Activity Report 2015

Project-Team DIANA

Design, Implementation and Analysis of Networking Architectures

RESEARCH CENTER
Sophia Antipolis - Méditerranée

THEME
Networks and Telecommunications

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Creation of the Team: 2013 January 01, updated into Project-Team: 2015 July 01

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1. Members

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2. Overall Objectives

2.1. Presentation of the team

The overall objective of the DIANA project-team is to provide network architectural support for improving citizen rights in the Internet. To do so, we will work to provide service transparency and user data control in the context of hundreds of billions of both wired and mobile devices. Our methodology includes advanced measurement techniques, design and implementation of architectural solutions, and their validation in adequate experimental facilities.

The high complexity of the Internet architecture, protocols and services, and the economic interests of the big stakeholders result in a lack of transparency concerning information of high interest to the connected “citizen” such as possible privacy leaks, root cause of service degradation or lock-in behavior. It is therefore important to enhance the network to provide service transparency to citizens.

On the other hand, the ossification of the Internet architecture around the IP protocol makes introduction of new functionalities in the network quite difficult. Users currently have no control on their contents and depend on big companies (e.g., Google drive, iCloud, dropbox, Microsoft OneDrive) to easily access and share data at the expense of their privacy. However, the recent development of software-defined network and network functions virtualization concepts open the perspective of faster deployment of network functionalities, as it abstracts the whole network as a single piece of software, instead of a large number of heterogeneous and dedicated devices to be configured one-by-one.

In the Diana team, we have two main research directions:

- designing and deploying a measurement plane providing network service transparency,
- defining and deploying an open network architecture for user control.

Our research program is presented briefly in the next section.

3. Research Program

3.1. Service Transparency

Transparency is to provide network users and application developers with reliable information about the current or predicted quality of their communication services, and about potential leakages of personal information, or of other information related to societal interests of the user as a "connected citizen" (e.g. possible violation of network neutrality, opinion manipulation). Service transparency therefore means to provide information meaningful to users and application developers, such as quality of experience, privacy leakages, or opinion manipulation, etc. rather than network-level metrics such as available bandwidth, loss rate, delay or jitter.

The Internet is built around a best effort routing service that does not provide any guarantee to end users in terms of quality of service (QoS). The simplicity of the Internet routing service is at the root of its huge success. Unfortunately, a simple service means unpredicted quality at the access. Even though a considerable effort is done by operators and content providers to optimise the Internet content delivery chain, mainly by over-provisioning and sophisticated engineering techniques, service degradation is still part of the Internet. The proliferation of wireless and mobile access technologies, and the versatile nature of Internet traffic, make end users quality of experience (QoE) forecast even harder. As a matter of fact, the Internet is missing a dedicated measurement plane that informs the end users on the quality they obtain and in case of substantial service degradation, on the origin of this degradation. The mPlane FP7 project (http://www.ict-mplane.eu) is devoted to building a distributed measurement infrastructure to perform active, passive and hybrid measurements in the wired Internet. However, the problem is exacerbated with modern terminals such as smartphones or tablets that do not facilitate the task for end users (they even make it harder) as they focus on simplifying the interface and limiting the control on the network, whereas the Internet behind is still the same in terms of the quality it provides. Interestingly, this same observation explains the existing difficulty to detect and prevent privacy leaks. We argue that the lack of transparency for diagnosing QoE and for detecting privacy leaks have the same root causes and can be solved using common primitives. For instance, in both cases, it is important to be able to link data packets to an application. Indeed, as the network can only access data packets, there must be a way to bind these packets to an application (to understand users QoE for this application or to associate a privacy leak to an application). This is however a complex task as the traffic might be obfuscated or encrypted. Our objectives in the research direction are the following:

- Design and develop measurement tools providing transparency, in spite of current complexity
- Deploy those measurement tools at the Internet's edge and make them useful for end users
- Propose measurements plane as an overlay or by exploiting in-network functionalities
- Adapt measurements techniques to network architectural change
- Provide measurements as native functionality in future network architecture

3.2. Open network architecture

We are surrounded by personal content of all types: photos, videos, documents, etc. The volume of such content is increasing at a fast rate, and at the same time, the spread of such content among all our connected devices (mobiles, storage devices, set-top boxes, etc) is also increasing. All this complicates the control of personal content by the user both in terms of access and sharing with other users. The access of the personal content in a seamless way independently of its location is a key challenge for the future of networks. Proprietary solutions exist, but apart from fully depending on one of them, there is no standard plane in the Internet for a seamless access to personal content. Therefore, providing network architectural support to design and develop content access and sharing mechanisms is crucial to allow users control their own data over heterogeneous underlying network or cloud services.

On the other hand, privacy is a growing concern for states, administrations, and companies. Indeed, for instance the French CNIL (entity in charge of citizens privacy in computer systems) puts privacy at the core of its activities by defining rules on any stored and collected private data. Also, companies start to use privacy preserving solutions as a competitive advantage. Therefore, understanding privacy leaks and preventing them is a problem that can already find support. However, all end-users do not *currently* put privacy as their first concern. Indeed, in face of two services with one of higher quality, they usually prefer the highest quality one whatever the privacy implication. This was, for instance, the case between the Web search service of Google that is more accurate but less privacy preserving than Bing. This is also the case for cloud services such as iCloud or Dropbox that are much more convenient than open source solutions, but very bad in terms of privacy. Therefore, to reach end-users, any privacy preserving solutions must offer a service equivalent to the best existing services.

We consider that it will be highly desirable for Internet users to be able to *easily* move their content from a provider to another and therefore not to depend on a content provider or a social network monopoly. This requires that the network provides built-in architectural support for content networking.

In this research direction, we will define a new *service abstraction layer* (SAL) that could become the new waist of the network architecture with network functionalities below (IP, SDN, cloud) and applications on top. SAL will define different services that are of use to all Internet users for accessing and sharing data (seamless content localisation and retrieval, privacy leakage protection, transparent vertical and horizontal handover, etc.). The biggest challenge here is to cope in the same time with large number of content applications requirements and high underlying networks heterogeneity while still providing efficient applications performance. This requires careful definition of the services primitives and the parameters to be exchanged through the service abstraction layer.

