



Project-Team REOP

***Réseaux d'opérateurs***

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## **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 monitoring: traffic analysis for security and estimating the 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.

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.

With 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 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 integrating new features in GMPLS (which is the current framework used in operators' networks to globally command their networks), or by providing another layer above GMPLS and above new optical network segments that allows to *stitch together* their respective mechanisms and thus obtain end-to-end control. This is facilitated by generalizing label switching in technologies used for transport networks. A likely candidate to provide this upper layer is related to Software Defined Networking (SDN) which is a tool that helps in network virtualization.

## 4 Application Domains

### 4.1 Inter-domain Issues

**Participants:** Maria Isabel Amigo, Alberto Blanc, Annie Gravey, Mohamed Karim Sbai, 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. The main consequence of this evolution is the question about 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 co-operation incentives problems between Network Service Providers like reputation or monetary issues for example by revenue sharing [11] or reimbursement when QoS is not fulfilled [32].

### 4.2 Information Centric Networking

**Participants:** Gwendal Simon, Annie Gravey, Mohamed Karim Sbai, Pratibha Mitharwal, Zhe Li, Wei You, Sandrine Vaton.

An Internet user cares more about *which* content (or information) it is interested in than about *the location* of the content. Unfortunately today's IP Network architecture relies on a host-to-host conversation model, which may have made sense in the last century but does no longer match the demands from end-users, content providers, and network operators. A very pragmatic approach to this problem has been provided by Content Distribution Networks (CDNs) that take charge of a large proportion of the contents distributed over the Internet today.

To address this fundamental issue, some network scientists support a clean-slate construction of an information-centric network (ICN) where content discovery is directly implemented in the inner routing protocols. Since 2009, the proposals related to ICN have flourished. While it is still difficult to predict whether these proposals have any chance to be implemented in a reasonably short term, current debates about the principles of ICNs lead to fundamental questions about the evolution of networks in general.

In parallel to clean-slate approaches, other groups attempt to patch the current architecture e.g. by proposing addressing schemes that separate *the location* from *the identity* of contents.

### 4.3 Network Monitoring

**Participants:** Sandrine Vaton, Tristan Groléat, Mohamed Karim Sbai, Maria Isabel Amigo, Géraldine Texier.

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

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).

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 necessary to characterize the network.

### 4.4 Mobility Management

**Participants:** Xavier Lagrange, Gwendal Simon, Kashif Munir.

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<sup>[Ber10]</sup> 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

#### 4.5 Radio and Optical Technologies for access and metro networks

**Participants:** Annie Gravey, Xavier Lagrange, Lida Sadeghioon, Moufida Feknous.

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 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 function.

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.

#### 4.6 Radio Resource Management and Energy Efficiency

**Participants:** Loutfi Nuaymi, Xavier Lagrange, Usama Mir, 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

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[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.

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 Lagrange<sup>1</sup>.

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.

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<sup>1</sup>Only participants in REOP are listed.

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 [3, 14]. 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/](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 Section 7.11). 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>.

## 6 New Results

### 6.1 Inter-domain issues

**Participants:** Isabel Amigo, Sandrine Vaton, Mohamed Karim Sbai, Géraldine Texier.

Autonomous System alliances or federations are envisioned to emerge in the near future as a means of selling end-to-end quality assured services through interdomain networks. This collaborative paradigm mainly responds to the ever increasing Internet traffic volumes that requires assured quality, and constitutes a new business opportunity for Network Service Providers (NSPs).

However, current Internet business rules are not likely to satisfy all involved partners in this emerging scenario. How the revenue is shared among NSPs must be agreed on in advance, and should enforce economical incentives to join an alliance and remain in it, so that the alliance remains stable. We have worked on the scenario of such federations, where service selling is formulated as a Network Utility Maximization (NUM) problem [1].

In this context, we have formally formulated the properties the revenue sharing (RS) method should fulfill and argued why the existing methods are not suitable. Finally, we have proposed a family of solutions to the RS problem such that the economical stability and efficiency of the alliance in the long term is guaranteed. The proposed method is based on solving a series of Optimization Problems and considering statistics on the incomes [11].

