informatics / *mathematics*

Ínría

Activity Report 2018

Project-Team DIANA

Design, Implementation and Analysis of Networking Architectures

Table of contents

Project-Team DIANA

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

Keywords:

Computer Science and Digital Science:

A1.1.13. - Virtualization
A1.2.1. - Dynamic reconfiguration
A1.2.2. - Supervision
A1.2.3. - Routing
A1.2.4. - QoS, performance evaluation
A1.2.5. - Internet of things
A1.2.9. - Social Networks
A1.3. - Distributed Systems
A1.3.4. - Peer to peer
A1.4. - Ubiquitous Systems

Other Research Topics and Application Domains:

B6.2. - Network technologies
B6.2.1. - Wired technologies
B6.2.2. - Radio technology
B6.2.3. - Satellite technology
B6.3.2. - Network protocols
B6.3.3. - Network Management
B6.3.4. - Social Networks
B8.5.2. - Crowd sourcing
B9.1.1. - E-learning, MOOC
B9.5.1. - Computer science
B9.5.6. - Data science
B9.8. - Reproducibility
B9.10. - Privacy

1. Team, Visitors, External Collaborators

Research Scientists
Walid Dabbous [Team leader, Inria, Senior Researcher, HDR]
Chadi Barakat [Inria, Senior Researcher, HDR]
Arnaud Legout [Inria, Researcher, HDR]
Damien Saucez [Inria, Researcher]
Thierry Turletti [Inria, Senior Researcher, HDR]

Post-Doctoral Fellows
Osama Arouk [Inria, until Sep 2018]
Giulio Grassi [Inria, from Oct 2018]
Tingting Yuan [Inria, from Nov 2018]

PhD Students

Othmane Belmoukadam [Univ Côte d'Azur, from Oct 2018]
Yanis Boussad [Univ Côte d'Azur]
Giuseppe Di Lena [Orange Labs, from Apr 2018]
Thibaut Ehlinger [Inria]
Imane Fouad [Inria]
Karyna Gogunska [Inria]
Muhammad Jawad Khokhar [Inria]
Mohamed Naoufal Mahfoudi [Inria]
Ghada Moualla [Inria]
Vitalii Poliakov [Univ de Nice - Sophia Antipolis]
Hardik Soni [Inria, until Apr 2018]
Imane Taibi [Inria]
Mathieu Thiery [Inria]
Thibaud Trolliet [Inria]

Technical staff
Abdelhakim Akodadi [Inria]
Zeineb Guizani [Inria, from Jul 2018]
Thierry Parmentelat [Inria]
Mondi Ravi [Inria]
Thierry Spetebroot [Inria, until Mar 2018]
David Migliacci [Inria]

Interns
Othmane Belmoukadam [Inria, from Mar 2018 until Aug 2018]
Othmane Bensouda Korachi [Inria, from Mar 2018 until Aug 2018]
Yonathan Bleyfuesz [Univ de Nice - Sophia Antipolis, from Feb 2018 until Aug 2018]
Laila Daanoun [Inria, from Mar 2018 until Aug 2018]
Mohamed Janati Idrissi [Inria, from Mar 2018 until Aug 2018]
Indukala Naladala [Inria, from May 2018 until Jul 2018]
Yevhenii Semenko [Univ Côte d'Azur, from Mar 2018 until Aug 2018]
Gayatri Sivadoss [Inria, from Mar 2018 until Aug 2018]
Alberto Zirondelli [Univ Côte d'Azur, from Mar 2018 until Aug 2018]

Administrative Assistant
Christine Foggia [Inria]

Visiting Scientists
Anas Errahali [Univ Côte d'Azur, from Nov 2018]
Antonello Florio [Univ Côte d'Azur, from Nov 2018]
Piergiorgio Ladisa [Univ Côte d'Azur, from Nov 2018]
Salaheddine Mesoik [Univ Côte d'Azur, from Nov 2018]
Katia Obraczka [University of California Santa Cruz, Jul 2018]
Youssef Rachid [Univ Côte d'Azur, from Nov 2018]
Tareq Si Salem [Univ Côte d'Azur, from Nov 2018]

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 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 project-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. Current state of the art activities are 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 concerning the Web search service of Google that is more accurate but less privacy preserving than Bing or Qwant. 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, more than fifteen years ago the Internet for the end-users was mostly the Web. Only ten 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

4.1.1. *Awards*

Karyna Gogunska's paper on "On the Cost of Measuring Traffic in a Virtualized Environment" [20] got the Best Student Paper Award at the IEEE Cloudnet 2018 in Japan.

4.1.2. *ANR JCJC DET4ALL*

Damien Saucez's project titled DET4ALL was accepted in the JCJC programme (2019-2021). The goal of this project is to apply the concept of network programmability to the world of industrial communicating systems.

4.1.3. *ACM SIGCOMM Artefact Evaluation Committee*

Our team organized the Reproducibility'17@SIGCOMM workshop (proposed and co-chaired by Damien Saucez). Based on the results of the workshop, we put in place the ACM SIGCOMM *Artefact Evaluation Committee* (AEC). The role of the AEC is to assess the reproducibility level of papers accepted to any ACM SIGCOMM sponsored conferences and journals during the year 2018. The reproducibility quality is awarded by ACM reproducibility badges [1]. Authors volunteered to be evaluated and we received 33 demands. In parallel to this effort, the organisers of the ACM CoNEXT'18 conference asked us to assess the reproducibility level of CoNEXT papers in 2018 as part of the publication process. We accepted and out of the 32 CoNEXT papers, 14 volunteered to be evaluated and 12 received an award. The result is that ACM CoNEXT'18 is the first ever ACM SIGCOMM sponsored conference to award reproducibility. Based on that the main ACM SIGCOMM conference has decided to make a trial in 2019 and integrate reproducibility evaluation as part of the publication process for 2019.

5. New Software and Platforms

5.1. ACQUAmobile

KEYWORDS: Android - Internet access - Performance measure - Quality of Experience

---

[1] http://www.acm.org/publications/policies/artifact-review-badging

FUNCTIONAL DESCRIPTION: ACQUA is an Application for prediCting QUality of Experience (QoE) at Internet Access. It is developed by the Diana team at Inria Sophia Antipolis – Méditerranée and was supported by Inria under the ADT ACQUA grant. The scientific project around ACQUA is supported by Inria Project Lab BetterNet and the French National Project ANR BottleNet. The project also got the approval of Inria COERLE and French CNIL for the part on experimentation with real users. 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, jitter, etc), ACQUA targets the estimated Quality of Experience (QoE) 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, or a model, that links the network-level and device-level measurements to the expected Quality of Experience. Supervised machine learning techniques are used to establish such link between measurements both at the network level and the device level, and estimations of the Quality of Experience for different Internet applications. The required data for such learning can be obtained either by controlled experiments as we did in [22], [21] on YouTube Quality of Experience, or by soliciting the crowd (i.e. crowdsourcing) for combinations (i.e. tuples) of measurements and corresponding application-level Quality of Experience. Our current work is concentrating on using the ACQUA principle in the estimation and prediction of the Quality of Experience for main user's applications. We refer to the web site of the project for further details.

The ACQUA Android application is supposed to be on one hand the reference application for QoE forecasting and troubleshooting for end users at their Internet access, and on the other hand, the feedback channel that allows end users to report to us (if they are willing) on their experience together with the corresponding network measurements so as to help us calibrating better and more realistic models. For this calibration, we are currently performing extensive, efficient and automatic measurements in the laboratory, we will count on end users to help us completing this dataset with further applications and more realistic network and user conditions.

ACQUA is mainly meant for end users, but it is also of interest to (mobile) network operators and to content providers to estimate the QoE of their customers and their networks without each time having to run expensive application-level traffic and to involve real users.

