editor), p. 50 – 62, Heidelberg, Germany, 2011.
- [2] A. AWANG, X. LAGRANGE, D. R. SANCHEZ, "RSSI-based forwarding for multihop wireless sensor networks", *Lecture notes in computer science 5733*, august 2009, p. 138 – 147.
- [3] P. BERTIN, S. BONJOUR, J.-M. BONNIN, "Distributed or centralized mobility ?", *in: IEEE Globecom'09 : Global communications conference*, 2009.

- [4] G. BERTRAND, S. LAHOUD, M. MOLNAR, G. TEXIER, *Inter-domain path computation with multiple QoS constraints*, Nova Science Publisher, Hauppauge NY, USA, 2010, ch. Recent advances in providing QoS and reliability in the future Internet backbone.
- [5] G. BERTRAND, S. LAHOUD, M. MOLNAR, G. TEXIER, *QoS routing and management in backbone networks*, IGI Global, Hershey, Pennsylvania, USA, 2010, ch. Intelligent quality of service technologies and network management: models for enhancing communication.
- [6] G. BERTRAND, S. LAHOUD, G. TEXIER, M. MOLNÁR, “A distributed exact solution to compute inter-domain multi-constrained paths”, *The Internet of the Future*, 2009, p. 21–30.
- [7] Y. CHEN, E. L. MERRER, Z. LI, G. SIMON, Y. LIU, “OAZE: a network-friendly distributed zapping system for peer-to-peer IPTV”, *Computer networks - The international journal of computer and telecommunications networking* 56, 1, january 2012, p. 365 – 377.
- [8] B. HAN, J. LEBLET, G. SIMON, “Hard multidimensional multiple choice knapsack problems, an empirical study”, *Computers & operations research* 37, 1, january 2009, p. 172 – 181.
- [9] X. LAGRANGE, “Throughput of HARQ protocols on a block fading channel”, *IEEE communications letters* 14, 3, march 2010, p. 257 – 259.
- [10] J. LEBLET, Z. LI, G. SIMON, D. YUAN, “Optimal network locality in distributed virtualized data-centers”, *Computer communications* 34, 16, october 2011, p. 1968 – 1979.
- [11] Z. LI, G. SIMON, A. GRAVEY, “Caching Policies for In-Network Caching”, *in: ICCCN 2012: IEEE International Conference on Computer Communication Networks*, IEEE (editor), 2012.
- [12] Z. LI, G. SIMON, “Time-shifted TV in content centric networks: the case for cooperative in-network caching”, *in: ICC2011: IEEE International Conference on Communications*, IEEE (editor), 2011.
- [13] U. MIR, L. NUAYMI, “LTE Pricing Strategies”, *in: VTC Spring 2013: Vehicular Technology Conference*, 2013.
- [14] M. T. NGO, A. GRAVEY, D. BHADAURIA, “Controlling QoS in EPON-based FTTH access networks”, *Telecommunication systems*, may 2010.
- [15] L. SADEGHIOON, A. GRAVEY, P. GRAVEY, “A label based MAC for OPS multi-rings”, *in: ONDM 2011 : 15th International Conference on Optical Network Design and Modeling*, 2011.
- [16] M. SAIDI, G. TEXIER, “Hybrid scale-based approximation algorithm for QoS routing”, *in: Telecommunications (ConTEL), Proceedings of the 2011 11th International Conference on*, IEEE, p. 367–374, 2011.
- [17] B. USCUMLIC, I. CERUTTI, A. GRAVEY, D. BARTH, P. CASTOLDI, M. MORVAN, P. GRAVEY, “Optimal dimensioning of the WDM unidirectional Ecoframe optical packet ring”, *Photonic network communications*, july 2011.

Doctoral dissertations and “Habilitation” theses

- [1] H. ALI AHMAD, *Design and Analysis of Distributed Mobility Management in IPv6 Mobile Networks*, PhD Thesis, RSM - Dépt. Réseaux, Sécurité et Multimédia (Institut Mines-Télécom-Télécom Bretagne-UEB), IRISA - Institut de recherche en informatique et systèmes aléatoires (UMR CNRS 6074), january 2014.

