RESEARCH CENTRE

Grenoble - Rhône-Alpes

IN PARTNERSHIP WITH:

Institut national des sciences appliquées de Lyon

2021 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 1

1 Team members, visitors, external collaborators 2

2 Overall objectives 3

3 Research program 3
3.1 Wireless network deployment . . . 4
3.2 Wireless data collection . . . 4
3.3 Network data exploitation . . . 4

4 Application domains 5
4.1 Smart Cities . . . 5

5 Social and environmental responsibility 5
5.1 Impact of research results . . . 5

6 Highlights of the year 6
6.1 Awards . . . 6

7 New software and platforms 6
7.1 New software . . . 6
7.1.1 PrivaMovApp . . . 6
7.1.2 urpolsens . . . 6
7.1.3 3M'Air . . . 7
7.1.4 eSmartCity . . . 7
7.1.5 Dense LoRaSim . . . 7
7.1.6 FLoRaSat . . . 7
7.2 New platforms . . . 8

8 New results 8
8.1 Wireless network deployment . . . 8
8.2 Wireless data collection . . . 10
8.3 Network data exploitation . . . 12

9 Bilateral contracts and grants with industry 13
9.1 Bilateral contracts with industry . . . 13
9.2 Bilateral grants with industry . . . 13

10 Partnerships and cooperations 14
10.1 International initiatives . . . 14
10.1.1 Associate Teams in the framework of an Inria International Lab or in the framework of an Inria International Program . . . 14
10.1.2 STIC/MATH/CLIMAT AmSud project . . . 14
10.1.3 Participation in other International Programs . . . 15
10.1.4 Inria international partners . . . 15
10.2 European initiatives . . . 16
10.2.1 FP7 & H2020 projects . . . 16
10.2.2 Other european programs/initiatives . . . 17
10.3 National initiatives . . . 17
10.3.1 Inria Mission Covid . . . 17
10.3.2 ANR . . . 17
10.3.3 GDR CNRS RSD - Pôle ResCom . . . 19
10.4 Regional initiatives . . . 19

11 Dissemination **19**
11.1 Promoting scientific activities . . . 19
11.1.1 Scientific events: organisation . . . 19
11.1.2 Journal . . . 20
11.1.3 Invited talks . . . 20
11.1.4 Leadership within the scientific community . . . 21
11.1.5 Scientific expertise . . . 21
11.1.6 Research administration . . . 21
11.2 Teaching - Supervision - Juries . . . 21
11.2.1 Teaching . . . 21
11.2.2 Supervision . . . 23
11.2.3 Juries . . . 24
11.3 Popularization . . . 25
11.3.1 Articles and contents . . . 25
11.3.2 Education . . . 26
11.3.3 Interventions . . . 26

12 Scientific production **26**
12.1 Major publications . . . 26
12.2 Publications of the year . . . 27
12.3 Other . . . 29

Project-Team AGORA

Creation of the 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

B6.2.3. – Satellite technology

B6.2.4. – Optic technology

B6.4. – Internet of things

B7.2. – Smart travel

B8.1.2. – Sensor networks for smart buildings

B8.2. – Connected city

1 Team members, visitors, external collaborators

Research Scientist

- Juan A. Fraire [Inria, Starting Faculty Position]

Faculty Members

- Hervé Rivano [Team leader, INSA Lyon, Professor, HDR]
- Walid Bechkit [INSA Lyon, Associate Professor]
- Alexandre Guitton [Université Clermont Auvergne, Professor, from Sep 2021, HDR]
- Oana Iova [INSA Lyon, Associate Professor]
- Razvan Stanica [INSA Lyon, Associate Professor, HDR]
- Fabrice Valois [INSA Lyon, Professor, HDR]

PhD Students

- Mohamed Anis Fekih [Univ de Lyon]
- Gwendoline Hochet Derevianckine [ERT Technologie, CIFRE, from Apr 2021]
- Kawtar Lasri [Institut national des postes et télécommunications Rabat - Maroc]
- Lucas Magnana [Univ de Lyon]
- Ichrak Mokhtari [INSA Lyon]
- Camille Moriot [INSA Lyon]
- Romain Pujol [INSA Lyon]
- Solohaja Rabenjamina [Inria]
- Zhiyi Zhang [INSA Lyon, from Sep 2021]

Technical Staff

- Manoel Dahan [Insavalor, Engineer, until Jul 2021]
- Alexandros Sidiras Galante [Inria, Engineer, from Sep 2021]
- Zhiyi Zhang [Inria, Engineer, until Aug 2021]

Interns and Apprentices

- Mehdi Ait Mesbah [Inria, from Apr 2021 until Sep 2021]
- Dylan Daujat [INSA Lyon, from Apr 2021 until Jun 2021]
- Lise Jacquot [Inria, from Sep 2021]
- Rachida Saroui [Inria, from Sep 2021]
- Tristan Sevel [INSA Lyon, from Apr 2021 until Jun 2021]

Administrative Assistants

- Laetitia Gauthe [Inria]
- Aurelie Reymond [INSA Lyon, from January 2021]
- Linda Soumari [INSA Lyon, until Janvier 2021]

2 Overall objectives

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 they provide, 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 high user density and mobility.

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. Note that our focus is not limited only to ICT in urban areas but can be extended to any scenario where coverage challenges meet density, such satellite-IoT constellations or networks for rural areas.

The Agora research team aims at contributing to the following consequent challenges of data collection wireless networks in smart environments:

- The **deployment of dense networks** is challenged by the scale of the problems and the versatility of the environment, with consequences on the optimization of the placement of both network devices and functions.
- **Data collection** and distribution communication protocols, designed for IoT network architectures, need a coherent rethinking to face issues on saturated cellular networks, star-topologies networks, and multi-hop networks unable to cover large areas.
- **Exploiting the data** carried by the network opens new questions on the network deployment and usage, by understanding the spatio-temporal dynamics of the users, and on in-network computations in order to reduce the traffic load or enhance the quality of the data.

We are not limited to any wireless technologies. Our research takes place in the context of three different wireless network topologies:

- **carefuly deployed** topologies such as cellular networks and environmental monitoring,
- **planned and dynamic** topologies such as fleet of drones and satellite communications,
- **uncontrolled** topologies such as individual IoT and self-deployable networks.

3 Research program

The Agora research program is presented in three axes. Our work shares the same general methodology that aims at combining:

- modeling to get insights on average and extreme behaviors, s
- imulation to investigate large scale networks and asymptotic behavior,
- experimental approaches to get insights from real devices and users.

Modeling is typically in the form of mathematical optimization, stochastic performance evaluation, or machine learning algorithms. Simulation is mostly done by discrete event simulations, for networks, environment or user mobility. Experiments can be done on proof-of-concept prototypes, lab-controlled test beds or real-world deployments and data collection.

3.1 Wireless network deployment

The team addresses challenges in the three following directions:

- We develop optimization models and heuristics for network component deployment, with a specific focus on wireless sensor networks (for monitoring environmental phenomena) and direct-to-satellite communications (to improve IoT coverage, especially for outside areas).
- We investigate the impact of network function deployment enabled by their virtualization on the performances of radio access networks and self-deployable cellular networks.
- We develop and experiment self-configuration and self-healing protocols to enable human free deployment.

3.2 Wireless data collection

In this axis, we investigate design challenges of network mechanisms and protocols such as medium access, medium sharing, and routing protocols.

- Such mechanisms are addressed with a focus on enabling self-organization, self-healing and opportunistic communications.
- New technologies such as low power and long range networks, non terrestrial networks, human-centric networks yield intermittent connectivity and dynamic architectures. We investigate them in terms of performance, scalability, sustainability, etc.
- We combine our expertise in these diverse architectures and consider hybrid networks, that we foresee as the relevant solution for supporting dense and dynamic topologies.

3.3 Network data exploitation

In this axis, we focus on the spatio-temporal characteristics of the network usage and data collected in the three following directions.

- Mobile data are analyzed to understand the coupling between users activity and the network usage.
- Data aggregation is investigated with the objective to have the most efficient and sober usage of wireless communications.
- Finally distributed sensor calibration will exploit the wireless network to increase the reliability of the collected data and ultimately improve the cost/quality trade-off of a wireless sensor network.

