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ACTIVITY REPORT

Project-Team AGORA

Wireless Networks for Digital Cities

IN COLLABORATION WITH: Centre d'innovation en télécommunications et intégration de services

DOMAIN

Networks, Systems and Services, Distributed Computing

THEME

Networks and Telecommunications

Inria

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2 Overall objectives

The main focus of the Agora team is on the specific challenges when considering wireless network architectures dedicated to urban environments, including connected and smart cities. The smart city represents a constantly reshaped concept, embracing the future of dense metropolitan areas. It refers to efficient and sustainable infrastructure, improving citizens' quality of life, and protecting the environment. However, a consensus on the Smart City philosophy is that it will be primarily achieved by leveraging a clever integration of Information and Communication Technologies (ICT) in the urban tissue.

Indeed, ICTs enable an evolution from the current duality between the physical world and its digitized counterpart to a continuum in which digital content and applications seamlessly interact with classical infrastructures and services. Smart Cities are often described by their digital services, which are inherently dependent on dense measurements of the city environment and activities, the collection of this data, its processing into information, and its redistribution. Therefore, the networking infrastructure is critical in enabling advanced services, particularly the wireless infrastructure that supports 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 to leverage the massive data collected by pervasive sensors, connected mobile or fixed devices, and social applications. We aim to capture these aspects and design network architectures and protocols that are relevant to them.

In addition to our focus on ICTs in urban areas, we also work on their extension to any scenario where coverage challenges meet high density, such as satellite-IoT constellations or networks for rural and geographically isolated areas.

While our work is grounded on the properties of the wireless technologies we study, including a significant experimental dimension, our ambition is to address more general scientific challenges of network architectures. We can cluster these architectures into three main kinds:

- Carefully deployed topologies such as cellular networks and environmental monitoring,
- Planned and dynamic topologies such as a fleet of drones and satellite communications,
- Uncontrolled topologies, such as individual IoT and self-deployable networks.

The team aims to contribute to the following consequent challenges of data collection wireless networks in smart environments:

Wireless network deployment The deployment of dense networks is challenged by the scale of the problems and the versatility of the environment, with consequences on optimizing the placement of both network devices and functions.

Wireless data collection Data collection and distribution communication protocols need a coherent rethinking to face issues on saturated cellular networks, star-topologies networks, and multi-hop networks unable to cover large areas.

Network data exploitation 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 in-network computations to reduce the traffic load or enhance the data quality.

3 Research program

The Agora research program is organized in three axes, which are addressed in the team following the same general methodology that aims at combining:

- Modeling to get insights on average and asymptotic behaviors,
- Simulation to investigate large-scale networks and average behavior,
- Experimentation to get validation from real devices and users.

Modeling is typically mathematical optimization, stochastic performance evaluation, or Machine Learning algorithms. Discrete event simulations mainly focus on networks, environments, or user mobility. Experiments can be conducted 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 deployments without human in the loop.

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, and 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 potential end device mobility. 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:

- We have a long line of collaborations with local authorities (Lyon Metropolis and the city of Lyon, city of Villeurbanne) and non-governmental organizations (Atmo-AuRA) on environmental issues such as air quality and urban warming. Indeed, since the preliminary project UrpolSens (*Wireless SENSor Networks for URban POLlution Monitoring*) 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 leverage an interdisciplinary approach to efficiently monitor chronic and accidental pollution as well as Urban Heat Island (UHI).

- Furthermore, we have developed at the Agora team a culture of collaborating with researchers in social and human sciences. This has been intiated within the LabEx IMU and the Ecole Urbaine de Lyon, and had been sustained in academic chairs and with industrial partners. Following this direction, and while collaborating with geographers, geomaticians and anthropologists, we have measured and studied the cyclist behavior and the cyclability of the urban environment. Our work on cyclist activity is trying to build a contribution to the necessary transition to decarbonized mobilities. In our recent efforts, we proposed deep reinforcement learning (DRL) solutions to optimize traffic light phases in order to increase the safety of cyclists. This is the first step toward replicating classic networking mechanisms (e.g., virtualization and adaptative scheduling) into dynamic urban infrastructures.

- Energy has always been an important metric in wireless networking research. More recently, we have started to investigate the energetic consumption of cellular networks in more details. A significant mechanism in reaching network flexibility is network slicing, but this introduces new challenges in the development of sustainable network operations. Guaranteeing slice requirements comes at the cost of additional energy consumption. To this end, we have been studing the problem of deploying network slices to minimize energy consumption and maximize the user quality of service (QoS).

- Moreover, since the introduction of the paradigm of self-deployable cellular networks, we have been investigating the evolution of the cellular network architecture and the impact of such networks on the control plane's protocols. In this regard, we are contributing to several aspects such as: network function placements, the user association procedure, mobility management, etc. We show that self-deployable cellular networks can be used for first responders when the telecommunication infrastructure is totally, or partially, damaged. Self-deployable cellular networks are a key enabler technology for humanitarian engineering to allow a fast and efficient deployment of a telecommunication infrastructure for NGOs.

- Finally, we are working on frugal AI in order to address the critical need for sustainability when training deep learning. The outcome of our research will allow us to achieve high energy gains with minimal accuracy loss. Our vision is that when AI is applied in embedded systems, it should be done while minimizing the pollution emissions associated with this technology.

6 Highlights of the year

6.1 Awards

- Oana Iova was named as "best junior researcher" in the field of computer networks and systems in France in 2024 (GDR CNRS RSD).

- Oana Iova holds the RIPEC-C3 (2022-2025).

- Hervé Rivano holds the PEDR (2021-2025).

- Walid Bechkit holds the PEDR (2021-2025).

- Razvan Stanica holds the PEDR (2020-2024).

- The paper [13] was runner-up for the best paper award at The 3rd Workshop on Security and Privacy in Connected Embedded Systems (SPICES @ EWSN 2024).

6.2 HDR and PhD defences

- Walid Bechkit defended his HDR in May, 2024.

- Lucas Magnana defended his PhD in February, 2024.

- Kawtar Lasri defended her PhD in February, 2024.

- Camille Moriot defended her PhD in September 2024.
- Gwendoline Hochet Dereviankine defended her PhD in December 2024.

6.3 Other highlights

- Oana Iova is now vice-dean of the International Affairs of INSA Lyon.

7 New software, platforms, open data

7.1 New software

7.1.1 Dense LoRaSim

Name: Extension to support dense LPWAN in LoRaSim

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

Participants: Fabrice Valois, Oana Iova, Hervé Rivano

7.1.2 ELoRa

Name: Extension of ELoRa to support the open source implementation of The Thing Stack

Keywords: LoRaWAN, Downlink scheduling, The Thing Stack

Functional Description: The ELoRa network simulator integrates the ns-3 simulator with the known CS network server. To recognize LoRaWAN packets and to manage the simulated LoRaWAN network, end devices must be registered on the network server. ELoRa uses libcurl to communicate with the REST API from the network server, and implements the Activation by Personalization (ABP) to register and activate end devices. We extended the ELoRa simulator to support the open source implementation of The Thing Stack maintained by The Things Industries. The main changes are related to the registration of end devices, as the commands to communicate with the REST API are different, as well as the parameters to be configured. Unlike the CS, the component that communicates with gateways is the Gateway Server. This structure also implements the UDP Packet Forwarder to forward and receive the DL and UL packets to and from the gateway, respectively. Moreover, the Gateway Server implements more operations than the CS Gateway Bridge, such as monitoring the time on air, the duty cycle and the dwell time.

Contact: Oana Iova

7.1.3 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

Participants: Juan Andres Fraire, Oana Iova, Fabrice Valois

7.1.4 UTOPIA-S

Name: aUTonomous OPtimised aIr quAlity - Software

Keywords: Air Quality, Sensors

Functional Description: Since 2015 we develop optimized, efficient and autonomous solutions for physical phenomenons monitoring. We focus on pollutants (large band of gasses and particles) and urban heat islands, but our solutions are very generic and can be adapted with ease to monitor other phenomenons.