- Authors: Thierry Spetebroot and Chadi Barakat
- Contact: Chadi Barakat
- URL: http://project.inria.fr/acqua/

5.2. ElectroSmart

KEYWORDS: Crowd-sourcing - UMTS - GSM - Bluetooth - Wi-Fi - 4G - 3G - 2G - Electromagnetic waves - Android - LTE

FUNCTIONAL DESCRIPTION: 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 is supported by the UCN@Sophia Labex in 2016/2017/2018 (funding the engineer Mondi Ravi), by an Inria ADT (funding the engineer Abdelhakim Akodadi) 2017/2018, by and Inria ATT (funding the business developer David Migliacci) in 2017/2018, and by the academy 1 of UCAJedi (funding a Ph.D. student Yanis Boussad) 2017/2020.

In August 2016, we released the first stable public release of ElectroSmart. On the 13th July 2018 we have 84 000 downloads in Google Play, an average score of 4.4/5, 30 000 active users, 850 millions measured signals.

We are in a process of creating a startup to commercialize the exposition maps we can build with the data we are collecting.

- Participants: Arnaud Legout, Abdelhakim Akodadi, Hackob Melconian, Inderjeet Singh and Mondi Ravi
- Contact: Arnaud Legout
- URL: https://es.inria.fr/home/index?path_prefix=en

5.3. OpenLISP

KEYWORDS: LISP - Routing - Control-plane
FUNCTIONAL DESCRIPTION: 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.

- Contact: Damien Saucez
- URL: http://www.openlisp.org/downloads

5.4. nepi-ng

KEYWORDS: Wireless network - Experimentation
FUNCTIONAL DESCRIPTION: In the specific context of R2lab, we have created a tool suite for orchestrating network experiments, that for historical reasons we refer to collectively as `nepi-ng`, for NEPI new generation. An umbrella website is available at https://nepi-ng.inria.fr/.

At this point, `nepi-ng` has a much smaller scope than its NEPI ancestor used to have, in that it only supports remote control of network experiments over `ssh`. As a matter of fact, in practice, this is the only access mechanism that we need to have for running experiments on both R2lab, and PlanetLab Europe.

The design of `nepi-ng` of course is modular, so that it will be perfectly possible to add other control mechanisms to this core if and when it becomes necessary.

`nepi-ng` is currently made of two separate python libraries:

- asynciojobs:
  - URL: http://asynciojobs.readthedocs.io/en/latest/
  - Version: asynciojobs v0.5.4
  - Keywords: networking experimentation, orchestration
  - License: CC BY-SA 4.0
  - Type of human computer interaction: python library
  - OS/Middleware: Linux
  - Required library or software: python-3.5 / asyncio
  - Programming language: python3
- apssh:
  - URL: http://apssh.readthedocs.io/en/latest/
  - Version: apssh v0.7.1
  - Keywords: networking experimentation, orchestration
  - License: CC BY-SA 4.0
  - Type of human computer interaction: python library
  - OS/Middleware: Linux
  - Required library or software: python-3.5 / asyncio
  - Programming language: python3
- Contact: Thierry Parmentelat
- URL: http://nepi-ng.inria.fr

5.5. Platforms

5.5.1. *Reproducible research Lab - R2lab*

Scientific evaluation of network protocols requires for experiments to be reproducible before they can be deemed valid. This is particularly difficult to obtain in the wireless networking area, where characteristics of wireless channels are known to be variable, unpredictable and hardly controllable.

The R2lab wireless testbed is built around an isolated and anechoic chamber, featuring RF absorbers preventing radio waves reflections and a Faraday cage blocking external interferences. This lab, named R2lab, represents an ideal environment for experiments reproducibility.

It represents a perfect facility for making wireless experiments reproducible. It has been operated for 3 years now, in the context of the FIT (Future Internet of Things) 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.

During 2018, our focus regarding R2lab has been set on enhancing the `nepi-ng` software toolkit, extending the set of tutorials and on deploying more network devices such as LoRa and Ettus USRP devices. The chamber now offers 19 USRP devices, as well as a couple of lime-sdr devices and a couple of E3372 LTE dongles. Moreover, two remotely controllable iphone are available. All these additions aim at widening even further the spectrum of experiments that the testbed can support.

Access to R2lab is open 24/7. We currently have around 150 active users from all over the world among them 45 new users registered in 2018. For more details see http://r2lab.inria.fr.

5.5.2. *Network simulator for aircrafts*

- Keywords: network, simulation, real-time
- Functional Description: In collaboration with Safran Electrical and Power we produced a network design tool for aircrafts. This tool simulates aircraft networks. The tool is about 10,000 lines of code, out of which we produced 2,000.
- Assessment: A-2up,SO-3,SM-2up,EM-4,SDL-3,OC-DA-CD-TPM
- Licence: confidential
- URL: confidential
- Contact: Damien Saucez

6. New Results

6.1. Service Transparency

6.1.1. *An Intelligent Sampling Framework for Controlled Experimentation and QoE Modeling*

Participants: Muhammad Jawad Khokhar, Nawfal Abbasi Saber, Thierry Spetebroot, Chadi Barakat.

For internet applications, measuring, modeling and predicting the quality experienced by end users as a function of network conditions is challenging. A common approach for building application specific Quality of Experience (QoE) models is to rely on controlled experimentation. For accurate QoE modeling, this approach can result in a large number of experiments to carry out because of the multiplicity of the network features, their large span (e.g., bandwidth, delay) and the time needed to setup the experiments themselves. However, most often, the space of network features in which experimentations are carried out shows a high degree of similarity in the training labels of QoE. This similarity, difficult to predict beforehand, amplifies the training cost with little or no improvement in QoE modeling accuracy. So, in this work, funded by ANR BottleNet and IPL BetterNet, we aim to exploit this similarity, and propose a methodology based on active learning, to sample the experimental space intelligently, so that the training cost of experimentation is reduced. We validate our approach for the case of YouTube video streaming QoE modeling from out-of-band network performance measurements, and perform a rigorous analysis of our approach to quantify the gain of active sampling over uniform sampling. We first develop the methodology for an offline case where a pool of scenarios to experiment with is available. Then, we present an online variant that does not require a pool of scenarios, but finds automatically and in an online manner the best scenarios to experiment with. This latter variant outperforms the offline variant both in terms of accuracy and computation complexity. It is published in [22]. The overall methodology and its specification to both the offline and the online cases are published in [15].

6.1.2. *A Methodology for Performance Benchmarking of Mobile Networks for Internet Video Streaming*

Participants: Muhammad Khokhar, Thierry Spetebroot, Chadi Barakat.

Video streaming is a dominant contributor to the global Internet traffic. Consequently, gauging network performance w.r.t. the video Quality of Experience (QoE) is of paramount importance to both telecom operators and regulators. Modern video streaming systems, e.g. YouTube, have huge catalogs of billions of different videos that vary significantly in content type. Owing to this difference, the QoE of different videos as perceived by end users can vary for the same network Quality of Service (QoS). In this work, funded by ANR BottleNet and IPL BetterNet, we present a methodology for benchmarking performance of mobile operators w.r.t Internet video that considers this variation in QoE. We take a data-driven approach to build a predictive model using supervised machine learning (ML) that takes into account a wide range of videos and network conditions. To that end, we first build and analyze a large catalog of YouTube videos. We then propose and demonstrate a framework of controlled experimentation based on active learning to build the training data for

the targeted ML model. Using this model, we then devise YouScore, an estimate of the percentage of YouTube videos that may play out smoothly under a given network condition. Finally, to demonstrate the benchmarking utility of YouScore, we apply it on an open dataset of real user mobile network measurements to compare performance of mobile operators for video streaming. This work is published in [21] and its extension to more sophisticated QoE models that consider other factors than interruptions is ongoing.

6.1.3. *On the Cost of Measuring Traffic in a Virtualized Environment*

Participants: Karyna Gogunska, Chadi Barakat.

