RESEARCH CENTRE

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2023 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

Inria

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1 Team members, visitors, external collaborators

Research Scientists

- Ahmed Boubrima [INRIA, ISFP, from Oct 2023]
- Juan Andres Fraire [INRIA, ISFP]

Faculty Members

- Hervé Rivano [Team leader, INSA LYON, Professor, HDR]
- Walid Bechkit [INSA LYON, Associate Professor]
- Alexandre Guitton [Université Clermont Auvergne, Professor, until Aug 2023, Délégation Inria, HDR]
- Oana Iova [INSA LYON, Associate Professor]
- Razvan Stanica [INSA LYON, Associate Professor, HDR]
- Fabrice Valois [INSA LYON, Professor, HDR]

Post-Doctoral Fellows

- Ahmed Boubrima [INSA LYON, Post-Doctoral Fellow, until Sep 2023]
- Mina Rady Abdelshahid Mouawad [INSAVALOR, until Sep 2023]

PhD Students

- Mohamed Sami Assenine [INSA LYON]
- Youssef Badra [INSA LYON]
- Anais Boumendil [INSA LYON]
- Geymerson Dos Santos Ramos [INRIA, from May 2023]
- Carlos Fernandez Hernadez [INSA LYON]
- Gwendoline Hochet Derevianckine [Semtech]
- Kawtar Lasri [INPT Rabat, Morocco]
- Lucas Magnana [INRIA, from Oct 2023]
- Lucas Magnana [UDL, until Sep 2023]
- Diego Maldonado Munoz [INSA LYON]
- Ichrak Mokhtari [UNIV LYON I, ATER, until Sep 2023]
- Camille Moriot [Rectorat (Académie de Lyon), from Sep 2023]
- Camille Moriot [INSA LYON, until Aug 2023]
- Sekinat Yahya [INSA LYON]
- Zhiyi Zhang [INSA LYON]

Technical Staff

- Thibault Bellanger [INSA LYON, Engineer]
- Solohaja Rabenjamina [INRIA, Engineer]
- Alexandros Sidiras Galante [INSA LYON, Engineer]

Interns and Apprentices

- Vincent Fromont [INSA LYON, from Jun 2023 until Jul 2023]
- Pablo Ilabaca Parra [INRIA, Intern, from Sep 2023]
- Sebastian Montoya Tapia [INRIA, Intern, from Mar 2023 until Jun 2023]
- Xinhua Wu [INRIA, Intern, from May 2023 until Aug 2023]

Administrative Assistants

- Fadila Naili [INSA LYON]
- Noemie Rodrigues [INRIA, from Nov 2023]
- Salwa Selmi [INRIA, until Sep 2023]

External Collaborator

- Alexis Duque [RTONE]

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 this data, their processing into information, and their redistribution. The networking infrastructure therefore plays 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 as 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 organized in three axes. All our works share the same general methodology that aims at combining:

- modeling to get insights on average and extreme behaviors,
- simulation to investigate large scale networks and asymptotic behavior,
- experimentation to get validation 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 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, 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 use cases: *i)* Static wireless low-cost sensor networks for air quality monitoring while designing efficient deployment and scheduling models,

[1] Project presentation.

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, and *iii)* drone fleet for monitoring pollution plumes while proposing adapted spatio-temporal prediction architectures and new anticipatory path planning approaches.

Our work on this side combines theory and real-word experiments where we design, set up and validate low-cost sensor based platforms. 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.

6 Highlights of the year

6.1 Awards

- Walid Bechkit holds the PEDR (2021-2025).
- Mohamed Anis Fekih received the best thesis award of INSA Lyon (Environment topic), 2023. His PhD thesis about *Low-cost Wireless Sensor Networks in Participatory Air Quality Monitoring* was defensed in February 2022.
- The paper [37] was runner-up for the best paper award at International Conference on Embedded Wireless Systems and Networks (EWSN), Rende, Italy, September 2023.
- The paper [42] was runner-up for the best paper award at Rencontres Francophones sur la Conception de protocoles, l'évaluation de performances et l'expérimentation de Réseaux de communication (CoRes), Cargese, France, May 2023.
- Juan A. Fraire had 7+ papers cited in the highlighted selection of IEEE ComSoc in the topic Best Readings in Satellite Mega Constellation, July 2023.
- Oana Iova holds the RIPEC-C3 (2022-2025).
- Oana Iova had 1 paper cited in the highlighted selection of IEEE ComSoc in the topic Best Readings in Satellite Mega Constellation, July 2023.
- Hervé Rivano holds the PEDR (2021-2025).
- Razvan Stanica holds the PEDR (2020-2024).
- Fabrice Valois had 1 paper cited in the highlighted selection of IEEE ComSoc in the topic Best Readings in Satellite Mega Constellation, July 2023.

6.2 PhD Defense

- PhD defense of Ichrak Mokhtari about *Spatio-temporal data analysis for dynamic phenomenon monitoring using mobile sensors*, INSA Lyon, June 2023.
- PhD defense of Mihai Popescu about *Connectivity constrained mobility in fleets of robots*, INSA Lyon, July 2023.
- PhD defense of Solohaja Rabenjamina about *Gestion de la Mobilité Urbaine et dans le Réseau Mobile à partir de Données de Téléphonie*, INSA Lyon, September 2023.

6.3 Others highlights

- Ahmed Boubrima joins Agora as a Starting Faculty Position, since Septembre 2023.
- Thanks to Oana Iova, Agora is leader in the new MOU between NII Japan, INSA Lyon, and Inria.

7 New software, platforms, open data

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

Participants: Walid Bechkit, Hervé Rivano

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

Participants: Walid Bechkit, Hervé Rivano

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

Participants: Oana Iova, Hervé Rivano

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

Participants: Fabrice Valois, Oana Iova, Hervé Rivano

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

Participants: Juan Andres Fraire, Oana Iova, Fabrice Valois

7.2 New platforms

Participants: Walid Bechkit, Oana Iova, Hervé Rivano, Alexandros Sidiras Galante, Razvan Stanica, Fabrice Valois.

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).

UTOPIA It is a platform of LoRaWAN-based low-cost sensor networks for industrial pollution monitoring sensor nodes that we designed and implemented for two projects. Sensor nodes that we designed and implemented have been used in two operational deployments: the first one was carried out on onshore industrial site for the assessment of pollutant emissions while the second one was operated on offshore site for monitoring occupational exposure to pollutants.