UTOPIA-S is an embedded software written in Arduino destined to run in a generic sensor architecture (UTOPIA-H) we developed for our global solution. UTOPIA-S allows an optimized, reliable and customizable use of the UTOPIA-H based sensor nodes.

Release Contributions: - Very low power consumption - Distant reconfiguration of LoRa parameters - Added support for other sensors - Improved stability - Data saving in a SD card - LoRa parameters saving in the EEPROM

Contact: Walid Bechkit

Participants: Walid Bechkit, Ahmed Boubrima, Hervé Rivano

7.2 New platforms

Participants: Hervé Rivano, Walid Bechkit, Oana Iova, Fabrice Valois, Ahmed Boubrima.

7.2.1 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 platform 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).

7.2.2 UrPolSens / UTOPIA-H platforms

We designed an energy-efficient air pollution monitoring platform from scratch. A microcontroller is integrated into a custom-designed printed circuit board. Using a high-precision ADC, a micro-SD card reader, and a LoRaWAN communication module, it drives several environmental probes, stores the measurements, and transmitting them to gateways. These can be connected to our servers through a 4G connection. The platform has been optimized to operate autonomously on solar energy over extended periods and refined for reliability. This platform meets industrial requirements, as part of our collaboration with the TotalEnergies LQA lab. It has been used in two operational deployments: the first on an onshore industrial site to assess pollutant emissions, and the second on an offshore site for monitoring occupational exposure to pollutants.

7.3 Open data

We are using different kinds of datasets, mainly metadata from the cellular network, mobility traces and air quality measurements. Unfortunately, none of these datasets can be disseminated.

The cellular network datasets are produced mainly by Orange which cannot disseminate them by law, for privacy reasons. In general, we have access to the data through their own system, or they share with us, under Non Disclosure Agreements, anonymized and aggregated data.

The bike mobility dataset that we have built is the collection of GPS traces contributed by volunteer citizens. However, we are not allowed to publicly disseminate the data, that are sensitive for privacy issues since there are mainly commuting. Even an internal reuse is complicated by law because of the consent form used during these campaigns.

The air quality measurements that we have collected on different experiments are also non disclosable because only approved organizations may provide information of this nature (such as ATMO that we are collaborating with).

However, since 2019, we have been continuously collecting a dataset of LoRa activity on the campus through our experimental platform. The dataset is not yet consolidated, mainly because of a lack of resources, but this will be the case in a short time. This dataset will be hopefully openly disseminated in 2025/2026. We assume it will be helpful for a wide public of researchers.

8 New results

8.1 Wireless network deployment

Participants: Walid Bechkit, Ahmed Boubrima, Juan A. Fraire, Hervé Rivano, Razvan Stanica.

Joint Mapping-Sensing Design of Wireless Sensor Networks for Urban Environmental Monitoring In [3], we focus on the application of air quality monitoring where wireless sensor networks collect pollution measurements to estimate ground-truth pollution maps. We present UrMapSens, a novel WSN design strategy that aims to optimize the deployment locations of sensor nodes and the estimation of urban pollution maps. Unlike prior work, UrMapSens performs the optimization of both sensor deployment locations and pollution maps' estimation in a joint way. We design our UrMapSens approach based on data assimilation by combining physical models' simulations and expected sensor measurements in the estimation process of air pollution maps. We use enhanced linearization techniques to provide a convex mathematical model based on mixed integer programming, which can be solved efficiently using numerical solvers. To validate UrMapSens in real-life scenarios, we designed an air pollution monitoring platform and used it to collect a dataset of nitrogen dioxide (NO2) concentrations in Lyon, France. Based on the experimentally collected dataset, we perform extensive evaluations of the proposed approach and show that our joint mapping-sensing design outperforms the prior work.

Informative and Communication-Efficient MultiAgent Path Planning for Pollution Plume Monitoring In [1], we propose an efficient framework for monitoring pollution plumes using sensor-equipped drones. Our approach leverages the power of Reinforcement Learning and Mutual Information to strategically plan drone paths in order to maximize the informativeness of the data collected while minimizing communication costs. We propose a multi-agent Independent Q-Learning scheme, where drones act independently but share a global team reward. The reward is calculated based on both the reduction in plume estimation uncertainty and the communication costs. The proposed framework is adaptable to various problem instances, making it suitable for monitoring diverse physical phenomena. We conduct extensive simulations showing the effectiveness of our approach in achieving high-quality plume monitoring, with an error in variance estimation ranging from 3% to 5% when compared with ground-truth value. The proposed framework is advantageous because it excels not only in providing a good solution but also in inferring it in a reasonable time especially compared to a solution provided by genetic-based heuristics.

On the Use of Mega Constellation Services in Space: Integrating LEO Platforms into 6G Non-Terrestrial Networks In [6], we propose a framework for integrating Low-Earth Orbit (LEO) platforms with Non-Terrestrial Networks (NTNs) in the emerging 6G communication landscape. Our work applies the Mega-Constellation Services in Space (MCSS) paradigm, leveraging LEO mega-constellations' expansive coverage and capacity, designed initially for terrestrial devices, to serve platforms in lower LEO orbits. Results show that this approach overcomes the limitation of sporadic and time-bound satellite communication links, a challenge not fully resolved by available Ground Station Networks and Data Relay Systems. We contribute three key elements: (i) a detailed MCSS evaluation framework employing Monte Carlo simulations to assess space user links and distributions; (ii) a novel Space User Terminal (SUT) design optimized for MCSS, using different configurations and 5G New Radio Adaptive Coding and Modulation; (iii) extensive results demonstrating MCSS's substantial improvement over existing Ground Station Networks and Data Relay Systems, motivating its role in the upcoming 6G NTNs.

Towards Optimal Placement of FreeSpace Optical Terminal on the Spacecraft Body Free-space optical (FSO) links have emerged as a promising solution for enabling high-speed data transfer in networked space systems. These links leverage highly directed optical beams amplified by telescopes that can be oriented using gimbal engines. However, the gimbal's limited swipe range poses a challenge in optimizing the placement of the FSO terminal on the satellite body. This placement directly impacts the feasible contact time, which is constrained by the gimbal motors' degree of freedom and speed as the satellites follow their orbital trajectories. In [9], we address the problem of optimizing the FSO terminal placement to maximize the aggregate effective contact time with the target. First, we formally describe the problem assumptions and perform baseline case studies to gain valuable insights. Next, we define appropriate metrics that capture the contact time performance to evaluate different placement strategies. Our core contributions are two heuristics, simulated annealing, and an evolutionary genetic algorithm to optimize the FSO terminal placement. We finally demonstrate through extensive simulation and analysis that our proposed optimization approaches can significantly improve the baseline contact time by up to 27.7%.

Network Storage Analysis via Semiring Geometry Interplanetary communications networks will need to handle the delays, disruptions, and disconnections inherent to space communications. The architecture of Delay Tolerant Networking (DTN) provides protocols and strategies to support these communications plans. In the past, routing models in DTN have focused on the forwarding aspects of store-carry-forward. Methods such as Contact Graph Routing, Contact Multigraph Routing, and Probabilistic Routing Protocol using the History of Encounters and Transitivity (PRoPHET) provide solutions for how to choose where to forward bundles through a network. However, these routing models often function bundle-by-bundle allowing them to set aside storage needs for each node. In order to bring our vision of a SSI (Solar System Internet) to reality, we will need to be able to predict and incorporate storage needs that satellites and rovers will require. In [2], we introduce a novel semiring model for contact-based routing protocols that includes a means of determining storage needs. Through proper analysis of the semiring structure, we show how to determine optimal storage structures in satellite networks. In addition, we run our analysis on simulated satellite networks to demonstrate the potential for working with these semiring models in a computational framework. We conclude by indicating future directions for semiring analysis is space communications.

8.2 Wireless data collection

Participants: Juan A. Fraire, Oana Iova, Hervé Rivano, Razvan Stanica, Fabrice Valois.