Assured Service Quality (ASQ) goods can be monitored in order to check the conformity of the delivered QoS to Service Level Agreements (SLAs). Monitoring QoS in an interdomain framework is a challenging task. We have designed [33] a monitoring solution for ASQ goods that span multiple domains. This solution has been implemented and tested in a laboratory testbed before its integration in a prototype of the EU FP7 ETICS project [7].

Then we have studied how feedback from the monitoring plane can be brought into the business plane. We have assumed that Assured-Quality Services are sold through first-price auctions, and that in case of failure, a percentage of the price paid for the service is given back to the buyers. In some simple cases we have derived the expression for the optimal bidding strategy and we have modeled the pricing problem through a Stackelberg game. The game has been solved in order to determine which percentage of reimbursement in case of service failures maximizes seller's revenue and leads to an equilibrium. In more complex scenarios where no closed form solution can be derived for the best bidding strategy we have studied numerical approaches in order to draw similar conclusions [32].

## 6.2 Information Centric Networking

**Participants:** Annie Gravey, Zhe Li, Gwendal Simon, Wei You, Mohamed Karim Sbai, Sandrine Vaton.

We have been focusing on the hardware architecture of ICN routers, especially the so-called *node* that has been defined in the popular Content-Centric Network (CCN) protocol. We observed that one of the most critical components of a CCN node, the Pending Interest Table (PIT), did not get much attention. The PIT is involved in the forwarding processes in both upstream (reception of Interest messages) and downstream (reception of Data messages) ways. On the one hand, the PIT should be large enough to store a high volume of information. On the other hand, the PIT should be quick enough to not become a bottleneck in message processing. In [30, 29], we proposed a novel implementation of PIT, named DiPIT. The idea is to deploy a small-size fast memory on every interface. Our approach relies on Bloom Filters in order to reduce the necessary memory space for implementing the PIT, completed with a central Bloom Filter for limiting the false positives generated by the individual Bloom Filters.

Another part of our research activity related to ICN has dealt with *in-network caching*. The ICN proposals have indeed enabled the exploitation of the caching resources in the new generation of routers (Content Routers or CR). So far, only a basic Least Recently Used (LRU) strategy implemented on every CR has been proposed. More generally, the research community lacks methods for analyzing and evaluating caching policies (other than LRU) in generic multi-cache topologies. In [20], we provide a model that approximates the hit-ratios of any multi-cache topology for the Least Recently/Frequently Used (LRFU) caching policies, which consist of a spectrum of policies based on a trade-off between recency and frequency. We also present a way to approximate the performances of the network of caches when the input traffic changes. The approximation results can be used to decide suitable policy for CR at different positions in the network topology. With appropriate policy for each single CR, we are able to improve the performance of the whole in-network caching system.

Then, we have worked on an evolutionary and pragmatic method to efficiently deploy an

ICN architecture based on the collaboration between service providers or traditional CDNs and peer-assisted CDNs operated by ISPs. In [19], we have proposed a network-friendly content delivery architecture that considers the complex video distribution chain and its associated business models. This comprehensive architecture allows a network operator to fully engineer video traffic distribution in order to both alleviate peering links' workload and improve delivered QoS. This proposal is fully compatible with Adaptive Bitrate Streaming (ABS) architectures, which are currently used to distribute video in the Internet.

### 6.3 Large scale delivery of multimedia

**Participants:** Eliya Buyukkaya, Jiayi Liu, Gwendal Simon.

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 developed solutions for three different multimedia applications:

First at all, we have worked on large-scale live streaming systems. These applications usually leverage Content Delivery Networks (CDNs). However CDNs can experience bottlenecks within their infrastructure. In particular, the “equipment bottleneck” occurs when the fan-out of a machine does not enable the concurrent transmission of a stream to multiple other equipments. In [31], we aimed to deliver a live stream to a set of destination nodes with minimum throughput at the source and limited increase of the streaming delay. We leveraged on rateless codes and cooperation among destination nodes. With rateless codes, a node is able to decode a video block of  $k$  information symbols after receiving slightly more than  $k$  encoded symbols. To deliver the encoded symbols, we used multiple trees where inner nodes forward all received symbols. Our goal was to build a diffusion forest that minimizes the transmission rate at the source while guaranteeing on-time delivery and reliability at the nodes. We made two contributions. When the network is assumed to be lossless and the constraint on delivery delay is relaxed, we gave an algorithm that computes a diffusion forest resulting in the minimum source transmission rate. We also proposed an effective heuristic algorithm for the general case where packet loss occurs and the delivery delay is bounded.