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 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 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 Social and environmental responsibility

5.1 Impact of research results

Some of our research activities are specifically focused on social and environmental responsibility, through crowd-sensing environmental monitoring.

Since the preliminary project UrpolSens (*Wireless SENSor Networks for URban POLlution Monitoring*[1]) funded in 2015 by the Labex IMU, the Agora Inria team is building a long success story about air and pollution monitoring. With several research projects and bilateral collaborations with companies (e.g., Total), we propose an interdisciplinary approach to efficiently monitor chronic and accidental pollution as well as Urban Heat Island (UHI) . We are focusing on three main uses cases: *i)* Static wireless low-cost sensor networks for air quality monitoring while designing efficient deployment and scheduling models, *ii)* participatory crowdsensing for UHI and air quality assessment while addressing the challenge of analyzing dense data from low-cost sensors and their contribution to the fine-grained mapping [22] and *iii)* drone fleet for monitoring pollution plumes while proposing adapted spatio-temporal prediction architectures and new anticipatory path planning approaches [6, 7].

Our work on this side combines theory and real-word experiments where we design, set up and validate low-cost sensor based platforms [2]. Moreover, we also keep our sights on social issues like the pollution perception by residents that we studied in the first axis and the citizen involvement in participatory sensing which was a key issue of the second axis. We hence believe that our work may have benefits to improve the human health and the resilience of the social system against pollution and UHI issues on one side and to better involve citizens in scientific issues on the other side.

[1] Project presentation.

6 Highlights of the year

- Juan A. Fraire joins Agora as a Starting Faculty Position, since January 2021.
- Walid Bechkit holds the PEDR (2021-2025).
- Alexandre Guitton joins Agora for 1-year Inria Delegation, since Septembre 2021.
- Alexandre Guitton holds the PEDR (2018-2022).
- Hervé Rivano holds the PEDR (2021-2025).
- Razvan Stanica holds the PEDR (2020-2024).

6.1 Awards

- Razvan Stanica has been named one of the two "best junior researchers" in the field of computer networks and systems in France in 2021 (GDR CNRS RSD).

7 New software and platforms

7.1 New software

7.1.1 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.

Contact: Razvan Stanica

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

7.1.2 urpolsens

Name: UrPolSens Platform

Keywords: Wireless Sensor Networks, Air Quality

Functional Description: A 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.

Contact: Walid Bechkit

Partner: Intelligence des Mondes Urbains

7.1.3 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.

Contact: Walid Bechkit

Partner: Intelligence des Mondes Urbains

7.1.4 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.

Contact: Oana Iova

7.1.5 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 created a fork to support ultra dense network emulation.

Contact: Fabrice Valois

7.1.6 FLoRaSat

Name: Extension of FLoRa for Direct-to-Satellite IoT

Keywords: Iot, Satellite, LoRaWAN

Functional Description: Direct to Satellite IoT (DtS-IoT) is a promising approach to deliver data transfer services to IoT devices in remote areas where deploying terrestrial infrastructure is not appealing or feasible. In this context, low-Earth orbit (LEO) satellites can serve as passing-by IoT gateways to which devices can offload buffered data to. However, transmission distances and channel dynamics, combined with highly constrained devices on the ground makes DtS-IoT a very challenging problem. To explore DtS-IoT, we propose to extend the Flora simulator based on Omnet++: i) to support Class B end-devices ii) to support LEO orbits iii) to support large scale satellite constellation. It allows us to model and simulate realistic DtS-IoT scenarios to measure the expected performance of LoRaWAN in a satellite context. Available on: https://gitlab.inria.fr/jfraire/florasat

Contact: Juan Andres Fraire

7.2 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 LoRaWAN 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).
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 an entire cellular network thanks to three software components of srsLTE. The cellular network is 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 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.

8 New results

8.1 Wireless network deployment

Participants: Walid Bechkit, Juan A. Fraire, Ichrak Mokhtari, Hervé Rivano, Razvan Stanica, Fabrice Valois, Zhiyi Zhang.

A generic framework for monitoring pollution plumes in emergencies using UAVs Monitoring air pollution plumes in emergency situations (industrial accidents, natural disasters, deliberate terrorist releases, etc.) becomes an issue of utmost importance in our society given the dramatic effects that the

released pollutants can cause. Considering these situations, the pollution plume is strongly dynamic leading to a fast dispersion of pollutants in the atmosphere. Thus, the need for real-time response is very strong and a solution to get precise mapping of pollution dispersion is required to mitigate risks. However, monitoring and forecasting air quality in real time in such situations remains a highly challenging endeavour. In [25], we suggest a systemic approach for monitoring dynamic air pollution based on aerial sensing (sensors mounted on UAVs). The proposed framework consists of a cycle with feedback loop which will constantly combine a spatio-temporal forecasting model based on a convolutional long short term memory (ConvLSTM) network with a data assimilation technique to get accurate pollution maps, while adjusting at each time the trajectories of drones following uncertainty forecasts. Our solution was evaluated and validated using a highly dynamic real world data set namely Fusion Field Trial 2007 (FFT07). The proposed strategy, together with the obtained evaluation results, are presented, and carefully analyzed.

Contact Plan Design for GNSS Constellations: A Case Study with Optical Inter-Satellite Links Optical Inter-Satellite Links (OISLs) are being considered for future Global Navigation Satellite System (GNSS) constellations. Thanks to OISLs, the constellation incorporates improved clock synchronization and precise ranging among the satellites, which are essential features to achieve accurate time and orbit determination. High data rate communications within the space segment also reduce ground segment dependency, by means of decentralized access to information. However, the dual optimization of data and navigation performance metrics requires a careful assignment of OISLs to the available laser communication terminals on-board. To this end, in [17], we present a Contact Plan Design (CPD) scheme based on a Degree Constrained Minimum Spanning Tree heuristic applied to such OISL-enabled GNSS (O-GNSS) constellations. Results on the Kepler system, a novel GNSS proposal, show that a fair distribution of connectivity among the constellation can be ensured while optimizing its range-based position estimation capabilities (PDOP). A PDOP improvement of 85% is reached on average by the optimized contact plan with respect to a generic scheduler that disregards the geometrical distribution of the chosen links.

On the Automation, Optimization, and In-Orbit Validation of Intelligent Satellite Constellation Operations Recent breakthroughs in technology have led to a thriving "new space" culture in low-Earth orbit (LEO) in which performance and cost considerations dominate over resilience and reliability as mission goals. These advances create a manifold of opportunities for new research and business models but come with a number of striking new challenges. In particular, the size and weight limitations of low-Earth orbit small satellites make their successful operation rest on a fine balance between solar power infeed and the power demands of the mission payload and supporting platform technologies, buffered by on-board battery storage. At the same time, these satellites are being rolled out as part of ever-larger constellations and mega-constellations. Altogether, this induces a number of challenging computational problems related to the recurring need to make decisions about which task each satellite is to effectuate next. Against this background, GOMSPACE and Saarland University have joined forces to develop highly sophisticated software-based automated solutions rooted in optimal algorithmic and self-improving learning techniques, all this validated in modern nanosatellite networked missions operating in orbit. In [26], we introduce the GOMSPACE Hands-Off Operations Platform (HOOP), an automated, flexible, and scalable end-to-end satellite operation framework for commanding and monitoring subsystems, single-satellites, or constellation-class missions. To this, the POWVER initiative at Saarland University has contributed state-of-the-art dynamic programming and learning techniques based on profound battery and electric power budget models. These models are continually kept accurate by extrapolating data from telemetry received from satellites. The resulting machine learning approach delivers optimal, efficient, scalable, usable, and robust flight plans, which are provisioned to the satellites with zero need for human intervention—but which are still under the full control of the mission operator. We report on insights gained while validating the integrated POWVER-HOOP approach in orbit on the dual-satellite mission GOMX–4 by GOMSPACE that is currently in orbit.