How does Wi-Fi 6 fare? An industrial outdoor robotic scenario Wi-Fi is a standard off-the-shelf solution for industrial robotics. The IEEE 802.11ax amendment extends it to support the 6 GHz band, 160 MHz bandwidth and bit-rates up to 9.6 Gbps. In [14], we evaluate the performance of Wi-Fi 6 compared to Wi-Fi 5 and Wi-Fi 4. We select 9 physical layers (PHYs) representing different Wi-Fi generations and we evaluate their performance in an industrial shipyard in the presence of high radio frequency interference and metallic obstructions. We deploy setup of a robotic station (STA) and a controller STA with three applications running in parallel: a robotic STA is sending a high throughput stream to a controller, a Robotic Operating System (ROS) application is sending time-critical control commands to the robotic STA, Precision Time Protocol (PTP) keeps synchronizing the clocks between both STAs. We evaluate the performance in terms of three Key Performance Indicators (KPIs): streaming throughput, IP-level delay using PTP, and Application-level delay of ROS control packets. The networks are run in: Short range Line of Sight (LoS), Medium range LoS, Long range None-LoS (NLoS), and Long range mixed settings. We note that depending on the PHY configuration, an older Wi-Fi generation may outperform Wi-Fi 6. We further observe trade-offs between the different PHYs: wide channel PHYs (e.g. 160 MHz) had best throughput reaching up to 900 Mbps while PHYs while 80 MHz or 20 MHz bandwidth achieved as low as 9 ms delay.

The Impact of Downlink Scheduling Policy on the Capacity of LoRaWAN LoRaWAN is a widely used wireless communication standard for the Internet of Things that enables the collection of measurement data from numerous monitoring applications (such as smart metering, pollution, and asset tracking). Most research work has been focused on the performance of LoRaWAN as a function of the uplink traffic, as this is the most common scenario. Nevertheless, downlink traffic is a fundamental building block of the LoRaWAN standard, and a crucial part of applications such as smart healthcare, where reliability is extremely important. In [5], we study the impact of the downlink traffic and different scheduling policies on the performance of LoRaWAN. We investigate: (i) the impact of an optimal schedule for the downlink traffic, (ii) the choice of the physical layer parameters used to send downlinks to end-devices during the second reception window, and (iii) the choice of the gateway that sends the downlinks. Our results show that even when using an optimal schedule, the presence of downlink traffic reduces the capacity of a LoRaWAN network up to 20%. The most limiting factor is the gateway, due to its duty cycle and half-duplex characteristics.

Downlink Scheduling in LoRaWAN: ChirpStack vs The Things Stack LoRaWAN is a key enabler for Internet of Things applications, providing long range communication at a low energy consumption. However, extensive use of downlink communication can reduce network capacity and increase uplink loss, as shown in several studies. The network server is responsible for scheduling downlink packets, while respecting strict timing constraints on the end devices and on the gateways. In [35], we present the first evaluation of downlink scheduling implemented by two widely used LoRaWAN network servers: ChirpStack and The Things Stack. Using the ELoRa emulation tool, we inject real LoRaWAN traffic into these network servers and analyze their downlink scheduling algorithms based on defined performance metrics such as reliability and schedule efficiency. Our findings indicate that The Things Stack has a more accurate scheduler, but more conservative, as it delivers less downlink packets. ChirpStack, on the other hand, with its simpler algorithm, performs comparably and even equals The Things Stack as the number of end devices increases.

Traffic control strategies for LPWAN in multigateway environments In [10], we focus on managing upstream traffic in multigateway Low-Power Wide Area Networks (LPWANs) to support efficient traffic from thousands of nodes. As LP-WANs face challenges such as increased collision probability and network saturation due to node densification, our research introduces a distributed and probabilistic traffic control protocol. This protocol aims to effectively manage network traffic, reduce collisions, and mitigate saturation issues, ensuring better performance and scalability in densely populated IoT environments. The protocol enables nodes to dynamically adapt their traffic to meet application needs, such as transmitting a defined number of measurements (K) within a designated time frame. This adjustment remains unaffected by the node count and network topology, focusing instead on the feedback message's destination to the network nodes, which is crucial for dynamically adapting traffic intensity and reducing collisions. We explore two feedback transmission strategies: a synchronous one, where all gateways transmit feedback simultaneously to all nodes, and a round-robin one, where one gateway at a time sends feedback to nodes within its coverage area. Based on simulation results, our evaluated strategies achieve substantial performance improvements over the Baseline LoRaWAN. Specifically, they demonstrate a network lifetime increase of up to 93.12%, a success rate increase of up to 96.34%, and a packet delivery ratio increase of up to 14.97%.

Trends in LPWAN Technologies for LEO Satellite Constellations in the NewSpace Context Our work in [11] focuses on a study that applies satellite constellations in Internet of Things (IoT) communications, specifically within low-power wide-area network (LPWAN) technologies in the NewSpace context. It comprehensively categorizes and describes the functionality and typology of low Earth orbits (LEOs), examines the societal impacts of these technologies, and provides an in-depth analysis of IoT communication architectures and protocols utilizing satellites. Additionally, the study identifies and addresses the challenges faced in this domain while highlighting future trends and developments. By collating and synthesizing pertinent information, this research offers a thorough overview of the opportunities and challenges in this evolving field of study.

Comparing Statistical, Analytical, and Learning-Based Routing Approaches for Delay-Tolerant Networks In delay-tolerant networks (DTNs) with uncertain contact plans, the communication episodes and their reliabilities are known a priori. To maximise the end-to-end delivery probability, a bounded network-wide number of message copies are allowed. The resulting multi-copy routing optimization problem is naturally modelled as a Markov decision process with distributed information. In [7], we provide an in-depth comparison of three solution approaches: statistical model checking with scheduler sampling, the analytical RUCoP algorithm based on probabilistic model checking, and an implementation of concurrent Q-learning. We use an extensive benchmark set comprising random networks, scalable binomial topologies, and realistic ring-road low Earth orbit satellite networks. We evaluate the obtained message delivery probabilities as well as the computational effort. Our results show that all three approaches are suitable tools for obtaining reliable routes in DTN, and expose a trade-off between scalability and solution quality.

A Stability-First Approach to Running TCP Over Starlink The end-to-end connectivity patterns between two points on Earth are highly volatile if mediated via a Low-Earth orbit (LEO) satellite constellation. This is rooted in the enormous speeds at which satellites in LEO must travel relative to the Earth's surface. While changes in end-to-end routes are rare events in stationary and terrestrial applications, they are a dominating factor for connection-oriented services running over LEO constellations and mega-constellations. In [15], we discuss how TCP-over-constellations is affected by the need for rerouting and how orbital route selection algorithms impact the end-to-end performance of communication. In contrast to the state of the art that primarily optimizes for instantaneous shortest routes (i.e. lowest delay), we propose several algorithms that have route stability and longevity in their focus. We show that this shift in focus comes with vastly improved end-to-end communication performance, and we discuss peculiar effects of the typical TCP-like implementations, taking inspiration from the Starlink constellation in our empirical investigations.

8.3 Network data exploitation

Participants: Walid Bechkit, Ahmed Boubrima, Juan A. Fraire, Hervé Rivano, Razvan Stanica.

Route Selection in Low-cost Participatory Mobile Sensing of Air Quality Mobile crowdsensing is a powerful paradigm that takes advantage of low-cost sensors and population density. It allows for large-scale deployments and collection of extensive data, offering a great advantage in multiple fields such as air pollution monitoring, which is a major concern worldwide. Given the mobile nature of the crowd, mobile crowdsensing platforms need to implement adequate route selection/planning solutions to better guide the crowd through the area of interest and maximize the quality of monitoring. In [8], we propose two route selection algorithms that take into consideration the low accuracy of low-cost sensors in order to find the most informative routes. The similarity-based route selection algorithm aims to maximize spatial coverage by reducing overlaps between participant routes. The cluster-based route selection takes advantage of hierarchical clustering to build groups of similar points of the map according to explanatory variables. We compare the proposed solutions to baseline route selection algorithms, and the results show that our solutions allow for a better estimation while being efficient in terms of travel distance.