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 platform 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: Mohamed Sami Assenine, Walid Bechkit, Thibault Bellanger, Gwendoline Hochet Derevianckine, Ichrak Mokhtari, Juan A. Fraire, Alexandre Guitton, Oana Iova, Hervé Rivano, Razvan Stanica, Fabrice Valois.

Cooperative Deep Reinforcement Learning for Dynamic Pollution Plume Monitoring using a Drone Fleet Monitoring pollution plumes is a key issue, given the harmful effects they cause. The dynamic of these plumes, which may be important due to meteorological conditions, makes their study difficult. Real-time monitoring in order to obtain an accurate mapping of the pollution dispersion is helpful and valuable to mitigate risks. We consider a fleet of cooperative drones carrying pollution sensors and operating in order to assess a pollution plume [17]. The latter is assumed to follow a Gaussian Process (GP) with varying parameters. For this use case, we propose an efficient approach to characterize spatially and temporarily the plume while optimizing the path planning of drones. In our approach, drones are guided by a Deep Reinforcement Learning (DRL) model called Categorical Deep Q-Network (Categorical DQN) to maximize the plume coverage while considering budget constraints. Specifically, we develop a scalable Independent Q-Learning (IQL) scheme that shares team rewards based on each drone's deployment relevance and therefore ensures cooperation. We evaluate the performance of the plume parameter estimation as well as the maps generated by the GP regression. By testing our framework on several plume scenarios, we show that it offers good results in terms of both estimation quality and run-time efficiency.

Opportunities and challenges of LoRa 2.4 GHz Internet of Things (IoT) technologies are increasingly used in our daily life. Among these technologies, LoRa is widely used for low power IoT data collection in wide areas. LoRa typically operates in sub-GHz bands which are region-specific, and thus has limited worldwide applications. The version of LoRa developed for the 2.4 GHz ISM band has spurred recent interest in the scientific community, as it enables the use of worldwide frequency channels. However, it requires the coexistence with numerous concurrent technologies within this 2.4 GHz band, and an evolution of the MAC and networking protocols for utilizing LoRaWAN connectivity. In [19], we make the first experimental comparison between LoRa sub-GHz and LoRa 2.4 GHz in both indoor and outdoor scenarios. We show that LoRa 2.4 GHz can have a communication range of more than 2 km outdoor, and it can achieve a packet delivery rate of at least 0.98 for a distance of up to 39 meters indoor with the presence of obstacles. We also make an extensive discussion on the researches challenges that need to be addressed in order to fully take advantage of this new technology.

Polygon-based algorithms for N-satellite constellations coverage computing Satellite Coverage Analysis is a fundamental performance assessment element in remote sensing and communications services projects. Coverage is a key parameter in the constellation operation and design for missions relying on several satellites. Since coverage areas over the surface of the Earth change with time, intersecting and drifting apart, the dynamics of every satellite influence the constellation's behavior as a whole. For this reason, every configuration change, be it in the number of satellites or their relative positions, heavily impacts the cost/performance of the mission. In [20], we present a constellation-to-ground coverage analysis model that enables the rapid evaluation of areas on the surface of the Earth. The method leverages geodetic projections and an oblate Earth model and uses dynamic transformation and anti-transformation techniques combined with polygon Boolean operations. Timestamped datasets are obtained to account for the dynamics of the scenario, which can be exploited in statistical coverage analysis of the constellation. Our empirical evaluations show that this approach is superior in accuracy and computation effort compared to traditional net-point techniques. While net-point approaches are at the core of state-of-the-art commercial software, they are approximate. We show that, for finer grid granularity, the netpoint schemes converge to our polygon-based results.

Everyone can slice LoRaWAN Long-Range Wide Area Networks (LoRaWAN) enable low-power data collection over long distances, and they are thus widely used for Internet of Things applications, despite their limitations to meet some traffic requirements (e.g., reliability). To achieve the quality of service

required by the applications, service differentiation is a promising approach which can be provided by network slicing. In [27], we show that related works are either incompatible with the LoRaWAN specifications, or do not isolate traffic, or assume an a priori known and stable traffic. In this paper, we propose a lightweight approach to achieve slicing in LoRaWAN, compatible with the LoRaWAN specifications. Our approach allows to isolate traffic, to protect confirmed traffic, and to deal with unsolicited traffic.

8.2 Wireless data collection

Participants: Walid Bechkit, Juan A. Fraire, Oana Iova, Kawtar Lasri, Mina Rady Abdelshahid Mouawad, Hervé Rivano, Fabrice Valois.

Heterogeneous IoT/LTE ProSe virtual infrastructure for disaster situations Natural disasters of any kind can have catastrophic consequences for properties, infrastructure, and human lives. During large-scale calamities, two common problems are faced: (i) the partial or even complete destruction of communications infrastructure, and (ii) the difficulty of collecting accurate information on the disaster area and trapped victims. These two problems prevent a quick and accurate assessment of damage, leading to inefficient rescue operations and putting the lives of rescuers and victims in great danger. The LTE Proximity Services (ProSe) and the Internet of Things (IoT) are promising technologies that can offer an efficient solution to the aforementioned problems in the form of a rapidly established emergency network for post-disaster management. In this [15], we propose a solution for the establishment of an efficient emergency communications network for post-disaster situations based on the LTE Device-to-Device ProSe (D2D ProSe) technology and IoT devices. It facilitates fast and efficient service discovery that allows querying heterogeneous IoT devices such as health sensors, wireless cameras, smartwatches, or any other relevant devices or sensors. The goal is to allow rescuers to have access to information produced by various things available during the rescue operation. We take advantage of LTE ProSe to create a distributed D2D broadcast backbone that enables efficient and reliable message dissemination while reducing energy consumption and achieving high coverage. We then add a multipath forwarding mechanism, in which each service type of IoT device is ensured an optimal path for its traffic. Unlike previous works, we fully implemented our solution in the NS3 simulator and relied on realistic models (wireless channels, energy, and mobility) to evaluate its performance compared to previous solutions, which we also implemented on NS3. The obtained results show that our solution achieves significant improvement compared to those proposed in the literature. The entire code used in this project is freely available to the community through GitHub.

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 [25] 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. This motivates further research in multi-PHY adaptation for KPIs specific to industrial robotics.

