RESEARCH CENTRE

**Grenoble - Rhône-Alpes**

**IN PARTNERSHIP WITH:**

**Institut national des sciences appliquées de Lyon**

2020

# ACTIVITY REPORT

Project-Team

# AGORA

## Wireless Networks for Digital Cities

**IN COLLABORATION WITH: Centre of Innovation in Telecommunications and Integration of services**

**DOMAIN**

**Networks, Systems and Services, Distributed Computing**

**THEME**

**Networks and Telecommunications**

# Contents

# Project-Team AGORA

*Creation of the Team: 2017 January 01, updated into Project-Team: 2018 April 01*


## Keywords

### Computer sciences and digital sciences

A1.2.1. – Dynamic reconfiguration

A1.2.3. – Routing

A1.2.4. – QoS, performance evaluation

A1.2.5. – Internet of things

A1.2.6. – Sensor networks

A7.1. – Algorithms

A8.2. – Optimization

### Other research topics and application domains

B3.4.3. – Pollution

B6.2.2. – Radio technology

B6.2.4. – Optic technology

B6.4. – Internet of things

B8.1.2. – Sensor networks for smart buildings

B8.2. – Connected city

# 1 Team members, visitors, external collaborators

## Research Scientist

- Juan Fraire [Inria, ISFP, From January 2021, Recruited in the 2020 session but recruitment postponed due to the COVID situation. Position started in January 2021.]

## Faculty Members

- Hervé Rivano [Team leader, INSA Lyon, Professor, HDR]
- Walid Bechkit [INSA Lyon, Associate Professor]
- Oana Iova [INSA Lyon, Associate Professor]
- Razvan Stanica [INSA Lyon, Associate Professor, HDR]
- Fabrice Valois [INSA Lyon, Professor, HDR]

## PhD Students

- Abderrahman Ben Khalifa [INSA Lyon, until July 2020]
- Rodrigue Domga Komguem [Université de Yaoundé - Cameroun, until Jul 2020]
- Mohamed Anis Fekih [Univ de Lyon]
- Kawtar Lasri [Institut national des postes et télécommunications Rabat - Maroc]
- Lucas Magnana [Univ de Lyon, from Oct 2020]
- Ichrak Mokhtari [INSA Lyon]
- Camille Moriot [INSA Lyon, from Sep 2020]
- Romain Pujol [INSA Lyon]
- Solohaja Rabenjamina [Inria]

## Technical Staff

- Manoel Dahan [INSA Lyon, Engineer]
- Zhiyi Zhang [Inria, Engineer, from Dec 2020]

## Interns and Apprentices

- Evelyne Akopyan [Inria, from Mar 2020 until Aug 2020]
- Theotime Balaguer [Inria, INSA Lyon, from Feb 2020 until Jul 2020]
- Hamza Benchekroun [INSA Lyon, from Mar 2020 until Jul 2020]
- Maxime Hartmann [INSA Lyon, from Apr 2020 until Jul 2020]
- Lucas Magnana [Univ Claude Bernard, from Feb 2020 until Aug 2020]
- Hamza Touizrat [INSA Lyon, from Apr 2020 until Jul 2020]
- Mouloud Yaici [Inria, until Jun 2020]

### Administrative Assistants

- Laetitia Gauthe [Inria]
- Linda Soumari [INSA Lyon]

### Visiting Scientist

- Priscila Solis Barreto [Université de Brasilia - Brésil, until Mar 2020]

## 2 Overall objectives

The Agora team is positioned in Inria research domain of "Networks, Systems and Services, Distributed Computing" under the theme "Networks and Telecommunications", as a joint team between Inria and INSA Lyon, within the CITI laboratory. The Agora team focus is on the wireless access part of the Internet, where several network architectures and paradigms co-exist: heterogeneous cellular networks, multi-hop wireless networks, wireless sensor networks, long-range low-power connectivity. We work on the deployment of these networking technologies and their combined exploitation, while understanding the spatio-temporal dynamics of users, machines and data.

The deployment of dense networks is challenged by large scale and dense scenarios, with consequences on the optimization of the placement of both the components and functionalities of the network. At the same time, Machine-to-Machine (M2M) communication protocols, designed for running on the Internet of Things (IoT) architectures, need a coherent rethinking to face issues on both saturated cellular networks and fresh deployments of multi-hop wireless networks unable to cover large areas. Exploiting the data carried by the network opens new questions on the network deployment and functioning, by understanding the spatio-temporal dynamics of the users or connected objects.

The main networking fact that motivates the direction of the Agora team is the coming saturation of cellular networks. Even though developed cities can rely on a full coverage of their territory with very high throughput wireless access networks, the expected - and already measured - tremendous growth of mobile data traffic will overwhelm these infrastructures without a dramatic change of communication paradigm.

**Beyond cellular networks.** The networking functions are today almost only managed through cellular infrastructures. Even current smart-metering network architectures follow a hierarchical organization alike cellular networks. This approach features a number of advantages, including pervasive geographical coverage, seamless connectivity, a good level of security and possibly guaranteed bandwidth and latency. However, this centralized paradigm is over twenty years old now. The coming saturation of the access network, and the explosion of popular, bandwidth-hungry digital services will make the recent and newest technologies, such as LTE and 5G, already unable to accommodate the future demand. A major trend is to decentralize the network operation, leveraging network function virtualization so as to make it more pervasive (Small Cells), heterogeneous (HetNets) and self-organizing (SON). A second trend is the virtualization of cellular network operations which gives new degree of freedom to deploy and to manage the network. Beyond cellular networks, multi-hop wireless mobile networks have been extensively studied in the literature, in particular wireless sensor networks, ad hoc networks, wireless mesh networks and vehicular networks. Such wireless multi-hop solutions met scarce practical success over the last decade, mainly because of the lack of a clear application context and of important use cases. There are however now mature technologies for some specific applications that provide a wealth of connectivity surrounding mobile devices. Combined with the emergence of long range low power technologies dedicated to small traffic IoT applications, one can foresee the emergence of hybrid network architectures (cellular and multi-hop, short range and long range) that need to be developed and evaluated.

**Low cost sensors and density.** We also witness the emergence of a new market of sensing devices that is closely related to the industrial effort toward the IoT. Recent breakthroughs in micro and nano technologies are indeed enabling dense deployments of low-cost sensing devices that produce reliable enough measurements of physical phenomena while being energetically autonomous. In monitoring applications, density is an opportunity because it allows to give redundancy of information, robustness, and to take benefit of spatial correlation for data gathering. Density is however challenging network infrastructures deployment and data collection. The deployment of such devices has to be suitable for the application and fitted to the constraints of the environment. Self-organization and self-healing are required for sustainable infrastructure management and operation. Combining all these notions into optimization models is an issue that needs to be addressed to understand and evaluate the relevant networking infrastructures and protocols. On the other hand, density is also an opportunity if one can understand and take advantage of the spatio-temporal characteristics of the data produced and the citizens behavior. Redundancy and correlations are a way to improve on data reliability and network usage.

# 3 Research program

## 3.1 Wireless network deployment

The deployment of networks has fostered a constant research effort for decades, continuously renewed by the evolution of networking technologies. Fundamentally, the deployment problem addresses the trade-off between the cost of the network to be minimized or fitted into a budget and the features and services provided by the system that should reach a target level or be maximized. The variety of cost models and type of features gives rise to a wide scientific field. There are several cost factors of network infrastructure: components (number and capacity), energy, man power (installation and maintenance), etc. The features of the network matter as much as the metric to evaluate them. Coverage and capacity are basic features for wireless networks on which we will focus in the following. One recurrent question is therefore: What are the optimal number and position of network components to deploy so that a given territory is covered and enough networking capacity is provided?

Traditional telecommunication infrastructures were made of dedicated components, each of them providing a given set of functions. However, recently introduced paradigms yield issues on the deployment of network functions. Indeed, the last decade saw a trend towards adding more intelligence within the network. In the case of the access network, the concept of Cloud Radio Access Network (C-RAN) emerged. In the backhaul, the Evolved Packet Core (EPC) network can also benefit from virtualization techniques, as the convergence point for multiple access technologies, as imagined in the case of future 5G networks. The performance limits of a virtualized EPC remain unknown today: Is the delay introduced by this new architecture compatible with the requirements of the mobile applications? How to deploy the different network functions on generic hardware in order to maximize the quality of service? More, recent embeded systems give us the opportunity to redefine the traditionnal architecture of cellular networks: it is now possible to co-locate the functions of the EPC and the ones of the RAN into a single device. Such device can be static or mobile (e.g. UAV). The architecture is no longer hiearachical and should be able to self-adapt to the environnement and the user demands. New challenges arise: how to connect such devices? where to activate the network functions (RAN & EPC) w.r.t. the capacity and the delay ? How to manage with user mobility when the device can also move?

**Network component deployment.** In this research direction, we address new issues of the optimal network deployment. In particular, we focus on the deployment of wireless sensor networks for environmental monitoring (e.g. atmospheric pollution). Most current air quality monitoring systems are using conventional measuring stations, equipped with multiple lab quality sensors. These systems are however massive, inflexible and expensive. An alternative – or complementary – solution is to use low-cost flexible wireless sensor networks. One of the main challenges is to introduce adequate models for the coverage of the phenomenon. Most of the state of the art considers a generic coverage formulation based on detection ranges that are not adapted to environmental sensing. For example, pollution propagation models should take into account the inherently stochastic weather conditions. An issue is to develop an adequate formulation and efficient integer linear programming (ILP) models and heuristics able to compute deployments at a relevant scale. In particular, it seems promising to adapt stochastic or robust optimization results of the operational research community in order to deal with uncertainty. Defining the quality of a coverage is also a modeling issue, which depends on the application considered. The detection of anomaly is close to a combinatorial problem. A more difficult objective is to deploy sensors in order to map the phenomenon by interpolation (or other reconstruction mechanisms). This challenge requires interdisciplinary research with fluid mechanics teams who develop numerical models of pollution propagation and practitioners like Atmo Auvergne-Rhône-Alpes.