HeatPulse: Thermal Attacks on Air Pollution Sensors Air pollution monitoring, especially using miniaturized and low-cost sensors, has been increasingly adopted across many application areas -including chemical and automotive industries, smart cities, and agriculture -to protect public health and comply with environmental regulations. In [13], we demonstrate a new security vulnerability that enables adversaries to remotely spoof low-cost air pollution sensors via long-range and highly localized thermal attacks. Modeling the key attack characteristics, we show how adversaries can exploit the temperature-dependent internal calibration process of air pollution sensors to strategically manipulate sensor measurements through induced heat signals, thereby deceiving the sensors. Using inexpensive laser pointers and commercial Nitrogen Dioxide pollution sensors, we design an evaluation testbed and experimentally show the attack's effectiveness in both indoor and outdoor environments.

On-Device Deep Learning: Survey on Techniques Improving Energy Efficiency of DNNs Providing high-quality predictions is no longer the sole goal for neural networks. As we live in an increasingly interconnected world, these models need to match the constraints of resource-limited devices powering the Internet of Things (IoT) and embedded systems. Moreover, in the era of climate change, reducing the carbon footprint of neural networks is a critical step for green artificial intelligence, which is no longer an aspiration but a major need. Enhancing the energy efficiency of neural networks, in both training and inference phases, became a predominant research topic in the field. Training optimization has grown in interest recently but remains challenging, as it involves changes in the learning procedure that can impact the prediction quality significantly. In [4], we present a study of the most popular techniques aiming to reduce the energy consumption of neural networks' training. We first propose a classification of the methods before discussing and comparing the different categories. In addition, we outline some energy measurement techniques. We discuss the limitations identified during our study as well as some interesting directions, such as neuromorphic and reservoir computing (RC).

A deep reinforcement solution to help reduce the cost in waiting time of securing a traffic light for cyclists Cyclists prefer to use infrastructures that separate them from motorized traffic. Using a traffic light to segregate car and bike flows, with the addition of bike-specific green phases, is a lightweight and cheap solution that can be deployed dynamically to assess the opportunity of a heavier infrastructure such as a separate bike lane. To compensate for the increased waiting time induced by these new phases, we introduce in [12] a deep reinforcement learning solution that adapts the green phase cycle of a traffic light to the traffic. Vehicle counter data are used to compare the DRL approach with the actuated traffic light control algorithm over whole days. Results show that DRL achieves better minimization of vehicle waiting time at every hours. Our DRL approach is also robust to moderate changes in bike traffic.

9 Bilateral contracts and grants with industry

Participants: Hervé Rivano, Fabrice Valois, Walid Bechkit, Juan A. Fraire, Oana Iova, Razvan Stanica.

- SPIE (2016-2027): Agora has been involved in two consecutive chairs with SPIE. The first was about IoT, and Razvan Stanica was responsible for the "cognitive networks" research axis. The followup is about AI applied to data flows and network infrastructure analysis. Walid Bechkit is co-responsible of the "embedded AI" research axis. Razvan Stanica is co-responsible of the "data-oriented protocols and infrastructures" research axis. Furthermore, SPIE is funding Audrey Nageotte's CIFRE PhD thesis (started in 2024) on "root cause analysis in network anomaly detection".

- Semtech (2021-2024): A trilateral contract with Semtech and the Université of Clermont Auvergne about the coexistence of LoRA 2.4GHz in the ISM band.

- Eiffage (2021-2025): A bilateral collaboration with Eiffage Energie Systèmes on the energy consumption measurement and modeling in 4G and 5G cellular networks.

- I2Cat (2023-2024): A research agreement with the i2Cat Institute from Barcelona in the context of Non-Terrestrial Networks and Inter-Satellite Links.
- Thalès (2024-2025): A bilateral contract with Thalès SIX GTS France in the SCAF project, on Dynamic neighborhood discovery in 3D networks.

10 Partnerships and cooperations

Participants: Hervé Rivano, Juan Fraire, Walid Bechkit, Oana Iova, Fabrice Valois, Razvan Stanica.

10.1 International research visitors

10.1.1 Visits of international scientists

- Lucas Santos de Oliveira, assistant professor, from State University of Southwestern Bahia, Brazil, from December 2023 to January 2024.
- Hnin Pann Phyu (ETS Montreal), 3-month PhD visit in 2024.

10.1.2 Visits to international teams

Research stays abroad

- Juan A. Fraire, Nanjing, China, 3-month visit in 2024.
- Razvan Stanica, ETS Montreal, Canada, 3-week visit in 2024.
- Diego Maldonado Munoz, NII, Tokyo, Japan, 5-month PhD visit in 2024.
- Diego Maldonado Munoz, Concordia University, Montreal, Canada, 4-month PhD visit in 2024.
- Carlos Fernandez Hernandez, Pontificia Universidad Católica de Chile, short PhD visit in 2024.
- Carlos Fernandez Hernandez, Universidad de Chile, short PhD visit in 2024

10.2 European initiatives

10.2.1 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 craw-lers 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

- ANR CoCo5G (Traffic Collection, Contextual Analysis, Data-driven Optimisation for 5G), 2023-2027, accepted in 2022
  - Participants: Hervé Rivano, Razvan Stanica.
  - The partners in this project are: Thales (leader), Orange, CNAM, Inria Agora, IMDEA Networks.
  - Summary: The objective of CoCo5G is to collect the first-of-its-kind longitudinal nationwide measurements dataset combining 4G and 5G data traffic. This dataset will then be used for an extensive analysis of the evolution (in France) and the dynamics of 5G traffic for various mobile services usages. This will represent a unique opportunity for the evaluation and tailoring of existing analytics for classification, prediction and anomaly detection within real-world high-detail per-service mobile network data. Finally, CoCo5G targets to demonstrate the integration of data analytics within next-generation cognitive network architecture in three practice case studies: energy-prudent 5G NR control, URLLC service support, and automated anomaly response in edge computing.
- ANR JCJC Demon (Deployment of Mobile base stations in cellular Networks), 2021-2024 (accepted in 2020)
  - Participants: Thibault Bellanger, Razvan Stanica (leader), Fabrice Valois, 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 Dereviankine, Oana Iova (leader), Fabrice Valois.
  - Summary: 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: Mohamed Sami Assenine, Walid Bechkit (leader), Ichrak Mokhtari, Hervé Rivano, Alexandros Sidiras Galante.
  - Summary: 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 STEREO (Space-Terrestrial Integrated IoT), 2023-2027, accepted in 2022
  - Participants: Juan A. Fraire, Oana Iova, Fabrice Valois.
  - The partners in this project are: Inria (leader of the project), IRIT / ENSEEIHT (UMR CNRS 5505), Kinésis, LAAS (CNRS UPR 8001), LIG / UGA (UMR CNRS 5217).
  - Summary: The objective of this project is to achieve a Space-Terrestrial Integrated Internet of Things (STEREO) network, in which IoT devices can seamlessly hook to gateways on ground or directly to low-Earth orbit (LEO) satellites when no network infrastructure is present. The feasibility and expected performance will be assessed by objectives described in this section: O.1) defining new network architectures, O.2) evaluating the enabling IoT technologies, O.3) designing the software components, and O.4) prototyping the hardware modules.