Routing in future space-terrestrial integrated networks with SATNET-OSPF Summary Connectivity in satellite networks is governed by the spacecraft nodes' orbital dynamics together with the planet's continuous rotation where ground nodes are located. The resulting time-dynamic but predictable topology demands the design of specific distributed routing schemes. However, terrestrial Internet routing schemes' maturity, proven scalability, and efficiency shall be leveraged whenever possible to facilitate space-terrestrial integration while reducing risk and costs. In line with this reflection, we introduce SATNET-OSPF: a backward-compatible satellite extension for the widely used Open Shortest Path First routing protocol [26]. The key features of SATNET-OSPF are (a) accurate routing interface mapping to inter-satellite links and ground-to-satellite links, (b) accelerated link-up/link-down event detection adapted to space-specific wireless technologies, (c) proactive routing and forwarding mechanism to take advantage of predicted link-down events, and (d) low memory footprint topology model to efficiently propagate the forthcoming space connectivity events via constrained telecommand links. Leveraging existing IPv6 and OSPFv3 open-source stacks, we implemented SATNET-OSPF in an actual space router comprising a space-grade SPARC V8 CPU and a radiation-hardened FPGA. Furthermore, we present the details of an emulation test bench supporting various configurations with COTS terrestrial OSPF routers that enabled a realistic performance evaluation of the SATNET-OSPF. Results show that SATNET-OSPF reduced OSPFv3 routing protocol overhead by up to 31%; shortened the link event detection delay by four orders of magnitude; decreased the routing outage by a factor of 22; and ensured flooding control message generation and forwarding times, as well as routing computing time, satisfy the original requirements (192, 37, and 17 ms, respectively).

FTM-Broadcast: efficient network-wide ranging Indoor geolocation has witnessed a significant advancement through the refinement of the 802.11 FTM (Fine Timing Measurement) protocol. Accurate indoor geolocation has numerous applications in areas such as asset tracking, indoor navigation, and location-based services. The standard 802.11 FTM protocol enables accurate indoor positioning by measuring the time-of-flight between a mobile device and multiple access points (APs). It can be generalized to device-to-device ranging. However, the conventional implementation of FTM suffers from increased complexity as the number of devices grows, limiting its scalability. FTM indeed involves a point-to-point exchange of messages between each pair of devices, leading to a quadratic increase in the number of messages as the number of neighboring devices increases. In [30], a breakthrough method is proposed to enhance the FTM protocol by leveraging broadcast communication, resulting in a substantial reduction in message complexity from quadratic to linear. By taking into account broadcast in the protocol, our approach eliminates the need for multiple individual exchanges and devises a mechanism where a single message from the mobile device is broadcasted to all neighbors simultaneously. Each message exchanged will then be useful for computing every pairwise time-of-flight, by piggybacking all timestamps, making the protocol more efficient and scalable. We conducted extensive simulated experiments to evaluate the performance of the enhanced FTM protocol. The results demonstrated the effectiveness of the proposed method, showcasing a substantial reduction in computational overhead compared to the conventional FTM implementation.

Recovering Headerless Frames in LR-FHSS Long-Range Frequency Hopping Spread Spectrum (LR-FHSS) is a recent modulation designed for communications from low-power ground end-devices to Low-Earth Orbit (LEO) satellites. To decode a frame, an LR-FHSS gateway must receive at least one header replica and a large proportion of payload fragments. However, LR-FHSS headers will likely be lost when there are many concurrent transmissions. In [37], we motivate the header loss problem with an analytical model, propose a linear programming model to extract headerless frames and design a cost-effective sliding window heuristic. Simulation results show that our approach exhibits near-optimal headerless detection and extraction results while ensuring a low computational cost. The proposed method is, therefore, suitable for future LR-FHSS gateways located onboard resource-constrained LEO satellites.

Probabilistic and distributed traffic control in LPWANs Low-power, low data transmission rates, and long-range wireless networks, also known as LPWANs, are intended to work best with equipment that uses few resources and can be used for many years thanks to their long battery life operation. This type of networks can handle traffic from nearly 1,000 nodes while maintaining a duty cycle of less than 1%.

However, as the nodes become denser, the number of collisions increases and network traffic management becomes mandatory. To address this concern, we propose a Distributed and Probabilistic Traffic Control algorithm (DiPTC) [21] that allows nodes to change their traffic in response to the application requirements (e.g., acquiring K measurements over a period of time) while being agnostic to the number of nodes or the network topology. When this requirement is not achieved, the gateway sends a feedback message to all the nodes so that they may adapt their traffic. We compare the proposed solution to LoRaWAN and to a Centralized Optimal Traffic Control solution (COTraC), in simulation. Compared to LoRaWAN, our algorithm proved successful in achieving the objective while minimizing collisions and extending the network lifetime threefold.

8.3 Network data exploitation

Participants: Walid Bechkit, Anais Boumendil, Pablo Ilabaca Parra, Juan A. Fraire, Razvan Stanica
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Where Are The (Cellular) Data? New generations of cellular networks are data oriented, targeting the integration of machine learning (ML) and artificial intelligence solutions. Data availability, required to train and compare ML-based networking solutions, is therefore becoming an important topic and a significant concern. Operators do collect data, but they rarely share it because of privacy concerns. In [16], we review the few publicly available cellular datasets, which created bursts of innovation with their release. The scarcity of such data is so acute that researchers are collecting network data using their own tools, developed in-house and covered by the second part of this survey.

Multi-slice privacy-aware traffic forecasting at RAN level: a scalable federated-learning approach Next-generation mobile networks are expected to meet the requirements of a wide range of new vertical services. Hence, the network slicing concept has been introduced, in which Mobile Virtual Network Operators (MVNOs) are allowed to provide various types of services over the same physical infrastructure, owned by an Infrastructure Provider (InP). To cope with an ever-changing traffic demand, MVNOs seek to preallocate/reconfigure the resources at the base stations in an anticipatory manner, based on traffic demand predictions. Ideally, conducting per-slice traffic forecasting requires information that is likely to disclose MVNO confidential information (i.e., business strategy or private user data). To secure data ownership while conducting traffic forecasting, we propose the Federated Proximal Long Short-Term Memory (FPLSTM) framework, which allows MVNOs to train their local models with their private dataset at each base station; subsequently, an associated InP global model can be updated through the aggregation of the local models [24]. The results obtained by training the models on a realworld dataset indicate that the forecasting performance of our proposed approach is as accurate as state-of-the-art centralized solutions, while improving data privacy. To enable scalability, we further propose the Information-based Clustering FPLSTM (IC-FPLSTM) and Random Clustering FPLSTM (RC-FPLSTM) frameworks, dealing with large-scale cellular networks. These solutions demonstrate computation and communication cost efficiency significantly above the state-of-the-art.