The current trend in application development and deployment is to package applications and services within containers or virtual machines. This results in a blend of virtual and physical resources with complex network interconnection schemas mixing virtual and physical switches along with specific protocols to build virtual networks spanning over several servers. While the complexity of this setup is hidden by private/public cloud management solutions, e.g. OpenStack, this new environment constitutes a challenge when it comes to monitor and debug performance related issues. In this work carried out in collaboration with the Signet team of I3S with the support of the UCN@Sophia Labex, we introduce the problem of measuring traffic in a virtualized environment and focus on one typical scenario, namely virtual machines interconnected with a virtual switch. For this scenario, we assess the cost of continuously measuring the network traffic activity of the machines. Specifically, we seek to estimate the competition that exists to access the physical resources (e.g., CPU) of the physical server between the measurement task and the legacy application activity. This work was published in the IEEE Cloudnet 2018 conference [20] where it was awarded the Best Student Award. The collaboration with I3S is pursued towards a controlled configuration and deployment of measurements tools in a way to limit their impact on the legacy data plane of virtualized environments.

6.1.4. *ElectroSmart*

Participants: Arnaud Legout, Mondi Ravi, David Migliacci, Abdelhakim Akodadi, Yanis Boussad.

We are currently evaluating the relevance to create a startup for the ElectroSmart project. We are quite advanced in the process and the planned creation is June 2019. There is a "contrat de transfer" ready between Inria and ElectroSmart to transfer the PI from Inria to the ElectroSmart company (when it will be created). Arnaud Legout the future CEO of the company obtained the "autorisation de création d'entreprise" from Inria. ElectroSmart has been incubated in PACA Est in December 2018.

The three future co-founder of ElectroSmart (Arnaud Legout, Mondi Ravi, David Migliacci) are following the Digital Startup training from Inria/EM Lyon. This training helped formalize and improve the product market fit and the business model. We are also preparing the iLab competition.

The business model of ElectroSmart is to create an affiliation strategy to help companies selling product to reduce EMF exposure to find potential clients. Indeed, ElectroSmart users represent a highly qualified database of people concerned by EMF exposure. This database is invaluable to these companies as it is an emerging market and it is hard for these companies to make efficient marketing campaigns. The benefit for the ElectroSmart users is to have access to negotiated and validated solutions to reduce their EMF exposure. We are currently validating this market. We started our first affiliation campaign in December 2018 with the Spartan company that sells radiation blocking boxers. We already have two more planned campaigns in 2019, with a goal of 5 campaigns in 2019.

6.2. Open Network Architecture

6.2.1. *Controller load in SDN networks*

Participant: Damien Saucez.

In OpenFlow, a centralized programmable controller installs forwarding rules into switches to implement policies. However, this flexibility comes at the expense of extra overhead in signalling and number of rules to install. The community considered that it was essential to install all rules and strictly respect routing requirements, hence working on making extra fast and large memory switches and controllers. Instead we took an opposite direction and came with a new vision that leverages the SDN concept and considers the network as a black box where tailored rules should be used only for network traffic that really matters while for the rest a good-enough (sub-optimal but cheap) default behaviour should be enough. In the past, we applied this vision to limit the needed memory on network switches in [7]. Lately, we proposed solutions to limit the number of exchanged messages between the switches and the controller. More precisely, in [19], we developed a distributed sampling adaptive algorithm that allows switches to locally decide if they can contact the controller or if instead they should make their own decision locally. Numerical evaluation and emulation in Mininet demonstrate the benefit of the approach. The results were published in IEEE INFOCOM 2018, April 2018.

6.2.2. *Resilient Service Function Chains in virtual networks*

Participants: Ghada Moualla, Damien Saucez, Thierry Turletti.

Virtualization of network functions has led to the whole new concept of Service Function Chaining (SFC) that aims at building on the fly network services by deploying them in the Cloud. A vast literature proposes techniques to build virtual service chains and map them into physical infrastructure to maximize performance while reducing costs. However, the resiliency of chains is not investigated. However, such service chains are used for critical services like e-health or autonomous transportation systems and thus require high availability. Respecting some availability level is hard in general, but it becomes even harder if the operator of the service is not aware of the physical infrastructure that will support the service, which is the case when SFCs are deployed in multi-tenant data centers. With this work, we propose algorithms to solve the placement of topology-oblivious SFC demands such that placed SFCs respect availability constraints imposed by the tenant. In order to be practically usable, i.e., without knowledge on future demands, we leverage the structural properties of multi-tier data-center topologies such as Fat-Tree or Sine and Leaf topologies to build fast yet efficient online algorithms. We explored two radically different approaches: a deterministic one and a stochastic one and results show that both can be used in very large scale data-centers (i.e., 40k nodes or more) and our simulation results show that the algorithms are able to satisfy as many demands as possible by spreading the load between the replicas and enhancing the network resources utilization [23].

Initial results were published in IEEE International Conference on Cloud Networking 2018, October 2018.

6.2.3. *Privacy preserving distributed services*

Participants: Damien Saucez, Yevhenii Semenko, Alberto Zirondelli.

Blockchains are expected to help in reducing dependency on centralized platforms (e.g., Uber, Airbnb). With this internship, we have designed a protocol to make a fully distributed, secured, and privacy protecting taxi service – a distributed version of Uber. The analytical study shows that in such system the privacy protection comes with an important overhead in network communications which raises reasonable doubt on the feasibility of actually using fully distributed platforms in an "internet-scale environment" even though our implementation on Android phones shows that it is technically possible to build such systems. This work is done in collaboration with the GREDEG [2], that is evaluating the incentives for users to move to fully distributed platforms that are privacy preserving but that require the users to play an active role in the system.

6.2.4. *P4Bricks: Enabling multiprocessing using Linker-based network data plane architecture*

Participants: Hardik Soni, Thierry Turletti, Walid Dabbous.

---

[2]Groupe de Recherche en Droit, Economie, Gestion, a research center related to both the CNRS and the University of Nice-Sophia Antipolis and dealing with economic, managerial and legal aspects. See http://unice.fr/laboratoires/gredeg in French.

Packet-level programming languages such as P4 usually require to describe all packet processing functionalities for a given programmable network device within a single program. However, this approach monopolizes the device by a single large network application program, which prevents possible addition of new functionalities by other independently written network applications. We propose P4Bricks, a system which aims to deploy and execute multiple independently developed and compiled P4 programs on the same reconfigurable hardware device. P4Bricks is based on a Linker component that merges the programmable parsers/deparsers and restructures the logical pipeline of P4 programs by refactoring, decomposing and scheduling the pipelines' tables. It merges P4 programs according to packet processing semantics (parallel or sequential) specified by the network operator and runs the programs on the stages of the same hardware pipeline, thereby enabling multiprocessing. We present the initial design of our system with an ongoing implementation and study P4 language's fundamental constructs facilitating merging of independently written programs [34], [12].

6.2.5. Applications in ITS Message Dissemination

Participants: Thierry Turletti.

We build upon our prior work on D2-ITS, a flexible and extensible framework to dynamically distribute network control to enable message dissemination in Intelligent Transport Systems (ITS), and extend it with handover and load balancing capabilities. More specifically, D2-ITS' new handover feature allows a controller to automatically "delegate" control of a vehicle to another controller as the vehicle moves. Control delegation can also be used as a way to balance load among controllers and ensure that required application quality of service is maintained. We showcase D2-ITS' handover and load-balancing features using the Mininet-Wifi network simulator/emulator. Our preliminary experiments show D2-ITS' ability to seamlessly handover control of vehicles as they move. This work has been presented at the 27th International Conference on Computer Communications and Networks (ICCCN 2018), Jul 2018, Hangzhou, China [17].

6.2.6. Low Cost Video Streaming through Mobile Edge Caching: Modelling and Optimization

Participants: Luigi Vigneri, Chadi Barakat.