- [2] M. M. ANIS, *Cooperative Retransmission of Broadcast Data Flows Via Cellular Networks*, PhD Thesis, RSM - Dépt. Réseaux, Sécurité et Multimédia (Institut Mines-Télécom-Télécom Bretagne-UEB), IRISA - Institut de recherche en informatique et systèmes aléatoires (UMR CNRS 6074), february 2014.
- [3] S. BEN HADJ SAID, *Contextual connectivity in multi-access architectures*, PhD Thesis, RSM - Dépt. Réseaux, Sécurité et Multimédia (Institut Mines-Télécom-Télécom Bretagne-UEB), IRISA - Institut de recherche en informatique et systèmes aléatoires (UMR CNRS 6074), décembre 2014.
- [4] T. GROLEAT, *High Performance Traffic Monitoring for Network Security and Management*, PhD Thesis, INFO - Dépt. Informatique (Institut Mines-Télécom-Télécom Bretagne-UEB), Lab-STICC - Laboratoire en sciences et technologies de l'information, de la communication et de la connaissance (UMR CNRS 6285), IRISA - Institut de recherche en informatique et systèmes aléatoires (UMR CNRS 6074), march 2014.
- [5] A. TRIKI, *Etude des techniques de transport de données par commutation de rafales optiques sans résolution spectrale de la contention*, PhD Thesis, INFO - Dépt. Informatique (Institut Mines-Télécom-Télécom Bretagne-UEB), may 2014.
- [6] W. YOU, *A Content-Centric Networking Node for a Realistic Efficient Implementation and Deployment*, PhD Thesis, INFO - Dépt. Informatique (Institut Mines-Télécom-Télécom Bretagne-UEB), IRISA - Institut de recherche en informatique et systèmes aléatoires (UMR CNRS 6074), january 2014.

Articles in referred journals and book chapters

- [7] H. ALI AHMAD, M. OUZZIF, P. BERTIN, X. LAGRANGE, "Performance Analysis on Network-based Distributed Mobility Management", *Wireless personal communications* 74, 4, january 2014, p. 1245 – 1263.
- [8] E. A. CELIS MUÑOZ, F. LE DENMAT, A. MORIN, X. LAGRANGE, "Multimedia content delivery trigger in a mobile network to reduce the peak load", *Annals of telecommunications - annales des télécommunications*, december 2014.
- [9] S. CHOY, B. WONG, G. SIMON, C. ROSENBERG, "A Hybrid Edge-Cloud Architecture for Reducing On-Demand Gaming Latency", *Multimedia Systems* 20, 5, october 2014, p. 503 – 519, Paru en ligne 11 avril 2014.
- [10] D. ESPES, X. LAGRANGE, L. A. SUAREZ RIVERA, "A cross-layer MAC and routing protocol based on slotted aloha for wireless sensor networks", *Annales des télécommunications- Annals of telecommunications*, 2014, Article paru en ligne - 26 avril 2014 - pagination en attente.
- [11] M. R. FEKNOUS, B. LE GUYADER, A. GRAVEY, "Revisiting Access and Aggregation Network Architecture", *Journal of advances in computer networks* 2, 3, september 2014, p. 163 – 168.
- [12] T. GROLEAT, M. ARZEL, S. VATON, "Stretching the edges of SVM traffic classification with FPGA acceleration", *IEEE transactions on network and service management* 11, 3, september 2014, p. 1 – 14.
- [13] T. GROLEAT, S. VATON, M. ARZEL, "High-Speed Flow-Based Classification on FPGA", *International journal of network management* 24, 4, august 2014, p. 253 – 271.

- [14] Z. LI, G. SIMON, “Cooperative Caching in a Content Centric Network for Video Stream Delivery”, *Journal of network and systems management*, 2014, p. 1 – 29, Paru en ligne - 16 janvier 2014 - pagination en attente.
- [15] J. LIU, S. AHMAD, E. BUYUKKAYA, G. SIMON, R. HAMZAOU, “Resource allocation in under-provisioned multioverlay peer-to-peer live video sharing services”, *Peer-to-peer networking and applications*, avril 2014, p. 1 – 15.
- [16] J. LIU, C. ROSENBERG, G. SIMON, G. TEXIER, “User-centric discretized delivery of rate-adaptive live streams in underprovisioned CDN networks”, *IEEE journal on selected areas in communications* 32, 4, avril 2014, p. 706 – 718.
- [17] K. MUNIR, X. LAGRANGE, P. BERTIN, M. OUZZIF, K. GUILLOUARD, “Performance analysis of mobility management architectures in cellular networks”, *Telecommunication systems*, december 2014, p. 1 – 17.