Two concurring factors make the concept behind SAL feasible and relevant today. First, the notion of scalable network virtualization that is a required feature to deploy SAL in real networks today has been discussed recently only. Second, the need for new services abstraction is recent. Indeed, fifteen years ago the Internet for the end-users was mostly the Web. Only eight years ago smartphones came into the picture of the Internet boosting the number of applications with new functionalities and risks. Since a few years, many discussions in the network communities took place around the actual complexity of the Internet and the difficulty to develop applications. Many different approaches have been discussed (such as CCN, SDN) that intend to solve only part of the complexity. SAL takes a broader architectural look at the problem and considers solutions such as CCN as mere use cases. Our objectives in this research direction include the following:

- Identify common key networking services required for content access and sharing
- Detect and prevent privacy leaks for content communication
- Enhance software defined networks for large scale heterogeneous environments
- Design and develop open Content Networking architecture
- Define a service abstraction layer as the thin waist for the future content network architecture
- Test and deploy different applications using SAL primitives on heterogeneous network technologies

3.3. Methodology

We follow an experimental approach that can be described in the following techniques:

- Measurements: the aim is to get a better view of a problem in quantifiable terms. Depending on the field of interest, this may involve large scale distributed systems crawling tools; active probing techniques to infer the status and properties of a complex and non controllable system as the Internet; or even crowdsourcing-based deployments for gathering data on real-users environments or behaviours.
- Experimental evaluation: once a new idea has been designed and implemented, it is of course very desirable to assess and quantify how effective it can be, before being able to deploy it on any realistic scale. This is why a wide range of techniques can be considered for getting early, yet as significant as possible, feedback on a given paradigm or implementation. The spectrum for such techniques span from simulations to real deployments in protected and/or controlled environments.

4. Highlights of the Year

4.1. Highlights of the Year

A second session of the Python MOOC by Arnaud Legout and Thierry Parmentelat has been programmed in 2015 and it was also a very big success: 9615 persons registered to the course, out of them 1487 qualified for the final attestation of achievement. This session is innovative in its form as well, since it introduced ipython notebooks as medium for complementing videos; this medium has allowed to add runnable/editable programs fragments inside written material, so that students can readily run and or modify the numerous examples that illustrate the languages' concepts. Arnaud and Thierry are preparing a sequel that will address python3; they also hope to be able to leverage on the notebooks technology, and to widen the spectrum of their day-to-day usages beyond educational purposes, and in particular towards research-oriented activities like runnable papers. For more details on this MOOC see https://www.france-universite-numerique-mooc.fr/courses/inria/41001S02/session02/about

4.1.1. Awards

Our paper Automating ns-3 Experimentation in Multi-Host Scenarios, got the Best Paper Award at the ns-3 Workshop (WNS3), May 2015, Barcelona, Spain. The NEPI experiment management framework is capable of automating deployment, execution, and result collection of experiment scenarios that combine ns-3 with multiple hosts in various ways, reducing the burden of manual scenario setup. The awarded paper describes the internals of the NEPI framework and demonstrates its usage for ns-3 multi-host scenarios with three example cases: a) running parallel simulations on a cluster of hosts, b) running distributed simulations spanning multiple hosts, and c) integrating live and simulated networks.

BEST PAPER AWARD:

[18]
A. QUEREILHAC, D. SAUCEZ, T. TURLETTI, W. DABBOUS. *Automating ns-3 Experimentation in Multi-Host Scenarios*, in "WNS3 2015", Barcelona, Spain, May 2015, https://hal.inria.fr/hal-01141000

5. New Software and Platforms

5.1. ACQUA

Participants: Chadi Barakat [contact], Thierry Spetebroot, Nicolas Aguilera Miranda, Damien Saucez.

ACQUA is an Application for prediCting Quality of User experience at Internet Access. It was supported by the French ANR CMON project on collaborative monitoring and will be supported in 2016 by both the Inria ADT ACQUA and the ANR Project BottleNet. ACQUA presents a new way for the evaluation of the performance of Internet access. Starting from network-level measurements as the ones we often do today (bandwidth, delay, loss rates, etc), ACQUA targets the estimated quality of experience related to the different applications of interest to the user without the need to run them (e.g. estimated Skype quality, estimated video streaming quality). An application in ACQUA is a function that links the network-level measurements to the expected quality of experience. In its first version (the version available online), ACQUA was concentrating on delay measurements at the access and on the detection and estimation of the impact of delay anomalies (local problems, remote problems, etc). The current work is concentrating on using the ACQUA principle in the estimation and prediction of the quality of experience of main user's applications (see section 6.1.1 for more details). An Android version is under development supported by the Inria ADT ACQUA.

- URL: http://team.inria.fr/diana/acqua/
- Version: 1.1
- ACM: C.2.2, C.2.3

- Keywords: Internet measurement, Internet Access, Quality of Experience
- License: GPL (3)
- Type of human computer interaction: GUI for client, Web interface for experimentation
- OS/Middleware: MS Windows
- Required library or software: visual studio http://www.visualstudio.com/en-us/products/visual-studio-express-vs.aspx
- Programming language: C# for client, java for server, CGI and Dummynet for experimentation

5.2. ElectroSmart

Participants: Arnaud Legout [contact], Inderjeet Singh, Maksym Gabielkov.

The Internet and new devices such as smartphones have fundamentally changed the way people communicate, but this technological revolution comes at the price of a higher exposition of the general population to microwave electromagnetic fields (EMF). This exposition is a concern for health agencies and epidemiologists who want to understand the impact of such an exposition on health, for the general public who wants a higher transparency on its exposition and the health hazard it might represent, but also for cellular operators and regulation authorities who want to improve the cellular coverage while limiting the exposition, and for computer scientists who want to better understand the network connectivity in order to optimize communication protocols. Despite the fundamental importance to understand the exposition of the general public to EMF, it is poorly understood because of the formidable difficulty to measure, model, and analyze this exposition.

The goal of the ElectroSmart project is to develop the instrument, methods, and models to compute the exposition of the general public to microwave electromagnetic fields used by wireless protocols and infrastructures such as Wi-Fi, Bluetooth, or cellular. Using a pluri-disciplinary approach combining crowd-based measurements, in-lab experiments, and modeling using sparse and noisy data, we address challenges such as designing and implementing a measuring instrument leveraging on crowd-based measurements from mobile devices such as smartphones, modeling the exposition of the general public to EMF to compute the most accurate estimation of the exposition, and analyzing the evolution of the exposition to EMF with time. This technological breakthrough will have scientific, technical, and societal applications, notably on public health politics, by providing the scientific community and potential users with a unique measuring instrument, methods, and models to exploit the invaluable data gathered by the instrument.

This project has been supported by the Inria ADT ElectroSmart in 2014 and 2015 and will be supported by a Labex funding in the next two years.

In 2015, we released the first alpha version of the application for tests with real users (10 volunteers) and we published an associated Web site http://es.inria.fr.

- URL: http://es.inria.fr
- Version: 1.0alpha
- Keywords: background electromagnetic radiations
- License: Inria proprietary licence
- Type of human computer interaction: Android application
- OS/Middleware: Android
- Required library or software: Android
- Programming language: Java
- Documentation: javadoc

5.3. NEPI

Participants: Thierry Turletti [correspondant], Alina Ludmila Quereilhac, Thierry Parmentelat, Mario Antonio Zancanaro.

NEPI, the Network Experimentation Programming Interface, is a framework to describe and orchestrate network experiments on a variety of network experimentation platforms, including simulators, emulators, live testbeds, and testbed federations. NEPI is capable of supporting arbitrary platforms through the use of a generic network experiment description model, based on abstracting network experiments as a collection of arbitrary resource objects, and through the generalization of the experiment life cycle for all resources. The common resource life cycle consists of the sequence of operations deploy, start, stop, and release. Different resource objects can implement specific versions of those operations to adapt to any platform. NEPI resolves experiment orchestration as an online scheduling problem.