Caching content at the edge of mobile networks is considered as a promising way to deal with the data tsunami. In addition to caching at fixed base stations or user devices, it has been recently proposed that an architecture with public or private transportation acting as mobile relays and caches might be a promising middle ground. While such mobile caches have mostly been considered in the context of delay tolerant networks, in this work done in collaboration with Eurecom with the support of the UCN@Sophia Labex, we argue that they could be used for low cost video streaming without the need to impose any delay on the user. Users can prefetch video chunks into their playout buffer from encountered vehicle caches (at low cost) or stream from the cellular infrastructure (at higher cost) when their playout buffer empties while watching the content. Our main contributions are: (i) to model the playout buffer in the user device and analyze its idle periods which correspond to bytes downloaded from the infrastructure; (ii) to optimize the content allocation to mobile caches, to minimize the expected number of non-offloaded bytes. We perform trace-based simulations to support our findings showing that up to 60 percent of the original traffic could be offloaded from the main infrastructure. These contributions were published in IEEE Transactions on Mobile Computing [16]. The part specifying the framework to a chunk-based scenario by accounting for partial storage of videos in vehicles was published in [25].

6.2.7. Cost Optimization of Cloud-RAN Planning and Provisioning for 5G Networks

Participants: Osama Arouk, Thierry Turletti.

We propose a network planning and provisioning framework that optimizes the deployment cost in C-RAN based 5G networks. Our framework is based on a Mixed Integer Quadratically Constrained Programming (MIQCP) model that optimizes "virtualized" 5G service chain deployment cost while performing adequate provisioning to address user demand and performance requirements. We use two realistic scenarios to showcase that our framework can be applied to different types of deployments and discuss the computational cost and scalability of our solution. This work has been presented at the IEEE International Conference on Communications, in May 2018, at Kansas City, MO, United States [18].

6.2.8. Slice Orchestration for Multi-Service Disaggregated Ultra Dense RANs

Participants: Osama Arouk, Thierry Turletti.

Ultra Dense Networks (UDNs) are a natural deployment evolution for handling the tremendous traffic increase related to the emerging 5G services, especially in urban environments. However, the associated infrastructure cost may become prohibitive. The evolving paradigm of network slicing can tackle such a challenge while optimizing the network resource usage, enabling multi-tenancy and facilitating resource sharing and efficient service-oriented communications. Indeed, network slicing in UDN deployments can offer the desired degree of customization in both vanilla Radio Access Network (RAN) designs, but also in the case of disaggregated multi-service RANs. We propose a novel multi-service RAN environment, i.e., RAN runtime, capable to support slice orchestration procedures and to enable flexible customization of slices as per tenant needs. Each network slice can exploit a number of services, which can either be dedicated or shared between multiple slices over a common RAN. The novel architecture we present concentrates on the orchestration and management systems. It interacts with the RAN modules, through the RAN runtime, via a number of new interfaces enabling a customized dedicated orchestration logic for each slice. We present results for a disaggregated UDN deployment where the RAN runtime is used to support slice-based multi-service chain creation and chain placement, with an auto-scaling mechanism to increase the performance. This work has been published in IEEE Communications Magazine [13].

6.3. Experimental Evaluation

6.3.1. nepi-ng: an efficient experiment control tool in R2lab

Participants: Thierry Parmentelat, Thierry Turletti, Walid Dabbous, Mohamed Naoufal Mahfoudi.

Experimentation is an essential step for realistic evaluation of wireless network protocols. The evaluation methodology entails controllable environment conditions and a rigorous and efficient experiment control and orchestration for a variety of scenarios. Existing experiment control tools such as OMF often lack in efficiency in terms of resource management and rely on abstractions that hide the details about the wireless setup. We propose `nepi-ng`, an efficient experiment control tool that leverages job oriented programming model and efficient single-thread execution of parallel programs using asyncio. `nepi-ng` provides an efficient and modular fine grain synchronization mechanism for networking experiments with light software dependency footprint. This work has been presented at the 12th ACM International Workshop on Wireless Network Testbeds, Experimental evaluation & CHaracterization (WINTECH) in November 2018 at New Delhi, India [24].

6.3.2. Using nepi-ng for Mesh Networks Experiments

Participants: Thierry Parmentelat, Thierry Turletti, Mohamed Naoufal Mahfoudi, Walid Dabbous.

We describe a demonstration run on R2lab, an open wireless testbed located in an anechoic chamber at Inria Sophia Antipolis. The demonstration consists in easily deploying a Wi-Fi mesh network. The nodes provisioning, configuration and the scenario orchestration and control are automatically done using the `nepi-ng` experiment orchestration tool. A performance comparison of two wireless mesh routing protocols in presence of controlled interference is shown. This demo has been presented at the 12th ACM International Workshop on Wireless Network Testbeds, Experimental evaluation & CHaracterization (WINTECH) in November 2018 at New Delhi, India [32].

6.3.3. R2Lab Testbed Evaluation for Wireless Mesh Network Experiments

Participants: Farzaneh Pakzad, Thierry Turletti, Thierry Parmentelat Mohamed Naoufal Mahfoudi, Walid Dabbous.

We have provided critical evaluations of new potential testbeds for the evaluation of SDN-based WMNs. We evaluated the R2Lab wireless testbed platform at Inria Sophia Antipolis, France. This testbed has 37 customisable wireless devices in an anechoic chamber for reproducible research in wireless WiFi and 4G/5G networks. Our work presents the first initial evaluation of the testbed for wireless multi-hop experiments, using traditional WMN routing protocols. Our results demonstrate the potential for SDN experiments. We believe this is an important contribution in its own right, since experimental validation is a key research methodology in this context, and trust in the validity of experimental results is absolutely critical.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Contracts with Industry

7.1.1. SAFRAN

Participants: Damien Saucez.

We have a bilateral contract covering 2017 and 2018 with Safran Electrical and Power in order to build a network simulator specialised for aeronautical networks.

7.2. Bilateral Grants with Industry

7.2.1. QWANT

Participants: Arnaud Legout.

The PIA ANSWER project is led by the QWANT search engine and the Inria Sophia Antipolis Méditerranée research center. This proposal is the winner of the "Grand Challenges du Numérique" (BPI) and aims to develop the new version of the search engine http://www.qwant.com with radical innovations in terms of search criteria, indexed content and privacy of users. In the context of this project, we got with Nataliia Bielova from the INDES project-team a funding for a 3 years Ph.D. working on Web tracking technologies and privacy protection.

8. Partnerships and Cooperations

8.1. Inria internal funding

8.1.1. ADT ACQUA

Participants: Chadi Barakat.

In the context of the Inria ADT call, we have a funding for a two year engineering position on the ACQUA project for the 2015-2017 period. Thierry Spetebroot is hired on this position. In 2017, this ADT got extended by six months beyond the two years period to therefore end on March 2018.

8.1.2. IPL BetterNet

Participants: Chadi Barakat.

The DIANA team is part of the Inria Project Lab BetterNet (http://project.inria.fr/betternet/). Within this lab, Inria has funded two PhD students in 2017 co-supervised by Chadi Barakat from the DIANA project-team. The first PhD student is Thibaut Ehlinger hosted within the DIANA team and co-supervised by Vassilis Christophides from the MiMove team in Paris. The second PhD student is Imane Taibi hosted by the Dionysos team in Rennes and co-supervied by Gerardo Rubino and Yassine Hadjadj-Aoul. Both PhDs started on the 1st of November 2017. Further in 2018, Inria funded a PostDoc position to supervise the experiments planned within the IPL and develop the data analysis part. This PostDoc position is occupied by Giulio Grassi who is co-supervised by Chadi Barakat from the DIANA project-team and Renata Teixeira from the MiMove project-team. Giulio Grassi started on October 1st, 2018 and is currently located in Paris.