Regarding the network connectivity, another challenge is to integrate suitable wireless link models accounting for the deployment environment. For example, modeling the integration of sensors in urban areas is challenging due to the presence of neighboring walls and obstacles, as well as moving vehicles and pedestrians that may induce field scattering. Also, the urban constraints and characteristics need to be carefully modeled and considered. Indeed, the urban environment yields constraints or facilities on the deployment of sensor nodes and gateways, such as their embedding within street furniture. Understanding the structure of these spatial constraints is necessary to develop efficient optimization methods able to compute on large scale scenarios.

**Network function deployment.** In this research direction, we do not address network virtualization per se, but the algorithmic and architectural challenges that virtualization brings in both radio access and core networks. As a first challenge, we focus on the evaluation of Cloud Radio Access Network solutions. The capacity of a C-RAN architecture and the way this compares to classical RAN is still an open question. The fact that C-RAN enables cooperation between the remote radio heads (RRH) served by the same base-band units (BBU) indicates an improved performance, but at the same time the resulting cells are much larger, which goes against the current trend of increasing capacity through the deployment of small cells. We propose to study the problem both from a user and a network perspective. On the user side, we use standard information theory tools, such as multiple-access channels to model C-RAN scenarios and understand their performance. On the network side, this translates in a resource allocation problem with cooperative base stations. We will extend our previous models for non-cooperative scenarios. As a second challenge, regarding the core network function deployment, we are interested in a kind of private cellular network such as self-deployable or Professional Mobile Radio (PMR) networks, deployed on-demand or not. These networks, used for public safety services and in scenarios like post-disaster relief or for private companies, present the particularity of an EPC formed by a mobile wireless network. Due to its nature, the network can not be pre-planned, and the different EPC functions need to be autonomously deployed on the available network elements. We study the EPC function deployment problem as an optimization problem, constrained by the user capacity requests. User attachment mechanisms are also investigated to optimize the user association mechanism thanks to the quality of service needed by the user, the network function distribution, the global user demand, and the source/destination of the flows. These challenges are tackled as centralized optimization problems, then extended to the context of real-time decisions. Finally, in order to complete these theoretical works based on ILP models and heuristics, experiments using srsLTE are used to evaluate our proposals.

## 3.2 Wireless data collection

Facing the growth of the mobile demand is the foremost challenge for mobile operators. In particular, a 100-fold increase in the number of supported connected devices, mostly newly connected objects with IoT trafic, is expected. A question therefore arises: how to cope with a dense set of IoT low bit rate traffics from energy and computing power constrained devices while classic cellular infrastructures are designed for the sparse high bit rate traffics from powerful devices?

A technological answer to the densification challenge is also embodied by long-range low-power networks such as SigFox, LoRa, NB-IoT, etc. In this context, the idea of offloading cellular traffic to different wireless access technologies is emerging as a very promising solution to relieve the traditional mobile network from its overwhelming load. In fact, offloading is already employed today, and, globally, 45% of total mobile data traffic was offloaded onto the fixed network through Wi-Fi or femtocells in 2013. Device-to-device (D2D) communications in hybrid networks, combining long-range cellular links and short-range technologies, opens even more possibilities. We aim at providing solutions that are missing for efficiently and practically mix multi-hop and cellular networks technologies.

**Cellular M2M.** Enabling a communication in a cellular network follows two major procedures: a resource allocation demand is first transmitted by the UE which, if successful, is followed by the actual data transmission phase, using dedicated resources allocated by the eNodeB (eNB) to the UE. This procedure was designed specifically for H2H traffic, which is bursty by nature, and it is based on the notions of session and call, activities that keep the user involved for a relatively long time and necessitate the exchange of a series of messages with the network. On the contrary, M2M traffic generates low amounts of data periodically or sporadically. Going through a signaling-heavy random access (RA) procedure to transmit one short message is strongly inefficient for both the M2M devices and the infrastructure.

In the perspective of cellular network evolution, we are investigating mechanisms that regulate the M2M traffics in order to obtain good performances while keeping a reasonable quality of service (QoS) for human-to-human (H2H) terminals. The idea of piggybacking the M2M data transmission within one of the RA procedure messages is tempting and it is now considered as the best solution for this type of traffic. This means that the M2M data is transmitted on the shared resources of the RACH, and raises questions regarding the capacity of the RACH, which was not designed for these purposes. In this regard, our analysis of the access capacity of LTE-A RACH procedure has to be adapted to multi-class scenarios, in order to understand the competition between M2M and H2H devices. Modeling based on Markov chains provides trends on system scale performances, while event-based simulations enable the analysis of the distribution of the performances over the different kinds of users. Combining both should give enough insights so as to design relevant regulation techniques and strategies. In particular two open questions that have to be tackled can be stated as: When should access resources be opened to M2M traffics without penalizing H2H performances? Does an eNodeB have a detailed enough knowledge of the system and transmit enough information to UE to regulate the traffics? The objective is to go to the analysis of achievable performances to actual protocols that take into account realistic M2M traffic patterns.

**Hybrid networks.** The first objective in this research axis is a realistic large-scale performance evaluation of Wi-Fi offloading solutions. While the mechanisms behind Wi-Fi offloading are now clear in the research community, their performance has only been tested in small-scale field tests, covering either small geographical areas (i.e. a few cellular base stations) and/or a small number of specific users (e.g. vehicular users). Instead, we evaluate the offloading performance at a city scale, building on real mobile network traces available in the team. First of all, through our collaboration with Orange Labs, we have access to an accurate characterization of the mobile traffic load at each base station in all major French cities. Second, a data collection application for Android devices has been developed in the team and used by hundreds of users in the Lyon metropolitan area. This application monitors and logs all the Wi-Fi access points in the coverage range of the smartphone, allowing us to build a map of Wi-Fi accessibility in some parts of the city. Combining these two data sources and completing them with simulation studies will allow an accurate evaluation of Wi-Fi offloading solutions over a large area.

On the D2D side, our focus is on the connected objects scenario, where we study the integration of short-range links and long-range technologies such as LTE, SigFox or LoRa. This requires the design of network protocols to discover and group the devices in a certain region. For this, we build on our expertise on clustering sensor and vehicular nodes. The important difference in this case is that the cellular network can assist the clustering formation process. The next step is represented by the selection of the devices that will be using the long-range links on behalf of the entire cluster. With respect to classical cluster head selection problems in ad-hoc networks, our problem distinguishes itself through device heterogeneity in terms of available communication technologies (not all devices have a long-range connection, or their quality is poor), energy resources (some devices might have energy harvesting capabilities) and expected lifetime. We will evaluate the proposed mechanisms both analytically (clustering problems are generally modeled by dominating set problems in graph theory) and through discrete-event simulation. Prototyping and experimental evaluation in cooperation with our industrial partners is also foreseen in this case.

## 3.3 Network data exploitation

Mobile devices are continuously interacting with the network infrastructure, and the associated geo-referenced events can be easily logged by the operators, for different purposes, including billing and resource management. This leads to the implicit possibility of monitoring a large percentage of the whole population with minimal cost: no other technology provides today an equivalent coverage. On the networking side, the exploration of data collected within the cellular network can be the enabler of flexible and reconfigurable cellular systems. In order to enable this vision, algorithmic solutions are needed that drive, in concert with the variations in the mobile demand, the establishment, modification, release and relocation of any type of resources in the network. This raises, in turn, the fundamental problem of understanding the mobile demand, and linking it to the resource management processes. More precisely, we contribute to answer questions about the correlation between urban areas and mobile traffic usage, in particular the spatial and temporal causalities in the usage of the mobile network.

In a different type of architecture, the one of wireless sensor networks, the spatio-temporal characteristics of the data that are transported can also be leveraged to improve on the networking performances, e.g. capacity and energy consumption. In several applications (e.g. temperature monitoring, intrusion detection), wireless sensor nodes are prone to transmit redundant or correlated information. This wastes the bandwidth and accelerates the battery depletion. Energy and network capacity savings can be obtained by leveraging spatial and temporal correlation in packet aggregation. Packet transmissions can be reduced with an overhead induced by distributed aggregation algorithms. We aim at designing data aggregation functions that preserve data accuracy and maximize the network lifetime with low assumptions on the network topology and the application.

**Mobile data analysis.** In this research axis, we delve deeper in the analysis of mobile traffic. In this sense, temporal and spatial usage profiles can be built, by including in our analysis datasets providing service-level usage information. Indeed, previous studies have been generally using call detail records (CDR) or, at best, aggregated packet traffic information. This data is already very useful in many research fields, but fine-grained usage data would allow an even better understanding of the spatiotemporal characteristics of mobile traffic. To achieve this, we exploit datasets made available by Orange Labs, providing information about the network usage for several different mobile services (web, streaming, download, mail, etc.).

To obtain even richer information, we combine this operator-side data with user-side data, collected by a crowdsensing application we developed within the PrivaMov research project. While covering hundreds of thousands of users, operator data only allows to localize the user at the cell level, and only when the user is connected to the network. The crowdsensing application we are using gathers precise GPS user localization data at a high frequency. Combining these two sources of data will allow us to gain insight in possible biases introduced by operator-side data and to infer microscopic properties which, correctly modeled, can be extended to the entire user population, even those for which we do not possess crowdsensed data.