In the context of Alina Quereilhac PhD, we generalized in 2015 the network experiments automation framework for arbitrary evaluation platforms, and for scenarios targeting any networking research domain. The proposed approach is based on abstracting the experiment life cycle for different platforms into generic steps that are valid for simulators, emulators, and testbeds. Based on these steps, a generic experimentation architecture was proposed and implemented, composed of an experiment model, an experimentation interface, and an orchestration algorithm. Three main aspects of the framework were evaluated: its extensibility to support heterogeneous platforms, its efficiency to orchestrate experiments, and its flexibility to support diverse use cases for different networking research domains, including education, platform management, and experimentation with testbed federations, and cross-platform and multi-platform scenarios. The results show that the proposed approach can be used to efficiently automate experimentation on heterogeneous evaluation platforms, for a wide range of scenarios.

On a much more practical level, NEPI is now available in a version numbered 6, that can run within both python2 and python3 environments.

- URL: http://nepi.inria.fr
- Version: 6.0
- ACM: C.2.2, C.2.4
- Keywords: networking experimentation, simulation, emulation
- License: GPL (3)
- Type of human computer interaction: python library
- OS/Middleware: Linux
- Required library or software: matplotlib - graphviz (both optional)
- Programming language: python2 or python3

5.4. ns-3

Participants: Walid Dabbous [contact], Thierry Turletti.

ns-3 is a discrete-event network simulator for Internet systems, targeted primarily for research and educational use. ns-3 includes a solid event-driven simulation core as well as an object framework focused on simulation configuration and event tracing, a set of realistic 802.11 MAC and PHY models, an IPv4, UDP, and TCP stack and support for nsc (integration of Linux and BSD TCP/IP network stacks). ns-3 is free software, licensed under the GNU GPLv2 license, and it is publicly available for research, development, and use. Our team has been involved in ns-3 project since 2006 and we are founding member of the ns-3 consortium including Washington University, Georgia Tech, CTTC, INESC PORTO as executive members. In 2015, using the NEPI framework, we worked on the automation of ns-3 experiments in multi-host scenarios with three example cases: a) running parallel simulations on a cluster of hosts, b) running distributed simulations spanning multiple hosts, and c) integrating live and simulated networks.

- URL: http://www.nsnam.org
- Version: ns-3.21
- Keywords: networking event-driven simulation
- License: GPL (GPLv2)

- Type of human computer interaction: programmation C++/python, No GUI
- OS/Middleware: Linux, cygwin, osX
- Required library or software: standard C++ library: GPLv2
- Programming language: C++, python
- Documentation: doxygen

5.5. DCE

Participants: Thierry Turletti [contact], Walid Dabbous.

DCE enables developers and researchers to develop their protocols and applications in a fully controllable and deterministic environment, where tests can be repeated with reproducible results. It allows unmodified protocol implementations and application code to be tested over large and possibly complex network topologies through the ns-3 discrete-event network simulator. The single-process model used in the DCE virtualization core brings key features, such as the possibility to easily debug a distributed system over multiple simulated nodes without the need of a distributed and complex debugger. Examples of tested applications over DCE include Quagga, iperf, torrent, thttpd, CCNx and various Linux kernel versions (from 2.6.36 to 3.12 versions). DCE was initially developed by Mathieu Lacage during his PhD thesis and is maintained by engineers in the team in collaboration with Hajime Tazaki from University of Tokyo. Our effort on DCE was reduced in 2015 due to lack of resources, but DCE/ns-3 represents an important component of R2lab in particular for performance comparison and hybrid (real/simulation/emulation) experiments. DCE is free software, licensed under the GNU GPLv2 license, and is publicly available for research, development, and use.

- URL: https://www.nsnam.org/overview/projects/direct-code-execution/
- Version: DCE-1.7
- Keywords: emulation, virtualization, networking event-driven simulation
- License: GPL (GPLv2)
- Type of human computer interaction: programmation C/C++, No GUI
- OS/Middleware: Linux
- Required library or software: standard C++ library: GPLv2
- Programming language: C++, python
- Documentation: doxygen

5.6. OpenLISP

Participant: Damien Saucez [contact].

Among many options tackling the scalability issues of the current Internet routing architecture, the Locator/Identifier Separation Protocol (LISP) appears as a viable solution. LISP improves a network's scalability, flexibility, and traffic engineering, enabling mobility with limited overhead. As for any new technology, implementation and deployment are essential to gather and master the real benefits that it provides. We propose a complete open source implementation of the LISP control plane. Our implementation is deployed in the worldwide LISP Beta Network and the French LISP-Lab testbed, and includes the key standardized control plane features. Our control plane software is the companion of the existing OpenLISP dataplane implementation, allowing the deployment of a fully functional open source LISP network compatible with any implementation respecting the standards. As of 2015, OpenLISP is still used to provide connectivity between satellite sites of the LISP-Lab project and has been used as LISP implementation for PACAO, an overlay aiming at optimising Cloud access in distributed data-centers.

- http://www.lisp-lab.org/
- Version: 3.2
- ACM: C.2.1, C.2.2, C.2.6

- Keywords: routing, LISP, control-plane
- License: BSD
- Type of human computer interaction: XML, CLI
- OS/Middleware: POSIX
- Required library or software: Expat 2
- Programming language: C
- Documentation: Unix man
- Deployment: ddt-root.org

5.7. Platforms

5.7.1. Reproducible research laboratory ($\mathrm{R^2LAB}$*)*

Scientific evaluation of network protocols requires that experiment results must be reproducible before they can be considered as valid. This is particularly difficult to obtain in the wireless networking domain, where characteristics of wireless channels are known to be variable, unpredictable and hardly controllable. We have built at Inria Sophia-Antipolis, in 2014, an anechoic chamber, with RF absorbers preventing radio waves reflections and with Faraday cage blocking external interferences. This lab, named $\mathrm{R^2lab}$, represents an ideal environment for experiments reproducibility. $\mathrm{R^2lab}$ has been announced for usage by the general public at the end of 2015. It was developed, and is now operated, in the context of the FIT 'Equipment of Excellence' project, and as such, it is now federated with the other testbeds that are part of the FIT initiative. This testbed is for the long-haul, and is scheduled to remain operational until at least 2020. Future work, in addition to regular operations, includes adding new hardware capabilities to the wireless nodes, such as USRP for running Software Defined Radio, as well as possibly OpenAirInterface for supporting 5G-like experiments.

For more details see http://r2lab.inria.fr.

