



Project-Team REOP

Réseaux d'opérateurs

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1 Team

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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 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: 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. 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 Information Centric Networking

Participants: Gwendal Simon, Annie Gravey, Mohamed Karim Sbai, 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 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, Serge Romaric Tembo, Santiago Ruano Rincon, 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 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.

4.4 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

4.5 Radio and Optical Technologies for access and metro networks

Participants: Annie Gravey, Xavier Lagrange, Bogdan Uscumlic, Lida Sadeghioon, Souheir Eido, Younes Khadraoui.

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

[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.

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 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.

4.6 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 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 criteria 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 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 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>. Blockmon has been presented at INFOCOM 2013 [36].

¹Only participants in REOP are listed.

5.3 High performance open source traffic generator

Participants: Tristan Groléat, Sandrine Vaton.

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 [25].

6 New Results

6.1 Inter-domain issues

Participants: Isabel Amigo, Sandrine Vaton, Romain Jacquet, Géraldine Texier.

Providing Assured-Quality Services over data networks has been a key objective for the past few decades. Research and commercial activities have been focused on several aspects related to this main objective, such as implementing services over heterogeneous networks, providing scalable solutions and verifying network performance.

However, less attention has been devoted to the interaction of these technical aspects with the business plane. Although several quality-based pricing schemes have been proposed, reimbursement proposals, while quite common in other scenarios as health, hotel reservation or airlines, are still rare in the field of Internet Economics.

We have proposed a simple pricing scheme and studied it in detail, in order to use Quality of Service monitoring information as feedback to the business plane, with the ultimate objective of improving the seller's revenue. In our framework, Assured-Quality Services are sold through first-price auctions, and in case of failure, a percentage of the price paid for the service is given back to the buyers. We derive the expression for the willingness to pay and we model the reimbursement problem through a zero-sum Stackelberg game. We show that the Nash equilibrium of such game implies reimbursing 100% in case of failures [6] [2].

6.2 Information Centric Networking

Participants: Annie Gravey, Zhe Li, Gwendal Simon, Wei You,.

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 [YMT⁺12], 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 [11], 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 studied techniques to integrate ICN into today's delivery networks, in particular the CDN. We have proposed a new implementation for CCN routers in order to coordinate with a regular CDN repository. For various reasons, the management of a repository managed by a third party provider is not trivial. The design of this node should fix the most critical issues by adding two new tables into the CCN node but without any modification to CCN protocol. We also study techniques that allow to leverage the caching capacity at the edge of the network to assist the delivery of content. We have designed a new protocol that allow to fill the Forwarding Interest Table (FIB) so that more options are explored by CCN nodes when the closest copy of a given content has to be discovered.

Finally, 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 [LSHA⁺12] and [10], we have proposed a network-friendly content delivery architecture that allows an ISP 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. In collaboration with colleagues from Orange Labs, in Lannion, we have shown in [24], using trace driven simulations exploiting traffic measurement

[YMT⁺12] W. YOU, B. MATHIEU, P. TRUONG, G. SIMON, J.-F. PELTIER, "DiPIT: a Distributed Bloom-Filter based PIT Table for CCN Nodes", *in: ICCCN 2012: 21th International Conference on Computer Communication Networks*, 2012.

[LSHA⁺12] Z. LI, M. K. SBAI, Y. HADJADJ-AOUL, D. ALLIEZ, G. SIMON, K. SINGH, G. MADEC, J. GARNIER, A. GRAVEY, "Network Friendly Video Distribution", *in: NoF 2012: 3rd International Conference on the Network of the Future*, 2012.

form the IP backbone network operated by Orange, that distributed caching in ISP networks is an efficient means of reducing load on critical links in the network. We have proposed simple business models that explain recent commercial conflicts between content providers (such as Google/YouTube) and ISPs (such as Free), and assess the profitability of in-network caching for ISPs.

The activity related to ICN within the Reop team has led to a PhD defence within the year [3].

6.3 Large scale delivery of multimedia

Participants: 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. This research topic has been typically addressed during a PhD thesis within the department [4].

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 [ZAB⁺12], 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.

Still in the large-scale live streaming application, we have also studied techniques to guarantee a decent quality of experience for end-users in the scenario where the delivery infrastructure has a reduced capacity. In the case of adaptive streaming, our main approach is to *not* send all representations to all edge-servers of the CDN. We have developed algorithms to build the delivery forest that ensure that the right video representation is properly sent to the right edge-servers [30, 31]. We have designed algorithms that are both fast and near-optimal in the sense that the approximation bound is close to zero when the CDN has a size that conforms current CDN infrastructure.