8.2. Regional Initiatives

8.2.1. ElectroSmart

Participants: Arnaud Legout, Mondi Ravi, David Migliacci, Abdelhakim Akodadi, Yanis Boussad.

The ElectroSmart project benefits form the following fundings:

- a 39 months engineering position from the UCN@Sophia Labex for the 2016-2019 period (Ravi Mondi is hired on this position)
- 30KEuros from Academy 1 of UCAJedi
- a two years engineering position from an Inria ADT for 2017/2019 (Abdelhakim Akodadi)
- a 18 months business developer from Inria ATT for june 2017-june 2019 (David Migliacci)
- a 3 years 2017/2020 Ph.D. thesis from Academy 1 of UCAJedi (Yanis Boussad)

8.2.2. D2D Indoor

Participants: Chadi Barakat, Zeineb Guizani.

This project is joint with the NFCOM startup in Nice, specialized in the development of new services for mobile phones. The project aims at leveraging mobile to mobile communications for offloading the cellular infrastructure, and will target a solution based on algorithms previously developed in the DIANA project-team (BitHoc and HBSD). The project got a funding for one year engineer from the Labex. Zeineb Guizani has been working on this project since July 2018.

8.3. National Initiatives

8.3.1. ANR

- **ANR JCJC DET4ALL** (2019-2021): Modern factories and industrial system massively rely on cyber physical systems with digital communications (e.g., to allow collaborative robots, for data analytics...). However, industrial networks are still mostly managed and conceived as collections of independent communicating units instead of one unified piece of software.

  The reason why the shift of paradigm did not occur yet to industrial digital communication networks is because industrial processes generally impose strong determinism and real-time constraints. As a result, industrial networks have a propensity of being physically segregated to contain potential malfunctions and simplify conception.

  With the DET4ALL project, we will apply the concept of network programmability to the world of industrial communicating systems. To that aim, we will construct and prove the essential building blocks that will allow to virtualise industrial networks:

  - algorithms to automatically provision the various components constituting industrial networks;
  - Domain Specific Languages (DSLs) to specify real-time communication schemes;
  - mechanisms to update on-the-fly the production infrastructures without service degradation.

  The impact of the DET4ALL project goes beyond technological advances; it will also bring a new vision on what production tools can become, namely agile systems in perpetual evolution.

- **ANR FIT** (2011-2019): 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 Equipements of 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. The project was extended for one year and will end in december 2019. See also http://fit-equipex.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.

8.4. European Initiatives

8.4.1. FP7 & H2020 Projects

- Program: FP7 FIRE programme
- Project acronym: Fed4Fire+
- Project title: Federation for FIRE Plus
- Duration: January 2017 - December 2021
- Coordinator: iMinds (Belgium)
- Other partners: 20 european partners including IMEC (Belgium), UPMC (Fr), Fraunhofer (Germany), TUB (Germany), etc.
- Web site: http://www.fed4fire.eu/
- Abstract: The Fed4FIRE+ project has the objective to run and further improve Fed4FIRE as best-in-town federation of experimentation facilities for the Future Internet Research and Experimentation initiative. Federating a heterogeneous set of facilities covering technologies ranging from wireless, wired, cloud services and open flow, and making them accessible through common frameworks and tools suddenly opens new possibilities, supporting a broad range of experimenter communities covering a wide variety of Internet infrastructures, services and applications. Fed4FIRE+ will continuously upgrade and improve the facilities and include technical innovations, focused towards increased user satisfaction (user-friendly tools, privacy-oriented data management, testbed SLA and reputation, experiment reproducibility, service-level experiment orchestration, federation ontologies, etc.). It will open this federation to the whole FIRE community and beyond, for experimentation by industry and research organisations, through the organization of Open Calls and Open Access mechanisms. The project will also establish a flexible, demand-driven framework which allows test facilities to join during the course of its lifetime by defining a set of entry requirements for new facilities to join and to comply with the federation. FIRE Experimental Facilities generate an ever increasing amount of research data that provides the foundation for new knowledge and insight into the behaviour of FI systems. Fed4FIRE+ will participate in the Pilot on Open Research Data in Horizon 2020 to offer open access to its scientific results, to the relevant scientific data and to data generated throughout the project's lifetime. Fed4FIRE+ will finally build on the existing community of experimenters, testbeds and tool developers and bring them together regularly (two times a year) in engineering conferences to have maximal interaction between the different stakeholders involved.

8.5. International Initiatives

8.5.1. Inria Associate Teams Involved in an Inria International Lab

8.5.1.1. DrIVE

Title: DrIVE: Distributed Intelligent Vehicular Environment - Enabling ITS through programmable networks

Inria International Lab: **Inria@SiliconValley**

International Partner (Institution - Laboratory - Researcher):

Ericsson Research, Indaiatuba-SP, BRAZIL (Brazil) Mateus Augusto Silva Santos

Start year: 2018

See also: https://team.inria.fr/diana/drive-associated-team/

Abstract: Transportation systems are part of our society's critical infrastructure and are expected to experience transformative changes as the Internet revolution unfolds. The automotive industry is a notable example: it has been undergoing disruptive transformations as vehicles transition from traditional unassisted driving to fully automated driving, and eventually to the self-driving model. Communication technology advancements such as support for vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication have been one of the key enablers of next generation transportation services, also known as Intelligent Transport Systems (ITS). However, ITS services and applications pose significant challenges to the underlying communication and network infrastructure due to their stringent low latency, reliability, scalability, and geographic decentralization requirements. The DrIVE associated team proposal aims at addressing such challenges by: (1) developing a programmable network control plane that will dynamically adjust to current environment conditions and network characteristics to support ITS' scalability, quality of service (QoS), and decentralization requirements, and (2) applying the proposed distributed network control plane framework to ITS applications, such as road hazard warning, autonomous- and self-driving vehicles, and passenger-centric services (e.g., infotainment and video streaming).

8.5.2. Inria Associate Teams Not Involved in an Inria International Labs

8.5.2.1. UHD-on-5G

Title: Ultra High Definition video streaming on future 5G networks

International Partner (Institution - Laboratory - Researcher):

National Institute of Information and Communications Technology (NICT) (Japan) - Hitoshi Asaeda

Start year: 2016

See also: https://team.inria.fr/diana/uhd-on-5g/

The aim of this collaboration is to design and develop efficient mechanisms for streaming UHD video on 5G networks and to evaluate them in a realistic and reproducible way by using novel experimental testbeds.

Our approach leverages and extends when necessary ICN and SDN technologies to allow very high quality video streaming at large scale. We also plan to use Virtual Network Functions (VNF) in order to place easily and dynamically different functions (e.g. transcoding, caching) at strategic locations within the network. Specifically, the placement of these functions will be decided by SDN controllers to optimize the quality of experience (QoE) of users. Moreover, we plan to integrate ICN functionalities (e.g., name-based forwarding and multipath transport using in-network caching) with SDN/NFV to provide better QoE and mobility services support to users than traditional IP architectures. Monitoring mechanisms such as the Contrace tool we developed in the SIMULBED associated team will be helpful to provide an accurate view of the network at the SDN controllers side. In addition, we will build a large-scale testbed to evaluate our solutions through reproducible experimentations based on two testbeds: the ICN wired CUTEi tesbed developed by NICT and the wireless R2lab testbed developed by Inria.

8.6. International Research Visitors

8.6.1. Visits of International Scientists

Katia Obraczka is Professor of Computer Engineering and Graduate Director at Department of Computer Engineering, UC Santa Cruz where she leads the Internetworking Research Group (i-NRG). She has visited us for four weeks in July 2018. The Labex UCN@Sophia has supported two one-month visits at the DIANA project-team, in July 2017 and during summer 2018 to work in particular on the decentralization of the SDN control plane applied to Intelligent Transport Systems (ITS). These two visits were very fruitful as they resulted in common publications [18], [17] and contributed to the start of the DrIVE Associated team.