Our second application was a multioverlay live video sharing service consisting of multiple independent peer-to-peer live video streaming systems. We had two distinct contributions. In [21], we addressed the interoverlay bandwidth competition problem caused when a user can simultaneously watch multiple live video streams. This problem is to find an upload bandwidth allocation between the overlays each peer has subscribed to. We showed that an allocation of upload resources that minimizes the wastage of resources (i.e., minimizes the upload bandwidth allocated to overprovisioned overlays) can be computed in polynomial time. In [4], we focused on zapping, which involves switching overlays and may introduce delays that can hurt the user experience. We presented a distributed system called OAZE (Overlay Augmentation for Zapping Experience) which speeds up the switching process and reduces the overall cross-domain traffic generated by the IPTV system. In OAZE, each peer maintains connections to other peers, not only in a given channel, but also in a subset of all channels to which the associated user is likely to zap. More specifically, we focused on the channel

assignment problem, *i.e.* determining, in a given P2P overlay, the optimal distribution of the responsibility to maintain contact peers to other channels. We proposed an approximate algorithm providing guaranteed performances, and a simpler and more practical one.

Finally, we observed that many of cloud computing's core design tenets, such as consolidating resources into a small number of datacenters and fine-grain partitioning of general purpose computing resources, conflict with an emerging class of multimedia applications that is highly latency sensitive and requires specialized hardware, such as graphic processing units (GPUs) and fast memory. In [15], we looked closely at one such application, namely, on-demand gaming (also known as cloud gaming), that has the potential to radically change the multi-billion dollar video game industry. We demonstrated through a large-scale measurement study that the current cloud computing infrastructure is unable to meet the strict latency requirements necessary for acceptable game play for many end-users, thus limiting the number of potential users for an on-demand gaming service. We further investigated the impact of augmenting the current cloud infrastructure with servers located near the end-users, such as those found in content distribution networks, and showed that the user coverage significantly increases even with the addition of only a small number of servers.

## 6.4 Network Monitoring

**Participants:** Tristan Groléat, Mohamed Karim Sbai, Sandrine Vaton.

We have worked on different aspects of network monitoring in the framework of the EU FP7 project DEMONS, the EU FP7 project ETICS, and the ANR project VIPEER.

In DEMONS we have contributed to the development of Blockmon (see Section 5.2). It is based on the notion of blocks which are elementary traffic processing units (e.g. packet counting, Bloom filters, etc...). Blocks can be inter-connected via gates in order to make a composition which can target a specific scenario. Different monitoring scenarios such as DDoS or VoIP threats detection have been envisioned in order to illustrate the capabilities of Blockmon. Optimization mechanisms in Blockmon include hardware traffic capture and processing and software optimization to accelerate the communication between blocks. Blockmon is distributed under BSD-style licence and will be presented at INFOCOM 2013 [14].

Another line of research around high speed traffic analysis concerns hardware accelerated traffic classification. Understanding the composition of the Internet traffic has many applications such as tracking bandwidth consuming applications, QoS-based traffic engineering and lawful interception of illegal traffic. Although many classification methods such as Support Vector Machines (SVM) have demonstrated their accuracy, not enough attention had been paid to the practical implementation of lightweight classifiers. In [16] we have considered the design of a real-time SVM classifier at many Gbps to allow online detection of categories of applications. This solution is based on the design of a hardware accelerated SVM classifier on a FPGA board (NetFPGA, COMBO).

## 6.5 Mobility Management

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

In 2012, the work on DMA has been extended in the framework of several thesis and one research contract with France Télécom : a performance analysis has been conducted to compare the cost of DMA against PMIP [10]. We consider the cost regarding the signaling load, processing, the data packet delivery and tunneling mechanisms. The results show that DMA outperforms PMIPv6 significantly even with highly mobile terminals because the anchor node is dynamically selected and can be generally close the current access point of the mobile node.