Privacy preservation is an important topic in the field of mobile data analysis. Mobile traffic data anonymization techniques are currently proposed, mainly by adding noise or removing information from the original dataset. While we do not plan to develop anonymization algorithms, we collaborate with teams working on this topic (e.g. Inria Privatics) in order to assess the impact of anonymization techniques on the spatio-temporal properties of mobile traffic data. Through a statistical analysis of both anonymized and non-anonymized data, we hope to better understand the usability of anonymized data for different applications based on the exploration of mobile traffic data.

**Data aggregation.** Data-aggregation takes benefit from spatial and/or temporal correlation, while preserving the data accuracy. Such correlation comes from the physical phenomenon which is observed. Temporal aggregation is mainly addressed using temporal series (e.g. ARMA) whereas spatial aggregation is led thanks to compressive sensing and/or sampling solutions. Our objective is to get rid of the assumption of knowing of the network topology properties and the data traffic generated by the application, in particular for dense and massive wireless networks. Note that we focus on data-aggregation with a networking perspective, not with the background of information theory.

The rational design of an aggregation scheme implies understanding data dynamics (statistical characteristics, information representation) and network dynamics (routing, medium sharing policies, node activity). We designed an aggregation framework for intra-sensor aggregation. For this, we characterize the raw data that are collected in order to understand the dynamics behind several key applications. The goal is to provide a taxonomy of the applications according to the data properties in terms of stationarity, dynamics, etc. We also aimed to design temporal aggregation functions without knowledge of the network topology and without assumptions about the application data. Such functions should be able to self-adapt to the environment evolution.

The question of spatial aggregation can be addressed not only on the point of view of spatial correlation, but also considering a spatial sampling. This is particulary true when considering long range IoT networks (e.g. LoRaWAN) composed of dozen of base stations and thousands of end nodes. In such case, the network capacity can be achieved leading to too many collisions, and poor performance. To avoid such situation, we propose to control the sending data thanks to a classic AIMD mechanism. Thus, we look for collecting a given number of data per time period, whatever in the network topology, but with respect to the application objective.

# 4 Application domains

## 4.1 Smart Cities

One major characteristic of modern societies is that they are prevalently urban. Consequently, the contributions of the Agora team are in particular applied to provide solutions tailored to the emergence of the Internet of Things (IoT) and to Smart Cities applications. A major motivation of the team is the forthcoming explosion of the number of connected devices and the numerous wireless network technologies, supporting the end device mobility or not. In particular, low cost - small data devices are supposed to be densely deployed in our environment, fostering the interest for a convergence of the traditional wireless networking paradigms.

Smart City is a constantly reshaped concept, embracing the future of dense metropolitan areas, with references to efficient and sustainable infrastructure, improving citizens' quality of life and protecting the environment. A consensus on the Smart City philosophy is however that it will be primarily achieved by leveraging a clever integration of Information and Communication Technologies (ICT) in the urban tissue. Indeed, ICTs are enabling an evolution from the current duality between the real world and its digitized counterpart to a continuum in which digital contents and applications are seamlessly interacting with classical infrastructures and services. Smart Cities are often described by the digital services that should be provided which are inherently dependent on dense measurements of the city environment and activities, the collection of these data, their processing into information, and their redistribution. The networking infrastructure plays therefore a critical role in enabling advanced services, in particular the wireless infrastructure supporting density and mobility. In such wireless network infrastructure, whether it is a cellular one or an IoT one, new features arise: mobile devices to provide connectivity (e.g. UAVs), on-demand deployment, heterogeneous technologies, that shape the future of wireless networks.

From a wireless networking viewpoint, the digitization of cities can be seen as a paradigm shift extending the Internet of Things (IoT) to a citizen-centric model in order to leverage the massive data collected by pervasive sensors, connected mobiles or fixed devices, and social applications.

# 5 Highlights of the year

- Walid Bechkit holds the PEDR (2017-2021).
- Hervé Rivano holds the PEDR (2017-2021).
- Razvan Stanica holds the PEDR (2020-2024).

## 5.1 Awards

- Ahmed Boubrima received the GDR RSD & ACM ASF Phd thesis award, 2020.
- Ahmed Boubrima received the best thesis award of INSA Lyon (Digital society and information topic), 2020.

# 6 New software and platforms

## 6.1 New software

### 6.1.1 PrivaMovApp

**Keyword:** Crowd-sensing

**Functional Description:** Agora is leading the development of an Android application for user data collection purposes. The application is based on the Funf framework, and is currently available on Google Play.

**Contact:** Razvan Stanica

**Participants:** Stéphane d'Alu, Hervé Rivano, Razvan Stanica, Solohaja Rabenjamina

#### 6.1.2 urpolsens

**Name:** UrPolSens Platform

**Keywords:** Wireless Sensor Networks, Air Quality

**Functional Description:** The micro-controller is integrated into a lab-designed printed circuit which includes among others: a high precision ADC, a micro-SD card reader and a radio communication module. The designed nodes measure the nitrogen dioxide (NO2) pollutant in addition to temperature and humidity, and transmit data using LoRa to a gateway, which is connected to our servers using a 4G connection. The sensors are also equipped with solar panels in order to extend their lifetime when their batteries are drained. Our platform has been operational in the downtown of the city of Lyon with 12 sensor nodes deployed in the Garibaldi street from mid-July to mid-October 2018. It has then been improved and generalized to match the need of the collaboration with Total LQA lab. It is now a versatile multi-sensors platform able to run autonomously on solar energy for months.

**Contacts:** Walid Bechkit, Hervé Rivano

**Partner:** Intelligence des Mondes Urbains

#### 6.1.3 3M'Air

**Name:** 3M'Air Platform

**Keywords:** Wireless Sensor Networks, Air Quality

**Functional Description:** We have built our own nodes equipped with multiple sensors measuring Nitrogen-Dioxide (NO2), Particulate Matter (PM1, PM2.5, PM10), temperature and humidity. They are battery-powered and equipped with a GPS module to have the position of the measurements. Data are stored on a micro SD card and at the same time sent over LoRa to a server we have developed that is responsible to store these data for future analysis. A web platform has also been developed to display the collected concentration measurements in real time. This developed solution is used in several participatory planned measurement campaigns in Lyon city.

**Contacts:** Walid Bechkit, Hervé Rivano

#### 6.1.4 eSmartCity

**Name:** eSmartCity Smart Lighting platform

**Keywords:** Lighting, Sensors

**Functional Description:** The objective is to analyze the pedestrian mobility on a street and to evaluate the opportunity to deploy a Smart Lighting solution. Mobility is monitored using PIR sensors and correlated with light, environment and noise sensor measurements. We are discussing with a company the opportunity to adapt our sensors to their own public lighting products.

**Contacts:** Oana Iova, Hervé Rivano

#### 6.1.5 Dense LoRaSim

**Name:** Extension to support dense LPWAN in LoRaSim

**Keyword:** LoRaWAN

**Functional Description:** In the settings of our dense networks research topic, we have modified the LoRaSim simulator so that it supports up to a million devices, while keeping a realistic modelisation of the channel. This will allow us to evaluate the scalability of different algorithms and protocols in a realistic scenario. We also create a fork to support ultra dense network emulation.

**Contacts:** Fabrice Valois, Oana Iova

### 6.2 New platforms

**PPAIR Plateforme LoRa - Campus Connecté** The project aims at providing a platform that offers connectivity through a long-range, low-energy network to smart objects. The platform uses LoRa technology, which offers a wide connectivity, covering the entire INSA Lyon campus and providing a data collection service to all campus users. The main purpose of the LoRa plateform is: *(i)* research (researchers can use it for studying reliability and capacity problems, privacy related challenges, etc.), and *(ii)* teaching (several courses from INSA, especially in the Telecom department can use this platform as a pedagogical tool).
Part of the software is mutualized with the University of Paris 13, where an equivalent LoRaWan testbed project is deployed at the campus of Université Sorbonne Paris Nord. The mutualization of the software tools allows us to conduct multi sites experiments, at Lyon and at Paris. Since 2019, this platform is used in the European Project Interreg Med ESMARTCITY and for the PHC Ulysses (joint collaboration with Nimbus Center, Ireland).

**UrPolSens Platform** We designed from scratch an energy efficient air pollution sensor network using Atmega micro-controllers and electrochemical air pollution probes. The micro-controller is integrated into a lab-designed printed circuit which includes among others: a high precision ADC, a micro-SD card reader and a radio communication module. The designed nodes measure the nitrogen dioxide (NO2) pollutant in addition to temperature and humidity and transmit data using LoRa to a gateway, which is connected to our servers using a 4G connection. The sensors are also equipped with solar panels in order to extend their lifetime when their batteries are drained. Our platform has been operational in the downtown of the Lyon city with 12 sensor nodes deployed in the Garibaldi street from mid-July to Mid-October 2018.

**3M'air sensor platform** We developed the 3M'Air sensor platform to be used in participatory sensing of temperature and air quality. We have built our own nodes equipped with multiple sensors measuring Nitrogen-Dioxide (NO2), Particulate Matter (PM1, PM2.5, PM10), temperature and humidity. They are battery-powered and equipped with a GPS module to have the position of the measurements. Data are stored on a micro SD card and at the same time sent over LoRa to a server we have developed that is responsible to store these data for future analyses. A web platform has also been developed to display the collected concentration measurements in real time. This developed solution is used in several participatory planned measurement campaigns in Lyon city.