[ZAB⁺12] F. ZHOU, S. AHMAD, E. BUYUKKAYA, G. SIMON, R. HAMZAOU, "Minimizing Server Throughput for Low-Delay Live Streaming in Content Delivery Networks", *in: NOSSDAV: 22nd SIGMM Workshop on Network and Operating Systems Support for Digital Audio and Video*, 2012.

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 [LAB⁺12], 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 [CML⁺12], 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 [CWSR12], 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.

Besides this piece of work, some partnerships with other institutions have also conducted to research activities and publications. In particular, in [7], a survey of the multiple peer-to-peer techniques that have been designed for large-scale virtual environments has been realized in collaboration with University Pierre et Marie Curie.

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- [LAB⁺12] J. LIU, S. AHMAD, E. BUYUKKAYA, G. SIMON, R. HAMZAOU, "Resource Allocation in Underprovisioned Multioverlay Live Video Sharing Services", *in: ACM Conext Capacity Sharing Workshop*, 2012.
- [CML⁺12] 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.
- [CWSR12] S. CHOY, B. WONG, G. SIMON, C. ROSENBERG, "The Brewing Storm in Cloud Gaming: A Measurement Study on Cloud to End-User Latency", *in: The 11th ACM Annual Workshop on Network and Systems Support for Games (Netgames)*, 2012.

6.4 Mobility Management

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

In 2013, the work on DMA has been extended in the framework of several theses and one research contract with France Télécom. We continued our study on the comparison between the different mobility solutions proposed in the literature. In [18], we present different Dynamic Mobility Management (DMM) approaches based on MIPv6 and PMIPv6, providing global and/or local mobility support. Then, we carry out qualitative and quantitative analyses. The analyses conclude the strong and weak points of the different approaches, comparing them with existing protocols. Both analyses encourage towards DMM as a promising scheme.

We proposed a novel dynamic Mobility Management scheme based on Mobile IPv6 (MIPv6) as opposed to the previous DMA solutions, which were based on PMIPv6. This new scheme is called Distributed Dynamic MIPv6 (DDM). It provides both local and global mobility support in a distributed and dynamic manner. In [17] we carry out a performance analysis in terms of mobility costs. The results show that DDM outperforms MIPv6 significantly in optimizing the network resources and their consumption.

Mobility can be managed at the network layer or at the application layer. The Session Initiation Protocol (SIP) can be used as a mobility management solution. In [15] and [16], we present a comparative analysis on the global mobility management schemes MIPv6, SIP and their integration. For each scheme, analytical models are developed for mobility costs taking into consideration all the related aspects. We consider the signaling, data packet delivery, tunneling, and processing costs.

In [29], we propose to combine network-based DMM with PMIPv6. Tunnels for data packets are dynamically configured according to both the mobility behavior and the number of active sessions. We illustrate the proposed scheme's initial attachment and handover procedures step-by-step in an environment and we develop an analytical cost model. Our analysis shows that the proposed scheme optimizes packet delivery paths and thus provides a cost reduction during the packet delivery compared to the existing schemes.

In [28], we study how DMM can be used as a solution to offload the cellular networks (e.g. LTE) by Wi-Fi networks. Unlike the current approach of 3GPP called IFOM (IP Flow Mobility), traffic offloading is achieved based on IP flow mobility in a distributed manner. The offloading point is thus also distributed. We show how the proposed host-based distributed mobility management protocol alleviates the high traffic loads in the evolution of the 3GPP core network architecture.

Another new approach that the team addressed in 2013 is the virtualization of control functions in the Evolved Packet Core (LTE/EPC). The Software Defined Networking (SDN) is an emerging trend that should be considered to allow easy and low-cost deployment of mobile core networks able to dynamically adapt to the current load conditions. As a first step in [21], we propose an OpenFlow-based control plane for LTE/EPC architectures. Using resiliency and load balancing use cases, we show that our proposal guarantees the on-demand connectivity service.

6.5 Radio and Optical Technologies for access and metro networks

Participants: Annie Gravey, Xavier Lagrange, Souheir Eido, Moufida Feknous, Lida Sadeghioon, Bogdan Uscumlic.