Publications in Conferences and Workshops

- [18] H. AL HAJ HASSAN, A. PELOV, L. NUAYMI, “Cost-Efficient Radio Resource Allocation in Hybrid Energy Cellular Networks”, *in: GLOBECOM 2014 - SAC : Global Communications conference - symposium on Selected Areas in Communications : Green Communication Systems and Networks*, 2014.
- [19] M. I. AMIGO, S. VATON, P. BELZARENA, “First-price auctions with reimbursement in NSP alliances with asymmetric buyers”, *in: LANC 2014 : 8th Latin America Networking Conference*, 2014.
- [20] R. CARE, H. AL HAJ HASSAN, L. A. SUAREZ RIVERA, L. NUAYMI, “Energy-Efficient Scheduling for Cloud Mobile Gaming”, *in: GLOBECOM 2014 : 2nd Workshop on Green Broadband access: energy efficient wireless and wired network solutions*, 2014.
- [21] Y. CHEN, X. LAGRANGE, “Downlink Capacity Gain Analysis of Mobile Relay in LTE-Advanced Network”, *in: CCNC 2014 : 11th Annual IEEE Consumer Communications & Networking Conference*, 2014.
- [22] Y. CHEN, P. MARTINS, L. DECREUSEFOND, X. LAGRANGE, F. YAN, “Stochastic analysis of a cellular network with mobile relays”, *in: GLOBECOM 2014 : IEEE Global communications conference*, 2014.
- [23] S. EIDO, A. GRAVEY, “How much LTE traffic can be offloaded?”, *in: EUNICE 2014 : 20th Eunice Open European Summer School and Conference - EUNICE/IFIP EG 6.2, 6.6*, Springer (editor), 8846 - LNCS (*Lecture Notes in Computer Science*), p. 48 – 58, 2014.
- [24] S. P. GOSSELIN, J. DE BIASIO, F. MOUFIDA, T. MAMOUNI, J. ALFONSO TORRIJOS, L. CUCALA, D. BREUER, E. WEIS, F. GEILHARDT, D. V HUGO, E. BOGENFELD, A. HAMIDIAN, N. FONSECA, Y. LIU, S. KUEHRER, A. GRAVEY, A. MITCSENKOV, J. GALAN, E. MASGRAU RITE, L. SIMON GOMEZ, L. ALONSO, S. HÖ ST, A. MAGEE, “Fixed and Mobile Convergence: Needs and Solutions”, *in: EW 2014 : proceedings of the 20th European Wireless Conference*, IEEE (editor), 2014.
- [25] A. GRAVEY, P. GRAVEY, M. MORVAN, L. SADEGHIOON, B. USCUMLIC, “QoS of Optical Packet Metro networks”, *in: OFC 2014 : the Optical Fiber Communication Conference and Exposition*, p. paper W1C.5 –, 2014.