**The AgoraLTEplateform (ALP)** The AgoraLTEplateform is leveraging the opensource srsLTE software suite and Software Defined Radio (SDR) to perform experimental research about autonomous and flexible cellular networks. This platforms emulates thanks to three software components of srsLTE an entire cellular network composed of three main elements: the core network (srsEPC) , the radio access network (srsENB) ans the user equipment (srsUE). Those elements can be run on several remote machines and operate an LTE connection by the means of SDR elements: USRP-2901 from National Instrument in our case. We also have at our disposal custom sim cards usable by any off-the-shelf smartphone that permit them to access the experimental network. This platform being run by a regularly updated open source code allows us to modify its structure, tune, add or remove network parameters and run the scientific experiments that are yet to few in the literature. This testbed is issued to investigate new user association mechanisms considering quality of service requirements, or emergency situations.

# 7 New results

## 7.1 Wireless network deployment

*Participants: Walid Bechkit, Manoel Dahan, Mohamed Anis Fekih, Oana Iova, Hervé Rivano, Razvan Stanica, Fabrice Valois.*

**Robust Planning and Operation of Multi-Cell Homogeneous and Heterogeneous Networks** In [6], we propose a robust planning tool that allocates power statically in homogeneous and heterogeneous cellular networks with non-regular base station (BTS) placement, to mitigate interference and improve overall performance. Each BTS will use the total available spectrum, but it will divide it into multiple sub-bands, and each BTS will transmit with a specific pre-computed power on each sub-band. We refer to such a power allocation as a power map. Our offline planning tool computes a robust power map for a given topology, by solving a non-convex, non-linear optimization problem, through simple transformations, based on geometric programming. The power map is computed based solely on the network topology, and it is made available to all BTSs that use it throughout the network operation to perform scheduling using a fast quasi-optimal online algorithm that we propose. We evaluate our planning tool for different homogeneous and heterogeneous networks (HetNets), first in a static setting where scheduling is performed optimally and then in a dynamic setting when scheduling is performed with our online scheduler. Results show that our solution significantly outperforms a classical equal power/fixed frequency reuse scheme in terms of sum-rate, by up to 30% in homogeneous networks and by up to 70% in HetNets.

**Participatory Air Quality and Urban Heat Islands Monitoring System** The widespread use of low-cost environmental monitoring systems, together with recent developments in the design of Internet of Things architectures and protocols, has given new impetus to smart city applications. Such progress should, in particular, considerably improve the fine characterization of a wide range of physical quantities within our cities. Indeed, the cost-effectiveness of these emerging sensors combined with their reduced size allows for high density deployments resulting in a higher spatial granularity. In [4], we briefly present the 3M'Air project that aims to explore the potential of participatory citizen measures using low-cost sensors in order to improve the local knowledge of air quality and temperature and then bridge the gap between individual exposure and regional measurements. We present then the design, implementation and evaluation of our low-cost, small-size WSN-based participatory monitoring system. This system is composed of mobile sensing nodes measuring temperature, humidity and a number of pollutants (NO2, PM1, PM2.5 and PM10). The collected data are sent to a server for analysis and building temperature and air quality maps. To validate our platform, we have carried out multiple tests to compare our sensor nodes to reference stations and to each other. We have also evaluated the energy consumption of our nodes under different configurations. The results are satisfactory and show that our nodes can be used in environmental participatory monitoring.

**Challenges of Designing Smart Lighting** Smart lighting is one of the main applications enabling the Smart Cities of today. Existing real life deployments have clearly shown that smart lighting drastically decreases the energy consumption of cities. However, with the plethora of solutions existing on the market today, it is difficult to find the one that fits the specific needs of each community. Our system can asses the gains of using a smart lighting system, and can use the collected data to give specific recommendations for the solution that should be implemented. In [21], we present the main challenges and problems that we encountered during the design of our prototype and system, and we discuss some lessons learned.

## 7.2 Wireless data collection

*Participants: Walid Bechkit, Abderrahman Ben Khalifa, Alexis Duque, Razvan Stanica.*

**Analytical and Simulation Tools for Optical Camera Communications** The use of LED-to-camera communication opens the door to a wide range of use cases and applications, with diverse requirements in terms of quality of service. However, while analytical models and simulation tools exist for all the major radio communication technologies, the only way of currently evaluating the performance of a network mechanism over LED-to-camera is to implement and test it. Our work [10] aims to fill this gap by proposing a Markov-modulated Bernoulli process to model the wireless channel in LED-to-camera communications, which is shown to closely match experimental results. Based on this model, we develop and validate CamComSim, the first network simulator for LED-to-camera communications.

**CCA Threshold Impact on the MAC Layer Performance in IoT Networks** While current medium access control solutions in low-power wide area networks are generally based on Aloha, recent studies demonstrated the interest of adding carrier sense mechanisms to the picture. In [18], we investigate the impact of the carrier sense threshold parameter in this particular context. We show that its impact on the average behavior of the network is limited, but this changes when looking at the individual node performance. Our simulation results demonstrate an important heterogeneity among nodes, both in terms of packet success probability and of energy consumption. Moreover, the performance of the nodes is strongly correlated with the percentage of contending nodes that they can sense. By simply using two different carrier sense thresholds in the network, we achieve an increased fairness among nodes.

**Service Oriented D2D Efficient Communication for Post-Disaster Management** In a post-disaster situation, the construction of replacement communication infrastructure is crucial for the success of rescue operations. LTE Device-to-Device Proximity Services and IoT are considered as key enabling technologies for the construction of such replacement networks. Existing techniques rely on smartphones as relay stations to build a replacement broadcast-based network that connects available devices. In many cases, the use of such networks requires querying a given type of IoT devices (e.g. surveillance cameras, heart-rate monitors, temperature sensors) depending on network users and service requirements. In such scenarios, incorporating all relays in the broadcast is inefficient and may lead to poor network performance. In [17], we propose constructing for each service type a sub-network of relay stations that ensure connectivity among IoT devices providing the same service type. The resulting sub-networks ensure an efficient and robust message dissemination, avoiding transmission redundancy, and resulting in higher energy savings as well as high coverage. These properties have been validated by implementing our solution in NS-3 by extending the LTE D2D ProSe module provided by NIST. Obtained results show significant improvements in terms of energy consumption, and packet delivery ratio.

## 7.3 Network data exploitation

*Participants: Walid Bechkit, Florentin Delaine, Ichrak Mokhtari, Hervé Rivano, Fabrice Valois*

**Classification of Data Aggregation Functions in Wireless Sensor Networks** Data aggregation is an effective traffic-saving solution in wireless sensor networks. A group of aggregation functions are proposed to save traffic and network capacity, thereby extending network lifetime. Unfortunately, how to select an appropriate function w.r.t a target accuracy and a given application is not well being discussed. Considering the forecasting aggregation functions, in [1] we propose classification of the functions to guild how to select the appropriate one. Using target accuracy (the accuracy requirement predefined by the application), the distribution of raw data and performance of the functions (modeled by a Markov Decision Process), we classify the functions into a map that shows which function performs better depending on target accuracy and the characterized data distribution.

**Framework for the Simulation of Sensor Networks Aimed at Evaluating In Situ Calibration Algorithms** The drastically increasing availability of low-cost sensors for environmental monitoring has fostered a large interest in the literature. One particular challenge for such devices is the fast degradation over time of the quality of their data. Therefore, the instruments require frequent calibrations. Traditionally, this operation is carried out on each sensor in dedicated laboratories. This is not economically sustainable for dense networks of low-cost sensors. An alternative that has been investigated is in situ calibration: exploiting the properties of the sensor network, the instruments are calibrated while staying in the field and preferably without any physical intervention. The literature indicates there is wide variety of in situ calibration strategies depending on the type of sensor network deployed. However, there is a lack for a systematic benchmark of calibration algorithms. In [2], we propose the first framework for the simulation of sensor networks enabling a systematic comparison of in situ calibration strategies with reproducibility, and scalability. We showcase it on a primary test case applied to several calibration strategies for blind and static sensor networks. The performances of calibration are shown to be tightly related to the deployment of the network itself, the parameters of the algorithm and the metrics used to evaluate the results. We study the impact of the main modelling choices and adjustments of parameters in our framework and highlight their influence on the results of the calibration algorithms. We also show how our framework can be used as a tool for the design of a network of low-cost sensors.

**Uncertainty-Aware Deep Learning Architectures for Highly Dynamic Air Quality Prediction** Forecasting air pollution is considered as an essential key for early warning and control management of air pollution, especially in emergency situations, where big amounts of pollutants are quickly released in the air, causing considerable damages. Predicting pollution in such situations is particularly challenging due to the strong dynamic of the phenomenon and the various spatio-temporal factors affecting air pollution dispersion. In addition, providing uncertainty estimates of prediction makes the forecasting model more trustworthy, which helps decision-makers to take appropriate actions with more confidence regarding the pollution crisis. In [5], we propose a multi-point deep learning model based on convolutional long short term memory (ConvLSTM) for highly dynamic air quality forecasting. ConvLSTM architectures combines long short term memory (LSTM) and convolutional neural network (CNN), which allows to mine both temporal and spatial data features. In addition, uncertainty quantification methods were implemented on top of our model's architecture and their performances were further excavated. We conduct extensive experimental evaluations using a real and highly dynamic air pollution data set called Fusion Field Trial 2007 (FFT07). The results demonstrate the superiority of our proposed deep learning model in comparison to state-of-the-art methods including machine and deep learning techniques. Finally, we discuss the results of the uncertainty techniques and we derive insights.