6. New Results

6.1. Service Transparency

6.1.1. From Network-level Measurements to Expected QoE: the Skype Use Case

Participants: Thierry Spetebroot, Nicolas Aguilera, Damien Saucez and Chadi Barakat.
Modern Internet applications rely on rich multimedia contents making the quality of experience (QoE) of end users sensitive to network conditions. Several models were developed in the literature to express QoE as a function of measurements carried out on the traffic of the applications themselves. In this contribution, we propose a new methodology based on machine learning able to link expected QoE to network and device level measurements outside the applications' traffic. This direct linking to network and device level measurements is important for the prediction of QoE. We prove the feasibility of the approach in the context of Skype. In particular, we derive and validate a model to predict the Skype QoE as a function of easily measurable network performance metrics. One can see our methodology as a new way of performing measurements in the Internet, where instead of expressing the expected performance in terms of network and device level measurements that only specialists can understand, we express performance in clear terms related to expected quality of experience for different applications. More details on this approach and on our application ACQUA can be found in section 5.1 , in the paper summarizing the results [16] and on the application web page http://team.inria.fr/diana/acqua/.

6.1.2. Towards a General Solution for Detecting Traffic Differentiation at the Internet Access

Participants: Ricardo Ravaioli and Chadi Barakat.

In recent years network neutrality has been widely debated from both technical and economic points of view. Various cases of traffic differentiation at the Internet access have been reported throughout the last decade, in particular aimed at bandwidth consuming traffic flows. In this contribution we present a novel application-agnostic method for the detection of traffic differentiation, through which we are able to correctly identify where a shaper is located with respect to the user and evaluate whether it affected delays, packet losses or both. The tool we propose, ChkDiff, replays the user's own traffic in order to target routers at the first few hops from the user. By comparing the resulting flow delays and losses to the same router against one other, and analyzing the behaviour on the immediate router topology spawning from the user end-point, ChkDiff manages to detect instances of traffic shaping. This contribution is published in [15] where we provide a detailed description of the design of the tool for the case of upstream traffic, the technical issues it overcomes and a validation in controlled scenarios. It is the result of collaboration with the SIGNET group at I3S in the context of a PhD thesis funded by the UCN@SOPHIA Labex.

6.1.3. A Diagnostic Tool for Content-Centric Networks

Participant: Thierry Turletti

In collaboration with our colleagues at NICT, Japan, we have proposed the Contrace tool for Measuring and Tracing Content-Centric Networks (CCNs). CCNs are fundamental evolutionary technologies that promise to form the cornerstone of the future Internet. The information flow in these networks is based on named data requesting, in-network caching, and forwarding – which are unique and can be independent of IP routing. As a result, common IP-based network tools such as ping and traceroute can neither trace a forwarding path in CCNs nor feasibly evaluate CCN performance. We designed "contrace," a network tool for CCNs (particularly, CCNx implementation running on top of IP) that can be used to investigate 1) the Round-Trip Time (RTT) between content forwarder and consumer, 2) the states of in-network cache per name prefix, and 3) the forwarding path information per name prefix. We report a series of experiments conducted using contrace on a CCN topology created on a local testbed and the GEANT network topology emulated by the Mini-CCNx emulator. The results confirm that contrace is not only a useful tool for monitoring and operating a network, but also a helpful analysis tool for enhancing the design of CCNs. Further, contrace can report the number of received interests per cache or per chunk on the forwarding routers. This enables us to estimate the content popularity and design more effective cache control mechanisms in experimental networks (see our publication in the IEEE Communication Magazine [9]).

6.1.4. An efficient packet extraction tool for large experimentation traces

Participants: Thierry Turletti and Walid Dabbous

Network packet tracing has been used for many different purposes during the last few decades, such as network software debugging, networking performance analysis, forensic investigation, and so on. Meanwhile, the size of packet traces becomes larger, as the speed of network rapidly increases. Thus, to handle huge amounts of traces, we need not only more hardware resources, but also efficient software tools. However, traditional tools are inefficient at dealing with such big packet traces. In this work, we propose pcapWT, an efficient packet extraction tool for large traces. PcapWT provides fast packet lookup by indexing an original trace using a Wavelet Tree structure. In addition, it supports multi-threading for avoiding synchronous I/O and blocking system calls used for file processing, and it is particularly efficient on machines with SSD disks. PcapWT shows remarkable performance enhancements in comparison with traditional tools such as tcpdump and most recent tools such as pcapIndex in terms of index data size and packet extraction time. Our benchmark using large and complex traces shows that pcapWT reduces the index data size down below 1% of the volume of the original traces. Moreover, packet extraction performance is 20% better than with pcapIndex. Furthermore, when a small amount of packets are retrieved, pcapWT is hundreds of times faster than tcpdump. This work has been done in collaboration with our colleagues at Universidad Diego Portales (UDP) and Universidad de Chile and has been published in the Computer Networks journal [10].

6.1.5. Social Clicks: What and Who Gets Read on Twitter?

Participants: Maksym Gabielkov and Arnaud Legout

Online news domains increasingly rely on social media to drive traffic to their website. Yet we know surprisingly little about how social media conversation mentioning an online article actually generates a click to it. Posting behaviors, in contrast, have been fully or partially available and scrutinized over the years. While this has led to multiple assumptions on the diffusion of information, each were designed or validated while ignoring this important step. We made a large scale, validated and reproducible study of social clicks, that is also the first data of its kind, gathering a month of web visits to online resources that are located in 5 leading news domains and that are mentioned in the third largest social media by web referral (Twitter). Our dataset amounts to 2.8 million posts, together responsible for 75 billion potential views on this social media, and 9.6 million actual clicks to 59,088 unique resources. We design a reproducible methodology, carefully corrected its biases, enabling data sharing, future collection and validation. As we prove, properties of clicks and social media Click-Through-Rates (CTR) impact multiple aspects of information diffusion, all previously unknown. Secondary resources, that are not promoted through headlines and are responsible for the long tail of content popularity, generate more clicks both in absolute and relative terms. Social media attention is actually long-lived, in contrast with temporal evolution estimated from posts or impressions. The actual influence of an intermediary or a resource is poorly predicted by their posting behavior, but we show how that prediction can be made more precise. The results are reported in an article under submission, no report available yet.

6.1.6. ReCon: Revealing and Controlling PII Leaks in Mobile Network Traffic

Participant: Arnaud Legout

It is well known that apps running on mobile devices extensively track and leak users' personally identifiable information (PII); however, these users have little visibility into PII leaked through the network traffic generated by their devices, and have poor control over how, when and where that traffic is sent and handled by third parties. In this work, we present the design, implementation, and evaluation of ReCon: a cross-platform system that reveals PII leaks and gives users control over them without requiring any special privileges or custom OSes. ReCon leverages machine learning to reveal potential PII leaks by inspecting network traffic, and provides a visualization tool to empower users with the ability to control these leaks via blocking or substitution of PII. We evaluate ReCon's effectiveness with measurements from controlled experiments using leaks from the 100 most popular iOS, Android, and Windows Phone apps, and via an user study with 92 participants. In this study, that was approved by the Inria Ethical Board (COERELE), we show that ReCon is accurate, efficient, and identifies a wider range of PII than previous approaches. The results are reported in an article under submission, no report available yet.

6.2. Open Network Architecture

6.2.1. Storage on Wheels: Offloading Popular Contents Through a Vehicular Cloud

Participants: Luigi Vigneri and Chadi Barakat.