Delay-based Core Network Placement in Self-Deployable Mobile Networks Self-deployable mobile networks represent a new type of cellular networks, that can be rapidly deployed, easily installed, and operated on demand, anywhere, anytime. They can provide network services when a classical cellular network fails, is not suitable, or does not exist. Using network virtualization techniques, core network and base station functions can be colocated together into a single equipment. This brings the network functions closer to the user, but the placement of the local core network has a significant impact on the network performance, mainly in terms of capacity and delay. In [29], we are focused on the delay minimization from BSs to the local core network. We propose a heuristic for the local core network placement, with the objective of reducing the delay. We show that the delay obtained by our solution decreases significantly compared to a strategy that places the local core network in order to maximize the capacity. We also show that considering a capacity-based placement strategy leads to infinite delay in some cases.

8.2 Wireless data collection

Participants: Walid Bechkit, Manoel Dahan, Mohamed Anis Fekih, Juan A. Fraire, Alexandre Guitton, Oana Iova, Kawtar Lasri, Hervé Rivano, Razvan Stanica, Fabrice Valois.

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 [12], 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 (NO_2, PM_1, $PM_{2.5}$ and PM_{10}). 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.

Uplink Transmission Probability Functions for LoRa-Based Direct-to-Satellite IoT Direct-to-Satellite IoT allows devices on the Earth surface to directly reach Low-Earth Orbit (LEO) satellites passing over them. Although an appealing approach towards a truly global IoT vision, scalability issues as well as highly dynamic topologies ask for dedicated protocol adaptations supported by novel models. In [27], we contribute to this research by introducing estimators and a transmission probability function to dynamically control the contending set of devices on a framed slotted Aloha model compatible with the LoRaWAN specification. In particular, we discuss techniques that account for particularities in the dynamics of sparse DtS-IoT constellations. Simulation analyses of a realistic case study show that >86% of the theoretical throughput is achievable in practice.

Centralized and Decentralized Routing Solutions for Present and Future Space Information Networks Space Information Networks (SINs) are pushing the boundaries of networking into near-Earth orbit and beyond. Nevertheless, the harsh and costly space context forces most riskprone missions to be designed with minimal chance of failure. The careful consideration of routing protocols used to connect the fleet is by no means the exception. Although decentralized SIN routing schemes received most of the attention of the research community, centralized approaches are captivating the industry, as these come with

tighter control and do enable troubleshooting of valuable space assets from a mission control center on ground. In [13], we settle the matter by qualitatively and quantitatively comparing both SIN paradigms. We propose two novel centralized routing schemes, and evaluate their resulting performance against Contact Graph Routing (CGR), the decentralized state-of-the-art. In this evaluation, computational effort, memory utilization, and energy consumption are taken as figures of merit. The outcome provides compelling evidence that centralized routing schemes can safely, successfully and efficiently connect SINs with up to 10k daily contacts, while CGR can be better entrusted with larger-scale SIN deployments.

Routing in Delay-Tolerant Networks under uncertain contact plans Delay-Tolerant Networks (DTN) enable store-carry-and-forward data transmission in networks challenged by frequent disruptions and high latency. Existing classification distinguishes between scheduled and probabilistic DTNs, for which specific routing solutions have been developed. In [18], we uncover a gap in-between where uncertain contact plans can be exploited to enhance data delivery in many practical scenarios described by probabilistic schedules available a priori. Routing under uncertain contact plans (RUCoP) is next formulated as a multiple-copy Markov Decision Process and then exported to local-knowledge (L-RUCoP) and Contact Graph Routing extensions (CGR-UCoP) which can be implemented in the existing DTN protocol stack. RUCoP and its derivations are evaluated in a first extensive simulation benchmark for DTNs under uncertain contact plans comprising both random and realistic scenarios. Results confirm that RUCoP and L-RUCoP closely approach the ideal delivery ratio of an oracle, while CGR-UCoP improves state-of-the-art DTN routing schemes delivery ratio up to 25%.

A New Distributed and Probabilistic Approach for Traffic Control in LPWANs Low-Power Wide Area Networks (LPWANs) are wireless networks with very low power consumption and wide area coverage. They are capable of supporting the traffic of nearly a thousand nodes with a duty cycle of less than 1%. However, the gradual densification of nodes increases the number of collisions and makes it more difficult to manage the upstream traffic. To mitigate this problem, in [24] we propose a new distributed and probabilistic traffic control algorithm, DiPTC, which allows nodes to adapt nodes traffic according to the needs of the application (e.g., receiving K measurements over a time period) while being agnostic to the number of nodes and to the network topology. A control message is broadcast by the gateway to all nodes each period when the objective is not reached, so that nodes can re-adapt their traffic. We evaluate the proposed solution in simulation and we compare it with the LoRaWAN protocol. The results show that our algorithm is able to reach the objective while keeping a low number of collisions, with a longer network lifetime. Compared to LoRaWAN, our solution shows a three times increase in the success rate and a decrease by a factor of 10 in the collision rate.

On the Use of Carrier Sense Mechanisms in Low-Power Wide Area Networks Adding carrier sense capabilities to nodes in low-power wide area networks is considered as a good strategy to cope with scalability problems. However, in settings with large cells, the clear channel assessment function will give imperfect results, producing scenarios rich in hidden nodes. In [23], we assess the impact of these hidden nodes, showing that the average gains with respect to an Aloha strategy are significantly decreasing as the number of hidden nodes increases. Moreover, in terms of energy, our results indicate that carrier sensing consumes 10 to 100 times more than a simple Aloha channel access. We also look at the individual node behavior, demonstrating an important heterogeneity among nodes, with performance generally correlated to the quality of the carrier sense mechanism.

Recovering Colliding LoRa Frames from Uncertainties Using LoRa Coding LoRa is one of the leading technologies for Low-Power Wide Area Networks and the Internet of Things. Collisions in LoRa might cause retransmissions, which negatively impact the network performance and scalability. Several algorithms have been proposed to decode colliding frames under specific conditions. However, there remain indistinguishable frames due to uncertainties in some or all symbols. In [28], we propose a general

algorithm that significantly improves the recovery capabilities of existing algorithms by leveraging the LoRa coding techniques. Simulation results show that our algorithm can significantly reduce the number of the failed decoding of LoRa frames and improve the performance of the network.

Exploiting Frame Aggregation to Enhance Access Point Selection IEEE 802.11 (known as Wi-Fi) has emerged as a vital wireless network access technology for mobile devices. By providing the potential for high connectivity speeds, this technology has led to a dramatic rise in the number of access points (APs). In such environments, mobile devices have the choice to join several Wi-Fi networks. Despite its importance to user Quality of Experience (QoE), the AP selection implemented in mobile devices is still trivial since it focuses at best on the received signal strength if not only the user's history. Crucial metrics that capture the overall dynamics of the AP load condition, such as the network load, are not taken into account. In [21], we propose to use the Busy Time Fraction (BTF) as a metric to choose the best AP to attach to. The BTF level of a given channel is inferred based on the frame aggregation scheme proposed since the 802.11n standard. In this regard, we propose an analytical model based on a Discrete-Time Markov chain that discerns the theoretical DownLink aggregation levels for probe traffic concurrent to cross traffic. We validate the accuracy of our proposed approach against ns-3 simulations under several scenarios.

8.3 Network data exploitation

Participants: Walid Bechkit, Ichrak Mokhtari, Hervé Rivano, Razvan Stanica.

Fine-Grained Human Mobility Trajectory Inference at Scale with Mobile Network Signaling Data Call detail records (CDR) collected by mobile phone network providers have been largely used to model and analyze human-centric mobility. Despite their potential, they are limited in terms of both spatial and temporal accuracy thus being unable to capture detailed human mobility information. Network Signaling Data (NSD) represent a much richer source of spatio-temporal information currently collected by network providers, but mostly unexploited for fine-grained reconstruction of human-centric trajectories. In [11], we present TRANSIT, TRAjectory inference from Network SIgnaling daTa, a novel framework capable of processing NSD to accurately distinguish mobility phases from stationary activities for individual mobile devices, and reconstruct, at scale, fine-grained human mobility trajectories, by exploiting the inherent recurrence of human mobility and the higher sampling rate of NSD. The validation on a ground-truth dataset of GPS trajectories showcases the superior performance of TRANSIT (80% precision and 96% recall) with respect to state-of-the-art solutions in the identification of movement periods, as well as an average 190 m spatial accuracy in the estimation of the trajectories. We also leverage TRANSIT to process a unique large-scale NSD dataset of more than 10 millions of individuals and perform an exploratory analysis of city-wide transport mode shares, recurrent commuting paths, urban attractivity and analysis of mobility flows.