A new host-based distributed mobility management support protocol designed for the current evolution of mobile network architectures was also proposed in [18]. Mobility anchors are distributed at an access network level and a mobile node is served by a close-by mobility anchor. While the mobile node changes its point of attachment to the Internet, it keeps previous IP address(es) for continuous communications established with the previous IP address(es). The performance analysis confirmed that the proposed DMM support protocol eliminates the limitations of Mobile IPv6 (MIPv6) while taking advantages of the current evolution of mobile network architectures. In addition, as the proposed protocol is based on MIPv6, it can be extended through existing MIPv6 extensions such as fast handover, flow management and multihoming.

Intelligent Transport Systems (ITS) for public transportation will be possible only if users can have a reliable and high bit-rate access to the Internet. It requires the development of mobile routers and network mobility protocols. In this context, security is mandatory as a lot of ITS applications are related to safety. However, both security and mobility may generate a lot of signalling. Hence, they should be jointly optimized. Nerea Toledo Gandarias who spent several monthes in RSM department addressed this issue in his thesis<sup>[Gan12]</sup>. In [8], we introduced the NeMHIP (Network Mobility Management Protocol based on Host Identity Protocol). The main idea behind NeMHIP is to have a global management of mobility for the whole embedded local network but to manage security association on an individual basis for each terminal in the local network. In NeMHIP both the data plane and the signalling plane are protected. Therefore, NeMHIP mitigates security attacks that compromise both end-user services and ITS operational services. We evaluated through analytical modelling the efficiency of NeMHIP in terms of signalling overhead and verified that it is more efficient with respect to signalling on equal terms of security support than other standard protocols like HIP-NEMO.

## 6.6 Radio and Optical Technologies for access and metro networks

**Participants:** Annie Gravey, Xavier Lagrange, Lida Sadeghioon, Moufida Feknous.

The work on access and metro networks based on optical technologies has first been pursued in 2012 by considering migration issues, between current architectures and others relying more fully on optical technologies.

Although many predict that xPON access is likely to replace xDSL access in fixed networks, it is still unclear how the cost induced by phasing out xDSL architectures in order to deploy

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[Gan12] N. T. GANDARIAS, *Network Mobility Management Protocols for ITS. The Secure and Efficient NeMHIP protocol*, PdD Thesis, Departamento ingeniería de comunicaciones, University of the Basque Country, Spain, avril 2012.

optical fibre covering a large proportion of the population can be met, and by whom. We have compared DSL and PON from a techno-economic point of view [9]. We also considered Long-Reach Optical Access, which augments the span of the access network. All potential solutions are evaluated on the basis of Payback Period, Net Present Value and Internal Rate of Return. The market is segmented in different areas depending on their respective households density, and various business models are considered, in order to assess the impact of public funding. The French market is shown to be the most demanding in Europe, due to its low broadband access tariffs. The paper shows that, unless the take up rate for optical access significantly increases beyond its actual value, the profitability of deploying optical access for the network operators is low.

Whereas the previous study focused mostly on the access segment, the major part of our results is related to the metro segment. [6] focuses on the metro segment and compares the power consumption for four different technologies: Ethernet, Reconfigurable Optical Add-Drop Multiplexers (ROADM), Optical Transport Networks (OTN), and an optical packet switching (OPS) solution called Packet Optical Add-Drop Multiplexers (POADM), which was recently proposed. A novel resource allocation strategy for POADMbased OPS multi-rate rings is proposed for the first time. The multi-rate POADM ring network resource allocation problem is shown to be NP-hard and solved using both an MILP formulation and a heuristic. The MILP formulation and the heuristic are compared, along with dimensioning results for Ethernet and ROADM/OTN ring networks. Results show that multirate POADM rings achieve savings up to 10% with respect to single-rate design and can be enabled by assigning a different rate to each wavelength. Furthermore, POADM rings can be up to 5 times more energy-efficient than Ethernet rings and 30% than ROADM rings, assuming similar network efficiencies.

Lastly we proposed innovative solutions for providing resilience in Optical Packet Multi-Ring networks based on POADMs. Each ring network is made of two unidirectional transparent WDM optical packet switched rings, each with a separate control channel synchronized with one or several data channels. Two rings networks are interconnected by two adjacent nodes in order to ensure resilience. Such a multi-ring network is a good candidate for replacing the current SDH multi-ring metro networks as it presents many features of a Transport Network. Contrarily to existing Ethernet rings or RPR networks, it is fully optically transparent within one ring, and may not access the client layer at interconnecting nodes, which allows to provision client layers only at the edges of this network. A multi-class label-based MAC has been proposed, and resilience mechanisms for both unicast [24] and multicast transport have been proposed.