Toward deep digital contact tracing: opportunities and challenges During the COVID-19 pandemic, digital contact tracing using mobile devices has been widely explored, with many proposals from academia and industry highlighting the benefits and challenges. Most approaches use Bluetooth low energy signals to learn and trace close contacts among users. However, tracing only these contacts can mask the risk of virus exposure in scenarios with low detection rates. To address this issue, we propose fostering users to exchange information beyond close contacts, particularly about prior “deep” contacts that may have transmitted the virus [18]. This presents new opportunities for controlling the spread of the virus, but also poses challenges that require further investigation. We provide directions for addressing these challenges based on our recent work developing a technological solution using this approach.

On data selection for the energy efficiency of neural networks: Towards a new solution based on a dynamic selectivity ratio In [28] we address the energy efficiency of neural networks training through data selection techniques. We first study the impact of a random data selection approach that renews the selected examples periodically during training. We find that random selection should be considered as a serious option as it allows high energy gains with small accuracy losses. Unexpectedly, it even outperforms a more elaborate approach in some cases. Our study of the random approach conducted us to observe that low selectivity ratios allow important energy savings, but also cause a significant accuracy decrease. To mitigate the effect of such ratios on the prediction quality, we propose to use a dynamic selectivity ratio with a decreasing schedule, that can be integrated to any selection approach. Our first results show that using such a schedule provides around 60% energy gains on the CIFAR-10 dataset with less than 1% accuracy decrease. It also improves the convergence when compared to a fixed ratio.

9 Bilateral contracts and grants with industry

9.1 Bilateral contracts with industry

Participants: Walid Bechkit, Juan A. Fraire, Oana Iova, Alexandros Sidiras Galante, Razvan Stanica, Fabrice Valois.

- We have contracted a serie of bilateral contracts with Total (2018-2022) 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 (2020-2023) on the use of IoT sensors and mobile data aggregation for detection of human presence for Smart Lighting application.
- The project SCAFcast in collaboration with Thalès SIX GTS France about multicast dissemination in fleet of drones with intermittent connectivity was accepted.
- The i2Cat Institute from Barcelona is a leading space networking research center in Catalunya. Previous collaborations from the researcher materialized into a collaboration research agreement in the context of Non-Terrestrial Networks (NTN) and Inter-Satellite Links (ISL). This project rendered multiple visits and workshops in Barcelona and provided the team with economic resources for various activities (2023-2024).

9.2 Bilateral grants with industry

Participants: Youssef Badra, Walid Bechkit, Alexandre Guitton, Gwendoline Hochet Derevianckine, Oana Iova, Razvan Stanica, Fabrice Valois, Sekinat Yahya.

- 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 Eiffage Energie Systèmes 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 Chair about AI applied to data flows and network infrastructure analysis, launched in 2022. Walid Bechkit is co-responsible of the "embedded AI" research axis in this collaboration, whereas Razvan Stanica is co-responsible of the "data-oriented protocols and infrastructures" research axis.

10 Partnerships and cooperations

10.1 International initiatives

10.1.1 STIC/MATH/CLIMAT AmSud projects

STARS

Participants: Juan A. Fraire.

Title: SaTellite networks Architectures pRotocols and informaticS

Partner Institution(s):

- Inria
- Laboratoire d'analyse et d'architecture des systèmes, CNRS UPR 8001, France
- Universidad Nacional de Córdoba, Argentina
- Universidad de Chile, Chile

Date/Duration: 2020 - 2023

Additionnal info/keywords: 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.

10.2 International research visitors

10.2.1 Visits of international scientists

Other international visits to the team

Megumi Kaneko

Status associate professor

Institution of origin: National Institute of Informatics

Country: Japan

Dates: April 2023

Context of the visit: research seminar and ongoing collaboration about LR-FHSS & DtS-IoT

Mobility program/type of mobility: research stay

Lucas Santos de Oliveira

Status assistant professor

Institution of origin: State University of Southwestern Bahia

Country: Brazil

Dates: From December 2023 to January 2024

Context of the visit: collaboration on human dynamics in cellular networks

Mobility program/type of mobility: research stay

10.2.2 Visits to international teams

Research stays abroad

Diego Maldonado Munoz

Visited institution: National Institute of Informatics

Country: Japan

Dates: April to August 2023

Context of the visit: research work about LR-FHSS and DtS-IoT

Mobility program/type of mobility: research stay

Oana Iova

Visited institution: National Institute of Informatics

Country: Japan

Dates: April 2023

Context of the visit: new collaboration about LR-FHSS and DtS-IoT

Mobility program/type of mobility: research stay

10.3 European initiatives

10.3.1 H2020 projects

- 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 (4years)
  - Coordinator: University of Twente, Netherlands
  - Other partners: Netherlands RWTH Aachen University, Germany Saarland University, 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.

- Program: H2020-ICT-2018-2020
  - Project acronym: BUGWRIGHT2
  - Project title: Autonomous Robotic Inspectionand Maintenance on Ship Hulls and Storage Tanks
  - Duration: 01/2020-03/2025
  - Coordinator: Georgia Tech Lorraine / UMI 2958 GT - CNRS
  - Other partners: 9 academics partners (CNRS, UPORTO, UIB, INSA, RWTH, UNI-KLU, NTNU, UT, WMU) and 11 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.

10.3.2 Other european programs/initiatives

- Program: CHIST-ERA 20202
  - 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
  - Otherpartners: 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.

10.4 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 Derevianckine, 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 rechercheche (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 PC:
      - PC2 NAI (Networks Architecture & Infrastructure and Networks, Cloud, & Sensing Convergence)
      - PC6 FITNESS (From IoT breakthroughs to Network Enhanced ServiceS)
      - 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)

- 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.

10.4.1 GDR CNRS RSD

- Ongoing participation (since 2006)
  Communication networks, working groups of GDR ASR/RSD, CNRS. 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 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-LyonATMO-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. More details on the site of the chair.

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

General chair, scientific chair

- Oana Iova and Fabrice Valois was chairs of the *Journées non thématiques du GDR CNRS Réseaux et Systèmes Distribués* (130+ attendees), Lyon, 26-27 Janvier 2023.

Member of the organizing committees

- Juan A. Fraire was involved in the organization of the Space-Terrestrial Internetworking Workshop (STINT), Aveiro, Portugal (Co-located with IEEE WiSEE), 2023.

- Thibault Bellanger, Carlos Fernandez Hernadez, Alexandre Guitton, Gwendoline Hochet Derevianckine, Kawtar Lasri, Lucas Magnana, persDiegoMaldonado Munoz, Camille Moriot, Alexandros Sidiras Galante, Sekinat Yahya, Zhiyi Zhang was involved in the organizing committee of of the *Journées non thématiques du GDR CNRS Réseaux et Systèmes Distribués* (130+ attendees), Lyon, 26-27 Janvier 2023.