Towards privacy-preserving publishing of record-level-truthful mobile phone trajectories Datasets of mobile phone trajectories collected by network operators offer an unprecedented opportunity to discover new knowledge from the activity of large populations of millions. However, publishing such trajectories also raises significant privacy concerns, as they contain personal data in the form of individual movement patterns. Privacy risks induce network operators to enforce restrictive confidential agreements in the rare occasions when they grant access to collected trajectories, whereas a less involved circulation of these data would fuel research and enable reproducibility in many disciplines. In [14], we contribute a building block towards the design of privacy-preserving datasets of mobile phone trajectories that are truthful at the record level. We design GLOVE, an algorithm that implements k-anonymity, hence solving the crucial unicity problem that affects this type of data while ensuring that the anonymized trajectories correspond to real-life users. GLOVE builds on original insights about the root causes behind

the undesirable unicity of mobile phone trajectories, and leverages generalization and suppression to remove them. Proof-of-concept validations with large-scale real-world datasets demonstrate that the approach adopted by GLOVE allows preserving a substantial level of accuracy in the data, higher than that granted by previous methodologies.

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 [15], 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.

Evaluating Regression Models for Temporal Prediction of Wi-Fi Device Mobility The ability to predict the arrival and residence time of mobile users at a particular place is essential for the development of a wealth of new applications and services, such as smart heating control, transportation planning or urban navigation. Previous techniques based on probabilistic models have not been able to perform such prediction accurately. In [20], we present two linear mobility models, namely Linear Regression, and Auto-Regression, to predict the temporal behavior, particularly the residence time, of individual users. We run performance evaluation experiments on two different WiFi mobility traces datasets made available through the CRAWDAD project. Our results show that using linear regression-based learning algorithms significantly improves the residence time prediction accuracy compared to state-of-the-art methods, and achieve prediction errors in the order of seconds or minutes for a large number of users.

9 Bilateral contracts and grants with industry

9.1 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 communications in noisy environments.

9.2 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.

- Semtech: Agora is involved in a research contract with Université of Clermont Auvergne and INSA Lyon about opportunities and challenges of LoRa 2.4GHz, since April 2021.
- Agora started a new industrial collaboration with Snef Telecom in December 2021, for a duration of 3.5 years. The topic of this collaboration is the energy consumption measurement and modelling in 4G and 5G cellular networks.
- Spie - INSA Lyon IoT Chaire: Agora is involved in the SPIE INSA Lyon IoT Chaire, launched in November 2016. Razvan Stanica is responsible of the “cognitive networks” research axes in this collaboration.

‘

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 Associate Teams in the framework of an Inria International Lab or in the framework of an Inria International Program

IOTA(i)

Title: Self-healing mechanisms for IoT networks based on IA paradigms

Duration: 2021 -> ongoing

Coordinator: Fabrice Valois

Partners:

- Université de Yaoundé, Cameroon

Inria contact: Fabrice Valois

Summary: In IOTA(i), we are focused on the design of self-healing mechanisms to allow dynamic adaptation of the main parameters of IoT networking protocols. We claim that self-healing is a continuous process based on measurements and monitoring of the network behavior to adapt the networking protocol configuration to the environment dynamic and application changes. We believe that machine learning will help us to continuously optimize the network.

10.1.2 STIC/MATH/CLIMAT AmSud project

STARS

Title: SaTellite networks Architectures pRotocols and informaticS

Duration: 2020 -> ongoing

Coordinator: Juan A. Fraire

Partners:

- Laboratoire d’analyse et d’architecture des systèmes, CNRS UPR8001, France
- Universidad Nacional de Córdoba, Argentina
- Universidad de Chile, Chile

Inria contact: Juan A. Fraire

Summary: In this project, we tackle the challenges involved in the modernization of satellite-based communications by considering the requirements and restrictions of the deployments of large-scale satellite constellations including nano and small satellites. The contributions of the participant institutions are threefold: 1) the application of state-of-the-art informatics for the operation and design of large scale satellite constellations; 2) the definition and evaluation of hybrid architectures with LPWA and nano/small satellite technologies, and 3) the design of networking protocols for challenging and restricted networks in space communications. Besides developing a strong international collaboration network around these topics, during the execution of this project we expect to provide student mobility and scientific training to the participants. Dissemination activities will also take place to share the results and possibly to incorporate new actors for further collaborations in the next stages of this research.

10.1.3 Participation in other International Programs

PHC Campus France:

Title: ConsoSmart

Partner Institution(s):

- Institut National des Postes et Télécommunications de Rabat, Morocco
- Université de Versailles Saint Quentin en Yvelines, France

Date/Duration: 2019-2021

Additionnal info/keywords: This project allows the PhD of Kawtar Lasri about uplink traffic control in LoRaWAN networks.

10.1.4 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.
- National Institute of Informatics, Tokyo, Japan. Joint work and publications around the modeling of the LoRa physical layer as well as collision management in LoRa networks, with Dr Megumi Kaneko.
- Rice University, USA. 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.

10.2 European initiatives

10.2.1 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: GeorgiaTech Lorraine / UMI2958GT-CNRS
  - Other partners: 9 academics partners (CNRS, UPORTO, UIB, INSA, RWTH, UNI-KLU, NTNU, UT, WMU) and 11 industrial partners (CETIM, LSL, RBP, BEYE, RINA, GLM, APDL, AASA, TRH, IEIC, DANAOS, SBK).
  - Abstract: The objective of BUGWRIGHT2 is 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: Horizon 2020 Research and Innovation Staff Exchange (RISE)
  - Project acronym: MISSION
  - Project title: Models in Space Systems: Integration, Operation, and Networking
  - Duration: 2021 -> ongoing (4 years)
  - Coordinator: University of Twente, Netherlands
  - Other partners: Netherlands RWTH Aachen University, Germany Saarland University, Germany, Universidad Nacional de Córdoba, Argentina Universidad Nacional de Río Cuarto, Argentina D3TN,Germany GOMspace, Luxembourg Ascentio, Argentina INVAP, Argentina Skyloom, Argentina Institute of Intelligent Software, Guangzhou (IISG), China
  - Abstract: Spacecraft must work robustly in the presence of uncertainties such as random hardware faults, operator mistakes, space debris, and radiation. Classic space missions address uncertainty via large safety margins and built-in redundancy, leading to a spiral of increasing cost and complexity. A recent trend is the small-business commercialisation of space using commercial-off-the-shelf components for networked constellations of small satellites. This "New Space" approach reduces component weight, size, price, and lead time, and makes innovation increasingly driven by software. This pertains especially to resource management and data handling, while simpler components and new interactions increase uncertainty, and come with less reliable parts. Thus, overall mission connectivity, efficiency, dependability and safety in the New Space needs to be achieved on a system level - for which there is no systematic approach yet. This is partly rooted in the empirical focus of many teams, and partly in a lack of easy-to-use methods to model, analyse, and guarantee system-level dependability. This interdisciplinary project sets out to solve this space engineering problem by exploiting highly advanced techniques from the forefront of computing science research, especially model-based algorithmics. We strive for sound and efficient software tools for the development of dependable, networked, and resource-aware New Space missions. For this, the MISSION project will develop an integrated model-based technology to establish and maintain system-level properties of critical space mission parameters. A strong consortium of excellent academic and industrial partners in Europe, Argentina and China have agreed on a joint research and knowledge sharing agenda that will foster a shared culture of research

and innovation, to finally deliver an ecosystem of easy-to-use methods and software tools to the New Space industry.