## 6.7 Radio Resource Management and Energy Efficiency

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

A great number of research papers and collaborative projects exist nowadays on the topic of energy efficiency. In [7], we first summarize the metrics used in the related literature for performance evaluation. Then, we focus on describing the current solutions proposed. The main approaches are reviewed: the component level research, where the efforts are mainly

concentrated on the power amplifier section; the cell layout adaptation including the cell zooming technique, and coverage extension methods like femtocells and relays; finally, we study the radio resource management (RRM) and the Cognitive radio (CR). These methods are analysed, compared, classified and then an integration model is proposed. We finally describe some major collaborative projects dedicated to this topic.

Efficient radio resource usage and quality of service (QoS) provision are important criterions in order to choose the right QoS policy for the LTE operators. In previous work, we have proposed to add a new database named as BSLRC (Base Station Load and Radio Conditions) to optimize the operator policy with regard to the radio efficiency. In [12], we extend our earlier work by addressing some novel concerns. As a first step, we start by calculating the signaling load due to the use of BSLRC. Then, for voice services the BSLRC method is compared with the explicit congestion notification (already proposed for LTE systems). Both BSLRC and ECN (Explicit Congestion Notification) share the same objective of optimizing the choice of codec rate with regard to radio use efficiency. We also propose some capacity estimates for video services as an extension to our previously proposed voice capacity estimations over LTE systems.

Hybrid ARQ (Automatic Repeat reQuest) protocols that combine Forward Error Correction and automatic requests are used in a lot of wireless networks. In classical approaches, retransmitted packets are different versions of the same user data. In order to improve HARQ performance, we proposed to construct redundancy packets by jointly encoding several data packets. This strategy is referred to as HARQ Multiple Packet Incremental Redundancy (MP-IR). It can eliminate imperfect feedback effect on performance at medium to high Signal to Noise Ratio (SNR) values. On the other hand, classical HARQ Single Packet Incremental Redundancy (SP-IR) strategy is more robust at low SNR. This has motivated us to introduce a hybrid SP-IR and MP-IR strategy. This strategy can benefit from SP-IR performance at low SNR and MP-IR performance at medium to high SNR as shown in [13]. More generally, in the PhD thesis of M.E. El Aoun in cooperation with Telecom Bretagne dept Signal and Communications and LabSTIC<sup>[Aou12]</sup>, different types of strategies that combine ARQ, Forward Error Correction, Single and Multiple Packet Retransmission have been studied. The original contribution is to analyse the performance not only from a throughput point of view but also from an energy efficiency point of view.

## 6.8 Other results

[25] [26] [27] [28] [23] [22] [17] [5] [12]

Loutfi Nuaymi has defended his "Habilitation à Diriger les Recherches" (HDR) on the management of radio ressources in cellular networks [1]. Sandrine Vaton has defended her "Habilitation à Diriger les Recherches" on theoretical and practical aspects of network monitoring [2]. Both HDR have been registered at the university of Rennes 1.

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[Aou12] M. E. AOUN, *Optimisation des techniques de codage pour les transmissions radio avec voie de retour*, PdD Thesis, SC - Dépt. Signal et Communications (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 - Télécom Bretagne - Université de Bretagne Occidentale - Université de Bretagne Sud), juillet 2012.

## 7 Contracts and Grants with Industry

### 7.1 Orange Labs contract on mobility management

**Participants:** Xavier Lagrange, Kashif Munir.

We started a 2-year (2010 - 2012) bilateral project with Orange Labs on mobility management. Currently network architectures are deployed in a hierarchical manner with a central gateway that concentrates the traffic towards mobile terminals. A more decentralized approach has been proposed in a joint research between Reop and Orange labs with DMA (Dynamic Mobility Anchoring) and is currently specified by IETF. The objective of Didagmo is to analyse the performance of DMA for large scale networks by use of stochastic analysis.

### 7.2 Orange Labs CIFRE contract on ICN

**Participants:** Gwendal Simon, Wei You.

We have a 3-year (2010 - 2013) bilateral CIFRE project with Orange Labs on Information-centric Networks. This contract funds the PhD thesis of Wei You.