8.6.2. Internships

Yevhenii Semenko and Alberto Zirondelli

> Date: from from Apr 2018 until Sep 2018
>
> Institution: Ubinet Master intern, University of Nice Sophia Antipolis
>
> Supervisor: Damien Saucez
>
> Subject: Privacy preserving taxi service with blockain

Laila Daanoun

> Date: from Apr 2018 until Aug 2018
>
> Institution: Ubinet Master intern, University of Nice Sophia Antipolis
>
> Supervisor: Damien Saucez
>
> Subject: The Network of the Future in Industry 4.0: Solving the Reachability problem

Gayatri Sivadoss

> Date: from Apr 2018 until Aug 2018
>
> Institution: Ubinet Master intern, University of Nice Sophia Antipolis
>
> Supervisor: Mohamed Naoufal Mahfoudi, Thierry Turletti and Walid Dabbous
>
> Subject: LoRa: Characterization and Range Extension in campus environment

Ohtmane Bensouda Korachi

> Date: from Apr 2018 until Aug 2018
>
> Institution: Ubinet Master intern, University of Nice Sophia Antipolis
>
> Supervisor: Mohamed Naoufal Mahfoudi, Thierry Turletti and Walid Dabbous
>
> Subject: Geolocation for LoRa Low Power Wide Area Network

Othmane Belmoukadam

> Date: from Mar 2018 until Aug 2018
>
> Institution: Ubinet Master intern, University of Nice Sophia Antipolis
>
> Supervisor: Chadi Barakat
>
> Subject: ACQUA - A data-driven approach for network and Quality of Experience monitoring

Yonathan Bleyfuesz

> Date: from Feb 2018 to Aug 2018
>
> Institution: International Master programme M1, University of Nice Sophia Antipolis
>
> Supervisor: Thierry Parmentelat
>
> Subject: Using `nepi-ng` to evaluate MANET routing protocols.

Indukala Naladala

Date: from May 2018 until Jul 2018

Institution: National Institute of Technology Karnataka, Surathkal, India

Supervisor: Thierry Turletti and Walid Dabbous

Subject: Integration of R2LAB with ns-3

Janati Idrissi

Date: from Mar 2018 until Aug 2018

Institution: Ubinet Master intern, University of Nice Sophia Antipolis

Supervisor: Arnaud Legout

Subject: Étude de la précision de la localisation dans ElectroSmart sous Android.

8.6.3. *Visits to International Teams*

Thierry Turletti visited NICT in Tokyo Japan in the context of the UHD-on-5G associated team in october 2018.

Thierry Turletti also visited UNICAMP in Campinas Bresil in the context of the UHD-on-5G associated team in october 2018.

9. Dissemination

9.1. Promoting Scientific Activities

Chadi Barakat is on the editorial board of the Computer Networks journal, and is on the Technical Program Committee for the ACM MECOMM Workshop held in conjunction with the ACM SIGCOMM 2018 conference, and for the Network Traffic Measurement and Analysis Conference (TMA 2019). He co-chaired the workshops at the ACM CoNext 2018 conference and will co-chair the Technical Program Committee for the CCDWN workshop 2019 to be held in conjunction with the WiOpt 2019 conference. He is currently the scientific referee for international affairs at Inria Sophia Antipolis and member of the Conseil d'Orientation Scientifique et Technologique at Inria within the working group of international affairs (COST-GTRI).

Walid Dabbous is chair of the scientific committee of the User Centric Networking (UCN@Sophia) Laroratory of Excellence, and member of the scientific committee of the Academy 1 of the UCAJedi Idex. He is also member of the Ubinet International Master program steering committee. He is chair of the Inria admissibility jury for the young graduate scientist ("CRCN") competitive selection.

Arnaud Legout is on the editorial board of the Computer Networks journal. Arnaud Legout is the president of the Commission of the users of IT resources of Sophia Antipolis Inria research center.

Damien Saucez has co-organised the ACM SIGCOMM Reproducilbity workshop. He is co-chair of the ACM SIGCOMM *Artefact Evaluation Committee* whose role is to assess the reproducibility level of papers accepted to ACM SIGCOMM sponsored conferences and journals. He was TPC co-chair of the 2018 ACM Workshop on ns-3. He was member of the TPCs of IEEE ICC 2018, DRCN 2018, ACM WNS3 2018 and is regular reviewer for IEEE, ACM, Elsevier, and Springer journals. Damien Saucez and Walid Dabbous participated to the organization of the first Grid'5000-FIT school in Sophia Antipolis in April 3-6 2018. See https://www.silecs.net/1st-grid5000-fit-school/ for more information.

Thierry Turletti, Senior ACM and IEEE member, served in 2018 in the program committees of the following international workshops and conferences: the 3rd CoRes Workshop at Roscoff, France in May 28-29, the 9th Workshop on ns-3 at Mangalore, India in June 13-14, the 13rd Workshop on Challenged Networks (CHANTS) at New Delhi, India in October 29 and IEEE Globecom at Abu Dabi, UAE in December 9-13. He 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. Thierry Turletti 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.

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 in Computer Science: Chadi Barakat, Computer Networks, 15 hours, M1, University of Nice Sophia Antipolis, France.

Master 1 in Computer Science: Chadi Barakat, Internet of the Future, 15 hours, M1, University of Nice Sophia Antipolis, France

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

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

Master 1 in Computer Science: 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.

E-learning

Python: Arnaud Legout and Thierry Parmentelat are co-authors of the MOOC Python 3 : "Python 3 : des fondamentaux aux concepts avancés du langage" that lasts 9 weeks on FUN (https://www.france-universite-numerique-mooc.fr/), UCA. For the second session there were 12748 registered persons. In total, this MOOC all on its editions has been followed by 57938 persons.

9.2.2. Supervision

PhD in progress: Othmane Belmoukadam started his PhD on "QoE aware content management in the Internet: caching and transport" in October 2018. He is supervised by Chadi Barakat and funded by the doctoral school EDSTIC of Université Côte d'Azur (UCA).

PhD in progress: Yanis Boussad started his PhD on "Large scale characterization of the exposition to microwaves" in October 2017. He is co-supervised with Leonardo Lizzi, LEAT.

PhD in progress: Giuseppe Di Lena started his PhD on "Building a resilience methodology for NFV/SDN " in Apr 2018. His PhD is co-supervised by Thierry Turletti and Damien Saucez.

PhD in progress: Thibaut Ehlinger: started his PhD on "Mapping Quality of Service metrics to user Quality of Experience in the Internet" in November 2017. He is co-supervised by Chadi Barakat and Vassilis Christophides (EPI MiMove, Inria Paris).

PhD in progress: Iman Fouad started her PhD on on Web tracking technologies and privacy protection in november 2017. Her thesis is co-supervised by Arnaud Legout and Nataliia Bielova (Indes).

PhD in progress: Karyna Gogunska works on "Empowering Virtualized Networks with Measurement As a Service (MaaS)". Her thesis is co-supervised by Chadi Barakat and Guillaume Urvoy-Keller (I3S).

PhD in progress: Muhammad Jawad Khokhar works on "From Network Level Measurements to Expected Quality of User Experience". His PhD is supervised by Chadi Barakat.

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: Vitalii Poliakov defended his PhD on "the application of Software Defined Networking on 5G networks in order to optimise the Quality of Experience of network services" in December 2018. His thesis was co-supervised by Damien Saucez and Lucile Sassatelli (I3S).

PhD: Hardik Soni defended his PhD on "Software Defined Networking in challenged environments" in April 2018. His thesis was co-supervised by Thierry Turletti and Walid Dabbous.

PhD in progress: Imane Taibi started his PhD in the Dionysos project-team on "Big data analysis for network monitoring and troubleshooting" in November 2017. She is co-supervised by Gerardo Rubino, Yassine Hadjadj-Aoul and Chadi Barakat.