In 2013, 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 started working on TWIN networks. The first point we addressed was related to 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. We have considered both centralized and distributed schedulers in [44], and shown that centralizing the scheduler's computation outperforms distributing this computation in terms of supported throughput. Moreover, in [43], we obtain preliminary results showing that an offline scheduler's computation using a static traffic matrix and deriving a schedule that exactly maximises the amount of available slots is more efficient than an on-line scheduler's computation method using in-service measurements of offered traffic, but relying on heuristics to obtain successive schedules.

TWIN scheduling relies on an exact knowledge of the latency between each source and each destination. As these distances slowly, schedulers have to be periodically re-computed to avoid collisions and inefficiencies. Slow variations may be due e.g. to temperature that varies between summer and winter but also between day and night. Important variations are due to recovery policies after failures. In all cases, it is necessary to monitor these latencies, and a process is proposed in [37] and [39].

We have pursued our work on resilience for POADM networks. 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. Contrarily to existing Ethernet rings or RPR networks, it is fully optically transparent, which allows to provision client layers only at the edges of this network. In [46] we present a method for optimal planning of bidirectional optical packet-switched rings. The optimal planning method is based on linear programming, and yields an optimal network design with minimum transportation cost per network link and receiver, for both 1+1 protection, which consist in doubling the capacity of each operational

²Only REOP participants are cited in the list of participants

connection in the ring and 1:N protection, in which the protection capacity is shared between multiple connections. By detailed simulations we studied the impact of different protection models on the cost of the network and its configuration, and the mutual interaction between protection methods and their effectiveness. The results suggest that the cost of 1+1 protection is up to 40% higher than the price of 1:N protection, and even up to 60% higher than the cost of the network without any protection.

Protection for TWIN networks has been addressed in [39]. We propose using a virtual ring joining all sources and destinations in order to support both an out-of-band control channel and all protection paths. The control channel may be used in particular to carry messages related to network discovery, synchronization and protection issues. Synchronization and failure notifications (generated by standard optical layer monitoring procedures) are processed by the central element in charge of resource allocation. The proposed TWIN layer protection approach avoids using lower layer protection techniques, which may strongly impact the fiber length distribution, and thus the associated scheduling mechanism, inside the different multipoint-to-point trees. The use of a single virtual control ring is well suited to networks with a limited extension such as metro networks. Our approach can however be extended to larger scale networks by using several control rings.

We also finalized our work regarding the impact of the POADM opportunistic access to slots on the design of POADM rings. Indeed, opportunistic access can lead to node instability. We have shown in [45] and [12] that using max-weight schedulers for selecting a given destination allows the derivation of conditions ensuring stable designs. Lastly [40] addresses the mapping of a given traffic matrix on sets of rings and point to point links. Our approach aims at providing packet-level grooming only where it is profitable. The method relies on splitting the original traffic matrix in two parts, which will be transported either through optical packets or through circuits, according to a maximum wavelength capacity threshold. The network dimensioning can be then performed for circuit and packet traffic matrices separately.

Lida Sadeghioon defended her thesis “Contribution to the design of optical-packet based metropolitan area networks” in October 2013.

6.6 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 [14], 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 analyzed, compared, classified and then an integration model is proposed. We finally describe some major collaborative projects dedicated to this topic. A first application of our study can be found in [13].

We investigate the use of renewable energy in wireless networks. This type of energy directly reduces the greenhouse gases emission and, in many cases, the operator energy costs. In [33], to the best of our knowledge for the first time, we introduce a new trade-off for energy-efficient wireless networks: between the user average satisfaction degree and the ratio of green (clean) renewable energy used in green wireless networks. We use a simple system model in order to obtain first results illustrating this trade-off. An intelligent battery-based system for a more efficient use of the renewable energy is included. The results show that for the model considered, only 25% of non-renewable energy guarantees more than 75% average user satisfaction.

We try to combine two or more approaches in order to obtain better energy efficiency future mobile networks. In [41], we propose to apply a green cell breathing technique on a hybrid network composed of small and large cell layers in a femto/macro- layer architecture. The scenario analyzed takes into account the potential case of users being blocked by the femto-layer due to access policies. By adding cell breathing into the macro layer, we have two ways of traffic redistribution in order to offload and deactivate a larger number of Macro-BSs and also maximize the benefits obtained from the hybrid infrastructure. We study the use of the green cell breathing technique for mobile network from a different perspective different to the well-known power/energy consumption. Normally, the literature shows the saving achieved by the green cell breathing technique but forgets the potential consequences of its utilization. In such sense, an undesired effect of applying such mechanism is the increase of transmission power of those cells expanded in size. The derived consequences of this latter, it is an increase of the associated electromagnetic radiation exposure on authorized workers as well as the general public nearby to the base stations. We analyze the use of cell breathing in a common LTE scenario in order to see how the recommendable levels extracted from the international regulation are exceeded or respected when the technique is used [42]. More details on this topic can be found in the PhD report of Luis Suarez [5].