Programmes et Equipements prioritaires de recherchecheche (PEPR)

- Project acronym: PEPR NF
  - Project title: Networks of the Future
  - Duration: 2023 - 2030
  - Budget: 65M€
  - Coordinators: CEA, CNRS, IMT
  - Inria participants: Inria project-teams AGORA, AIO, COATI, DIANA, DYOGENE, ERMINE, FUN, MARACAS, NEO, RESIST, TRIBE
  - Summary: The 5G network and the networks of the future represent a key issue for French and European industry, society and digital sovereignty. This is why the French government has decided to launch a dedicated national strategy. One of this strategy's priority ambitions is to produce significant public research efforts so the national scientific community contributes fully to making progress that clearly responds to the challenges of 5G and the networks of the future. In this context, the CNRS, the CEA and the Institut Mines-Télécom (IMT) are co-leading the '5G' acceleration PEPR to support upstream research into the development of advanced technologies for 5G and the networks of the future. Inria is involved into 8 research projects over the 10 supported by the program, with the participation of 11 teams of the theme "Networks and Telecommunications" and the coordination of the PC9-Founds.
  - Agora is contributor to the following PCs: PC2 NAI (Networks Architecture and Infrastructure and Networks, Cloud, and Sensing Convergence), PC6 FITNESS (From IoT breakthroughs to Network Enhanced ServiceS), and PC7 JEN (Just Enough Network).
- Project acronym: PEPR MOBIDEC

  - Project title: Digitalisation et Décarbonation de Mobilités
  - Duration: 2023 - 2030
  - Budget: 20M€
  - Coordinators: IFP Energies nouvelles (IFPEN), Université Gustave Eiffel
  - Inria participants: Agora, COATI, FUN, TRiBE
  - Summary: The goal of PEPR MOBIDEC is to develop sober, sovereign and resilient mobility, by placing the collection, analysis and processing of mobility data at the heart of its work. It aims to understand and anticipate the mobility behaviours of goods and people, to facilitate the interpretation and processing of data, and to offer decision-making tools to simulate the impact of public policies in advance, or to assess the perJnence of a new transport offer.
  - Agora is contributor to the following PC: PC3 MOB-SCI-DATA FACTORY

- Project acronym: PEPR CLOUD
  - Project title: Development of advanced cloud technologies
  - Duration: 2023-2030
  - Budget: 56M€
  - Coordinators: CEA, Inria
  - Inria participants: at least Agora :)
  - Summary: The aim is to support the development of French Cloud players in four key areas: developing innovative Cloud and Edge Computing solutions, creating shared data spaces, training and retraining human resources, and supporting research, innovation and technology maturation.
  - Agora is contributor of the following PC: PC8 SILECS (Super Infrastructure for Large-Scale Experimental Computer Science).

10.4 GDR CNRS RSD

- Communication networks, working groups of GDR ASR/RSD, CNRS (ongoing participation since 2006): Oana Iova is in charge of the mentorship actions (e.g., seminars) for the GDR RSD. Razvan Stanica is member of the scientific council of the GDR RSD. Fabrice Valois is member of the steering committee of the GDR RSD and also co-chair of the Networking axis of the GDR RSD. All the members of Agora are regular participants to the GDR RSD.

10.5 Regional initiatives

INSA-Lyon - ATMO-Aura Chair, L'air : un enjeu de santé et d'innovation, une mobilisation citoyenne (2020-Present). Walid Bechkit and Hervé Rivano are deeply involved in this Chair proposal and its animation.

11 Dissemination

Participants: Hervé Rivano, Juan A. Fraire, Walid Bechkit, Oana Iova, Razvan Stanica, Fabrice Valois, Ahmed Boubrima.

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

Member of the organizing committees

- Juan A. Fraire was in the organizing committee of the STINT (Space-Terrestrial Internetworking) Workshop, Mountain View, California, USA, 2024.
- Juan A. Fraire was involved in the organization of Non-Terrestrial Networks (NTN) Days in Grenoble in October 2024 at the Grenoble Alpes University.
- Razvan Stanica was Publications Chair for the conference 6GNet 2024.

11.1.2 Scientific events: selection

Member of the conference program committees

- Oana Iova was member in the TPC of : ACM IPSN 2024, EWSN 2024, IEEE WiMob 2024, and Cores 2024.
- Razvan Stanica was member in the TPC of : IEEE SECON 2024, IEEE WCNC 2024, IEEE WiMob 2024, IFIP Networking 2024, and WONS 2024.
- Fabrice Valois was member in the TPC of : IEEE ICC 2024, IEEE WCNC 2024, IEEE Globecom 2024, IEEE ISCC 2024, IEEE PIMRC 2024, IEEE WiMob 2024, and IEEE Infocom NetRobiCS Worshop 2024.
- Juan A. Fraire was member in the TPC of : IEEE Globecom 2024, IEEE ICC 2024, IEEE MeditCom 2024, IEEE WiSEE 2024, and IEEE SMC-IT 2024.

11.1.3 Invited talks

- Juan A. Fraire gave a keynote seminar "On the Role of AI in Satellite Mega-Constellations" at IEEE ICC Workshop on Satellite Mega-Constellations in the 6G Era, Denver, CO, USA, June 2024.
- Juan A. Fraire was invited by Juan Clemente from the Universidad Complutense and NATO to present the IMPACT project at the NATO Workshop, Madrid, 2024.
- Walid Bechkit gave a keynote seminar "Wireless Sensor Networks for Environmental Monitoring: From Measurement to Data Collection and Analysis — Bridging Theory with Practice" at the L2TI lab. scientific day, Paris, 2024.

11.1.4 Leadership within the scientific community

- Juan A. Fraire is a member of the board of the Interplanetary Networking Special Interest Group (IPNSIG).
- Juan A. Fraire is an academic stakeholder of the Dynamic Coalition on the Interplanetary Internet in the Internet Governance Forum (IGF).
- Oana Iova is in charge of the mentorship actions (e.g., seminars) for the GDR RSD (since 2021).
- Hervé Rivano is a member of the scientific council of France Ville Durable since 2021.
- Hervé Rivano is a member of the steering committee of the Science Po Lyon chaire "Transformation de l'action publique", since 2019.
- Razvan Stanica is a member of the scientific council of the GDR RSD (since 2022).
- Fabrice Valois is the chair of the scientific committee of the Labex IMU (since 2022).
- Fabrice Valois is a member of the steering committee of the GDR RSD (since 2022).

- Fabrice Valois is a co-chair of the Networking axis of the GDR RSD (since 2022).
- Fabrice Valois is a member of the steering committee of the LPWAN Days (since 2023).
- Fabrice Valois is a member of the COURSE, which is in charge of identifying and defining use cases, applications, and scenarios for the national testbed SLICE-FR (networking and cloud), since 2023.

11.1.5 Scientific expertise

- Walid Bechkit was member of the recruitment committee for ATER positions (CITI research laboratory, Telecom department, INSA Lyon) in 2024.
- Walid Bechkit is part of the scientific board of the "Conseil Économique, Social et Environnemental Régional - CESER - ATMO-AURA" since 2022.
- Oana Iova was member of the following recruitment committees:
  - Faculty researcher CRCN, INRAE, 2024
  - Assistant professor position, INSA Lyon, 2024.
- Hervé Rivano was member of the following recruitment committees:
  - Assistant professor position, ENTPE, 2024.
- Razvan Stanica was part of the Hcérés committee for the DAVID laboratory, 2024.
- Fabrice Valois was member of the following assistant professor committees:
  - Assistant professor position, IMT Atlantique, 2024.

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

Bachelor and License

- Walid Bechkit, Introduction to wireless sensor networks, 70h, L2, INSA Lyon.
- Oana Iova, Introduction to research, 20h, L3, Telecom. Dpt. INSA Lyon.
- Oana Iova, IP Networks, 12h, L3, Telecom. Dpt. INSA Lyon.
- Oana Iova, Computer Networks - Advanced notions, 20h, L3, INSA Lyon.
- Oana Iova, Network Automation Project in GNS3, 20h, L3, Telecom. Dpt. 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.
- Razvan Stanica, Internet Metrology, 16h, L3, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, IP Networks, 24h, L3, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Medium Access Control, 38h, L3, Telecom. Dpt. INSA Lyon.
- Ahmed Boubrima, IP Networks, 24h, L3, Telecom. Dpt. INSA Lyon.
- Ahmed Boubrima, Medium Access Control, 20h, L3, Telecom. Dpt. INSA Lyon.