# 8 Bilateral contracts and grants with industry

## 8.1 Bilateral contracts with industry

- We have contracted a first bilateral contract with Total (2018-2021) where we work with the laboratory LQA of Total on the design and the test of autonomous low cost air quality sensors. The Lora-based developed platform is currently deployed and evaluated by LQA.
- We have contracted bilateral cooperation with NRGYBox (2020-2021) on the use of IoT sensors and mobile data aggregation for detection of human presence for Smart Lighting application.
- We have contracted bilateral cooperation with SafeHear on wireless group communications (2020-2021). The goal is to design group communication protocol with respect to QoS criterion (jitter, goodput, packet loss) for short range commuications in noisy environments.

## 8.2 Bilateral grants with industry

- Common Laboratory Inria/Nokia Bell Labs - ADR Network Information Theory: Agora is part of the ADR Network Information Theory of the common laboratory Inria/Nokia Bell Labs.
- Spie - INSA Lyon IoT Chaire: Agora is involved in the SPIE INSA Lyon IoT Chaire, launched in November 2016. The IoT Chaire partially funds the PhD thesis of Abderrahman Ben Khalifa.

- Volvo - INSA Lyon Chaire: Agora is involved in the Volvo Chaire at INSA Lyon, on the area of autonomous electrical distribution vehicle in urban environments. Razvan Stanica is a member in the steering committee of this structure.

# 9 Partnerships and cooperations

## 9.1 International initiatives

### 9.1.1 Inria international partners

**Informal international partners**

- **Biskra University, Algeria**. Joint publications and visits about, optimal temperature aware UAV operations, WiFi based trace analysis and D2D communications for disaster scenarios from Prof. Abdelmalik Bachir.
- **Digital Catapul, London, UK**. Collaboration around LoRa experiments with Dr. Ramona Marfievici.
- **IMDEA, Madrid, Spain**. Joint publications and projects around mobile trafic analysis with Dr. Marco Fiore.
- **ETS Montréal, Université du Québec, Canada**. Joint publications and projects around cellular networks and trafic analysis with the group of Prof. Diala Naboulsi.
- **Rice University**. Collaboration around network deployment and data assimilation for air quality monitoring with the group of Prof. Edward W. Knightly.
- **University of Edinburgh, UK**. Joint publications and visits to/from the group of Dr. Paul Patras.
- **University of Waterloo, ON, Canada**. Joint publications and visits around self-deployable cellular networks to/from the group of Prof. Catherine Rosenberg.

### 9.1.2 Participation in other international programs

**PHC Campus France**

- **University College Cork, Ireland**. PHC Ulysses (2019-2020) on real-world characterisation of long range wireless newtorks, a collaboration with Khaled Abdelfadeel.
- **INPT Rabat, Morocco**. PHC Toubkal (2019-2021) on efficient data collection for smart building and smart city applications, a collaboration with the group of Prof. Loubna Echabbi.

## 9.2 International research visitors

### 9.2.1 Visits of international scientists

- Priscilla Solis, Professor, Brasilia University, Brazil, visiting the Agora team , CITI, INSA Lyon, (January-February).

## 9.3 European initiatives

### 9.3.1 FP7 & H2020 Projects

- Program: H2020-ICT-2018-2020
  - Project acronym: BUGWRIGHT2
  - Project title: Autonomous Robotic Inspection and Maintenance on Ship Hulls and Storage Tanks
  - Duration: 01/2020 - 03/2025

- Coordinator: Georgia Tech Lorraine / UMI 2958 GT-CNRS
- Other partners: 9 academics partners (CNRS, UPORTO, UIB, INSA, RWTH, UNI-KLU, NTNU, UT, WMU) and 11 industrials partners (CETIM, LSL, RBP, BEYE, RINA, GLM, APDL, AASA, TRH, IEIC, DANAOS, SBK).
- Abstract: The objective of BUGWRIGHT2 is be to bridge the gap between the current and desired capabilities of ship inspection and service robots by developing and demonstrating an adaptable autonomous robotic solution for servicing ship outer hulls. By combining the survey capabilities of autonomous Micro Air Vehicles (MAV) and small Autonomous Underwater Vehicles (AUV), with teams of magnetic-wheeled crawlers operating directly on the surface of the structure, the project inspection and cleaning system will be able to seamlessly merge the acquisition of a global overview of the structure with performing a detailed multi-robot visual and acoustic inspection of the structure, detecting corrosion patches or cleaning the surface as necessary – all of this with minimal user intervention.

- Program: Interreg Med
  - Project acronym: ESMARTCITY
  - Project title: Enabling Smarter City in the MED Area through Networking
  - Duration: 02/2018 - 07/2020
  - Coordinator: Abruzzo Region, Italy
  - Other partners: ARIC and RWG (Greece), APEGR (Spain), RAIS (Bosnia and Herzegovina), ENA (Portugal), MCM and PoliMi (Italy), Capergies (France)
  - Abstract: The project has its primary objective in improving the innovation capacity of MED cities by creating innovation ecosystems, which involve actors of the quadruple helix (Citizens, Businesses Operators, Research, Universities and Public Authorities), and in applying the Smart City concept, which utilizes digital and energy saving technologies to allow better services for the citizen with less impact on the environment, producing furthermore new employability and living scenarios. To achieve this goal, the project envisages the pilot testing of the Smart City concept to provide specific services to citizens in the field of intelligent urban districts, energy efficiency of buildings and smarter public lighting.

## 9.4 National initiatives

### 9.4.1 Inria Mission Covid

- SafeCityMap project: mobile network data analysis covering the firstCovid lockdown to map the epidemic risk factor.
  Coordinators: Aline Viana (Inria Tribe), Razvan Stanica (Inria Agora).
  Participants: Solohaja Rabenjamina (Inria Agora), Haron Calegari Fantecele (LNCC, Brazil) Artur Ziviani (LNCC, Brazil).
  Human mobility properties have been investigated at length using mobile phone data. However, the COVID-19 pandemic highly perturbed our mobility patterns and use of urban spaces. This raises two important questions, addressed in the SafeCityMap project. First of all, we investigate how mobility patterns at an urban scale were affected by the pandemic, and especially by harsh lockdown conditions in Spring 2020. Second, we argue that the modeling of such patterns can provide a clear association with the epidemic spread, such as for COVID-19, in different areas of a city. By understanding how different types of areas are visited in a city, SafeCityMap aims to track the temporal evolution of the potential risk of virus spread in these areas.

### 9.4.2 ANR

- ANR CANCAN 2019 - 2022
  Participants: Solohaja Rabenjamina, Razvan Stanica.
  The partners in this project are: CEDRIC, Inria, Orange Labs, with Thalès Communications &

Security leading the project.
The ANR CANCAN (Content and context based adaptation in mobile networks) targets the following objectives: *i)* collecting novel measurement datasets that describe mobile network data traffic at unprecedented spatial and temporal accuracy levels, and for different mobile services separately. The datasets will be gathered in an operational nationwide network, *ii)* evaluating existing analytics for classification, prediction and anomaly detection within real-world high-detail per-service mobile network data, and tailoring them to the specifications of the management of resources at different network levels, and *iii)* demonstrating the integration of data analytics within next-generation cognitive network architectures in several practical case studies.

- ANR MAESTRO 5G 2019 - 2022
  Participants: Hervé Rivano, Razvan Stanica.
  The partners in this project are: CEDRIC, Inria, L2S, LIA, Nokia Bell Labs, TSP, with Orange Labs leading the project.
  The ANR MAESTRO 5G (Management of slices int he radio access of 5G networks) is expected to provide: *i)* a resource allocation framework for slices, integrating heterogeneous QoS requirements and spanning on multiple resources including radio, backhauling/fronthauling and processing resources in the RAN, *ii)* a complete slice management architecture including provisioning and re-optimization modules and their integration with NFV and SDN strata, *iii)* a business layer for slicing in 5G, *iv)* a demonstrator showing the practical feasibility as well as integration of the major functions and mechanisms proposed by the project, on a 5G Cloud RAN platform. The enhanced platform is expected to support the different 5G services.
- ANR CoWorkWorlds 2018 - 2020.
  Participants: Solohaja Rabenjamina, Razvan Stanica.
  The ANR CoWorkWorlds (Sustainability and spatiality in co-workers' mobility practices) project is led by ENTPE. Its focus is on the study of co-working environments, and more precisely on the mobility behavior of users of such spaces. Our role in the project is to collect and analyse mobility data from a set of users, using the PrivaMov smartphone application.

#### 9.4.3 GDR CNRS RSD - Pôle ResCom

- Ongoing participation (since 2006)
  Communication networks, working groups of GDR ASR/RSD, CNRS (https://gdr-rsd.cnrs.fr/pole_rescom). Hervé Rivano is member of the scientific committee of ResCom.

### 9.5 Regional initiatives

- Labex IMU 3M'Air 2018-2021
  Participants: Walid Beckhit, Ahmed Boubrima, Manoel Dahan, Mohamed Anis Fekih, Ichrak Mokhtari, Hervé Rivano.
  The partners in this project are: EVS, LMFA, Métropole de Lyon, Ville de Lyon , Atmo AURA, Météo France, Lyon Météo. Inria Agora is the leader of this project.
  The 3M'Air project explores the potential of participatory sensing to improve local knowledge of air quality and urban heat islands. The main aim of this project is therefore to equip citizens with low-cost mobile sensors and then ensure an efficient real-time data collection and analysis. This allows to obtain a finer spatiotemporal granularity of measurements with lighter installation and operational costs while involving citizens.

## 10 Dissemination

### 10.1 Promoting scientific activities

#### 10.1.1 Scientific events: organisation

- Oana Iova, Laetitia Lécot-Gauthé and Razvan Stanica was Local Organization Co-Chairs of EWSN 2020, Lyon, France, (in cooperation with ACM SIGBED and ACM SIGMOBILE).