11.1.2 Scientific events: selection

Member of the conference program committees

- Oana Iova was member of the following TPC: Rencontres francophones sur la conception de protocoles, l'évaluation de performance et l'expérimentation des réseaux de communication (CORES), ACM Internet Measurement Conference (IMC, Posters track), International Conference on Embedded Wireless Systems and Networks (EWSN), IEEE International Conference on Distributed Computing Systems (ICDCS), IEEE International Conference on Wireless and Mobile Computing, Networking And Communications (WiMob), IEEE International Conference on Wireless for Space and Extreme Environments (WISEE).

- Razvan Stanica was member of the following TPC: IFIP Networking, IEEE International Conference on Sensing, Communication, and Networking (SECON), IEEE International Conference on Communications (ICC), IEEE Conference on Wireless Communications and Networking (WCNC), Annual Conference on Wireless On-demand Network Systems and Services (WONS), IEEE International Conference on Wireless and Mobile Computing, Networking And Communications (WiMob).

- Fabrice Valois was member of the following TPC: IEEE Future Networks World Forum (FNWF), IEEE Global Communications Conference (Globecom), IEEE International Conference on Communications (ICC), IEEE Symposium on Computers and Communications (ISCC), IEEE International Wireless Communications & Mobile Computing Conference (IWCMC), IEEE International Mediterranean Conference on Communications and Networking (MeditCom), IEEE Conference on Wireless Communications and Networking (WCNC), IEEE International Conference on Wireless and Mobile Computing, Networking And Communications (WiMob), IEEE International Workshop on Wireless Sensing and Actuating Robotic Networks (WiSARN).

11.1.3 Journal

Reviewer - reviewing activities

- Walid Bechkit was reviewer for IEEE Transactions on Mobile Computing.

11.1.4 Invited talks

- Anais Boumendil and Walid Bechkit gave a pitch on the energy effeciency of deep neural networks as part of the Digital weeks at INSA-Lyon, Lyon, April 2023.
- Walid Bechkit gave a seminar on LoRa-based WSNs for air quality moinitring at Schneider Electric, Grenoble, June 2023.
- Walid Bechkit gave an invited talk as part of the INSA-Lyon scientific day on environment, Lyon, October 2023.
- Juan A. Fraire was invited to give a talk about Routing in the Interplanetary Internet of Things, IEEE 9th World Forum on Internet of Things, Portugal, October 2023
- Juan A. Fraire was invited to give a talk about Delay-Tolerant Networking Modeling and Experimentation, IEEE Cognitive Communications for Aerospace Applications (CCAA), July 2023.
- Juan A. Fraire was invited to give a talk about Interplanetary Internet of Things: Protocols, Routing, and Simulation, i2Cat Workshop, Universidad Politecnica de Catalunya, Spain, October 2023.
- Oana Iova gave an invited talk about Low Power Wide Area Networks Experimental Results, National Institute of Informatics, Japan, April 2023.

11.1.5 Leadership within the scientific community

- 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 chair of the scientific council of the Labex IMU.
- Fabrice Valois is member of the steering committee of the GDR RSD.
- Fabrice Valois is chair of the Networking axis of the GDR RSD.
- Fabrice Valois is member of the COURSE, in charge to identify and to define use cases, applications, and scenarios for the national testbed SLICE-FR (networking and cloud).

11.1.6 Scientific expertise

- Walid Bechkit is member of "Club des experts" of the "Conseil Économique, Social et Environnemental Régional - CESER - ATMO-AURA".
- Walid Bechkit was expert for ANR project, 2023.
- Walid Bechkit was expert for one application for CIFRE grant, 2023.
- Oana Iova was member of the following recruitment committee:
  - Associate professor position, INSA Hauts de France.
  - Associate professor position, INSA Lyon.
  - Associate professor position, Université Toulouse Jean Jaurès.
  - Associate professor position, INP Toulouse.
- Fabrice Valois was member of the following recruitment committee:
  - Associate professor position, Computer Science / web development, LIMOS, Université Clermont Auvergne.
  - Associate professor position, Computer Science / Networking / HPC, I-Cube, IUT Robert Schumann, Université de Strasbourg.
  - Associate professor position, Computer Science / Adaptivity and programmability of networks, IRIT, Université Toulouse 3.

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, Fondations of Computer Networks, 20h, L3, 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, 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.
- Ahmed Boubrima, Performance evaluation of telecom networks, 40h, M1, Telecom. Dpt. 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.
- 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, 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, 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, Local loop (ADSL & Fiber access), 10h, M1, Telecom. Dpt. INSA Lyon.
- Fabrice Valois, Performance evaluation of network, 32h, M1, Telecom. Dpt. INSA Lyon.

Apprenticeship (license and master)

- Master: Walid Bechkit, Performance evaluation of telecom networks, 50h, 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 was vice-dean of the Telecommunications Department of INSA Lyon in charge of the international affairs until November 2023.
- Oana Iova was coordinator leader of the Information Science & Technology semester at the INSA Lyon until November 2023
- Oana Iova is member of the TC department executive committee.
- 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.
- Fabrice Valois is in charge of the international affairs of the Telecommunications Department since December 2023

11.2.2 Supervision

- Masters
  - xxx
- PhD Thesis (defended in 2023)
  - Ichrak Mokhtari, Spatio-temporal data analysis for dynamic phenomenon monitoring using mobile sensors, INSA Lyon, June 2023
  - Mihai Popescu, Connectivity constrained mobility in fleets of robots, INSA Lyon, July 2023.
  - Solohaja Rabenjamina, Gestion de la Mobilité Urbaine et dans le Réseau Mobile à partir de Données de Téléphonie, INSA Lyon, September 2023.
- PhD Thesis (started in 2023)
  - 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.
- PhD Thesis (on going)
  - 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).
  - Gwladys Djuikom, Mobility analysis using cellular data, since 10/2021. Advisors: Diala Naboulsi (ETS Montréal, Québec, Canada), Razvan Stanica.
  - Mohamed El Emary, Taskoff loading in airborne-assisted networks, since 07/2021. Advisors: Diala Naboulsi (ETS Montréal, Québec, Canada), Razvan Stanica.
  - 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: 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.
  - Diego Maldonado Munoz, Adaptations, Optimizations, and Learning Approaches for Direct-to-Satellite Internet of Things, since 12/2022. Adivsors: Juan A. Fraire, Hervé Rivano.
  - Camille Moriot, DDos Attacks and their impacts on the Internet Architecture, since 09/2020. Advisors: François Lesueur (IRISA / UBS) 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.
  - 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.