Master

- Walid Bechkit, Performance evaluation of telecom networks, 30h, M1, Telecom. Dpt. INSA Lyon.
- Walid Bechkit, Wireless networks: architecture and security, 60h, M2, Telecom. Dpt. INSA Lyon.
- Walid Bechkit, Network acces control, 6h, M2, Telecom. Dpt. INSA Lyon.
- Walid Bechkit, Wireless networks: architecture and security, 30h, Master Cyber Security, INSA Lyon.
- Walid Bechkit, Network acces control, 6h, M2, Master Cyber Security, INSA Lyon.
- Juan A. Fraire, Satellite Communications and Navigation, 32h, M2, Telecom. Dpt. INSA Lyon.
- Juan A. Fraire, Space Informatics, 32h, M2, Saarland University (Germany).
- Juan A. Fraire, Mission Analysis, 12h, M1/M2, Argentinian Space Agency.
- Oana Iova, Network routing protocols, 66h, M1, Telecom. Dpt. INSA Lyon.
- Oana Iova, Long range networks, 10h , M2, Telecom. Dpt. INSA Lyon.
- Oana Iova, Projet Innovant, 30h, 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, Content delivery networks (routing protocols), 10h, M2, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Cellular networks, 18h, M1, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Private cellular networks, 28h, M1, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Performance evaluation of network, 32h, 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 vice-dean of the International Affairs of 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 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.
- Fabrice Valois is in charge of the international affairs of the Telecommunications Department since December 2023.

11.2.2 Supervision

- Masters:
  - Marcos Antonio Rojas Mardones, Experiments on LR-FHSS in an urban scenarios, from 04/2024 until 10/2024. Advisors: Oana Iova and Juan A. Fraire.
  - Moez Zarrouk, Performance evaluation of low-cost air pollution sensors, from 03/2024 until 09/2024, Advisors: Ahmed Boubrima, Hervé Rivano.
  - Mohammed Tiouti, Victim localization in rescue missions using drone networks, from 03/2024 until 09/2024, Advisors: Ahmed Boubrima, Hervé Rivano.
- PhD thesis (defended in 2024):
  - Lucas Magnana, De la ville intelligente à la ville prédictive, application aux modes de transport actifs, defended in 02/2024. Advisors: Nicolas Chiabaut (LICIT, ENTPE / IFSTTAR), Hervé Rivano.
  - Kawtar Lasri, Data collection and distributed spatial coordination in LPWAN networks, defended in 02/2024. Advisors: Oana Iova, Yann Ben Maissa (INPT Rabat, Morocco), Fabrice Valois.
  - Camille Moriot, DDos Attacks and their impacts on the Internet Architecture, defended in 09/2024. Advisors: François Lesueur (IRISA / UBS) Nicolas Stouls (CITI), Fabrice Valois.
  - Gwendoline Hochet Derevianckine,Faisabilité et performances d'un réseau LoRaWAN dans la bande ISM 2.4GHz, defended in 12/2024. Advisors: Alexandre Guitton (UCA), Oana Iova, Baozhu Ning (Semtech), Fabrice Valois.
- PhD thesis (started in 2024):
  - Alexander Choquenaira Florez, Big Data and Machine Learning Methods for Direct-to-Satellite Internet of Things, since 03/2024, Advisors: Juan A. Fraire and Hervé Rivano.
  - Audrey Nageotte, Root cause analysis in network anomaly detection, since 11/2024, Advisor: Razvan Stanica.
  - Guillermo Benito Calvino, Victim localization in rescue missions using drone networks, since 11/2024. Advisors: Ahmed Boubrima, Hervé Rivano.
- PhD thesis (ongoing during 2024):
  - Mohammed Sami Assenine, Apprentissage par renforcement pour l'optimisation de la mobilité dans les réseaux de capteurs sans fil : application au suivi de la pollution, since 10/2022. Advisors: Walid Bechkit, Hervé Rivano.
  - Youssef Badra, Measuring and modelling energy consumption in cellular networks, since 03/2022. Advisor: Razvan Stanica.
  - Anais Boumendil, Vers des modèles d'apprentissage automatique à faible consommation d'énergie pour les plateformes à ressources limitées, since 11/2022. Advisor: Walid Bechkit Pierre-Edouard Portier (LIRIS / INSA Lyon), Frédéric Le Mouël (CITI / INSA Lyon), Malcolm Egan (CITI / INSA Lyon).
  - Diego Maldonado Munoz, Adaptations, Optimizations, and Learning Approaches for Direct-to-Satellite Internet of Things, since 12/2022. Adivsors: Juan A. Fraire, Hervé Rivano.
  - Sekinat Yahya, Energy consumption optimisation in cellular networks, since 02/2022. Advisor: Razvan Stanica.
  - Zhiyi Zhang, Deployment and management of mobile base stations, since 10/2021. Advisors: Razvan Stanica, Fabrice Valois.
  - Carlos Fernandez Hernandez , Optimization of the downlink in LoRaWAN, since 01/2023. Advisors: Oana Iova, Fabrice Valois.
  - Geymerson Ramos, 5G networks mobile data analytics, since 05/2023. Advisor: Razvan Stanica.

11.2.3 Juries

- Hervé Rivano was the jury president of the following PhD defenses:
  - N. Shakoori, Optimal Dynamic Routing for Urban Networks : a Mathematical Programming Approach with Complete Integration of Traffic Flow Features, INSA LYON / ENTPE, 2024.
  - S. Pelissier, Privacy-preserving communications for the IoT, INSA Lyon, 2024.
- Hervé Rivano was a jury member of the following HDR defenses:
  - W. Bechkit, Contributions to Wireless Sensor Networks for Air Quality Monitoring, CITI/Agora, INSA Lyon, 2024.
  - C. Caillouet, modelisation et Optimisation des réeseaux sans fil : De l'usage des drones aux réeseaux LoRaWAN, I3S/Coati, Université de Nice Sophia Antipolis, 2024.
- Razvan Stanica was a jury member of the following PhD defense:
  - E. Akopyan, Fiabilité de l'architecture réseau des systèmes spatiaux distribués sur essaims de nanosatellites, Université de Toulouse, 2024.
- Fabrice valois was the jury president of the following PhD defense:
  - J. Koteich, Novel Context Aware Opportunistic Data Forwarding Strategy in Wireless Networks, Inria / Université de Lille, 2024.
- Fabrice Valois was a jury member (rapporteur) of the following HDR defense:
  - R. Kacimi, De l'Internet des objets aux réseaux véhiculaires : techniques d'accès, dissémination et délestage de données. Université Paul Sabatier, IRIT, 2024.

11.3 Popularization

- Walid Bechkit hosted 5 middle and high school trainees during short internships lasting one to two weeks each, developing tailored curricula for their training.
- Juan A. Fraire contributed with the 100-year vision video for popularization of the Interplanetary Internet (link to video, link to IPNSIG posting).
- Hervé Rivano was invited to design and participate to a round table "Le numérique peut-il vraiment accompagner la transition des territoires ?" lors de "Numérique en Commun 2024", with département de la Savoie, CEREMA, IGN, and Régie de Gestion des Données Savoie Mont Blanc (09/2024).
- Hervé Rivano was invited to the Radio Anthropocène show "Intelligences artificielles, et villes démocratiques, un amour impossible ?" (podcast) with Nathalie Vernus-Prost (Lyon Metropolis), and David Leicher-Auchapt, general data officer of Lyon Metropolis (05/2024).
- Hervé Rivano gave a Masterclass "Villes intelligentes : enjeux techniques, sociaux et politiques", during the festival A l'Ecole de l'Anthropocène (03/2024).

12 Scientific production

12.1 Major publications

[1] M. S. Assenine, W. Bechkit and H. Rivano. 'Informative and Communication-Efficient Multi-Agent Path Planning for Pollution Plume Monitoring'. In: WoWMoM 2024 - 25th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks. Perth, Australia, 4th June 2024. URL: https://inria.hal.science/hal-04604336 (cit. on p. 9).

[2] W. Bernardoni, R. Kassouf-Short, R. Cardona, B. Heller, J. Curry, D. Spivak and J. A. Fraire. 'Network Storage Analysis via Semiring Geometry'. In: 2024 IEEE Aerospace Conference. Big Sky, France: IEEE, 2nd Mar. 2024, pp. 1–19. DOI: 10.1109/AERO58975.2024.10521207. URL: https://hal.science/hal-04711322 (cit. on p. 10).