The increasing demand for mobile data is overloading the cellular infrastructure. Small cells and edge caching is being explored as an alternative, but installation and maintenance costs for sufficient coverage are significant. In this work, we perform a preliminary study of an alternative architecture based on two main ideas: (i) using vehicles as mobile caches that can be accessed by user devices; compared to small cells, vehicles are more widespread and require lower costs; (ii) combining the mobility of vehicles with delayed content access to increase the number of cache hits (and reduce the load on the infrastructure). Contrary to standard DTN-type approaches, in our system max delays are guaranteed to be kept to a few minutes (beyond this deadline, the content is fetched from the infrastructure). We first propose an analytical framework to compute the optimal number of content replicas that one should cache, in order to minimize the infrastructure load. We then investigate how to optimally refresh these caches to introduce new contents, as well as to react to the temporal variability in content popularity. Simulations suggest that our vehicular cloud considerably reduces the infrastructure load in urban settings, assuming modest penetration rates and tolerable content access delays. This work is currently under submission; it is the result of collaboration with the Mobile Communications Department at Eurecom in the context of a PhD thesis funded by the UCN@SOPHIA Labex.

6.2.2. Geographically Fair In-Network Caching for Mobile Data Offloading

Participant: Chadi Barakat
Data offloading from the cellular network to low-cost WiFi has been the subject of several research works in the last years. In-network caching has also been studied as an efficient means to further reduce cellular network traffic. In this contribution, done jointly with the Maestro project-team, we consider a scenario where mobile users can download popular contents (e.g., maps of a city, shopping information, social media, etc.) from WiFi-enabled caches deployed in an urban area. We study the optimal distribution of contents among the caches (i.e., what contents to put in each cache) to minimize users' access cost in the whole network. We argue that this optimal distribution does not necessarily provide geographic fairness, i.e., users at different locations can experience highly variable performance. In order to mitigate this problem, we propose two different cache coordination algorithms based on gossiping. These algorithms achieve geographic fairness while preserving the minimum access cost for end users. More details on this contribution can be found in [12].

6.2.3. Virtual Service Providers (vSP)

Participant: Damien Saucez
The ability of SOHO networks to connect to the Internet through several Internet service providers, gives high potential to enable rich cloud-based network services for enterprises. Nevertheless, it remains a huge challenge for SOHOs to leverage such multi-homing and cloud networking capabilities. For such a reason, we introduced the vSP concept (virtual Service Provider). The idea of vSP is to hide the technical complexity inherent to multi-homing and allow SOHOs to seamlessly use their cloud resources. The role of the vSP is to orchestrate traffic between the different Internet Services Providers (ISPs) in order to maximize the cloud service performance without requiring any intervention of the SOHO network administrator. This ongoing work is done in collaboration with Telecom ParisTech, Ericsson, LISPERS.net, and Cisco Systems and is presented in two papers [19], [20] and detailed in one IETF Internet-draft [19].

6.2.4. Rules Placement Problem in OpenFlow Networks

Participants: Xuan Nam Nguyen, Damien Saucez, Chadi Barakat and Thierry Turletti
Software-Defined Networking (SDN) abstracts low-level network functionalities to simplify network management and reduce costs. The OpenFlow protocol implements the SDN concept by abstracting network communications as flows to be processed by network elements. In OpenFlow, the high-level policies are translated into network primitives called rules that are distributed over the network. While the abstraction offered by OpenFlow allows to potentially implement any policy, it raises the new question of how to define the rules and where to place them in the network while respecting all technical and administrative requirements. We proposed a comprehensive study of the so-called OpenFlow rules placement problem with a survey of the various proposals intending to solve it [11] and developed an offline optimization framework for this problem with a polynomial time approximation in [13].

6.3. Experimental Evaluation

6.3.1. Automating ns-3 Experimentation in Multi-Host Scenarios

Participants: Alina Ludmila Quereilhac, Damien Saucez, Thierry Turletti and Walid Dabbous
ns-3 is a flexible simulator whose capabilities go beyond running purely synthetic simulations in a local desktop. Due to its ability to run unmodified Linux applications, to execute in real time mode, and to exchange traffic with live networks, ns-3 can be combined with live hosts to run distributed simulations or to transparently integrate live and simulated networks. Nevertheless, setting up ns-3 multi-host experiment scenarios might require considerable manual work and advanced system administration skills. The NEPI experiment management framework is capable of automating deployment, execution, and result collection of experiment scenarios that combine ns-3 with multiple hosts in various ways, reducing the burden of manual scenario set up. We proved that this approach can be used to seamlessly running parallel simulations on a cluster of hosts, running distributed simulation spanning multiple hosts, and integrating live and simulated networks. This work has been published in [18] and has been awarded as the best paper of the workshop.

6.3.2. DiG: Emulating Data Centers and Cloud Architectures in a Grid Network

Participants: Hardik Soni, Thierry Turletti, Damien Saucez

We are witnessing a considerable amount of research work related to data-center and cloud infrastructures but evaluations are often limited to small scale scenarios as very few researchers have access to a real infrastructure to confront their ideas to reality. We have designed an experiment automation tool, called DiG (Data-centers in the Grid), which explicitly allocates physical resources in grids to emulate data-center and cloud networks. DiG allows one to utilize grid infrastructures to evaluate research ideas pertaining to data-centers and cloud environments at massive scale and with real traffic workload. We have automated the procedure of building target network topologies while respecting effective performance capacity of available physical resources in the grid against the demand of links and hosts in the experiment. We demonstrate a showcase where DiG automatically builds a large data-center topology composed of hundreds of servers executing various Hadoop intensive workloads (see our demo abstract at IEEE NFV/SDN 2015 in [24]).

7. Bilateral Contracts and Grants with Industry

7.1. Programmable data plane network functions

In the context of the common Inria - Alcatel Lucent Bell-Labs laboratory on Communication networks of the future, we participate to the Content Centric Networking ADR (Action de Recherche). In the context of this ADR, a post-doctoral position is working on the Most network applications and network functions today are implemented using specialized hardware middleboxes. The dedicated specialized hardware makes packet processing rates match that of the line rates that has been difficult to achieve on general purpose hardware. Recently the advancement in general purpose processors has made it possible to use general purpose CPU's for packet processing at line rates. If general purpose CPU's can replace dedicated hardware, this will drastically reduces the cost as the network functions can be moved from dedicated hardware to software. Currently, Virtualization has been promoted to realize network functions on general purpose computing devices and this currently popular in both academia and industry. There are a number of problems with using virtualization to realize network functions, the most important being the latency introduced by the software stacks. In this work, we will be looking at alternative approaches to implementing network functions on general purpose hardware. One of the main outcomes will be an approach that performs much better than the existing solutions. One of the goals of the work will be to find appropriate use cases for which the proposed architecture is a clear advantage with respect to other NFV solutions. Alcatel Lucent has joined Nokia in 2015. See http://company.nokia.com/en.