11.2.3 Juries

- Oana Iova was an examiner of the following PhD defense :
  - Weixuan Xiao, Techniques de décodage pour annuler les collisions dans LoRa Université Clermont Auvergne, June 2023.
  - Alessandro Aimi, Algorithms for reliability insurance and traffic differentiation in low power internet of things communication networks, CNAM, September 2023.
  - Farzad Veisi, Software Defined Industrial Internet of Things, University of Strasbourg, ICube, November 2023.
  - Joakim Eriksson, Scalable and Interoperable Low-Power Internet of Things Networks, Uppsala University, Sweden, December 2023.
- Hervé Rivano was reviewer of the following HDR:
  - Angelo Furno, Approches fondées sur les données pour améliorer la résilience des réseaux de transport à grande échelle, Université Gustave Eiffel, November 2023.
- Hervé Rivano was an president of the jury of the following PhD defense :
  - Mahdi Sharara, Resource Allocation in Future Radio Access Networks, Université Paris Saclay, March 2023.
- Hervé Rivano was an reviewer of the following PhD defense :
  - Guillaume Beduneau, Prédiction de comportement des algorithmes coopératifs dans les réseaux véhiculaires, Université de Technologie de Compiègne, March 2023.
  - Igor Dias da Silva, Optimisation du déploiement et de la coordination de drones pour les applications d'exploration et de surveillance, Université Côte d'Azur, September 2023.
  - Firmin Kateu, Des solutions basées sur les smarphones pour des soins de santé accessibles et en continus, Toulouse INP, November 2023.
  - Nina Santi, Prédiction des besoins pour la gestion de serveurs mobiles en périphérie, Université de Lille, December 2023.
  - Mohamed Idir, Analyse et développement de modèles statistiques pour l'estimation et la prédiction spatiale et temporelle de la pollution atmosphérique à partir de données issues de capteurs mobiles, Université Paris Saclay, December 2023.
- Razvan Stanica was a reviewer of the following PhD defense :
  - Chaima Zoghlami, Amélioration des systèmes de communication V2X pour la perception coopérative : sécurité des usagers de la route, Toulouse 3, October 2023.
- Razvan Stanica was an examiner of the following PhD defense :
  - Razanne Abu-Aisheh, Context-Aware Information Gathering and Processing Towards Supporting Autonomous Systems in Industry 4.0 Scenarios, Sorbonne Université, February 2023.
  - Fabien Meslet-Millet, Apprentissage profond pour le trafic réseau : classification, génération et compression, Toulouse INP, November 2023.
- Fabrice Valois was a reviewer of the following HDR:
  - Nancy El Rachkidy, Étude et amélioration des performances d'un réseau LoRa, LIMOS, Université Clermont Auvergne, November 2023.
- Fabrice Valois was a reviewer of the following PhD defense :
  - Mishra Debashisha, Exploiting the synergies of unmanned aerial vehicles (UAVs) and 5G network, LORIA, Université de Lorraine, June 2023.

- Fabrice Valois was an examiner of the following PhD defense :
  - Lucas Bréhon-Grataloup, Architectures de communication pour les véhicules autonomes connectés, IRIT, Université Toulouse 3, November 2023.
  - Arnol Lemogue, Réduction de l'impact du paradigme REST sur le DNS en utilisant des Technologies pour l'Internet des Objets, IRISA, IMT Atlantique, December 2023.

11.3 Popularization

11.3.1 Internal or external Inria responsibilities

- Oana Iova is in charge of Sustainable and socially responsible development (DDRS) for Agora.
- Hervé Rivano is the best ever REP.

11.3.2 Articles and contents

- Alexandre Guitton is co-author of this popularization article about collision in LoRa network: "Signaux radio superposés : problème et solution", *in* La minute recherche, W. Xiao, N. El Rachkidy, A. Guitton, Université Clermont Auvergne, March 2023.

11.3.3 Education

- Hervé Rivano was invited by the French ambassy in Luxembourg for a discussion with high-school students, a visit of a smart city project, a popularization keynote, and a discussion diner with the Ambassador, Luxembourg, December 2023.
- Hervé Rivano was invited for a talk at the doctoral popularization seminar MOMI, Sophia Antipolis, April 2023.

11.3.4 Interventions

- Fabrice Valois gave a talk about *Une histoire des communications*, Exposition Brickus Maximus, Musée Lugdunum, Lyon, November 2023.
- Fabrice Valois gave a talk about *Une vision globale des communications*, Médiation Campus du Numérique, Inria / INSA Lyon, Lyon, December 2023.

12 Scientific production

12.1 Major publications

[1] S. Abdellatif, O. Tibermacine, W. Bechkit and A. Bachir. 'Heterogeneous IoT/LTE ProSe virtual infrastructure for disaster situations'. In: *Journal of Network and Computer Applications (JNCA)* 213 (Apr. 2023), p. 103602. DOI: 10.1016/j.jnca.2023.103602. URL: https://hal.science/hal-04274006.

[2] M. Amini, R. Stanica and C. Rosenberg. 'Where Are The (Cellular) Data?' In: *ACM Computing Surveys* (20th July 2023). DOI: 10.1145/3610402. URL: https://hal.science/hal-04189564.

[3] M. S. Assenine, W. Bechkit, I. Mokhtari, H. Rivano and K. Benatchba. 'Cooperative Deep Reinforcement Learning for Dynamic Pollution Plume Monitoring using a Drone Fleet'. In: *IEEE Internet of Things Journal* (13th Oct. 2023), pp. 1–14. DOI: 10.1109/JIOT.2023.3328242. URL: https://inria.hal.science/hal-04316013.

[4] T. Bellanger, A. Guitton, R. Stanica and F. Valois. 'Everyone can slice LoRaWAN'. In: IEEE International Conference on Wireless and Mobile Computing, Networking and Communications. Montréal, Canada, 21st June 2023. URL: https://hal.science/hal-04089968.

[5] A. Boumendil, W. Bechkit and K. Benatchba. 'On data selection for the energy efficiency of neural networks: Towards a new solution based on a dynamic selectivity ratio'. In: ICTAI 2023 - IEEE 35th International Conference on Tools with Artificial Intelligence. Atlanta (GA), United States, Nov. 2023. DOI: 10.1109/ICTAI59109.2023.00054. URL: https://hal.science/hal-04282114.