[3] A. Boubrima, W. Bechkit, H. Rivano and L. Soulhac. 'UrMapSens: Joint Mapping-Sensing Design of Wireless Sensor Networks for Urban Environmental Monitoring'. In: *IEEE Sensors Journal* (2024), pp. 1–13. DOI: 10.1109/JSEN.2024.3450898. URL: https://inria.hal.science/hal-04707912. In press (cit. on p. 9).

[4] A. Boumendil, W. Bechkit and K. Benatchba. 'On-Device Deep Learning: Survey on Techniques Improving Energy Efficiency of DNNs'. In: *IEEE Transactions on Neural Networks and Learning Systems* (2024). DOI: 10.1109/TNNLS.2024.3430028. URL: https://inria.hal.science/hal-04662357 (cit. on p. 13).

[5] C. Caillouet, A. Guitton, O. Iova and F. Valois. 'The Impact of Downlink Scheduling Policy on the Capacity of LoRaWAN'. In: GLOBECOM 2024 - IEEE Global Communications Conference. Cape Town / Le Cap, South Africa, 8th Dec. 2024. URL: https://hal.science/hal-04694132 (cit. on p. 11).

[6] G. M. Capez, M. A. Cáceres, R. Armellin, C. P. Bridges, J. A. Fraire, S. Frey and R. Garello. 'On the Use of Mega Constellation Services in Space: Integrating LEO Platforms into 6G Non-Terrestrial Networks'. In: *IEEE Journal on Selected Areas in Communications* (2024), pp. 1–1. DOI: 10.1109/JSAC.2024.3459078. URL: https://hal.science/hal-04711308 (cit. on p. 10).

[7] P. R. d'Argenio, J. A. Fraire, A. Hartmanns and F. Raverta. 'Comparing Statistical, Analytical, and Learning-Based Routing Approaches for Delay-Tolerant Networks'. In: *ACM Transactions on Modeling and Computer Simulation* (25th May 2024). DOI: 10.1145/3665927. URL: https://hal.science/hal-04711324 (cit. on p. 12).

[8] M. A. Fekih, W. Bechkit and H. Rivano. 'Route Selection in Low-cost Participatory Mobile Sensing of Air Quality'. In: IEEE Consumer Communications & Networking Conference. Las Vegas (USA), United States, Jan. 2024. URL: https://hal.science/hal-04376972 (cit. on p. 12).

[9] J. A. Fraire, J. A. Ruiz-De-Azua and E. Fernandez-Nino. 'Towards Optimal Placement of Free-Space Optical Terminal on the Spacecraft Body'. In: *IEEE Transactions on Aerospace and Electronic Systems* (2024), pp. 1–15. DOI: 10.1109/TAES.2024.3435176. URL: https://hal.science/hal-04711310 (cit. on p. 10).

[10] K. Lasri, Y. Ben Maissa, O. Iova and F. Valois. 'Traffic control strategies for LPWAN in multigateway environments'. In: The 20th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob). Paris, France, 21st Oct. 2024. URL: https://hal.science/hal-04693666 (cit. on p. 11).

[11] O. Ledesma, P. Lamo and J. A. Fraire. 'Trends in LPWAN Technologies for LEO Satellite Constellations in the NewSpace Context'. In: *Electronics* 13.3 (31st Jan. 2024), p. 579. DOI: 10.3390/electronics13030579. URL: https://hal.science/hal-04711323 (cit. on p. 12).

[12] L. Magnana, H. Rivano and N. Chiabaut. 'A deep reinforcement solution to help reduce the cost in waiting time of securing a traffic light for cyclists.' In: *Journal of Cycling and Micromobility Research* (Dec. 2024). DOI: 10.1016/j.jcmr.2024.100046. URL: https://inria.hal.science/hal-04300866 (cit. on p. 13).

[13] N. Morand, A. Boubrima, W. Bechkit and Z. Shaikhanov. 'HeatPulse: Thermal Attacks on Air Pollution Sensors'. In: *The 3rd Workshop on Security and Privacy in Connected Embedded Systems (SPICES @ EWSN 2024)*. The 3rd Workshop on Security and Privacy in Connected Embedded Systems (SPICES @ EWSN 2024). The 3rd Workshop on Security and Privacy in Connected Embedded Systems (SPICES @ EWSN 2024). Abu Dhabi, United Arab Emirates, 10th Dec. 2024. URL: https://inria.hal.science/hal-04708004 (cit. on pp. 6, 13).

[14] M. Rady, O. Iova, H. Rivano, A. Deligianni and L. Drikos. 'How does Wi-Fi 6 fare? An industrial outdoor robotic scenario'. In: *Ad Hoc Networks* (Jan. 2024), p. 103418. DOI: 10.1016/j.adhoc.2024.103418. URL: https://inria.hal.science/hal-04412477 (cit. on p. 10).

[15] G. Stock, J. A. Fraire, S. Henn, H. Hermanns and A. Schmidt. 'A Stability-First Approach to Running TCP Over Starlink'. In: 2024 IEEE International Conference on Communications Workshops (ICC Workshops). Denver, France: IEEE, 9th June 2024, pp. 1708–1713. DOI: 10.1109/ICCWorkshops59551.2024.10615714. URL: https://hal.science/hal-04711313 (cit. on p. 12).

12.2 Publications of the year

International journals

[16] J. A. Fraire, S. Henn, G. Stock, R. Ohs, H. Hermanns, F. Walter, L. van Broock, G. Ruffini, F. Machado, P. Serratti and J. Relloso. 'Quantitative analysis of segmented satellite network architectures: A maritime surveillance case study'. In: *Computer Networks* 255 (Feb. 2024), p. 110874. DOI: 10.1016/j.comnet.2024.110874. URL: https://hal.science/hal-04762695.

[17] A. Furno, A. F. Zanella, R. Stanica and M. Fiore. 'Spatial and Temporal Exploratory Factor Analysis of Urban Mobile Data Traffic'. In: *Data Science for Transportation* 6.4 (15th Mar. 2024). DOI: 10.1007/s42421-024-00089-y. URL: https://inria.hal.science/hal-04813320.

[18] A. Hameed, J. Violos, N. Santi, A. Leivadeas and N. Mitton. 'FeD-TST: Federated Temporal Sparse Transformers for QoS prediction in Dynamic IoT Networks'. In: *IEEE Transactions on Network and Service Management* (8th Nov. 2024). DOI: 10.1109/TNSM.2024.3493758. URL: https://hal.science/hal-04774861.

[19] O. Ledesma, P. Lamo, J. A. Fraire, M. Ruiz and M. A. Sánchez. 'Architectural Framework and Feasibility of Internet of Things-Driven Mars Exploration via Satellite Constellations'. In: *Electronics* 13.7 (30th Mar. 2024), p. 1289. DOI: 10.3390/electronics13071289. URL: https://hal.science/hal-04711319.

[20] R. Ortigueira, S. Montejo-Sánchez, S. Henn, J. Fraire and S. Céspedes. 'Satellite Visibility Prediction for Constrained Devices in Direct-to-Satellite IoT Systems'. In: *IEEE Sensors Journal* 24.16 (15th Aug. 2024), pp. 26630–26644. DOI: 10.1109/JSEN.2024.3418728. URL: https://hal.science/hal-04711312.

[21] W. Xiao, N. El Rachkidy and A. Guitton. 'Improving collision resolution of superposed LoRa signals using a Slot-Free Decoding Scheme'. In: *Ad Hoc Networks* 157 (Apr. 2024), p. 103442. DOI: 10.1016/j.adhoc.2024.103442. URL: https://uca.hal.science/hal-04498037.

International peer-reviewed conferences

[22] A. Boubrima, Z. Shaikhanov and E. Knightly. 'Toward Accurate Environmental Mapping using Balloon-based UAVs'. In: IEEE Consumer Communications & Networking Conference. Vol. IEEE CCNC 2024. IEEE CCNC 2024. Las vegas, NV (US), United States, 9th Jan. 2024, pp. 1–8. URL: https://inria.hal.science/hal-04442942.