### 7.3 Orange Labs CIFRE contracts on mobility management

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

We have five 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)
- Network as a service : What can be offered by access network part ? (Lounes Baleh)
- 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 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.

## 7.5 ANR ViPEER

**Participants:** Annie Gravey, Gwendal Simon, Zhe Li, Sandrine Vaton, Mohamed Karim Sbai, Pratibha Mitharwal.

- Title: Distributed content Delivery Networks for intra-domain video delivery
- Framework: ANR Verso
- Duration: 2009-2012
- Partners : Orange Labs, Eurecom, Envivio, INRIA, NDS technologies
- Abstract: The main objective of the Vipeer project is to provide methods allowing a network operator to have explicit control on traffic flows related to video distribution. VIPEER builds upon the collaboration between a traditional CDN and a peer-assisted CDN or "distributed CDN" (dCDN), i.e. an overlay controlled by the network operator using P2P paradigms. The peers in the dCDN may be network elements such as network nodes or boxes located at customers' premises. In the latter case, the box is actually split between a private part which is directly under the customer's control and a "public" part that is managed within the distributed overlay, by the network operator.
- See also : <http://recherche.telecom-bretagne.eu/vipeer/description/>

## 7.6 FUI Zewall

**Participants:** Loutfi Nuaymi, Gwendal Simon.

For Telecom Bretagne, this project also includes some researchers from the OCIF team: Bruno Stevant and Ahmed Bouabdallah.

- Title: Zewall
- Framework: FUI11
- Duration: 2011-2013
- Partners: Orange Labs, Le Telegramme, Nexcom, Niji, Saooti, ST Ericsson, Telecom Bretagne.

- Abstract: Smartphones are everywhere, and with their built-in cameras the possibilities are endless. Let's imagine; Spectators film several football matches in a local championship at the same time. These images are sent in real time to a Web portal, a portal where people can see any of the matches live, make comments, react to results and so on. This scenario is one of the usage cases studied by the Zewall project. Its objective is to create the conditions which will enable self-shot videos to be sent from smartphones, the different sources to be combined on the Internet and the videos to be broadcast live. While it looks simple, the local football multiplex example is based on a host of future technologies, starting with fourth generation mobile networks and a new Internet language version. With this live collaborative video solution, Zewall is targeting social networks, information sites and commercial sites. It will lead to two real-scale experiments in Brest as, in addition to the technological challenge, Zewall is exploring the uses of tomorrow.

## 7.7 FUI Odisea

**Participants:** Annie Gravey, Gwendal Simon, Karine Pires.

- Title: Odisea
- Framework: FUI11
- Duration: 2011-2014
- Partners : Orange labs, Telecom SudParis, Technicolor, University Pierre et Marie Curie, Enovance, Ubistorage
- Abstract: The ODISEA project aims to provide an open and distributed storage cloud by designing an architecture exploiting storage resources and services deployed within the network as well as that of the end users. The latter is particularly interesting since a large quantity of today's as well as tomorrow's content is user generated. The project analyses requirements emerging from three domains. The first domain is health with the emergence of telemedicine and the needs to store, process and serve medical images. The second addresses domestic users to allow them to backup personal content on the cloud as well as to share such content in a manner similar to social networks. Finally the project also analyses use cases emerging from small and medium companies.

## 7.8 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://www.inrets.fr/linstitut/unites-de-recherche-unites-de-service/leost/projets/projets-en-cours/systuf.html>

## 7.9 CELTIC SASER

**Participants:** Annie Gravey.

- 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
- 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>