10.2.2 Other european programs/initiatives

- Program: CHIST-ERA 2020
  - Project acronym: ECOMOME
  - Project title: Measurement and Optimisation of Energy Consumption in Cellular Networks
  - Duration: 02/2022-01/2025 (accepted in 09/2021)
  - Coordinator: INSA Lyon
  - Other partners: ETS Montréal, Québec, Canada ; IMDEA, Madrid, Spain ; Politehnica university of Timisoara, Romania.
  - Abstract: This project addresses the problem of accurately modelling and optimising the energy consumption of a mobile network, with a focus on 4G and 5G technologies. This will be achieved through three main research axes. The first contribution will be represented by the first independent measurement study of energy consumption in a mobile network. The second objective of the project is to use this measurement data in order to design accurate energy consumption models for mobile networks. Finally, the project also targets the proposal of energy efficient networking solutions. Indeed, the measurement data and the energy consumption models will allow us to detect the most energy-hungry phases in a mobile network. To reduce their impact, we will propose network intelligence solutions, which are based on observing the traffic transported by the network, detecting whenever the network settings are over-consuming, and adapting the network configuration with energy efficiency metrics in mind.

10.3 National initiatives

10.3.1 Inria Mission Covid

- SafeCityMap project: mobile network data analysis covering the first Covid 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.

10.3.2 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 CoWorkWorlds 2018 - 2021.
  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.

- ANR JCJC Demon (Deployment of Mobile base stations in cellular Networks), 2021-2024 (accepted in 2020)
  Participants: Fabrice Valois, Razvan Stanica (leader), Zhiyi Zhang.
  The main objective of the DEMON project is to enable an architectural shift and provide dedicated solutions for rapidly deployable mobile base stations. Three main challenges can be outlined in this new approach. The first problem is the initial deployment of mobile base stations in the target geographical area. The second challenge is the configuration of the radio access network to provide the required capacity. Finally, the permanent reconfiguration of the network needs to be considered, accounting not only for UE, but also for base station movement.

- ANR JCJC Doll (Efficient DOwnLink Communication for Increased LoRaWAN Capacity), 2022-2025 (accepted in 2021)
  Participants: Alexandre Guitton, Gwendoline Hochet, Oana Iova (leader), Fabrice Valois.
  The goal of this project is to propose a downlink strategy that will unleash the full potential of LoRaWAN networks and push the deployment of new applications that until now could not properly take advantage of the downlink communication available in LoRaWAN. In order to increase network capacity under confirmed traffic, while maintaining a reliable uplink communication and a low energy consumption for the end devices, we set the following objectives: *i)* understand and quantify the consequences of overlapping uplink and downlink communications, *ii)* evaluate and improve gateway selection algorithm for downlink communication, and *iii)* propose an energy efficient scheduling for handling acknowledgements.

- ANR JCJC Dron-Map (Réseau de drones pour le suivi de panaches de pollution dans les situations d'urgence), 2021-2024 (accepted in 2021)
  Participants: Walid Bechkit (leader), Mohamed Anis Fekih, Ichrak Mokhtari, Hervé Rivano.
  The DRON-MAP project focuses on the use of cooperative UAV networks for pollution plume monitoring in emergency situations (industrial accidents, natural disasters, deliberate terrorist releases, etc.). The deployment of a UAV network in these situations face different scientific and technical challenges such as taking into account the strong plume dynamics, the timely data analysis, the reliable communication and coordination between UAVs and the planning of optimal trajectories. The objective of DRON-MAP project is to address these challenges while proposing a new global and systemic approach. Based on reliable communications and coordination between drones, our approach will federate an instantaneous estimation and a prediction of the plume evolution with efficient anticipatory algorithms of optimal path planning. A network testbed of few communicating UAVs will be set up in order to assess real-world feasibility and performance at a small scale.

- 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 in the 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 Plan de relance - mesure de préservation de l'emploi de R&D
  Participants: Walid Bechkit, Hervé Rivano, Razvan Stanica.
  Agora started a collaboration with Rtone in December 2021, for a duration of 2 years. The objective of this collaboration is to integrate artificial intelligence solutions in the control of a fleet of drones for pollution monitoring purposes.

10.3.3 GDR CNRS RSD - Pôle ResCom

- Ongoing participation (since 2006)
  Communication networks, working groups of GDR ASR/RSD, CNRS. Oana Iova is member of the steering committee of the GDR RSD. Razvan Stanica is member of the scientific council of the GDR RSD.

10.4 Regional initiatives

- Ecole Urbaine de Lyon, Institut Convergence (2017-2027)
  - Participants: Hervé Rivano.
  - The partners are: Université Lyon 1, Université Lyon 2, Université Lyon 3, Université Jean Monnet Saint-Étienne, ENS Lyon, INSA de Lyon, CNRS, Ecole Centrale de Lyon, Sciences Po Lyon, VetAgroSup, ENSAL, ENSSIB, ENTPE, Ecole des Mines de Saint-Étienne, IFSTTAR, Inria, INRA, ISARA, UGA.
  - Through its experimental interdisciplinary project for research, doctoral training and the economic, social and cultural promotion of scientific knowledge, the Lyon Urban School is breaking new ground by establishing an emerging field of knowledge and expertise: the Urban Anthropocene.
- Labex IMU 3M'Air, 2018-2021
  - Participants: Walid Beckhit, Manoel Dahan, Mohamed Anis Fekih, Ichrak Mokhtari, Hervé Rivano, Alexandros Sidiras Galante.
  - 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.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

General chair, scientific chair

- Alexandre Guitton and Oana Iova were general co-chairs of the LPWAN Days, GDR CNRS RSD, Clermont-Ferrand, France, 2021.

Member of the organizing committees

- Juan A. Fraire was in the organizing committee of the STINT (Space-Terrestrial Internetworking) Workshop, Online edition.
- Alexandre Guitton and Oana Iova were in the organizing committee of the LPWAN Days (Low Power Wire Area Networks), GDR CNRS RSD, Clermont-Ferrand, France 2021.

Member of the conference program committees

- Walid Bechkit was member of the TPC of IEEE LCN.
- Alexandre Guitton was member of the following conferences: IEEE Globecom, IEEE ICC, IEEE PIMRC.
- Oana Iova was member in the TPC of the following conferences: EWSN, IEEE ICDCS, ACM/IEEE IoTDI.
- Razvan Stanica was member in the TPC of the following conferences: IFIP Networking, IEEE SECON, IEEE ICC, IEEE GlobeCom, IEEE WCNC, IEEE PIMRC, IEEE ISC2, IFIP WD, ICIN, NoF, ISNCC, UNet, MobiArch.
- Fabrice Valois was in the TPC of the following conferences: ÌEEE 5G World Forum, IEEE AINA, IEEE ICC, IEEE ICT, IEEE Globecom, IEEE IWCMC, IEEE WCNC, WiSARN.

11.1.2 Journal

Member of the editorial boards

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

Reviewer - reviewing activities

- Alexandre Guitton was reviewer for the following journals: Elsevier Ad Hoc Networks, Elsevier Pervasive Mobile Computing, Springer Wireless Networks, IEEE Communications Letters.
- Oana Iova was reviewer for the following journals: Elsevier Ad Hoc networks, IEEE Internet of Things, IEEE Communications Letters, Wiley Internet Technologies Letters.
- Razvan Stanica was reviewer for the following journals: IEEE Transactions on Mobile Computing, IEEE Transactions on Network and Service Management, IEEE Communications Magazine, IEEE Communication Letters, Computer Networks, Ad-Hoc Networks, Wireless Networks, Vehicular Communications, Transactions on Big Data, Sustainable Computing: Informatics and Systems, Digital Communications and Networks.

11.1.3 Invited talks

- Juan A. Fraire was invited speaker for Groupe de travail sur l'évaluation de performances des réseaux, Fédération Informatique de Lyon, France.
- Hervé Rivano was invited speaker at the « Artificial Intelligence and public spaces » seminar of the Science Po Lyon chaire « Transformation de l'action publique ».
- Hervé Rivano was invited speaker at a Smart Cities and Artificial Intelligence workshop of EM Lyon.
- Hervé Rivano gave a talk on deploying wireless sensors for monitoring urban heat island in elementary schools at the Lyon Metropolis.