- Hervé Rivano was Local Organization Co-Chair of Algotel/CoRes 2020, Lyon, France.

**General chair, scientific chair**

- Oana Iova was co-chair of NewNets 2020 - 2nd Workshop on Emerging Technologies and Trends in Engineering Low-Power Networks, August 31 - September 3, 2020, Cork, Ireland (online).
- Oana Iova was Poster/demo co-chair of ISCC 2020: 24rh IEEE Symposium on Computers and Communications, July 2020, Rennes, France (online).
- Oana Iova was Publicity co-chair ACM/IEEE IoTDI 2020 - 5th ACM/IEEE Conference on Internet of Things Design and Implementation, April 2020, Sydney, Australia (online).
- Razvan Stanica was publication chair for NoF 2020, 11th International Conference on Network of the Future, October 2020, Bordeaux, France (online).
- Fabrice Valois was General Chair of EWSN 2020, Lyon, France, (in cooperation with ACM SIGBED and ACM SIGMOBILE).

**Member of the organizing committees**

- Evelyne Akopyan, Mohamed Anis Fekih, Ichrak Mokhtari, Romain Pujol, were involved in the local organization of EWSN 2020, Lyon, France, (in cooperation with ACM SIGBED and ACM SIGMOBILE)

### 10.1.2 Scientific events: selection

**Member of the conference program committees**

- Walid Bechkit was in the TPC of the following conferences: IEEE ICCCN, IEEE LCN.
- Oana Iova was in the TPC of the following conferences: SECON IAUV Workshop, IEEE ISCC, UrbCom, PhD Forum IEEE WoWMoM, EWSN, AdHoc-Now.
- Razvan Stanica was in the TPC of the following conferences: IFIP Networking, IEEE ICC, IEEE GlobeCom, IEEE PIMRC, IEEE VTC Spring/Fall, ICIN, NoF, ISNCC.
- Fabrice Valois was in the TPC of the following conferences: IEEE Globecom, IEEE ICC, IEEE ICT, IEEE IWCMC, IEEE WCNC, AINA,WiSARN.

### 10.1.3 Journal

**Member of the editorial boards**

- Fabrice Valois is associated editor for Annals of Telecommunications (IF: 1.412).

**Reviewer - reviewing activities**

- Oana Iova was reviewer for the following journals: Elsevier Computer Networks, Transactions on Mobile Computing.
- Razvan Stanica was reviewer for the following journals: IEEE Transactions on Mobile Computing, IEEE Transactions on Network and Service Management, IEEE Transactions on Vehicular Technology, IEEE Communications Magazine, IEEE Communication Letters, Computer Networks, Journal of Information Security and Applications, Microprocessors and Microsystems, Open Geosciences.

#### 10.1.4 Invited talks

- Oana Iova was invited speaker for Groupe de travail sur l'évaluation de performances des réseaux, Fédération Informatique de Lyon, France.
- Romain Pujol was invited speaker for Groupe de travail sur l'évaluation de performances des réseaux, Fédération Informatique de Lyon, France.
- Hervé Rivano was invited keynote speaker for the CIoT conference https://ciot2020.dnac.org/keynote/, 4th Conference on Cloud and Internet of Things, Niteroi, Brazil, October 2020.

#### 10.1.5 Leadership within the scientific community

- Oana Iova co-organized a series of seminars for helping PhD students and postdocs prepare for their career in academia or in public research centers (e.g. CNRS, Inria).

#### 10.1.6 Scientific expertise

- Walid Bechkit is expert of the CESR AURA (Conseil économique, social et environnemental régional, Région Auvergne Rhône Alpes).
- Oana Iova was member of the following associate professor recruitment committees: Université de Nantes, Univerité de Strasbourg.
- Hervé Rivano was coordinator of a recruitment committee for an associate professor position at INSA Lyon and was member of a committee for a full professor position at Université de la Réunion.
- Hervé Rivano was in the PhD grant attribution committee of Ecole Urbaine e Lyon
- Hervé Rivano was member of the RSD GdR best PhD prize committee.
- Razvan Stanica was a member in a recruitment committee for an associate professor position at INSA Lyon.
- Razvan Stanica is co-leader of the topic System/Network/Telelcommunication of the Fédération d'Informatique de Lyon, since 2020.
- Fabrice Valois was member of the following associate professor / full professor recruitment committees: Université de Clermont Auvergne, Université de Toulouse (president of the committee).

### 10.2 Teaching - Supervision - Juries

#### 10.2.1 Teaching

**Bachelor and License**

- Walid Bechkit, Introduction to wireless sensor networks, 50h, L2, INSA Lyon.
- Oana Iova, Introduction to research, 20h, L3, Telecom. Dpt. INSA Lyon.
- Oana Iova, Smart city: networking challenges, 8h, L3, Smart Program, INSA Lyon (lectures given in english).
- Oana Iova, Internet of connected things, 3h, L3, Innov Program, INSA Lyon (lectures given in english).
- Hervé Rivano, Algorithms and programming, 165h, L1 - L2, INSA Lyon.
- Hervé Rivano, Sensors data engineering project, 34h, L2, INSA Lyon.
- Licence: Hervé Rivano, Programming robot control, 20h, L2, INSA Lyon.
- Fabrice Valois, IP Networks, 36h, L3, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Medium Access Control, 54h, L3, Telecom. Dpt. INSA Lyon.

**Master**

- Walid Bechkit, Performance evaluation of telecom networks, 100h, M1, Telecom. Dpt. INSA Lyon.
- Walid Bechkit, Cryptography and communication security, 30h, M1, Telecom. Dpt., INSA Lyon.
- Walid Bechkit, Wireless networks: architecture and security, 30h, M2, INSA Lyon.
- Walid Bechkit, Network Acces Control, 6h, M2, Telecom. Dpt. INSA Lyon.
- Oana Iova, Network and System Programming, 108h, M1, Telecom. Dpt. INSA Lyon.
- Oana Iova, Network Routing Protocols, 66h, M1, Telecom. Dpt. INSA Lyon.
- Oana Iova, Long Range Networks, 10h , M2, Telecom. Dpt. INSA Lyon.
- Oana Iova, IoT technical project, 8h, M2, Telecom. Dpt. INSA Lyon.
- Hervé Rivano, Smart Cities and IoT, 44h, M2, Telecom. Dpt. INSA Lyon.
- Hervé Rivano, Smart Cities, Master Cities, Environment and Urbanism, University of Lyon.
- Razvan Stanica, Mobile Networks, 30h, M1, Telecom. Dpt. INSA Lyon.
- Razvan Stanica, Mobile Networks, 34h, M1, INSA EuroMed, Fés, Morocco.
- Razvan Stanica, Content Delivery Networks (routing protocols), 10h, M2, Telecom. Dpt. INSA Lyon.
- Razvan Stanica, Forgotten Network Technologies, 32h, M2, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Content Delivery Networks (end-to-end applications), 10h, M2, Telecom. Dpt. INSA Lyon.

**Apprenticeship (license and master)**

- Licence: Oana Iova, Network and System Programming, 44h, L3, Telecom. Dpt. INSA Lyon.
- Licence: Razvan Stanica, IP Networks, 36h, L3, Telecom. Dpt. INSA Lyon.
- Licence: Fabrice Valois, Medium Access Control, 54h, L3, Telecom. Dpt. INSA Lyon.
- Master: Walid Bechkit, Performance evaluation of telecom networks, 100h, M1, Telecom. Dpt. INSA Lyon.
- Master: Oana Iova, Network Routing Protocols, 20h, M1, Telecom. Dpt. INSA Lyon.
- Master: Fabrice Valois, Mobile Networks, 30h, M1, Telecom. Dpt. INSA Lyon..

**Administration and services linked to teaching activities**

- Walid Bechkit is an elected member of the Telecommunication department council at INSA Lyon.
- Walid Bechkit is the head of the networking teaching team in the Telecommunications department at INSA Lyon, coordinating all the courses in the networking domain.
- Oana Iova is the head of international relations at the Telecommunications department of INSA Lyon.
- Hervé Rivano is responsible for the coordination of all courses in the Smart Cities and IoT option at the INSA Lyon Telecommunications department.
- Hervé Rivano is responsible of the Smart program (international teaching program with Tohoku University and Tokyo University) about Smart Cities.

- Hervé Rivano is responsible of the IoT specialization of the Innov program (INSA Lyon and US students).
- Hervé Rivano animates the working group for the evolution of the algorithms and computerscience teaching of the FIMI department of INSA Lyon for 2021 and 2022.
- Hervé Rivano is referent DSI in the FIMI Dpt., INSA Lyon.
- Razvan Stanica is responsible of the research option at the Telecommunications department of INSA Lyon.
- Razvan Stanica is vice dean of the Telecommunications department of INSA Lyon, in charge of education related affairs.

#### 10.2.2 Supervision

- PhD in progress: Nour Bouzouita, Traffic aggregation in Wi-Fi networks, since 11/2018. Advisors: Anthony Busson (Univ. Lyon 1, LIP), Hervé Rivano.
- PhD in progress: Mohamed Anis Fekih, Urban pollution using wireless sensor networks, since 11/2018. Advisors: Walid Bechkit, Hervé Rivano.
- PhD in progress: Kawtar Lasri, Data collection and distributed spatial coordination in LPWAN networks, since 01/2019. Advisors: Oana Iova, Fabrice Valois.
- PhD in progress: Lucas Magnana, De la ville intelligente à la ville prédictive, application aux modes de transport actifs, since 10/2020. Advisors: Nicolas Chiabaut (LICIT, ENTPE / IFSTTAR), Hervé Rivano.
- PhD in progress: Ichrak Mokhtari, Spatio-temporal analysis of pollution data from low cost sensors, since 11/2019. Advisors: Walid Bechkit, Hervé Rivano.
- PhD in progress: Camille Moriot, DDos Attacks and their impacts on the Internet Architecture, since 09/2020. Advisors: François Lesueur (CITI) Nicolas Stouls (CITI), Fabrice Valois.
- PhD in progress: Mihai Popescu, Connectivity constrained mobility in fleets of robots, since 11/2015. Advisors: Olivier Simonin (Inria CHROMA), Anne Spalanzanni (Inria CHROMA), Fabrice Valois.
- PhD in progress: Romain Pujol, Data collection in dynamic wireless networks, since 11/2018. Advisors: Razvan Stanica, Fabrice Valois.
- PhD in progress: Solohaja Rabenjamnia, Data analysis of cellular trafic, since 11/2018. Advisors: Hervé Rivano, Razvan Stanica.