7.2. Privacy leaks monitoring and control

We are collaborating with the startup Novathings to deploy early stage privacy leaks monitoring and control solutions. We have proposed in Meddle a VPN based infrastructure performing SSL-bumping in order to capture all the mobile data traffic and to inspect even the SSL flows. The biggest advantage is that, as most mobile platforms support VPNs, we don't need any installation or root access on the devices to perform traffic redirection and inspection. We have a Carnot funding for a one year engineer position that started in April 2015 to implement a new solution on a home appliance sold by Novathings to improve transparency and control for personal devices.

We implemented a first prototype on a raspberry Pi device and started an integration following the Novathings graphical chart. See http://www.novathings.com/#/?lang=en.

8. Partnerships and Cooperations

8.1. Regional Initiatives

- **Plate-forme Telecom (Com4innov)** (2011-2017) is a DGCIS funded project, in the context of the competitivity cluster SCS, that aims at providing to PACA region industrials wishing to develop or validate new products related to future mobile networks and services and M2M application, a networking infrastructure and tools helpful for development, test and validation of those products. Other partners : 3Roam, Audilog Groupe Ericsson, Ericsson, Eurecom, Inria, iQsim, MobiSmart, Newsteo, OneAccess, Orange Labs, SCS cluster, ST Ericsson, Telecom Valley. Our contribution is centred around providing a test methodology and tools for wireless networks experimentation. In the context of this project we have realized a study on MPTCP performance in a wireless-wired environment with Orange Labs Sophia. The software tools that were developed in the project have been integrated in the $\mathrm{R^2lab}$ anechoic chamber.

8.2. National Initiatives

8.2.1. ANR

- **ANR FIT** (2011-2018): FIT (Future Internet of Things) aims at developing an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It will provide this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project will give French Internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the Future Internet. FIT is one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Équipements d'Excellence" (Equipex) research grant programme. The project will benefit from a 5.8 million euro grant from the French government. Other partners are UPMC, IT, Strasbourg University and CNRS. See also http://fit-equipex.fr/.
- **ANR DISCO** (2014-2016): DISCO (DIstributed SDN COntrollers for rich and elastic network services) aims at exploring the way how Software Defined Networking changes network monitoring, control, urbanisation and abstract description of network resources for the optimisation of services. The project works throughout experimentations and application use cases on the next generation of Software-Defined Networking solutions for large and critical distributed systems. The project will study the distribution of the current SDN control plane and the optimization of network operations that the integrated system view of cloud computing-based architectures allows. See also http://anr-disco.ens-lyon.fr/.
- **ANR REFLEXION** (2015-2017): REFLEXION (REsilient and FLEXible Infrastructure for Open Networking) research project will study the robustness and scalability of the current SDN architectures and the flexibility leveraged by SDN for provisioning resources and virtualized network functions (VNF). The project will address four main scientific objectives: (1) Fault and disruption management for virtualized services, (2) Robust and scalable control plane for next generation SDN, (3) Dynamic performance management of low level resources in SDN/NFV environments and (4) Distribution and optimization of virtual network functions in SDN environments. Our contribution in this project will be focused on fault and disruption management for virtualized services. See also http://anr-reflexion.telecom-paristech.fr/.
- **ANR BottleNet** (2016-2019): BottleNet aims to deliver methods, algorithms, and software systems to measure Internet Quality of Experience (QoE) and diagnose the root cause of poor Internet QoE. This goal calls for tools that run directly at users' devices. The plan is to collect network and application performance metrics directly at users' devices and correlate it with user perception to model Internet QoE, and to correlate measurements across users and devices to diagnose poor

Internet QoE. This data-driven approach is essential to address the challenging problem of modeling user perception and of diagnosing sources of bottlenecks in complex Internet services. ANR BottleNet will lead to new solutions to assist users, network and service operators as well as regulators in understanding Internet QoE and the sources of performance bottleneck.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

Program: FP7 FIRE programme

Project acronym:

Project title: Fed4Fire

Duration: October 2012 - October 2016

Coordinator: iMinds (Belgium)

Other partners: 17 european partners including iMinds (Belgium), IT Innovation (UK), UPMC (Fr), Fraunhofer (Germany), TUB (Germany), UEDIN (UK), NICTA (Australia), etc.

Web site: http://www.fed4fire.eu/

Abstract: Fed4FIRE will deliver open and easily accessible facilities to the FIRE experimentation communities, which focus on fixed and wireless infrastructures, services and applications, and combinations thereof. The project will develop a demand-driven common federation framework, based on an open architecture and specification. It will be widely adopted by facilities and promoted internationally. This framework will provide simple, efficient, and cost effective experimental processes built around experimenters' and facility owners' requirements. Insight into technical and socio-economic metrics, and how the introduction of new technologies into Future Internet facilities influences them, will be provided by harmonized and comprehensive measurement techniques. Tools and services supporting dynamic federated identities, access control, and SLA management will increase the trustworthiness of the federation and its facilities. A FIRE portal will offer brokering, user access management and measurements. Professional technical staff will offer first-line and second-line support to make the federation simple to use. The project will use open calls to support innovative experiments from academia and industry and to adapt additional experimentation facilities for compliance with Fed4FIRE specifications. A federation authority will be established to approve facilities and to promote desirable operational policies that simplify federation. A Federation Standardization Task Force will prepare for sustainable standardization beyond the end of the project. The adoption of the Fed4FIRE common federation framework by the FIRE facilities, the widespread usage by both academic and industrial experimenters, and the strong links with other national and international initiatives such as the FI-PPP, will pave the way to sustainability towards Horizon 2020.

8.3.2. EIT KIC funded activities

Program: FNS Future Networking Solutions Action Line

Project acronym: NFMD

Project title: Networks for Future Media Distribution (14082)

Duration: January 2015 to December 2015

Coordinator: Acreo, Sweden

Other partners: VTT (Finland), Ericsson, Lund University, SICS (Sweden).

Abstract: The EIT ICT Labs' Networks for Future Media Distribution (NFMD)' activity 14082 has as a specific innovation object set out in the application. The caching algorithm are evaluated and implemented as a proof-of-concept and integrated in the NetInf Information Centric Networking prototype. The field test at the Nordic Ski Championship in Falun was used to gain experience with the NetInf technology in a larger setting to be able to improve the implementations towards production quality. We furthermore in detail analyse and evaluate the test with the purpose to

understand the benefits and limitations of the technology. The work on QoE metrics and tools aims to further develop and launch a service “streamingkollen.se” and “ACQUA" that enable consumers to measure the expected media quality that can be achieved with the user’s current network connection and equipment. One result of the development is in open source code contributions. Related standardisation activities and business model analysis are also carried out in the activity. Of particular interest for this year is the business interest of INDRA in transferring the results in the area of QoE to a new line of monitoring systems.

8.4. International Initiatives

8.4.1. Inria International Labs

We collaborate with Javier Bustos from Inria Chile and his group on the measurements and analysis of users’ quality of experience. This collaboration fits within our respective projects Adkinton Mobile and ACQUA, and aims at collecting measurements of both network and experience, and at using these measurements for the analysis and calibration of users’ experience new models and for the design of network troubleshooting techniques in case of service degradation. In 2015, we hosted a student from Inria Chile who worked with us on setting up an experimental platform for Quality of Experience Measurement instantiated to the particular case of YouTube streaming. We also worked together on the Skype use case and published the results in [16].