In [23] we study an approach based on the fact that some services or some users can accept some delay. Queuing a few service requests can be used to switch on base stations or wireless access points only when there is enough traffic and is then 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 [50] and [22], we study how mobile relays can be used in the context of public transportation.

For massive distribution of the same content (video, audio, text,...) broadcast technologies are the most efficient ones. However, as shown in [20], 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 [19] we analyze the load over the LTE access network due to the retransmission of the missing sequences of a DVB transmission. It was found that along with achieving a correct DVB flow using LTE network, it is also possible to save a fair amount of DVB transmission power for a reasonable load over the LTE network.

6.7 Other results

[1] [8] [9] [11] [26] [27] [34] [35] [38] [47] [48] [49] [51]

7 Contracts and Grants with Industry

7.1 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.

7.2 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)
- 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

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 IPcentric 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 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://systuf.ifsttar.fr/>

7.9 CELTIC SASER-SAVENET

Participants: Annie GraveyBogdan 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>

7.10 FP7 CNG

Participants: Gwendal Simon, Jiayi Liu, Eliya Buyukkaya.

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

- 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, 2010-2013
- 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 Telecom Bretagne: Francois Le Pennec, 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)
- 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/>

7.14 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.

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

- 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 Dissemination

8.1 Organization of conferences

International Workshop on TRaffic Analysis and Classification (TRAC) This workshop is colocated with IWCMC. The TRAC series serves as a forum for scientists and engineers in academia and industry to exchange and discuss their experiences and research results about all aspects of traffic classification, characterization, and analysis. The fourth edition of the workshop has been organized in July 2013 in Cagliari, Italy. The TPC of TRAC 2013 was chaired by Sandrine Vaton (REOP team), together with Christian Callegari (university of Pisa, Italy).

International Workshop on Advanced Internet Charging and QoS Technology (ICQT) This workshop is colocated with CNSM. The goal of the ICQT series is to discuss the latest research results and practices concerning the consolidation and combination of technical and economic mechanisms for enabling a fast, guaranteed, and efficient charging and pricing of services as well as other business related and regulatory issues for the future evolution of the Internet and the telecommunications business in general. ICQT 2013 has been organized in Zürich, Switzerland, in October 2013. The TPC of ICQT 2013 was chaired by Sandrine Vaton (REOP team), together with Tuan Anh Trinh (BME, Budapest, Hungary).

8.2 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 2013, IEEE International Conference on Communications
- CAMAD 2013, 18th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks
- ICC 2013, the second IEEE International Conference on Communications in China
- WCNC 2013, IEEE Wireless Communications and Networking Conference
- PIMRC 2013, IEEE 24th International Symposium on Personal, Indoor and Mobile Radio Communications
- Wimob 2013, 9th International Conference on Wireless and Mobile Computing, Networking and Communications

- ICACCI 2013, IEEE Second International Conference on Advances in Computing, Communications and Informatics
- Globecom 2013, IEEE Global Communications Conference
- ONDM 2013, 17th International Conference on Optical Networking Design and Modeling
- ETS 2013, 2nd European Teletraffic Seminar
- Eunice 2013, 19th Conference on Information and Communications Technologies

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- WPMC 2013, The 16th International Symposium on Wireless Personal Multimedia Communications.

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- WCNC 2013, IEEE Wireless Communications and Networking Conference, Paris, France, April, 2013
- WPMC 2013, Wireless Personal Multimedia Communications, June, 2013
- 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 2013, IEEE Global Communications Conference
- ICCCN 2013, 21st IEEE International Conference on Computer Communication Networks
- LCN 2013, 39th IEEE Conference on Local Computer Networks
- Packet Video 2013, 20th IEEE International Packet Video Workshop
- Netgames 2013, 12th ACM Workshop on Network and Systems Support for Games
- Eunice 2013, 19th Conference on Information and Communications Technologies
- Nem Summit 2013
- Algotel 2013

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

- Next Generation Internet conference (NGI 2013)

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