## 7.10 FP7 CNG

**Participants:** Gwendal Simon, Jiayi Liu, Eliya Buyukkaya.

- Title: Community Network Games
- Framework: The CNG project is funded under the ICT (Information and Communication Technologies) priority of the European Union's FP7 (Seventh Framework Programme).
- Duration: 30 months
- Partners : Exent (Coordinator), Computer Technology Institute (CTI), De montfort University, Kaltura, Redbedlam, European Game Developer Federation (EGDF), i2 media.
- Abstract: Massive Multiplayer Online Games (MMOGs) are growing exponentially due to advances in the generation of engaging immersive content and the availability of high speed and capacity networks. One of the main characteristics of the MMOGs is that they enable users to become members of active communities with common interests, shared adventures and common objectives. Enabling thousands of users to communicate with each other in a 3D online world creates large network demands, in terms of required bandwidth and low latency for the users to have a rewarding experience. CNG intends to enhance collaborative activities between online gamers by developing new tools for the generation and distribution of UGC within existing MMOGs. CNG team will research and develop in-game community activities using in-game graphical insertion technology (IGIT) and a P2P (peer-to-peer) architecture for the distribution of video and other UGC. The project intends to research and develop new sophisticated techniques for P2P 3D/Video streaming that are "friendly" to the MMOG client server traffic. Additionally, the Community Network Game project will support and enhance community activities between gamers which may be enhancing many current MMOGs, without the need to redevelop their game code. For this purpose, the InGame Graphics Insertion Technology (IGIT) can be used to change existing game graphics and to add additional windows on demand (e.g., browser, chat, etc.) that can be inserted floating on or out of the game area. CNG, with the use of IGIT, will allow the addition of new engaging community services without a need to change the game code, and without adding new processing or network loads to the MMOGs' central servers.
- See also : <http://www.cng-project.eu>

## 7.11 FP7 DEMONS

**Participants:** Sandrine Vaton, Tristan Groléat, Mohamed Karim Sbai.

- Title: DEcentralized, cooperative and privacy-preserving MONitoring for trustworthi-nesS (DEMONS)

- Framework: european collaborative research project within the ICT theme of the 7th Framework Programme of the European Union that contributes to the objective "Network of the Future" of the Work Programme
- Duration: september 2010 – march 2013 (30 months)
- Partners : TID (Telefonica), NEC Europe, CNIT (Italy), FTW Vienna, TPSA (Poland), France Télécom, Institut Mines Télécom, ETH Zürich, Singular Logic, INVEA-Tech, ICCS (Athens), OPTENET, KYOS
- Abstract: In summary, the core problem in cooperative network monitoring and mitigation is that incidents impacting the security and reliability of a given network today are complex, with threats widely distributed among attackers, intermediary systems, indirect targets, and direct targets, all potentially lying in different organizations, parts of the network, and national jurisdictions. The legal, organizational, and technical infrastructure to respond to these incidents must therefore be distributed and cooperative. DEMONS project addresses the major challenges of cooperative network monitoring.
- See also : <http://fp7-demons.eu/>

## 7.12 FP7 ETICS

**Participants:** Sandrine Vaton, Maria Isabel Amigo, Mohamed Karim Sbai, Géraldine Texier.

- Title: Economics and Technologies for Inter-carriers Services (ETICS)
- Framework: EU FP7
- Duration: january 2010 – march 2013 (36 monts + extension of 3 months)
- Partners: Alcatel Lucent Bell Labs France, Alcatel Lucent Italy, RAD Data Communications (Israel), Marben Products (France), Nextworks (Italy), British Telecommunications, Deutsche Telekom, Orange Labs, Telefonica I+D (Spain), Telenor (Norway), Athens University of Economics and Business, FTW Vienna, Institut Mines Télécom, Politecnico di Milano, PRISM (Université de Versailles), Technion (Israel), Primetel (Cyprus), University of Stuttgart
- Abstract: ETICS aims at creating a new ecosystem of innovative QoS-enabled interconnection models between Network Service Providers allowing for a fair distribution of revenue shares among all the actors of the service delivery value-chain. To achieve these objectives, ETICS analyses, specifies and implements new network control, management and service plane technologies for the automated end-to-end QoS-enabled service delivery across heterogeneous carrier networks. ETICS includes a large number of partners that, participating to several key projects, have matured strong expertise. ETICS prototypes on control, management, and service planes also leverages an important background on implementations and performance assessment. They allow demonstrating and testing the

effectiveness of new business models as well as how agile network service creation, activation, monitoring and billing for interconnected fixed and mobile operators will improve time to market of new services and reduce operational costs and complexity. Therefore, increasing the economic efficiency of access and transport infrastructures, the transition to new generation equipments will be incentivized.