#### 10.2.3 Juries

- Oana Iova was a PhD Mid-term examiner in the following PhD committees:
  - Samira Abboud, Study and improvement of long-range communication technologies for wireless sensor networks, LIMOS, June, 2020.
  - Guéréguin Sidibé, Architecture materielle et protocoles pour réseaux de capteurs sans fils adaptés à la surveillance environmnetale, LIMOS, June, 2020.
  - Mouna Karoui, Contributions à l'amélioration des performances des communications dédiées aux services C-ITS, LIMOS, June, 2020.
- Oana Iova was a member in the following PhD defense committees:
  - Juliette Garcia, Opportunistic Data Collection and Routing in Segmented Wireless Sensor Networks, ENAC Toulouse, Dec. 2020.

  - Samira Abboud, Study and improvement of long-range communication technologies for wireless sensor networks, Université Clermont Auvergne, LIMOS, Oct. 2020.

- Hervé Rivano was a president and examiner in the following PhD defense committee:
  - V. Morel, Enhancing Information and Consent in the Internet of Things, INSA Lyon, September 2020.

- Hervé Rivano was a reviewer in the following PhD defense committees:
  - F. Mkacher, Optimization of Time Synchronization Techniques on Computer Networks, Université Grenoble Alpes, June 2020.
  - C. Bertero, Perception de l'environnement urbain à l'aide d'une flotte de capteurs sur des vélos. Application à la pollution de l'air, Université Fédérale Toulouse Midi-Pyrénées, June 2020.
  - M. A. Falek, Efficient Route Planning for Dynamic and Multimodal Transportation Network, Université Strasbourg, December 2020.

- Razvan Stanica was a member in the following PhD mid-term committees:
  - T. Alhajj, Optimisation of Very Low Latency 5G Networks, IMT Atlantique, May 2020.
  - D. Do Couto Teixeira, Understanding, Explaining and Enhancing Predictability Estimates in Human Mobility, Institut Polytechnique de Paris, May 2020.
  - L. Amichi, Understanding Individuals' Proclivity to Explore, Institut Polytechnique de Paris, June 2020.
  - L. Chetot, User Detection in Non-Coherent Multiple Access Channel, INSA Lyon, July 2020.

- Razvan Stanica was a reviewer in the following PhD defense committee:
  - M. Nunez Ochoa, Adaptive Protocol for the Self-Deployment of Wireless Sensor Networks in Constrained Environments, Université Grenoble Alpes, June 2020.
  - A. Blaise, Novel Anomaly Detection and Classification Algorithms in IP and Mobile Networks, Sorbonne Université, December 2020.

- Fabrice Valois was a reviewer in the following PhD defense committee:
  - R. Navas, Improving the Resilience of the Constrained Internet of Things : A Moving Target Defense approach, Lab-STICC, IMT Atlantique, 2020.
  - J. Garcia, Opportunistic Data Collection and Routing in Segmented Wireless Sensor Networks, ENAC, 2020.
  - C. Bertier, Quantification in Device-to-Device Networks: From Link Estimation to Graph Utility, LIP6, Sorbonne Université, 2020.
  - T.-H. To, Energy Saving Protocols for the Internet of Things, LIG, UGA, 2020.

- Fabrice Valois was a member in the following PhD defense committees:
  - M. Dahhani, Performances des réseaux locaux millimétriques, IRIT, ENSHEEIT, 2020.
  - C. Vargas, Etude du relayage entre terminaux pour la connectivité des objets dans les réseaux 5G, IMT Atlantique, 2020.

## 10.3 Popularization

### 10.3.1 Articles and contents

- Hervé Rivano wrote a tribune entitled "Une ville intelligente et démocratique donne forcément une place centrale à la formation" in Le Monde journal [1].
- Hervé Rivano co-authored with N. Stouls and J.F. Tregouet a tribune entitled "Transitions énergétiques et numériques, éléments d'une démocratie technique informée" in A.O.C journal [2].

### 10.3.2 Interventions

- Hervé Rivano is member of the steering comitee of the "Transformation de l'action publique" of Science Po Lyon and give a keynote talk at the seminar "Intelligence artificielle, algorithmes et monde public".
- Hervé Rivano organized and animated a "Mercredi de l'Anthropocene" session on environmental and urban footprint of smart cities[3].
- Hervé Rivano has recorded a podcast with Ecole Urbaine de Lyon and "We are Europe" on the novel "Les Furtifs" written by Alain Damasio [4].
- Hervé Rivano gave media interview on urban heat islands and the monitoring of schoolyards of Villeurbane (M6 and BFM TV, july 2020), on socio-politic issues of contact tracing application (La Croix, May 2020), on smart cities (Journal des Nouvelles Urbanités, June 2020).
- Hervé Rivano animated a workshop for children on air quality with Imagineo during the "Fete de la Science" [5].
- Hervé Rivano was invited to a public debate on 5G by the city of St Germain au Mont d'Or [6].
- Hervé Rivano was invited by the Forum Smart Cities of La Réunion island.

# 11 Scientific production

## 11.1 Major publications

[1] J. Cui, K. Boussetta and F. Valois. 'Classification of Data Aggregation Functions in Wireless Sensor Networks'. In: *Computer Networks* (2020), pp. 1–13. DOI: 10.1016/j.comnet.2020.107342. URL: https://hal.inria.fr/hal-02751372.

[2] F. Delaine, B. Lebental and H. Rivano. 'Framework for the Simulation of Sensor Networks Aimed at Evaluating In Situ Calibration Algorithms'. In: *Sensors* 20.16 (Jan. 2020), 38p. DOI: 10.3390/s20164577. URL: https://hal.archives-ouvertes.fr/hal-02936662.

[3] A. Duque, R. Stanica, H. Rivano and A. Desportes. 'Analytical and Simulation Tools for Optical Camera Communications'. In: *Computer Communications* 160 (July 2020), pp. 52–62. DOI: 10.1016/j.comcom.2020.05.036. URL: https://hal.inria.fr/hal-02909386.

[4] M. A. Fekih, W. Bechkit, H. Rivano, M. Dahan, F. Renard, L. Alonso and F. Pineau. 'Participatory Air Quality and Urban Heat Islands Monitoring System'. In: *IEEE Transactions on Instrumentation and Measurement* (Oct. 2020), p. 14. DOI: 10.1109/TIM.2020.3034987. URL: https://hal.archives-ouvertes.fr/hal-03084917.

[1] https://www.lemonde.fr/economie/article/2020/10/10/une-ville-intelligente-democratique-donne-forcement-une-place-centrale-a-la-formation_6055549_3234.html
[2] https://aoc.media/analyse/2020/11/08/transitions-energetiques-et-numeriques-elements-dune-democratie-technique-informee/
[3] https://www.sondekla.com/user/event/10642
[4] https://medium.com/anthropocene2050/les-furtifs-dalain-damasio-par-hervé-rivano-f08732a6a99e
[5] https://www.fetedelascience.fr/atelier-de-recherche-participative-qualite-de-l-air-urbain
[6] https://www.saintgermainaumontdor.org/évènement/rencontre-debat-la-5g/

[5] I. Mokhtari, W. Bechkit, H. Rivano and M. R. Yaici. 'Uncertainty-Aware Deep Learning Architectures for Highly Dynamic Air Quality Prediction'. In: *IEEE Access* (Jan. 2021), pp. 1–14. DOI: 10.1109/ACCESS.2021.3052429. URL: https://hal.inria.fr/hal-03118464.

[6] Y. Özcan, J. Oueis, C. Rosenberg, R. Stanica and F. Valois. 'Robust Planning and Operation of Multi-Cell Homogeneous and Heterogeneous Networks'. In: *IEEE Transactions on Network and Service Management* 17.3 (2020), pp. 1805–1821. DOI: 10.1109/TNSM.2020.3001691. URL: https://hal.archives-ouvertes.fr/hal-02909390.

## 11.2 Publications of the year

### International journals

[7] M. Adam, N. Ortar, L. Merchez, G.-H. Laffont and H. Rivano. 'Susciter la parole des cyclistes : traces GPS et vidéos au service de l'entretien'. In: *EspacesTemps.net* (Nov. 2020). DOI: 10.26151/espacestemps.net-z2wh-1074. URL: https://halshs.archives-ouvertes.fr/halshs-02991654.

[8] J. Cui, K. Boussetta and F. Valois. 'Classification of Data Aggregation Functions in Wireless Sensor Networks'. In: *Computer Networks* (2020), pp. 1–13. DOI: 10.1016/j.comnet.2020.107342. URL: https://hal.inria.fr/hal-02751372.

[9] F. Delaine, B. Lebental and H. Rivano. 'Framework for the Simulation of Sensor Networks Aimed at Evaluating In Situ Calibration Algorithms'. In: *Sensors* 20.16 (1st Jan. 2020), 38p. DOI: 10.3390/s20164577. URL: https://hal.archives-ouvertes.fr/hal-02936662.