PhD in progress: Mathieu Thiery started his PhD in the Privatics project-team on "Data protection of connected objects and smartphones" in April 2017. He is co-supervised by Vincent Roca and Arnaud Legout.

PhD in progress: Thibaud Trolliet started his PhD on "Exploring trust on Twitter" in octobre 2017. He is co-supervised with Frederic Giroire.

9.2.3. *Juries*

Chadi Barakat served as reviewer of Muhammad Ikram thesis, "Analysis and Design of Secure and Privacy Preserving Systems" defended in April 2018 at the University of New South Wales and Data61, Australia.

Walid Dabbous served as reviewer of Cédric Baudoin HDR thesis "Optimisation et intégration des réseaux de télécommunication par satellite" in INP Toulouse, defended in january 17, 2018.

Walid Dabbous served as a jury member for the mid-term review of the Ph.D. thesis of Sumit Kumar (Eurecom) for his thesis entitled "Simultaneous multi-standard SDR platform" in january 18, 2018.

Walid Dabbous served as a jury chair person for the Ph.D. thesis defense of Dolière Francis Somé on "Web Applications Security and Privacy" on october 29, 2018 (Inria, Indes project-team).

Damien Saucez served as jury member of Chi Dung Phung PhD defence, UPMC, Paris. The thesis on "Enriching the Internet control-plane for improved traffic engineering" was defended on March 30, 2018.

Damien Saucez served as jury member of Yue Li PhD defense, Telecom ParisTech, Paris. The thesis on "Future Internet Services based on LISP Technology" was defended on April 26, 2018.

Thierry Turletti served as a jury member for the mid-term review of the Ph.D. thesis of Andrea Tomassilli on "the integration of Network Functions Virtualization (NFV) techniques with Software-Defined Networking (SDN)." on May 24, 2018 (Inria, COATI project-team).

Thierry Turletti served as a jury member for the mid-term review of the Ph.D. thesis of Chia-Yu Chang on "Cloudification and Slicing in 5G Radio Access Network" on June 28, 2018 (Eurecom).

Thierry Turletti served as reviewer of Elie Bouttier PhD thesis, "Livraison de contenus sur un réseau hybride satellite / terrestre", defended on July 5, 2018 at INP Toulouse, France.

Thierry Turletti served as reviewer of Raphael Naves PhD thesis, "Apport de la gestion des interférences aux réseaux sans-fil multi-sauts: Le cas du Physical-Layer Network Coding" defended on November 19, 2018 at INP Toulouse, France.

Thierry Turletti served as reviewer and president of Imad Alawe PhD thesis "Architectures evaluation and dynamic scaling for 5G mobile core networks", defended on November 21, 2018 at Université de Rennes 1, France.

9.3. Popularization

9.3.1. Interventions

Chadi Barakat keeps participating to the organization of the Mediterranean Students Days @ Campus SophiaTech. The sixth edition took place on Feb 12 - 14, 2018. All details on this event can be found at http://univ-cotedazur.fr/events/meddays. He also participated to the organization of the French-American Doctoral Exchange Seminar (FADEx) 2018 held in June 2018 on the three French sites Sophia Antipolis, Grenoble, and Paris.

Damien Saucez is part of the MASTIC (https://project.inria.fr/mastic) group at Inria. MASTIC groups all the activities for scientific dissemination for Inria Sophia Antipolis. Within the team, we gave a 3h game-based class to 12 collège interns that made an internship at Inria in December to introduce them to the fundamental algorithms used in the Internet (shortest-path, longest prefix matching, distance-vector, AIMD). Damien Saucez was involved in the organization of the "Journée portes-ouvertes" of the Inria Sophia Antipolis premises. Specifically, DIANA presented R2LAB and Electrosmart.

10. Bibliography

Major publications by the team in recent years

[1] M. GABIELKOV, A. RAMACHANDRAN, A. CHAINTREAU, A. LEGOUT. *Social Clicks: What and Who Gets Read on Twitter?*, in "ACM SIGMETRICS / IFIP Performance 2016", Antibes Juan-les-Pins, France, June 2016, https://hal.inria.fr/hal-01281190

[2] M. GABIELKOV, A. RAO, A. LEGOUT. *Studying Social Networks at Scale: Macroscopic Anatomy of the Twitter Social Graph*, in "ACM Sigmetrics 2014", Austin, United States, June 2014, https://hal.inria.fr/hal-00948889

[3] M. J. KHOKHAR, N. A. SABER, T. SPETEBROOT, C. BARAKAT. *An Intelligent Sampling Framework for Controlled Experimentation and QoE Modeling*, in "Computer Networks", December 2018, vol. 147, pp. 246-261 [*DOI :* 10.1016/J.COMNET.2018.10.011], https://hal.inria.fr/hal-01906145

[4] Y.-H. KIM, A. QUEREILHAC, M. A. LARABI, J. TRIBINO, T. PARMENTELAT, T. TURLETTI, W. DABBOUS. *Enabling Iterative Development and Reproducible Evaluation of Network Protocols*, in "Computer Networks", January 2014, vol. 63, pp. 238-250, https://hal.inria.fr/hal-00861002

[5] M. N. MAHFOUDI, T. PARMENTELAT, T. TURLETTI, W. DABBOUS, R. KNOPP. *Deploy a 5G network in less than 5 minutes: Demo Abstract*, August 2017, ACM SIGCOMM Posters and Demos, Poster, https://hal.inria.fr/hal-01580065

[6] M. N. MAHFOUDI, T. TURLETTI, T. PARMENTELAT, F. FERRERO, L. LIZZI, R. STARAJ, W. DABBOUS. *ORION: Orientation Estimation Using Commodity Wi-Fi*, in " Workshop on Advances in Network Local-ization and Navigation (ANLN)", Paris, France, May 2017, pp. 1033-1038, https://hal.archives-ouvertes.fr/hal-01424239

[7] X.-N. NGUYEN, D. SAUCEZ, C. BARAKAT, T. TURLETTI. *OFFICER: A general Optimization Framework for OpenFlow Rule Allocation and Endpoint Policy Enforcement*, in "The 34th Annual IEEE International Conference on Computer Communications (INFOCOM 2015)", Hongkong, China, IEEE, April 2015, https://hal.inria.fr/hal-01104519

[8] D. SAUCEZ, L. IANNONE, O. BONAVENTURE. *Locator/ID Separation Protocol (LISP) Threat Analysis*, April 2016, Internet Engineering Task Force (IETF), Request for Comments: 7835, https://hal.inria.fr/hal-01423162

[9] H. SONI, W. DABBOUS, T. TURLETTI, H. ASAEDA. *NFV-based Scalable Guaranteed-Bandwidth Multicast Service for Software Defined ISP networks*, in "IEEE Transactions on Network and Service Management", December 2017, vol. 14, n° 4, 14 p. [*DOI : 10.1109/TNSM.2017.2759167*], https://hal.inria.fr/hal-01596488

[10] L. VIGNERI, T. SPYROPOULOS, C. BARAKAT. *Low Cost Video Streaming through Mobile Edge Caching: Modelling and Optimization*, in "IEEE Transactions on Mobile Computing", 2018 [*DOI : 10.1109/TMC.2018.2861005*], https://hal.inria.fr/hal-01855304

Publications of the year

Doctoral Dissertations and Habilitation Theses

[11] V. POLIAKOV. *Combining in-network caching, HTTP Adaptive Streaming and Multipath to improve video Quality Of Experience*, Université Côte d'Azur, December 2018, https://hal.archives-ouvertes.fr/tel-01968837

[12] H. SONI. *Towards network softwarization : a modular approach for network control delegation*, Université Côte d'Azur, April 2018, https://tel.archives-ouvertes.fr/tel-01867973