[6] Y. Busnel and H. Rivano. 'FTM-Broadcast: Efficient Network-wide Ranging'. In: *13th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2023)*. IPIN 2023: 13th International Conference on Indoor Positioning and Indoor Navigation. 13th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2023). Nuremberg, Germany: IEEE; IEEE, Sept. 2023, pp. 1–6. DOI: 10.1109/IPIN57070.2023.10332504. URL: https://hal.science/hal-04184961.

[7] R. Cherini, R. Detke, J. Fraire, P. G. Madoery and J. M. Finochietto. 'Toward Deep Digital Contact Tracing: Opportunities and Challenges'. In: *IEEE Pervasive Computing* (2023), pp. 1–11. DOI: 10.1109/MPRV.2023.3320987. URL: https://hal.science/hal-04282277.

[8] G. H. Derévianckine, A. Guitton, O. Iova, B. Ning and F. Valois. 'Opportunities and Challenges of LoRa 2.4 GHz'. In: *IEEE Communications Magazine* (2023). DOI: 10.1109/MCOM.010.2200566. URL: https://hal.science/hal-04020100.

[9] J. A. A. Fraire, A. Guitton and O. Iova. 'Recovering Headerless Frames in LR-FHSS'. In: *International Conference on Embedded Wireless Systems and Networks (EWSN)*. International Conference on Embedded Wireless Systems and Networks. Rende, Italy, 25th Sept. 2023, pp. 1–11. URL: https://hal.science/hal-04152028.

[10] S. M. Henn, J. A. Fraire and H. Hermanns. 'Polygon-Based Algorithms for N -Satellite Constellations Coverage Computing'. In: *IEEE Transactions on Aerospace and Electronic Systems* (2023), pp. 1–17. DOI: 10.1109/TAES.2023.3289479. URL: https://hal.science/hal-04189476.

[11] K. Lasri, Y. Ben Maissa, L. Echabbi, O. Iova and F. Valois. 'Probabilistic and distributed traffic control in LPWANs'. In: *Ad Hoc Networks* 143 (Apr. 2023). DOI: 10.1016/j.adhoc.2023.103121. URL: https://hal.science/hal-04457728.

[12] H. P. Phyu, R. Stanica and D. Naboulsi. 'Multi-Slice Privacy-Aware Traffic Forecasting at RAN Level: A Scalable Federated-Learning Approach'. In: *IEEE Transactions on Network and Service Management* (17th Apr. 2023). DOI: 10.1109/TNSM.2023.3267725. URL: https://hal.science/hal-04189562.

[13] 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.

[14] H. Yan, L. Qiao, W. Wu, J. A. Fraire, D. Zhou, L. Li and Y. Xu. 'Routing in future space-terrestrial integrated networks with SATNET-OSPF'. In: *International Journal of Satellite Communications and Networking* (31st Aug. 2023). DOI: 10.1002/sat.1495. URL: https://hal.science/hal-04282266.

12.2 Publications of the year

International journals

[15] S. Abdellatif, O. Tibermacine, W. Bechkit and A. Bachir. 'Heterogeneous IoT/LTE ProSe virtual infrastructure for disaster situations'. In: *Journal of Network and Computer Applications (JNCA)* 213 (Apr. 2023), p. 103602. DOI: 10.1016/j.jnca.2023.103602. URL: https://hal.science/hal-04274006.

[16] M. Amini, R. Stanica and C. Rosenberg. 'Where Are The (Cellular) Data?' In: *ACM Computing Surveys* (20th July 2023). DOI: 10.1145/3610402. URL: https://hal.science/hal-04189564.

[17] M. S. Assenine, W. Bechkit, I. Mokhtari, H. Rivano and K. Benatchba. 'Cooperative Deep Reinforcement Learning for Dynamic Pollution Plume Monitoring using a Drone Fleet'. In: *IEEE Internet of Things Journal* (13th Oct. 2023), pp. 1–14. DOI: 10.1109/JIOT.2023.3328242. URL: https://inria.hal.science/hal-04316013.

[18] R. Cherini, R. Detke, J. Fraire, P. G. Madoery and J. M. Finochietto. 'Toward Deep Digital Contact Tracing: Opportunities and Challenges'. In: *IEEE Pervasive Computing* (2023), pp. 1–11. DOI: 10.1109/MPRV.2023.3320987. URL: https://hal.science/hal-04282277.

[19] G. H. Derévianckine, A. Guitton, O. Iova, B. Ning and F. Valois. 'Opportunities and Challenges of LoRa 2.4 GHz'. In: *IEEE Communications Magazine* (2023). DOI: 10.1109/MCOM.010.2200566. URL: https://hal.science/hal-04020100.

[20] S. M. Henn, J. A. Fraire and H. Hermanns. 'Polygon-Based Algorithms for N -Satellite Constellations Coverage Computing'. In: *IEEE Transactions on Aerospace and Electronic Systems* (2023), pp. 1–17. DOI: 10.1109/TAES.2023.3289479. URL: https://hal.science/hal-04189476.

[21] K. Lasri, Y. Ben Maissa, L. Echabbi, O. Iova and F. Valois. 'Probabilistic and distributed traffic control in LPWANs'. In: *Ad Hoc Networks* 143 (Apr. 2023). DOI: 10.1016/j.adhoc.2023.103121. URL: https://hal.science/hal-04457728.

[22] D. Moura, G. Ramos, A. Aquino and A. Loureiro. 'A Centrality Approach to Select Offloading Data Aggregation Points in Vehicular Sensor Networks'. In: *IEEE Transactions on Intelligent Transportation Systems* 24.11 (1st Aug. 2023), pp. 11639–11653. DOI: 10.1109/TITS.2023.3297886. URL: https://hal.science/hal-04189908.

[23] H. P. Phyu, D. Naboulsi and R. Stanica. 'Machine Learning in Network Slicing - A Survey'. In: *IEEE Access* 11 (17th Apr. 2023), pp. 39123–39153. DOI: 10.1109/ACCESS.2023.3267985. URL: https://hal.science/hal-04189558.

[24] H. P. Phyu, R. Stanica and D. Naboulsi. 'Multi-Slice Privacy-Aware Traffic Forecasting at RAN Level: A Scalable Federated-Learning Approach'. In: *IEEE Transactions on Network and Service Management* (17th Apr. 2023). DOI: 10.1109/TNSM.2023.3267725. URL: https://hal.science/hal-04189562.

[25] 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.

[26] H. Yan, L. Qiao, W. Wu, J. A. Fraire, D. Zhou, L. Li and Y. Xu. 'Routing in future space-terrestrial integrated networks with SATNET-OSPF'. In: *International Journal of Satellite Communications and Networking* (31st Aug. 2023). DOI: 10.1002/sat.1495. URL: https://hal.science/hal-04282266.