11.1.4 Leadership within the scientific community

- Walid Bechkit is co-facilitator of the digital program FSPI-LISEN, *l'intelligence sociale et le numérique*, (2020-2021).
- Juan A. Fraire is member of the steering committee of the STINT (Space-Terrestrial Internetworking) Workshop.
- Alexandre Guitton is member of the steering committee of the LPWAN Days.
- 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).
- Oana Iova is member of the steering committee of the LPWAN Days.
- Hervé Rivano is member of the scientific council of France Ville Durable since 2021.
- Hervé Rivano is member of the steering committee of the Science Po Lyon chaire « Transformation de l'action publique" since 2019.
- Hervé Rivano is deputy French representative within COST action CA18204 « Dynamics of place-making and digitization in Europe's cities » since 2019.

11.1.5 Scientific expertise

- Walid Bechkit was president of the recruitment committee for an ATER position (CITI research laboratory, Telecom department, INSA Lyon).
- Hervé Rivano was president of an associate professor committee for INSA Lyon.
- Hervé Rivano was member of the Research Director recruitment committee of IFSTTAR.
- Razvan Stanica was member of the associate professor recruitement committee at Université Paris Saclay.
- Fabrice Valois was member of the Hcérés committee for the XLIM (UMR CNRS 7252).
- Fabrice Valois was president of the Hcérés committee for the CNRS MIRES research federation.
- Fabrice Valois was member of the following associate professor / full professor committees: IMT Atlantique, Université Clermont Auvergne (president of the committee).

11.1.6 Research administration

- Hervé Rivano is member of the board of Ecole Urbaine de Lyon since 2018.
- Razvan Stanica is co-leader of the topic System/Network/Telelcommunication of the Fédération d'Informatique de Lyon, since 2020.
- Fabrice Valois is member of the scientifc council of Labex IMU.

11.2 Teaching - Supervision - Juries

11.2.1 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, Computer Networks - Advanced notions, 20h, L3, INSA Lyon.

- Hervé Rivano, Algorithms and programming, 165h, L1 - L2, INSA Lyon.
- Hervé Rivano, Sensors data engineering project, 34h, L2, INSA Lyon.
- Hervé Rivano, Programming robot control, 20h, L2, INSA Lyon.
- Fabrice Valois, IP Networks, 24h, L3, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Medium Access Control, 38h, 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.
- Juan A. Fraire, Satelite communications, 32h, M2, Telecom. Dpt. INSA Lyon.
- Alexandre Guitton, Network and security, 8h, M1, University of Clermont Auvergne.
- Alexandre Guitton, Network management and supervision, 10h, M2, University of Clermont Auvergne.
- Alexandre Guitton, Computer architecture, 6h, M1, University of Clermont Auvergne.
- Alexandre Guitton, Long range networks, 6h, M2, INSA Lyon.
- Alexandre Guitton, Advanced network simulation, 24h, M2, INSA Lyon.
- Alexandre Guitton, Network security, 2h, M2, 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, Advanced Network Simulation, 32h, M2, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Cellular networks, 18h, M1, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Content delivery networks (end-to-end applications), 6h, M2, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Performance evaluation of network, 32h, M1, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Short range wireless communications, 2h, M2, Telecom. Dpt. INSA Lyon.

Apprenticeship (license and master)

- Licence: Razvan Stanica, IP Networks, 36h, L3, Telecom. Dpt. INSA Lyon.
- Licence: Fabrice Valois, Medium Access Control, 16h, 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, 44h, 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.
- Oana Iova is coordinator leader of the Information Science & Technology semester at the INSA Lyon.
- 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 is the head of the Computer Science discipline in FIMI department of INSA Lyon.
- 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.
- Fabrice Valois is in charge of the Humanities course about creative process in Modern Art, Science and technology.

11.2.2 Supervision

- Master
  - Mehdi Ait Mesbah, Developping an OMNET++ module for Satellite-IoT communication, 04-09/2021 Advisors: Juan A. Fraire, Oana Iova, Fabrice Valois.
  - Déborah Conforto-Nedelmann, sensor calibration and data adjustment of air quality low-cost sensors, 02-07/2021. Advisors: Claire Chappaz (ATMO), Steve Micallef (ATMO), Hervé Rivano.
  - Lise Jacquot, Energy Consumption Measurement in Cellular Networks, since 09/2021. Advisor: Razvan Stanica.
  - Adam Ben Ltaifa, Correlated Time Series Forecasting, 03-08/2021. Advisor: Razvan Stanica.
  - Rachida Saroui, Impact du lien descendant sur la performance de LoRaWAN, since 09/2021. Adivsors: Alexandre Guitton, Oana Iova.
- PhD

- Nour Bouzouita, Traffic aggregation in Wi-Fi networks, since 11/2018. Advisors: Anthony Busson (Univ. Lyon 1, LIP), Hervé Rivano.
- Gwladys Djuikom, Mobility analysis using cellular data, since 102021. Advisors: Diala Naboulsi (ETS Montréal, Québec, Canada), Razvan Stanica.
- Mohamed El Emary, Task offloading in airborne-assisted networks, since 07/2021. Advisors: Diala Naboulsi (ETS Montréal, Québec, Canada), Razvan Stanica.
- Mohamed Anis Fekih, Urban pollution using wireless sensor networks, since 11/2018. Advisors: Walid Bechkit, Hervé Rivano.
- Gwendoline Hochet-Derevianckine, Faisabilité et performances d'un réseau LoRaWAN dans la bande ISM 2.4GHz, since 04/2021. Advisors: Alexandre Guitton, Oana Iova, Baozhu Ning (Semtech), Fabrice Valois.
- Kawtar Lasri, Data collection and distributed spatial coordination in LPWAN networks, since 01/2019. Advisors: Loubna Echabbi (INPT Rabat, Morocco), Oana Iova, Yann Ben Maissa (INPT Rabat, Morocco), Fabrice Valois.
- 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.
- Ichrak Mokhtari, Spatio-temporal analysis of pollution data from low cost sensors, since 11/2019. Advisors: Walid Bechkit, Hervé Rivano.
- Camille Moriot, DDos Attacks and their impacts on the Internet Architecture, since 09/2020. Advisors: François Lesueur (CITI) Nicolas Stouls (CITI), Fabrice Valois.
- Hnin Pann Phyu, End-to-end mobile network slicing, since 10/2020. Advisors: Diala Naboulsi (ETS Montréal, Québec Canada), Razvan Stanica.
- Mihai Popescu,Connectivity constrained mobility in fleets of robots, since 11/2015. Advisors: Olivier Simonin (CITI, INSA Lyon), Anne Spalanzanni (LIG, UGA), Fabrice Valois.
- Romain Pujol, User association in self-deployable cellular network, since 11/2018. Ad- visors: Razvan Stanica, Fabrice Valois.
- Solohaja Rabenjamnia, Data analysis of cellular trafic, since 11/2018. Advisors: Hervé Rivano, Razvan Stanica.

11.2.3 Juries

- Walid Bechkit was a reviewer in the following PhD defense committee:
  - Adda Boualem, Stratégies d'amélioration de la couverture dans les RCSF, ESI-Alger, 2021.
- Alexandre Guitton was a reviewer in the following PhD defense committee:
  - T. Attia, Optimization and experimental characterization of Low Power Wide Area Networks, LIG, UGA, 2021.
- Oana Iova was examiner in the following PhD defense committee:
  - M. Rady Abdelshahid Mouawad, Agile Multi-PHY Wireless Networking, Inria, Sorbonne Université, 2021.
- Hervé Rivano was reviewer in the following PhD defense committee:
  - K. Karroum, Algorithmes d'optimisation pour la surveillance et l'estimation de la pollution de l'air, LPCA, Université du Littoral Côte d'Opale, 2021.
  - C. Veve, Détection de zones spatio-temporelles à fort potentiel, pour contribuer à la mise en place de services de mobilité partagée et de microtransit, LICIT, ENTPE, 2021.
- Razvan Stanica was reviewer in the following PhD defense committee:

  - O. Shrit, Coordination automatique d'une flotte de quadcopter à l'aide de communications ad hoc, LRI, Université Paris Saclays, 2021.
  - R. Singh, On mobile usage data analysis, data-driven network optimization and data syntesis, University of Edinburgh, 2021.
  - A. Thibaud, Répartition de flux dans les réseaux de contenu, application à un contexte satellite, IRIT, ENSEEIHT.
  - D. Do Couto Teixeira, Predictability in Human Mobility : Interpretability, Extensions and Applications, Institut Polytechnique de Paris & Universidade Federal de Minas Gerais, 2021.