[23] R. L. Bull, R. M. Dudukovich, J. A. Fraire, N. Kortas, R. Kassouf-Short, A. Smith and E. Schweinsberg. 'Network Emulation Testbed Capabilities for Prototyping Space DTN Software and Protocols'. In: IEEE INFOCOM 2024 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS). Vancouver, France: IEEE, 20th May 2024, pp. 1–8. DOI: 10.1109/INFOCOMWKSHPS61880.2024.10620672. URL: https://hal.science/hal-04711318.

[24] G. O. Djuikom Foka, S. Rabenjamina, R. Stanica and D. Naboulsi. 'Human Presence Hotspot Extraction: A Mobile Network Data-Oriented Analysis'. In: NetMob 2024 - International Conference on the Analysis of Mobile Phone Datasets. Washinghton DC, United States, 7th Oct. 2024. URL: https://inria.hal.science/hal-04741769.

[25] S. I. Montoya, D. Maldonado, J. A. Fraire and S. Céspedes. 'On the Role of Delay Tolerant Networks and Contact Graph Routing in Direct-to-Satellite IoT'. In: 2024 IEEE 10th International Conference on Space Mission Challenges for Information Technology (SMC-IT). Mountain View, France: IEEE, 15th July 2024, pp. 151–160. DOI: 10.1109/SMC-IT61443.2024.00024. URL: https://inria.hal.science/hal-04884425.

[26] H. B. Pasandi, J. A. Fraire, S. Ratnasamy and H. Rivano. 'A Survey on Direct-to-Device Satellite Communications: Advances, Challenges, and Prospects'. In: LEO-NET '24: Proceedings of the 2nd International Workshop on LEO Networking and Communication. Washington DC USA, United States: ACM, 18th Nov. 2024, pp. 7–12. DOI: 10.1145/3697253.3697265. URL: https://inria.hal.science/hal-04791559.

[27] G. S. Ramos, R. Stanica, R. G. Pinheiro and A. L. Aquino. 'Optimizing Vehicular Users Association in Urban Mobile Networks'. In: WCNC 2024 - IEEE Wireless Communications and Networking Conference. Dubai, United Arab Emirates: IEEE, 3rd July 2024, pp. 1–6. DOI: 10.1109/WCNC57260.2024.10570709. URL: https://inria.hal.science/hal-04642478.

[28] C. Rojas, J. A. Fraire, F. Patrone and M. Marchese. 'Advanced Constellation Emulation and Synthetic Datasets Generation for Non-Terrestrial Networks'. In: 2024 IEEE International Mediterranean Conference on Communications and Networking (MeditCom). Madrid, France: IEEE, 8th July 2024, pp. 37–43. DOI: 10.1109/MeditCom61057.2024.10621248. URL: https://hal.science/hal-04711311.

[29] S. Yahya and R. Stanica. 'Assessing the Energy Impact of Cell Switch Off at an Urban Scale'. In: STWiMob 2024 - 17th International Workshop on Selected Topics in Wireless and Mobile Computing. Paris, France, 21st Oct. 2024. URL: https://hal.science/hal-04767323.

National peer-reviewed Conferences

[30] Y. Busnel and H. Rivano. 'FTM-Broadcast : Détermination efficace de coordonnées sur un réseau à grande échelle'. In: *CoRes 2024: 9èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication*. CoRes 2024: 9èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Saint-Briac-sur-Mer, France, 27th May 2024. URL: https://hal.science/hal-04569538.

[31] G. H. Derévianckine, A. Guitton, O. Iova, B. Ning and F. Valois. 'Mais qui se cache ici ?' In: *CoRes 2024: 9èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication*. CoRes 2024 - 9èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Saint-Briac-sur-Mer, France, 27th May 2024. URL: https://hal.science/hal-04567441.

[32] Z. Zhang, R. Stanica and F. Valois. 'De l'intérêt d'utiliser des stations de base mobiles pour les premiers secours !' In: *CoRes 2024: 9èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication*. CoRes 2024: 9èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Saint-Briac-sur-Mer, France, 27th May 2024. URL: https://hal.science/hal-04560566.

Conferences without proceedings

[33] A. Y. Choquenaira-Florez. 'On the role of ML in Satellite IoT: A survey of techniques, challenges and future directions'. In: NTN Days 2024. Grenoble, France, 18th Oct. 2024. URL: https://hal.science/hal-04953754.

[34] F. Dobler, M. R. Mardones, O. Alphand, D. Donsez, J. A. Fraire, M. Heusse and O. Iova. 'In-vivo experiments on LR-FHSS modulation'. In: Journées LPWAN 2024. Pau (FRA), France, 8th July 2024. URL: https://hal.science/hal-04777306.

[35] C. Fernandez Hernandez, O. Iova and F. Valois. 'Downlink Scheduling in LoRaWAN: ChirpStack vs The Things Stack'. In: IEEE Latin-American Conference on Communications. Medellin, Colombia, 6th Nov. 2024. URL: https://inria.hal.science/hal-04801287 (cit. on p. 11).

[36] A. Le Bihan, J. A. A. Fraire and F. Flentge. 'Enhanced Custody Transfer and Status Reporting for Delay Tolerant Space Networks'. In: NTN Days 2024. Grenoble, France, 17th Oct. 2024. URL: https://hal.science/hal-04774786.

[37] A. Schmidt, H. Hermanns, J. A. A. Fraire, R. Ohs, G. Stock and S. M. Henn. ‘Be The (Route) Change’. In: NTN Days 2024. Grenoble, France, 17th Oct. 2024. URL: https://hal.science/hal-04953827.

Scientific book chapters

[38] C. E. Budde, P. D’argenio, J. A. A. Fraire, A. Hartmanns and Z. Zhang. ‘Modest Models and Tools for Real Stochastic Timed Systems’. In: *Principles of Verification: Cycling the Probabilistic Landscape*. Vol. 15261. Lecture Notes in Computer Science. Springer Nature Switzerland, 13th Nov. 2024, pp. 115–142. DOI: 10.1007/978-3-031-75775-4_6. URL: https://hal.science/hal-04825963.

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

[39] *Proceedings of the 3rd International Conference on 6G Networking (6GNet 2024)*. 2024 3rd International Conference on 6G Networking (6GNet). IEEE, Dec. 2024. DOI: 10.1109/6GNet63182.2024. URL: https://hal.science/hal-04816232.

Doctoral dissertations and habilitation theses

[40] W. Bechkit. ‘Contributions to Wireless Sensor Networks for Air Quality Monitoring’. INSA Lyon, 24th May 2024. URL: https://hal.science/tel-04777652.

[41] G. H. Derévianckine. ‘Feasibility and Performance of a LoRa 2.4 GHz Network’. Insa Lyon, 17th Dec. 2024. URL: https://hal.science/tel-04858023.

[42] L. Magnana. ‘Learning algorithms for urban cycling : Implicit models and dynamic infrastructure’. INSA Lyon, 14th Feb. 2024. URL: https://hal.science/tel-04487508.

[43] C. Moriot. ‘Methodology for socio-organizational characterization of IP addresses applied to security’. INSA de Lyon, 24th Sept. 2024. URL: https://inria.hal.science/tel-04819452.

Reports & preprints

[44] G. H. Derévianckine, A. Guitton, O. Iova, B. Ning and F. Valois. *Hate or Love in the 2.4 GHz ISM band: The Story of LoRa® and IEEE 802.11g*. 4th Dec. 2024. URL: https://hal.science/hal-04815177.

[45] S. M. Henn, J. A. A. Fraire, N. Accettura, S. Céspedes and H. Hermanns. *Multi-Gateway LoRaWAN Throughput Modeling in Direct-to-Satellite IoT Constellations*. 22nd Oct. 2024. URL: https://laas.hal.science/hal-04749023.

[46] I. Mokhtari, W. Bechkit, M. S. Assenine and H. Rivano. *Navigating the Smog: A Cooperative Multi-Agent RL for Accurate Air Pollution Mapping through Data Assimilation*. 17th July 2024. DOI: 10.48550/arXiv.2407.12539. URL: https://hal.science/hal-04777681.