8.4.2. Inria International Partners

8.4.2.1. Informal International Partners

We have collaborated with researchers at NICT, Japan to propose the Contrace tool for measuring and tracing Content-Centric Networks (CCNs). The tool allows to estimate the content popularity and can help in designing more effective cache control mechanisms.

We have an ongoing collaboration with Katia Obraczka’s team at UCSC on the decentralization of the SDN control plane, following our previous COMMUNITY associated team.

We have collaborated with researchers at Universidad Diego Portales (UDP) and Universidad de Chile to design PcapWT, an efficient packet extraction tool for large experimentation traces.

We are collaborating with Augustin Chaintreau from Columbia University on the use of social networks to attrack traffic on news media sites.

We are collaborating with David Choffnes from Northeastern University on the detection, analysis, and prevention of privacy leaks from mobile devices.

We have designed and demonstrated a solution for virtual Service Providers in SOHO networks in collaboration with Ericsson and LISPERS.net (http://www.lispers.net/). The principle is to allow homenets and SOHO networks to use services normally available only for large networks. This, thanks to the virtualization of the Internet connections by the mean of overlay routing. We implemented a demonstrator using LISP implementation provided by LISPERS.net and deployed it in Google Cloud. The key element of the concept is a virtual CPE that has been implemented on a Raspberry Pi demonstrating the potential of the solution for IoT. A demonstration of the fully functional system can be watched at https://www.youtube.com/watch?v=Gzk-h5UK54E.

We collaborate with the CRISTAL Lab at ENSI in Tunisia on memory optimizations for content routing. See [17] for more details.

8.5. International Research Visitors

8.5.1. Visits of International Scientists

8.5.1.1. Internships

Nicolas Aguilera Miranda

Date: from October 2014 February 2015

Institution: University of Chile, CIRIC

Supervisor: Chadi Barakat

Subject: Measurements of users' quality of experience over Adkintun Mobile

Brahim Bellaoui

Date: from Mar 2015 until Aug 2015

Institution: University of Nice Sophia Antipolis

Supervisor: Thierry Turletti, Damien Saucez and Walid Dabbous

Subject: Optimization Framework and Fault Management for NFV and SDN

Yuri Bushnev

Date: from June 2015 until Aug 2015

Institution: Saint Petersburg State University

Supervisor: Thierry Turletti and Damien Saucez

Subject: Robust programmable communication networks

Anuvabh Dutt

Date: from Aug 2015 until Sep 2015

Institution: University of Nice Sophia Antipolis, International Master 1

Supervisor: Arnaud Legout

Subject: Analysis of Hashtag Relations to Identify Unusual User Activities on Twitter

Anastasia Kuznetsova

Date: from July 2015 until Aug 2015

Institution: University of Nice Sophia Antipolis, International Master 1

Supervisor: Arnaud Legout

Subject: Analysis of Hashtag Relations to Identify Unusual User Activities on Twitter

Mohamed Naoufal Mahfoudi

Date: from Mar 2015 until Aug 2015

Institution: University of Nice Sophia Antipolis, Ubinet Master

Supervisor: Walid Dabbous and Thierry Turletti

Subject: Reproducible and Realistic wireless Experiments in an Anechoic Chamber

Thierry Spetebroot

Date: from March 2015 until August 2015

Institution: Polytech Nice Sophia, Ubinet Master

Supervisor: Chadi Barakat

Subject: From network-level measurements to expected Quality of Experience for Video applications

8.5.2. Visits to International Teams

Walid Dabbous visited NICT in Tokyo Japan in the context of the Simulbed associated team. He also participated to the French-Japanese workshop dedicated to Cybersecurity in Tokyo, on April 1st to 3rd 2015.

Arnaud Legout visited Columbia University from August 31st to September in the context of the collaboration with Augustin Chaintreau.

8.5.2.1. Research stays abroad

Maksym Gabielkov visited Columbia University for 6 months (from June 15 to December 15). He collaborated with Augustin Chaintreau and his team on the topic "Social Clicks: What and Who Gets Read on Twitter?"

Xuan Nam Nguyen visited Aalto University for 3 months (from June to August). He collaborated with Jose Costa Requena team on "Versatile Caching Framework for LTE".

9. Dissemination

9.1. Promoting Scientific Activities

Walid Dabbous is in member of the technical program committee of the IEEE INFOCOM International Workshop on Computer and Networking Experimental Research Using Testbeds, CNERT 2016. He gave an invited talk on Realistic and Reproducible Wireless Networking Experiments at the REPPAR'2015 workshop at Vienna. He is founding member of the ns-3 consortium and co-organized the ns-3 workshop in May 2015. He is vice-president of the PlanetLab Europe consortium. He co-organizes the workshop on Future challenges in User-Centric Networks, co-located with Sigmetrics 2016 in June 2016. He is member of the scientific council of the Inria Bell-Labs laboratory on Communication networks of the future. He also servers as a chair of the scientific committee of the User Centric Networking (UCN@Sophia) Laroratory of Excellence. He is member of board of directors of the Telecom Platform Association responsible for the deployment and operation of the Com4Innov mutualized platform. He co-organized the joint UCN@Sophia Labex - Com4Innov day on research and experimentation. He is also member of the Ubinet International Master program steering committee. He is member of the Inria Sophia Antipolis project committee's bureau (Bureau du CP).

Thierry Turletti, Senior ACM and IEEE member, served in 2015 in the program committees of the following international workshops: the 21th Packet Video Workshop, Sydney, Australia, USA, June 4-5, 2015, the 6th Workshop on ns-3 at Barcelona, Spain, May 13, 2015, the 10th ACM Mobicom Workshop on Challenged Networks at Paris, France, September 11, 2015, the 11th ACM SIGCOMM Asian Internet Engineering Conference (AINTEC), Bangkok, Thailand, November 2015 and the 13th ACM International Symposium on Mobility Management and Wireless Access (MOBIWAC), Cancun, Mexico, November 2015; Thierry Turletti is member of the Editorial Boards of the Journal of Mobile Communication, Computation and Information (WINET) published by Springer Science and of the Advances in Multimedia Journal published by Hindawi Publishing Corporation. He is president of the Committee for Technological Development (CDT) and member of the committee NICE that studies postdoc and visiting researcher applications at Inria Sophia Antipolis

Chadi Barakat is on the editorial board of the Computer Networks journal, on the Technical Program Committee for the Traffic Monitoring and Analysis (TMA) 2015 workshop, the Passive and Active Measurement (PAM) 2016 Conference, the Algotel 2016 Conference, the ACM SIGCOMM 2015 Posters and Demos Session, and Publicity Co-Chair for ACM SIGCOMM 2015. He is currently the scientific referee for international affairs at Inria Sophia Antipolis and member of the Conseil d'Orientation Scientifique et Technologique (COST) at Inria within the working group of international affairs (COST-GTRI).