- Fabrice Valois was reviewer in the following PhD defense committee:
  - T. Attia, Optimization and experimental characterization of Low Power Wide Area Networks, LIG, UGA, 2021.
  - A. Bitaillou, Réseaux cognitifs sans fil pour des applications industrielles 4.0, LS2N, Université Nantes, 2021.
  - R. Costa, Tactful Networking as a cornerstone for opportunistic human-aware D2D communication, Institut Polytechnique de Paris, 2021.
  - O. Dieng, Low-Cost Localization Methods with LPWAN IoT to Prevent Cattle Rustling in Africa, University of Gaston Berger of Saint Louis, Senegal, 2021

- Fabrice Valois was examiner and president in the following HDR defense committee:
  - G. Z. Papadopoulos, Reliable and Available Low-Power Wireless Mesh Networks, LIP, IMT Atlantique, 2021.

- Fabrice Valois was examiner in the following PhD defense committee:
  - S. Sampayo, Polymorphic network protocol suite in heterogeneous wake-up IoT networks, Icube, Université de Strasbourg, 2021.

11.3 Popularization

11.3.1 Articles and contents

The term "Smart City" is gradually being replaced by "Learning City", which seems to be more concerned with placing residents at the center of urban issues. Behind this change in vocabulary is the notion of the "smart and connected citizen" that should also be questioned. To this end, in October 2020, the Lyon Urban School organized a one-day seminar bringing together academics and professionals to critically discuss existing tools for training and mobilizing citizens around the issues of learning by doing, illiteracy, loss of momentum and public resistance, as well as the promise of a participatory renewal thanks to digital technology. The importance of these questions was underlined by the unprecedented (and since repeated) experience of the first confinement, during which digital technologies were solicited to replace physical presence, particularly in the teaching sector.

The seminar was structured around three cross-conversations on three themes:

1. Digital teaching
2. The Fab City
3. Digital citizenship

Multiple resources (texts, videos, drawings) are available here in order to make public the content of these exchanges which could not take place in an open and public way as we would have liked [34].

11.3.2 Education

Hervé Rivano co-organized a one week workshop for master and PhD students on creating radio reportage within Ecole Urbaine de Lyon (blog post and podcast).

Hervé Rivano co-organized a one week inter-master workshop on « Active mobility and smart cities in public spaces » with Ecole Urbaine de Lyon, gathering student from TC department of INSA Lyon, Institut d'Urbanisme de Lyon and ESAA La Martinière Diderot. An exhibition with the results is organized in 2022 (11/2021) (blog post).

Hervé Rivano gave a talk on the environmental impact of networking infrastructure at the « Objective 21 » conference organized by TC students of INSA Lyon (05/2021)

Hervé Rivano was invited speaker at an Smart Cities and Artificial Intelligence workshop of EM Lyon (05/2021).

Hervé Rivano gave a seminar on LoraWan at IMERIR (06/2021).

11.3.3 Interventions

Hervé Rivano gave a talk on deploying wireless sensors for monitoring urban heat island in elementary schools at the Lyon Metropolis.

Hervé Rivano organized and animated a Ecole Urbaine de Lyon radio show « Mercredi de l'anthropocene » on predictive cities (04/2021) (news article and podcast) and one on « designed sobriety » (06/2021) (podcast).

Hervé Rivano was invited speaker to a TUBA « meet-up » on responsible digitalization (03/2021).

12 Scientific production

12.1 Major publications

[1] L. Bonnetain, A. Furno, N.-E. El Faouzi, M. Fiore, R. Stanica, Z. Smoreda and C. Ziemlicki. 'TRANSIT: Fine-Grained Human Mobility Trajectory Inference at Scale with Mobile Network Signaling Data'. In: *Transportation research. Part C, Emerging technologies* 130 (Sept. 2021), pp. 1–34. DOI: 10.1016/j.trc.2021.103257. URL: https://hal.inria.fr/hal-03299297.

[2] M. A. Fekih, W. Bechkit, H. Rivano, M. Dahan, R. Florent, L. Alonso and F. Pineau. 'Participatory Air Quality and Urban Heat Islands Monitoring System'. In: *IEEE Transactions on Instrumentation and Measurement* 70 (2021), pp. 1–14. URL: https://hal.archives-ouvertes.fr/hal-03084917.

[3] J. A. A. Fraire and E. L. Gasparini. 'Centralized and Decentralized Routing Solutions for Present and Future Space Information Networks'. In: *IEEE Network* 35.4 (July 2021), pp. 110–117. DOI: 10.1109/MNET.011.2100102. URL: https://hal.archives-ouvertes.fr/hal-03494101.

[4] M. Gramaglia, M. Fiore, A. Furno and R. Stanica. 'GLOVE: towards privacy-preserving publishing of record-level-truthful mobile phone trajectories'. In: *ACM/IMS Transactions on Data Science* 2.3 (1st Aug. 2021), pp. 1–36. URL: https://hal.archives-ouvertes.fr/hal-03264757.

[5] 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. Proceedings of 35th International Conference on Advanced Information Networking and Applications (AINA-2021). Toronto, Canada: IEEE, 12th May 2021, pp. 1–10. URL: https://hal.archives-ouvertes.fr/hal-03178390.

[6] I. Mokhtari, W. Bechkit and H. Rivano. 'A generic framework for monitoring pollution plumes in emergencies using UAVs'. In: IJCNN 2021 - International Joint Conference on Neural Networks. Proceedings of 2021 International Joint Conference on Neural Networks (IJCNN). Online, United States, 18th July 2021, pp. 1–9. URL: https://hal.archives-ouvertes.fr/hal-03343645.

[7] 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.

[8] A. Nardin, J. Fraire and F. Dovis. 'Contact Plan Design for GNSS Constellations: A Case Study with Optical Inter-Satellite Links'. In: *IEEE Transactions on Aerospace and Electronic Systems* (1st Dec. 2021), pp. 1–1. DOI: 10.1109/TAES.2021.3135025. URL: https://hal.archives-ouvertes.fr/hal-03494137.

[9] F. D. Raverta, J. A. A. Fraire, P. G. Madoery, R. A. Demasi, J. M. Finochietto and P. R. D'argenio. 'Routing in Delay-Tolerant Networks under uncertain contact plans'. In: *Ad Hoc Networks* 123 (2021), pp. 1–16. DOI: 10.1016/j.adhoc.2021.102663. URL: https://hal.archives-ouvertes.fr/hal-03494116.

[10] G. Stock, J. A. Fraire, H. Hermanns, E. Cruz, A. Isaacs and Z. Imbrosh. 'On the Automation, Optimization, and In-Orbit Validation of Intelligent Satellite Constellation Operations'. In: Small Satellite Conference. Proceedings of the Small Satellite Conference. Logan, United States, 1st July 2021. URL: https://hal.archives-ouvertes.fr/hal-03494123.

12.2 Publications of the year

International journals

[11] L. Bonnetain, A. Furno, N.-E. El Faouzi, M. Fiore, R. Stanica, Z. Smoreda and C. Ziemlicki. 'TRANSIT: Fine-Grained Human Mobility Trajectory Inference at Scale with Mobile Network Signaling Data'. In: *Transportation research. Part C, Emerging technologies* 130 (Sept. 2021), pp. 1–34. DOI: 10.1016/j.trc.2021.103257. URL: https://hal.inria.fr/hal-03299297.

[12] M. A. Fekih, W. Bechkit, H. Rivano, M. Dahan, R. Florent, L. Alonso and F. Pineau. 'Participatory Air Quality and Urban Heat Islands Monitoring System'. In: *IEEE Transactions on Instrumentation and Measurement* 70 (2021), pp. 1–14. URL: https://hal.archives-ouvertes.fr/hal-03084917.