[10] A. Duque, R. Stanica, H. Rivano and A. Desportes. 'Analytical and Simulation Tools for Optical Camera Communications'. In: *Computer Communications* 160 (1st July 2020), pp. 52–62. DOI: 10.1016/j.comcom.2020.05.036. URL: https://hal.inria.fr/hal-02909386.

[11] M. A. Fekih, W. Bechkit, H. Rivano, M. Dahan, F. Renard, L. Alonso and F. Pineau. 'Participatory Air Quality and Urban Heat Islands Monitoring System'. In: *IEEE Transactions on Instrumentation and Measurement* (30th Oct. 2020), p. 14. DOI: 10.1109/TIM.2020.3034987. URL: https://hal.archives-ouvertes.fr/hal-03084917.

[12] M. Fiore, P. Katsikouli, E. Zavou, M. Cunche, F. Fessant, D. Le Hello, U. M. Aivodji, B. Olivier, T. Quertier and R. Stanica. 'Privacy in trajectory micro-data publishing: a survey'. In: *Transactions on Data Privacy* 13 (2020), pp. 91–149. URL: https://hal.inria.fr/hal-02968279.

[13] I. Mokhtari, W. Bechkit, H. Rivano and M. R. Yaici. 'Uncertainty-Aware Deep Learning Architectures for Highly Dynamic Air Quality Prediction'. In: *IEEE Access* (Jan. 2021), pp. 1–14. DOI: 10.1109/ACCESS.2021.3052429. URL: https://hal.inria.fr/hal-03118464.

[14] Y. Özcan, J. Oueis, C. Rosenberg, R. Stanica and F. Valois. 'Robust Planning and Operation of Multi-Cell Homogeneous and Heterogeneous Networks'. In: *IEEE Transactions on Network and Service Management* 17.3 (2020), pp. 1805–1821. DOI: 10.1109/TNSM.2020.3001691. URL: https://hal.archives-ouvertes.fr/hal-02909390.

[15] A. Sassi, A. Bachir and W. Bechkit. 'Evaluating Regression Models for Temporal Prediction of Wi-Fi Device Mobility'. In: *Wireless Personal Communications* (16th Sept. 2020). DOI: 10.1007/s11277-020-07785-2. URL: https://hal.archives-ouvertes.fr/hal-03094754.

### International peer-reviewed conferences

[16] S. Abdellatif, O. Tibermacine, W. Bechkit and A. Bachir. 'Efficient Distributed D2D ProSe-Based Service Discovery and Querying in Disaster Situations'. In: The International Conference on Advanced Information Networking and Applications (AINA-2020). Caserta, Italy, 28th Mar. 2020, pp. 910–921. DOI: 10.1007/978-3-030-44041-1_79. URL: https://hal.archives-ouvertes.fr/hal-03094740.

[17] S. Abdellatif, O. Tibermacine, W. Bechkit and A. Bachir. 'Service Oriented D2D Efficient Communication for Post-Disaster Management'. In: IWCMC 2020 - 16th International Wireless Communications and Mobile Computing. Limassol, Cyprus, 15th June 2020, pp. 970–975. DOI: 10.1109/IWCMC48107.2020.9148538. URL: https://hal.archives-ouvertes.fr/hal-03094697.

[18] A. Ben Khalifa and R. Stanica. 'CCA Threshold Impact on the MAC Layer Performance in IoT Networks'. In: VTC Spring 2020 - IEEE 91st Vehicular Technology Conference. Antwerp, Belgium, 25th May 2020. URL: https://hal.inria.fr/hal-02878723.

[19] N. e. h. Bouzouita, A. Busson and H. Rivano. 'Analytical study of frame aggregation level to infer IEEE 802.11 network load'. In: IWCMC 2020 - 16th International Wireless Communications and Mobile Computing. Limassol, Cyprus, 15th June 2020, pp. 952–957. DOI: 10.1109/IWCMC48107.2020.9148448. URL: https://hal.archives-ouvertes.fr/hal-02925958.

[20] S. D'Alu, O. Iova, O. Simonin and H. Rivano. 'Demo: In-flight Localisation of Micro-UAVs using Ultra-Wide Band'. In: *EWSN '20 Proceedings of the 2020 International Conference on Embedded Wireless Systems and Networks.* EWSN 2020 - International Conference on Embedded Wireless Systems and Networks. Lyon, France, 17th Feb. 2020. URL: https://hal.archives-ouvertes.fr/hal-02421783.

[21] M. Dahan, A. A. Mbacké, O. Iova and H. Rivano. 'Challenges of Designing Smart Lighting'. In: EWSN 2020 - International Conference on Embedded Wireless Systems and Networks. Lyon, France, 17th Feb. 2020, pp. 1–6. URL: https://hal.archives-ouvertes.fr/hal-02431771.

[22] M. A. Fekih, I. Mokhtari, W. Bechkit, Y. Belbaki and H. Rivano. 'On the Regression and Assimilation for Air Quality Mapping Using Dense Low-Cost WSN'. In: *International Conference on Advanced Information Networking and Applications.* AINA2020 - 34th International Conference on Advanced Information Networking and Applications. Vol. 1151. Advances in Intelligent Systems and Computing book series. Caserte, Italy, 28th Mar. 2020, pp. 566–578. DOI: 10.1007/978-3-030-44041-1_51. URL: https://hal.archives-ouvertes.fr/hal-03084455.

[23] A. Lahmadi, A. Duque, N. Heraief and J. Francq. 'MitM Attack Detection in BLE Networks using Reconstruction and Classification Machine Learning Techniques'. In: MLCS 2020 - 2nd Workshop on Machine Learning for Cybersecurity. Ghent, Belgium, 14th Sept. 2020, pp. 1–16. URL: https://hal.inria.fr/hal-02948407.

[24] Z. Zhang, R. Stanica and F. Valois. 'Delay-based Core Network Placement in Self-Deployable Mobile Networks'. In: WCNC 2021 - IEEE Wireless Communications and Networking Conference. Nanjing, China, 29th Mar. 2021. URL: https://hal.inria.fr/hal-03183703.

### National peer-reviewed Conferences

[25] N. E. H. Bouzouita, A. Busson and H. Rivano. 'Etude du niveau d'agrégation des trames dans les réseaux IEEE 802.11 pour l'évaluation du niveau de charge'. In: CORES 2020 – 5ème Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Lyon, France, 28th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02710445.

[26] A. Duque, R. Stanica, A. Desportes and H. Rivano. 'Evaluation des performances des communications optiques LED-à-caméra'. In: CORES 2020 - Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Lyon, France, 28th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02878140.

[27] K. Lasri, L. Echabbi, O. Iova, Y. Ben Maissa and F. Valois. 'Contrôle du trafic dans un réseau LPWAN : approche distribuée et probabiliste'. In: Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication ou CORES2020". lyon, France, 28th Sept. 2020. URL: https://hal.archives-ouvertes.fr/hal-02776997.

### Conferences without proceedings

[28] K. Lasri, Y. Ben Maissa, L. Echabbi, O. Iova and F. Valois. 'A New Distributed and Probabilistic Approach for Traffic Control in LPWANs'. In: AINA 2021 - 35th International Conference on Advanced Information Networking and Applications. Toronto, Canada, 12th May 2021, pp. 1–10. URL: https://hal.archives-ouvertes.fr/hal-03178390.

#### Scientific book chapters

[29] M. Adam and H. Rivano. 'Données. Quand le numérique produit et gouverne la ville'. In: *Le Capital dans la cité*. http://www.editionsamsterdam.fr/le-capital-dans-la-cite/, 8th Oct. 2020, pp. 125–137. URL: https://halshs.archives-ouvertes.fr/halshs-03027296.

#### Edition (books, proceedings, special issue of a journal)

[30] P. Chemouil, F. Krief, T. Hoßfeld, T. Ahmed, R. Stanica and S. Secci, eds. *Proceedings of the 2020 International Conference on the Network of the Future*. 2020 11th International Conference on Network of the Future (NoF). Bordeaux, 2nd Nov. 2020. DOI: 10.1109/NoF50125.2020. URL: https://hal.archives-ouvertes.fr/hal-03104311.

#### Doctoral dissertations and habilitation theses

[31] A. Ben Khalifa. 'Medium Access Control Layer for Dedicated IoT Networks'. INSA Lyon, 30th July 2020. URL: https://hal.inria.fr/tel-03090324.

[32] R. Domga Komguem. 'Autonomous wireless sensor network architecture for vehicular traffic monitoring at an intersection'. Université de Lyon; Université de Yaoundé II, 6th July 2020. URL: https://tel.archives-ouvertes.fr/tel-03088530.

#### Reports & preprints

[33] R. Stanica, Y. Mouline, J.-M. S. Gorce, C. Goursaud and O. Iova. *IoT Anywhere - Comment choisir sa technologie d'accès ?* INSA LYON; SPIE ICS, 20th Jan. 2020. URL: https://hal.inria.fr/hal-03020299.

## 11.3 Other

#### Scientific popularization

[34] H. Rivano. 'Une ville intelligente et démocratique donne forcément une place centrale à la formation'. In: *Le Monde.fr* (10th Oct. 2020). URL: https://hal.inria.fr/hal-03105100.

[35] H. Rivano, N. Stouls and J.-F. Trégouët. 'Transitions énergétiques et numériques, éléments d'une démocratie technique informée'. In: *AOC [Analyse Opinion Critique]* (9th Nov. 2020). URL: https://hal.inria.fr/hal-03105102.