Arnaud Legout is on the editorial board of the Computer Networks journal, and was PC member of the ACM CoNEXT 2015 conference. Arnaud Legout is the president of the Commission of the users of IT resources of Sophia Antipolis Inria research center.

Damien Saucez is member of the TPC of DRCN 2016 and CCNC 2016. Damien Saucez is secretary and document shepherding at the IETF LISP working group (details about the secretary and shepherd roles can be found in RFC 2418 and RFC 4858). Damien Saucez is secretary of the Project Committee (CP) at Inria Sophia Antipolis Méditerranée.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

Master Ubinet: Chadi Barakat and Walid Dabbous, Evolving Internet, 31.5 hours, M2, University of Nice-Sophia Antipolis, France.

Master Ubinet: Chadi Barakat and Walid Dabbous, Internet Measurements and New Architectures, 31.5 hours, M2, University of Nice-Sophia Antipolis, France.

Master 1 International: Chadi Barakat, Algorithms for Networking, 22.5 hours, M1, University of Nice-Sophia Antipolis, France.

Master Estel: Chadi Barakat, Voice over IP, 9 hours, University of Nice-Sophia Antipolis, France.

Master RISM: Chadi Barakat, Mobility and wireless networking, 10.5 hours, University of Avignon, France.

Master Ubinet: Arnaud Legout, From BitTorrent to Privacy, 36 hours, M2, University of Nice-Sophia Antipolis, France.

Master 1 International: Arnaud Legout, Oral and written communications, 18 hours, M1, University of Nice-Sophia Antipolis, France.

Master IUP GMI: Damien Saucez, Security and privacy in networks, 38h, M2, University of Avignon, France.

IUT : Damien Saucez, Advanced Network Services and Operator Network Technologies, 27h, L1 and L2, University of Nice-Sophia Antipolis, France.

E-learning

Mooc: Arnaud Legout and Thierry Parmentelat, Python : des fondamentaux à l'utilisation du langage, 7 weeks, FUN (https://www.france-universite-numerique-mooc.fr/), Inria, 9615 registered persons, 1487 qualified for the final attestation of achievement.

9.2.2. Supervision

PhD in progress: Maksym Gabielkov works on "Information propagation in social networks" since October 2012. His thesis is supervised by Arnaud Legout.

PhD: Alina Quereilhac defended her PhD on "A Platform and Domain Independent Approach to Network Experiment Automation" in June 2015. Her thesis was co-supervised by Walid Dabbous and Thierry Turletti.

PhD in progress: Mohamed Naoufal Mahfoudi works on cross-layer optimization techniques for next generation MIMO-based networks since November 2015. His thesis is co-supervised by Walid Dabbous and Robert Staraj (LEAT).

PhD in progress: Ghada Moualla works on "the problem of network faults and how to circumvent them by the means of Software Defined Networking, virtualization, and service function chaining" since November 2015. Her thesis is co-supervised by Thierry Turletti and Damien Saucez.

PhD in progress: Xuan Nam Nguyen works on "Software Defined Networking in challenged environments", since October 2012. His thesis is co-supervised by Thierry Turletti and Walid Dabbous.

PhD in progress: Vitalii Poliakov works on "the application of Software Defined Networking on 5G networks in order to optimise the Quality of Experience of network services" since November 2015. His thesis is co-supervised by Damien Saucez and Lucile Sassatelli (I3S).

PhD in progress: Hardik Soni works on "Software Defined Networking in challenged environments" since September 2014. His thesis is co-supervised by Thierry Turletti and Walid Dabbous.

PhD in progress: Riccardo Ravaioli works on "Active and Passive Inference of Network Neutrality" since October 2012. His thesis is co-supervised by Chadi Barakat and Guillaume Urvoy-Keller (I3S).

PhD in progress: Luigi Vigneri works on "Vehicles as a Mobile Cloud: Leveraging mobility for content storage and dissemination" since April 2014. His thesis is co-supervised by Chadi Barakat and Thrasyvoulos Spyropoulos (Eurecom).

9.2.3. Juries

Chadi Barakat served as reviewer of Quentin Jacquemart PhD thesis, "Towards Uncovering BGP Hijacking Attacks" defended in October at Eurecom.

Chadi Barakat served as reviewer of Florin Coras PhD thesis, "On the Scalability of LISP and Advanced Overlaid Services " defended in July 2015 at Polytechnic University of Catalonia (UPC), Barcelona.

Chadi Barakat served as reviewer of Pavlos Sermpezis PhD thesis, "Performance Analysis of Mobile Social Networks with Realistic Mobility and Traffic Patterns" defended in February 2015 at Eurecom.

Thierry Turletti served as examiner of Diala Naboulsi PhD thesis, "Analysis and exploitation of mobile traffic datasets", defended in September 2015 at INSA Lyon.

Walid Dabbous served as reviewer of Patrick Senac HDR thesis, "L'Internet de l'extrême. Modèles, protocoles et mécanismes de bout en bout pour les réseaux de communication de nouvelle génération" defended in October 2015 at UPMC.

Walid Dabbous served as reviewer of Gwendal Simon HDR thesis, "Massive Interactive Multimedia Services Over the Internet" defended in April 2015 at Télécom Bretagne, Univ. of Rennes 1.

Walid Dabbous served as reviewer of Natalya Rozhnova PhD thesis, "Congestion control for Content-Centric Networking" defended in May 2015 at UPMC.

Thierry Turletti served as examiner and president of Haiyang Jiang PhD thesis, "Research on parallelization of nework intrusion detection system", defended in May 2015 at Univ. of Grenoble.

Thierry Turletti served as reviewer of Peng He PhD thesis, "Design and evaluation of high performance software based packet classi cation systems", defended in May 2015 at Univ. of Grenoble.

Thierry Turletti served as reviewer of Michelle Tortelli PhD thesis, "Information-Centric Networking: Routing Design and Performance Evaluation Methodologies", defended in January 2015 at Politecnico di Bari.

9.3. Popularization

Chadi Barakat presented ACQUA at the Scientific Day of the Afnic (JCSA 2015). See https://www.afnic.fr/fr/l-afnic-en-bref/actualites/actualites-generales/9333/show/jcsa15-retour-sur-la-journee-du-conseil-scientifique-de-l-afnic-2015.html.

Walid Dabbous was invited again in october 2015 to present Future Internet challenges to high school students at CIV for the Science Week (Fête de la science).

Arnaud Legout presented at lycée Amiral de grasse to students in première and terminale a conference on privacy in the Internet in April 2015.

Damien Saucez has made a speech on the reproducibility of experimentation at the Journée Cloud 2015 of the GdR RSD Cloud Action Transverse (see https://rsd-cloud.lip6.fr/journee.html).

10. Bibliography

Major publications by the team in recent years

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[2] D. CAMARA, H. TAZAKI, E. MANCINI, M. LACAGE, T. TURLETTI, W. DABBOUS. *DCE: Test the real code of your protocols and applications over simulated networks*, in "IEEE Communications Magazine", 2014, https://hal.inria.fr/hal-00927519

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