- See also: <https://www.ict-etics.eu/>

### 7.13 CELTIC Opera Net 2

**Participants:** Loutfi Nuaymi, Hussein Al Haj Hassan.

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

- Title: Optimising Power Efficiency in Mobile RAdio Networks 2
- Framework: Celtic (European) Projects
- Duration: oct 2011 - Sept 2014
- 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)
- 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/>

## 8 Other Grants and Activities

### 8.1 International Collaborations

**STIC AmSud MAITRE** Sandrine Vatou is the international coordinator of a STIC AmSud project: Monitoring, Analysis and Traffic Engineering in Heterogeneous Networks (MAITRE). This is a two years long project that started in January 2011 (January 2010–December 2012). The MAITRE consortium is made up of Télécom Bretagne, IIE (UdelaR, Uruguay), UBA (Buenos Aires, Argentina), and LAAS/CNRS. From the REOP project the participants are Sandrine Vatou, Maria Isabel Amigo and Géraldine Texier. The PhD of Maria Isabel Amigo is co-advised by Télécom Bretagne and IIE and fun

### Visiting researchers

- Professor Pablo Belzarena from IIE (UdelaR, Uruguay) has been invited for a two weeks long stay at Télécom Bretagne in Brest in may-june 2012. This stay has been funded by the STIC AmSud project MAITRE. The main goal of this stay was to progress on the PhD of Maria Isabel Amigo which is co-advised by Télécom Bretagne and IIE.

## 8.2 European Initiatives

**NoE EuroNF Participants:** Annie Gravey, Sandrine Vaton, Géraldine Texier.

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 ended in June 2012 (see [http://euronf.enst.fr/en\\_accueil.html](http://euronf.enst.fr/en_accueil.html)).

## 9 Dissemination

### 9.1 Organization of conferences

**International Workshop on TRaffic Analysis and Classification (TRAC)** Sandrine Vaton is the chairman of the International Workshop on Traffic Analysis and Classification (TRAC). This workshop is colocated with IWCMC and dedicated to traffic monitoring and analysis. The third edition of this workshop has been organized in august 2012 in Limassol, Cyprus.

### 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 2012, she served in the Program Committee of the following conferences:

- ICC 2012, ICC 2013, IEEE International Conference on Communications
- CAMAD 2012, 17th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks
- ICC 2012, the first IEEE International Conference on Communications in China
- WCNC 2012, IEEE Wireless Communications and Networking Conference
- PIMRC 2012, IEEE 23rd International Symposium on Personal, Indoor and Mobile Radio Communications
- Wimob 2012, 8th International Conference on Wireless and Mobile Computing, Networking and Communications

- NOTERE/CFIP 2012, 15th CFIP (Colloque francophone sur l'ingénierie des protocoles) and 11th NOTERE (Nouvelles Technologies de la Répartition)
- Networks 2012, 15th International Telecommunications Network Strategy and Planning Symposium
- Internet 2012, The Fourth International Conference on Evolving Internet
- Eunice 2012, 18th Conference on Information and Communications Technologies

Xavier Lagrange is member of the scientific committee of Annals Of Telecommunications published by Springer. He also serves in the Program Committee of the following conferences:

- ISWCS 2012, The Ninth International Symposium on Wireless Communication Systems, Paris, France, August 28-31, 2012
- WPMC 2012, The 15th International Symposium on Wireless Personal Multimedia Communications, Taipei, Taiwan, Sept 24-27, 2012

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

- WCNC 2012, IEEE Wireless Communications and Networking Conference, Paris, France, April, 2012
- WPMC 2012, Wireless Personal Multimedia Communications, September, 2012
- VTC 2013 Spring, Vehicular Technology Conference Spring 2013, June 2013

Gwendal Simon serves in the Program Committee of the following conferences:

- ICC 2013, IEEE International Conference on Communications
- Globecom 2012, IEEE Global Communications Conference
- ICCCN 2012, 21st IEEE International Conference on Computer Communication Networks
- LCN 2012, 38th IEEE Conference on Local Computer Networks
- Packet Video 2012, 19th IEEE International Packet Video Workshop
- Netgames 2012, 11th ACM Workshop on Network and Systems Support for Games
- Eunice 2012, 18th Conference on Information and Communications Technologies
- Nem Summit 2012
- Algotel 2012

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

- Next Generation Internet conference (NGI 2012)

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### Doctoral dissertations and “Habilitation” theses

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