- [26] A. GRAVEY, B. USCUMLIC, Y. POINTURIER, P. GRAVEY, L. ALAHDAB, I. POPESCU, “Efficient Resource Allocation in Time-Domain Wavelength Interleaved Networks”, *in: ONDM 2014 : 18th International Conference on Optical Network Design and Modeling*, IEEE (editor), p. 293 – 298, 2014.
- [27] R. JACQUET, G. TEXIER, A. BLANC, “Computing end-to-end QoS paths in the Internet considering multiple alliances”, *in: Telecommunications Network Strategy and Planning Symposium (Networks), 2014 16th International*, p. 1–6, Sept 2014.
- [28] Y. KHADRAOUI, X. LAGRANGE, A. GRAVEY, “A Survey of Available Features for Mobile Traffic Offload”, *in: EW 2014 : proceedings of the 20th European Wireless Conference*, IEEE (editor), p. 1 – 4, 2014.
- [29] Y. KHADRAOUI, X. LAGRANGE, “Virtual residential gateways: Architecture and performance”, *in: EuCNC2014 : 23rd European Conference on Networks and Communications*, 2014.
- [30] T. V. LA, F. LE PENNEC, M. AUBRÉE, T. GALKIN, S. ELENGA, L. NUAYMI, “Small Wind Turbines on Pylon Powering Base Transceiver Stations: A Study of Radio Interactions”, *in: INTELEC 2014 : 36th International Telecommunications Energy Conference*, p. 1 – 6, 2014.
- [31] X. LAGRANGE, “Very Tight Coupling between LTE and Wi-Fi for Advanced Offloading Procedures”, *in: WCNC 2014 : IEEE Wireless Communications and Networking Conference*, 2014.
- [32] L. LOISEAU, N. MONTAVONT, X. LAGRANGE, “Opportunistic Relays in 802.11 Networks”, *in: IEEE Vehicular Technology Conference*, IEEE (editor), p. 1 – 6, Canada, 2014.
- [33] P. MAILLÉ, K. PIRES, G. SIMON, B. TUFFIN, “How Neutral is a CDN: An Economic Approach”, *in: CNSM 2014 : 10th International Conference on Network and Service Management*, 2014.
- [34] P. MITHARWAL, C. LOHR, A. GRAVEY, “Survey on Network Interface Selection in Multihomed Mobile Networks”, *in: EUNICE 2014 : 20th Eunice Open European Summer School and Conference - EUNICE/IFIP EG 6.2, 6.6*, Springer (editor), 8846 - LNCS (Lecture Notes in Computer Science), p. 134 – 146, 2014. Advances in Communication Networking : 20th EUNICE/IFIP EG 6.2, 6.6 International Workshop.
- [35] J. P. MUNOZ GEA, R. APARICIO PARDO, H. WEHBE, L. NUAYMI, G. SIMON, “Optimization Framework for Uplink Video Transmission in HetNets”, *in: MOVID 2014 : ACM Workshop on Mobile Video Delivery*, ACM (editor), p. Article n06 –, 2014.
- [36] K. PIRES, G. SIMON, “DASH in Twitch: Adaptive Bitrate Streaming in Live Game Streaming Platforms”, *in: VideoNext 2014 : 1st Workshop on Design, Quality and Deployment of Adaptive Video Streaming*, 2014. Part of the CoNEXT 2014 conference.
- [37] Y. POINTURIER, B. USCUMLIC, A. GRAVEY, M. LOTT, Q. WEI, “A Comparison of Sub-wavelength Optical Switching Networks for LTE Mobile Backhauling”, *in: ICTON 2014 : 16th International Conference on Transparent Optical Networks*, IEEE (editor), p. 1 – 4, 2014. Paru en ligne - pagination en attente.
- [38] I. POPESCU, B. USCUMLIC, Y. POINTURIER, P. GRAVEY, M. MORVAN, A. GRAVEY, “A cost comparison of survivable subwavelength switching optical metro networks”, *in: ITC 26 : proceedings of the 2014 26th International Teletraffic Congress*, 2014.

- [39] I. POPESCU, B. USCUMLIC, Y. POINTURIER, P. GRAVEY, M. MORVAN, A. GRAVEY, “Cost of Protection in Time-Domain Wavelength Interleaved Networks”, *in: NOC 2014 : 19th European Conference on Network and Optical Communications*, p. 108 – 114, 2014.
- [40] L. A. SUAREZ RIVERA, L. NUAYMI, C. PERSON, J.-M. BONNIN, “Impact of Energy-Efficient Cell-Breathing on the Electromagnetic Radiation Levels of Mobile Phone Devices”, *in: PIMRC 2014 : IEEE 25th International Symposium on Personal, Indoor and Mobile Radio Communications*, 2014.
- [41] L. TONI, R. APARICIO PARDO, G. SIMON, P. FROSSARD, A. BLANC, “Optimal Set of Video Representations in Adaptive Streaming”, *in: MMSys 2014 : ACM Multimedia Systems conference*, p. 271 – 282, 2014.
- [42] A. TRIKI, R. APARICIO PARDO, P. GAVIGNET, B. ARZUR, A. GRAVEY, E. LE ROUZIC, “Is It Worth Adapting Sub-Wavelength Switching Control Plane to Traffic Variations?”, *in: ONDM 2014 : 18th International Conference on Optical Network Design and Modeling*, IEEE (editor), p. 186 – 191, 2014.