[13] J. A. A. Fraire and E. L. Gasparini. 'Centralized and Decentralized Routing Solutions for Present and Future Space Information Networks'. In: *IEEE Network* 35.4 (July 2021), pp. 110–117. DOI: 10.1109/MNET.011.2100102. URL: https://hal.archives-ouvertes.fr/hal-03494101.

[14] M. Gramaglia, M. Fiore, A. Furno and R. Stanica. 'GLOVE: towards privacy-preserving publishing of record-level-truthful mobile phone trajectories'. In: *ACM/IMS Transactions on Data Science* 2.3 (1st Aug. 2021), pp. 1–36. URL: https://hal.archives-ouvertes.fr/hal-03264757.

[15] 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.

[16] A. Nardin, F. Dovis and J. Fraire. 'Empowering the Tracking Performance of LEO-Based Positioning by Means of Meta-Signals'. In: *IEEE Journal of Radio Frequency Identification* 5.3 (Sept. 2021), pp. 244–253. DOI: 10.1109/JRFID.2021.3077082. URL: https://hal.archives-ouvertes.fr/hal-03494115.

[17] A. Nardin, J. Fraire and F. Dovis. 'Contact Plan Design for GNSS Constellations: A Case Study with Optical Inter-Satellite Links'. In: *IEEE Transactions on Aerospace and Electronic Systems* (1st Dec. 2021), pp. 1–17. DOI: 10.1109/TAES.2021.3135025. URL: https://hal.archives-ouvertes.fr/hal-03494137.

[18] F. D. Raverta, J. A. A. Fraire, P. G. Madoery, R. A. Demasi, J. M. Finochietto and P. R. D'argenio. 'Routing in Delay-Tolerant Networks under uncertain contact plans'. In: *Ad Hoc Networks* 123 (2021), pp. 1–16. DOI: 10.1016/j.adhoc.2021.102663. URL: https://hal.archives-ouvertes.fr/hal-03494116.

[19] J. Rimani, L. Mascolo and J. A. Fraire. 'A parametric data handling evaluation framework for autonomous lunar networks'. In: *CEAS Space Journal* (22nd Sept. 2021), pp. 1–12. DOI: 10.1007/s12567-021-00390-4. URL: https://hal.archives-ouvertes.fr/hal-03494119.

[20] A. Sassi, A. Bachir and W. Bechkit. 'Evaluating Regression Models for Temporal Prediction of Wi-Fi Device Mobility'. In: *Wireless Personal Communications* 116.1 (2021), pp. 2169–2186. DOI: 10.1007/s11277-020-07785-2. URL: https://hal.archives-ouvertes.fr/hal-03094754.

International peer-reviewed conferences

[21] N. e. h. Bouzouita, A. Busson and H. Rivano. 'Exploiting Frame Aggregation to Enhance Access Point Selection'. In: PE-WASUN '21 - 18th ACM International Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks. Alicante, Spain: ACM, 22nd Nov. 2021, pp. 1–8. DOI: 10.1145/3479240.3488507. URL: https://hal.inria.fr/hal-03362285.

[22] M. A. Fekih, W. Bechkit and H. Rivano. 'On the Data Analysis of Participatory Air Pollution Monitoring Using Low-cost Sensors'. In: ISCC 2021 - 26th IEEE Symposium on Computers and Communications. Proceedings of 2021 IEEE Symposium on Computers and Communications (ISCC). Athènes, Greece, 8th Sept. 2021, pp. 1–7. URL: https://hal.archives-ouvertes.fr/hal-03347020.

[23] A. B. Khalifa, R. Stanica and H. Rivano. 'On the Use of Carrier Sense Mechanisms in Low-Power Wide Area Networks'. In: WD 2021 - 13th IFIP Wireless Days. Paris, France, 30th June 2021, pp. 1–5. URL: https://hal.inria.fr/hal-03299130.

[24] 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. Proceedings of 35th International Conference on Advanced Information Networking and Applications (AINA-2021). Toronto, Canada: IEEE, 12th May 2021, pp. 1–10. URL: https://hal.archives-ouvertes.fr/hal-03178390.

[25] I. Mokhtari, W. Bechkit and H. Rivano. 'A generic framework for monitoring pollution plumes in emergencies using UAVs'. In: IJCNN 2021 - International Joint Conference on Neural Networks. Proceedings of 2021 International Joint Conference on Neural Networks (IJCNN). Online, United States, 18th July 2021, pp. 1–9. URL: https://hal.archives-ouvertes.fr/hal-03343645.

[26] G. Stock, J. A. Fraire, H. Hermanns, E. Cruz, A. Isaacs and Z. Imbrosh. 'On the Automation, Optimization, and In-Orbit Validation of Intelligent Satellite Constellation Operations'. In: SmallSat 2021 - 35 th Annual Small Satellite Conference. Proceedings of the Small Satellite Conference. Logan, United States, 7th Aug. 2021, pp. 1–18. URL: https://hal.archives-ouvertes.fr/hal-03494123.

[27] K. Vogelgesang, J. A. A. Fraire and H. Hermanns. 'Uplink Transmission Probability Functions for LoRa-Based Direct-to-Satellite IoT: A Case Study'. In: GLOBECOM 2021 - IEEE Global Communications Conference. Proceedings of IEEE Globecom 2021. Madrid, Spain: IEEE, 7th Dec. 2021, pp. 1–6. URL: https://hal.archives-ouvertes.fr/hal-03494140.

[28] W. Xiao, N. E. Rachkidy and A. Guitton. 'Recovering Colliding LoRa Frames from Uncertainties Using LoRa Coding'. In: LCN 2021 - IEEE 46th Conference on Local Computer Networks. Edmonton, Canada: IEEE, 4th Oct. 2021, pp. 327–330. DOI: 10.1109/LCN52139.2021.9524949. URL: https://hal.archives-ouvertes.fr/hal-03412369.

[29] 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: IEEE, 29th Mar. 2021, pp. 1–6. URL: https://hal.inria.fr/hal-03183703.

National peer-reviewed Conferences

[30] N. Bennani, S. Cazalens, V. Cheutet, C. Leschi, O. Merveille, C. Moriot, D. Muller, T. Pecatte, C. Pothier, C. Rigotti, H. Rivano and N. Stouls. 'Apprivoiser l'hétérogénéité en informatique 1ère année'. In: 7e Colloque pédagogie et formation 2021. Valenciennes, France, 20th May 2021, pp. 1–6. URL: https://hal.inria.fr/hal-03230531.

Conferences without proceedings

[31] L. Merchez, M. Adam and H. Rivano. 'Cartographier la cyclabilité, enjeux méthodologiques et mises en débat autour du cas de Lyon'. In: CARTOMOB 2021 - Colloque international Cartomob « Tous (im)mobiles, tous cartographes ? » En ligne (Toulouse), France, 14th June 2021. URL: https://hal.archives-ouvertes.fr/hal-03509687.

Scientific book chapters

[32] M. Adam, N. Ortar, L. Merchez, G.-H. Laffont and H. Rivano. 'Conducting Interviews with Maps and Videos to Capture Cyclists' Skills and Expertise'. In: *Becoming Urban Cyclists: From Socialization to Skills*. University of Chester Press, 31st Jan. 2022, pp. 18–43. URL: https://hal.archives-ouvertes.fr/hal-03552634.

Reports & preprints

[33] H. C. Fantecele, S. Rabenjamina, A. Carneiro Viana, R. Stanica and A. Ziviani. *SafeCityMap (1st phase) – COVID INRIA mission: Investigating population mobility habits in metropolitan zones and the lockdown impact using mobile phone data*. Inria, 21st July 2021. URL: https://hal.inria.fr/hal-03219274.

Other scientific publications

[34] H. Rivano, L. Herrmann and J. Kratochvil. *Qui sont les smart citizens ?* Dec. 2021. URL: https://hal.inria.fr/hal-03471259.

12.3 Other

Scientific popularization

[35] J. Galet, A. Rousseau, H. Rivano and J. Chabassier. 'Des outils de médiation innovants inspirés par des travaux de recherche : 3 exemples'. In: Science and You 2021 - Colloque international Science&You. Metz, France, 16th Nov. 2021. URL: https://hal.archives-ouvertes.fr/hal-03514473.