International peer-reviewed conferences

[27] T. Bellanger, A. Guitton, R. Stanica and F. Valois. 'Everyone can slice LoRaWAN'. In: IEEE International Conference on Wireless and Mobile Computing, Networking and Communications. Montréal, Canada, 21st June 2023. URL: https://hal.science/hal-04089968.

[28] A. Boumendil, W. Bechkit and K. Benatchba. 'On data selection for the energy efficiency of neural networks: Towards a new solution based on a dynamic selectivity ratio'. In: ICTAI 2023 - IEEE 35th International Conference on Tools with Artificial Intelligence. Atlanta (GA), United States, Nov. 2023. DOI: 10.1109/ICTAI59109.2023.00054. URL: https://hal.science/hal-04282114.

[29] A. Boumendil, W. Bechkit, P.-E. Portier, F. Le Mouël and M. Egan. 'Grow, prune or select data: which technique allows the most energy-efficient neural network training?' In: 2023 IEEE 35th International Conference on Tools with Artificial Intelligence (ICTAI). Atlanta (GA), United States, Nov. 2023. DOI: 10.1109/ICTAI59109.2023.00051. URL: https://hal.science/hal-04282146.

[30] Y. Busnel and H. Rivano. 'FTM-Broadcast: Efficient Network-wide Ranging'. In: *13th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2023)*. IPIN 2023: 13th International Conference on Indoor Positioning and Indoor Navigation. 13th International Conference on Indoor Positioning and Indoor Navigation (IPIN 2023). Nuremberg, Germany: IEEE; IEEE, Sept. 2023, pp. 1–6. DOI: 10.1109/IPIN57070.2023.10332504. URL: https://hal.science/hal-04184961.

[31] J.-T. Chen, M. Kaneko and A. Guitton. 'An Auction-based Assignment Method for LoRa Multi-Gateway Networks'. In: IEEE International Conference on Communications. Rome, Italy, 28th May 2023. URL: https://hal.science/hal-04077972.

[32] S. d'Alu, H. Rivano and O. Simonin. 'TDoA for in-flight relative localization in UAV swarm using Ultra-Wide Band'. In: *CEUR Workshop Proceedings*. IPIN 2023 - 13th International Conference on Indoor Positioning and Indoor Navigation. IPIN-WiP 2023 Indoor Positioning and Indoor Navigation - Work-in-Progress Papers 2023. Nuremberg, Germany, Sept. 2023. URL: https://hal.science/hal-04240297.

[33] G. O. Djuikom Foka, R. Stanica and D. Naboulsi. 'Handover Forecasting in Cellular Networks: A Spatio-temporal Graph Neural Network Approach'. In: NoF 2023 - 14th International Conference on Network of the Future. Izmir, Turkey, 4th Oct. 2023. URL: https://hal.science/hal-04189574.

[34] A. Durand, N. El Rachkidy and A. Guitton. 'MADERE: Mobile Adaptive Datarate for LoRaWAN'. In: IEEE Wireless Communications and Networking Conference. Glasgow, United Kingdom, 26th Mar. 2023. URL: https://hal.science/hal-03896512.

[35] M. El-Emary, A. Ranjha, D. Naboulsi and R. Stanica. 'Energy-Efficient Task Offloading and Trajectory Design for UAV-based MEC Systems'. In: *2023 19th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*. WiMob 2023 - 19th International Conference on Wireless and Mobile Computing, Networking and Communications. Montreal, Canada: IEEE, 21st June 2023, pp. 274–279. DOI: 10.1109/WiMob58348.2023.10187721. URL: https://hal.science/hal-04189569.

[36] C. Fernández Hernández, G. H. Derévianckine, A. Guitton, O. Iova and F. Valois. 'Indoor Performance Evaluation of LoRa 2.4 GHz'. In: IEEE Wireless Communications and Networking Conference. Glasgow, United Kingdom, 26th Mar. 2023. URL: https://hal.science/hal-03896550.

[37] J. A. A. Fraire, A. Guitton and O. Iova. 'Recovering Headerless Frames in LR-FHSS'. In: *International Conference on Embedded Wireless Systems and Networks (EWSN)*. International Conference on Embedded Wireless Systems and Networks. Rende, Italy, 25th Sept. 2023, pp. 1–11. URL: https://hal.science/hal-04152028.

[38] O. de Jonckère, J. A. Fraire and S. Burleigh. 'Enhanced Pathfinding and Scalability with Shortest-Path Tree Routing for Space Networks'. In: ICC 2023 - IEEE International Conference on Communications. Rome, Italy: IEEE, 28th May 2023, pp. 4082–4088. DOI: 10.1109/ICC45041.2023.10279514. URL: https://hal.science/hal-04282298.

[39] H. Pann Phyu, D. Naboulsi, R. Stanica and G. Poitau. 'Towards Energy Efficiency in RAN Network Slicing'. In: LCN 2023 - IEEE 48th Conference on Local Computer Networks. Daytona Beach, United States, 1st Oct. 2023. URL: https://hal.science/hal-04189587.

[40] G. S. Ramos, G. Santos, D. L. L. Moura, D. Fernandes, F. Queiroz, R. Osvaldo A., R. Stanica and A. Aquino. 'Left on read: Human behavior characterization based on messaging service applications'. In: *NetMob 2023: Book of Abstracts*. NetMob 2023: Book of Abstracts. Madrid, Spain, 4th Oct. 2023. URL: https://hal.science/hal-04269561.

[41] Z. Zhang, R. Stanica and F. Valois. 'Movable Base Stations in Mobile Networks for Emergency Communications'. In: PIMRC 2023 - IEEE 34th Annual International Symposium on Personal, Indoor and Mobile Radio Communications. Toronto, Canada, 5th Sept. 2023. URL: https://hal.science/hal-04189583.

National peer-reviewed Conferences

[42] C. Fernández Hernández, G. H. Derévianckine, A. Guitton, O. Iova and F. Valois. 'On a testé pour vous : LoRa 2.4 GHz à l'intérieur'. In: *CoRes 2023 - 8èmes Rencontres Francophones sur la Conception de protocoles, l'évaluation de performances et l'expérimentation de Réseaux de communication*. CoRes 2023 - 8èmes Rencontres Francophones sur la Conception de protocoles, l'évaluation de performances et l'expérimentation de Réseaux de communication. Cargese, France, 22nd May 2023. DOI: 10.5281/zenodo.7106073. URL: https://hal.science/hal-04087091.

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