Articles in International Peer-Reviewed Journals

[13] C.-Y. CHANG, N. NIKAEIN, O. AROUK, K. KATSALIS, A. KSENTINI, T. TURLETTI, K. SAMDANIS. *Slice Orchestration for Multi-Service Disaggregated Ultra Dense RANs*, in "IEEE Communications Magazine", 2018, vol. 56, n° 8, 8 p. [*DOI : 10.1109/MCOM.2018.1701044*], https://hal.inria.fr/hal-01730597

[14] M. FLITTNER, M. N. MAHFOUDI, D. SAUCEZ, M. WÄHLISCH, L. IANNONE, V. BAJPAI, A. AFANASYEV. *A Survey on Artifacts from CoNEXT, ICN, IMC, and SIGCOMM Conferences in 2017*, in "ACM SIGCOMM Computer Communication Review", April 2018, vol. 48, n° 1, pp. 75-80, https://hal.inria.fr/hal-01968401

[15] M. J. KHOKHAR, N. A. SABER, T. SPETEBROOT, C. BARAKAT. *An Intelligent Sampling Framework for Controlled Experimentation and QoE Modeling*, in "Computer Networks", December 2018, vol. 147, pp. 246-261 [*DOI : 10.1016/J.COMNET.2018.10.011*], https://hal.inria.fr/hal-01906145

[16] L. VIGNERI, T. SPYROPOULOS, C. BARAKAT. *Low Cost Video Streaming through Mobile Edge Caching: Modelling and Optimization*, in "IEEE Transactions on Mobile Computing", 2018 [*DOI : 10.1109/TMC.2018.2861005*], https://hal.inria.fr/hal-01855304

Invited Conferences

[17] A. KAUL, L. XUE, K. OBRACZKA, M. A. S. SANTOS, T. TURLETTI. *Handover and Load Balancing for Distributed Network Control: Applications in ITS Message Dissemination*, in "The 27th International Conference on Computer Communications and Networks (ICCCN 2018)", Hangzhou, China, July 2018, https://hal.inria.fr/hal-01849907

International Conferences with Proceedings

[18] O. AROUK, T. TURLETTI, N. NIKAEIN, K. OBRACZKA. *Cost Optimization of Cloud-RAN Planning and Provisioning for 5G Networks*, in "ICC 2018 - IEEE International Conference on Communications", Kansa City, MO, United States, May 2018, https://hal.inria.fr/hal-01707682

[19] F. DE PELLEGRINI, L. MAGGI, A. MASSARO, D. SAUCEZ, J. LEGUAY, E. ALTMAN. *Blind, Adaptive and Robust Flow Segmentation in Datacenters*, in "INFOCOM 2018 - IEEE International Conference on Computer Communications", Honolulu, United States, April 2018, https://hal.inria.fr/hal-01666905

[20] K. GOGUNSKA, C. BARAKAT, G. URVOY-KELLER, D. LOPEZ-PACHECO. *On the Cost of Measuring Traffic in a Virtualized Environment*, in "IEEE International Conference on Cloud Networking", Tokyo, Japan, October 2018, https://hal.inria.fr/hal-01870293

[21] M. J. KHOKHAR, T. SPETEBROOT, C. BARAKAT. *A Methodology for Performance Benchmarking of Mobile Networks for Internet Video Streaming*, in "MSWIM 2018 - The 21st ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems", Montreal, Canada, October 2018, https://hal.inria.fr/hal-01855264

[22] M. J. KHOKHAR, T. SPETEBROOT, C. BARAKAT. *An Online Sampling Approach for Controlled Experimentation and QoE Modeling*, in "ICC 2018 - IEEE International Conference on Communications", Kansas City, United States, May 2018 [*DOI :* 10.1109/ICC.2018.8422954], https://hal.inria.fr/hal-01677378

[23] G. MOUALLA, T. TURLETTI, D. SAUCEZ. *An Availability-aware SFC placement Algorithm for Fat-Tree Data Centers*, in "IEEE International Conference on Cloud Networking", Tokyo, Japan, October 2018, https://hal.inria.fr/hal-01869949

[24] T. PARMENTELAT, T. TURLETTI, W. DABBOUS, M. N. MAHFOUDI, F. BRONZINO. *nepi-ng: an efficient experiment control tool in R2lab*, in "ACM WiNTECH 2018 - 12th ACM International Workshop on Wireless Network Testbeds, Experimental evaluation & CHaracterization", New Delhi, India, November 2018, pp. 1-8, https://hal.inria.fr/hal-01857266

[25] L. VIGNERI, T. SPYROPOULOS, C. BARAKAT. *A Two-Step Chunk-Based Algorithm for Offloading Streaming Traffic through a Vehicular Cloud*, in "19th IEEE International Workshop on Signal Processing Advances in Wireless Communications", Kalamata, Greece, June 2018, https://hal.inria.fr/hal-01796994

Conferences without Proceedings

[26] Y. LI, A. ABOUSEIF, D. SAUCEZ, L. IANNONE. *LISP-Views: Monitoring LISP at Large Scale*, in "Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication", Roscoff, France, May 2018, https://hal.archives-ouvertes.fr/hal-01784729

[27] F. PAKZAD, M. PORTMANN, T. TURLETTI, T. PARMENTELAT, M. MAHFOUDI, W. DABBOUS. *R2Lab Testbed Evaluation for Wireless Mesh Network Experiments*, in "International Telecommunication Networks and Applications Conference - ITNAC '18", Sydney, Australia, November 2018, https://hal.archives-ouvertes.fr/hal-01968766

[28] V. POLIAKOV, L. SASSATELLI, D. SAUCEZ. *Adaptive video streaming and multipath: can less be more?*, in "ICC 2018 - IEEE International Conference on Communications", Kansas City, MO, United States, May 2018, https://hal.archives-ouvertes.fr/hal-01726486

[29] V. POLIAKOV, D. SAUCEZ, L. SASSATELLI. *An ns-3 distribution supporting MPTCP and MPEG-DASH obtained by merging community models*, in "WNS3 2018 - Workshop on ns-3", Mangalore, India, June 2018, pp. 1-3, https://hal.archives-ouvertes.fr/hal-01825592

Research Reports

[30] G. MOUALLA, T. TURLETTI, D. SAUCEZ. *An Availability-aware SFC placement Algorithm for Fat-Tree Data Centers*, Inria, August 2018, https://hal.inria.fr/hal-01859599

[31] Y. SEMENKO, D. SAUCEZ. *Distributed Privacy Preserving Platform for Ridesharing Services*, Inria - Sophia Antipolis, January 2019, https://hal.inria.fr/hal-01968399

Other Publications

[32] Y. BLEYFUESZ, T. PARMENTELAT, T. TURLETTI, F. PAKZAD, M. MAHFOUDI, W. DABBOUS. *Demo: Using nepi-ng for Mesh Networks Experiments*, November 2018, pp. 1-2, WINTECH 2018 - 12th ACM International Workshop on Wireless Network Testbeds, Experimental evaluation & CHaracterization, Poster, https://hal.inria.fr/hal-01869979

[33] I. FOUAD, N. BIELOVA, A. LEGOUT, N. SARAFIJANOVIC-DJUKIC. *Tracking the Pixels: Detecting Web Trackers via Analyzing Invisible Pixels*, December 2018, working paper or preprint, https://hal.inria.fr/hal-01943496

[34] H. SONI, T. TURLETTI, W. DABBOUS. *P4Bricks: Enabling multiprocessing using Linker-based network data plane architecture*, February 2018, working paper or preprint, https://hal.inria.fr/hal-01632431

[35] T. SPETEBROOT, C. BARAKAT, M. J. KHOKHAR, T. EHLINGER. *ACQUA – Forecasting Quality of Experience*, February 2018, 1 p. , MOMI 2018 - Le Monde des Mathématiques Industrielles, Poster, https://hal.inria.fr/hal-01731583