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Activity Report 2018

Project-Team AGORA

ALGorithmes et Optimisation pour Réseaux Autonomes

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

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Networks and Telecommunications

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1. Team, Visitors, External Collaborators

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2. Overall Objectives

2.1. Overall Objectives

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

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

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

Beyond cellular networks. The networking functions are today almost only managed through cellular infrastructures. Even current smart-metering network architectures follow a hierarchical organization alike cellular networks. This approach features a number of advantages, including pervasive geographical coverage, seamless connectivity, a good level of security and possibly guaranteed bandwidth and latency. However, this centralized paradigm is over twenty years old now. The access network capacity has already reached its limit, and the explosion of popular, bandwidth-hungry digital services will make the newest technologies, such as LTE, already unable to accommodate the future demand - expected to grow 11-fold in 2018, with respect to 2014. A clear trend is to decentralize the network operation, leveraging network function virtualization so as to make it more pervasive (Small Cells), heterogeneous (HetNets) and self-organizing (SON). Beyond cellular networks, multi-hop wireless mobile networks have been extensively studied in the literature, in particular wireless sensor networks, ad hoc networks, wireless mesh networks and vehicular networks. Such wireless multi-hop solutions met scarce practical success over the last decade, mainly because of the lack of a clear application context and of important use cases. There are however now mature technologies for some specific applications and provide a wealth of connectivity surrounding mobile devices. Combined with the emergence of long range low power technologies dedicated to small traffic IoT applications, one can foresee the emergence of hybrid networks architectures (cellular and multi-hop) that need to be developed and evaluated.

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

3. Research Program

3.1. Wireless network deployment

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

Traditional telecommunication infrastructures were made of dedicated components, each of them providing a given set of functions. However, recently introduced paradigms yield issues on the deployment of network functions. Indeed, the last decade saw a trend towards adding more intelligence within the network. In the case of the access network, the concept of Cloud Radio Access Network (C-RAN) emerged. In the backhaul, the Evolved Packet Core (EPC) network can also benefit from virtualization techniques, as the convergence point for multiple access technologies, as imagined in the case of future 5G networks. The performance limits of a virtualized EPC remain unknown today: Is the delay introduced by this new architecture compatible with the requirements of the mobile applications? How to deploy the different network functions on generic hardware in order to maximize the quality of service?

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

Regarding the network connectivity, another challenge is to integrate suitable wireless link models accounting for the deployment environment. For example, modeling the integration of sensors in urban areas is challenging due to the presence of neighboring walls and obstacles, as well as moving vehicles and pedestrians that may induce field scattering. Also, the urban constraints and characteristics need to be carefully modeled and considered. Indeed, the urban environment yields constraints or facilities on the deployment of sensor nodes and gateways, such as their embedding within street furniture. Understanding the structure of these spatial constraints is necessary to develop efficient optimization methods able to compute on large scale scenarios.
Network function deployment. In this research direction, we do not address network virtualization per-se, but the algorithmic and architectural challenges that virtualization brings in both radio access and core networks. As a first challenge, we focus on the evaluation of Cloud Radio Access Network solutions. The capacity of a C-RAN architecture and the way this compares to classical RAN is still an open question. The fact that C-RAN enables cooperation between the remote radio heads (RRH) served by the same base-band units (BBU) indicates an improved performance, but at the same time the resulting cells are much larger, which goes against the current trend of increasing capacity through the deployment of small cells. We propose to study the problem both from a user and a network perspective. On the user side, we use standard information theory tools, such as multiple-access channels to model C-RAN scenarios and understand their performance. On the network side, this translates in a resource allocation problem with cooperative base stations. We will extend our previous models for non-cooperative scenarios. Regarding the core network function deployment, we are interested in the specific case of Professional Mobile Radio (PMR) networks. These networks, used for public safety services and in scenarios like post-disaster relief, present the particularity of an EPC formed by a mobile wireless network. Due to its nature, the network can not be pre-planned, and the different EPC functions need to be autonomously deployed on the available network elements. We study the EPC function deployment problem as an optimization problem, constrained by the user capacity requests. User attachment mechanisms will also be proposed, adapted to the network function distribution, the global user demand, and the source/destination of the flows. These challenges are tackled as centralized optimization problems, then extended to the context of real-time decisions. Finally, in order to complete these theoretical work based on ILP models and heuristics, experiments using OpenAir Interface are used to evaluate our proposals.

3.2. Wireless data collection

With an anticipated 11-fold growth between 2014 and 2018, facing the growth of the mobile demand is the foremost challenge for mobile operators. In particular, a 100-fold increase in the number of supported connected devices, mostly newly connected objects with M2M trafic, is expected. A question therefore rises: how to cope with a dense set of M2M low bit rate traffics from energy and computing power constrained devices while classic cellular infrastructure are designed for the sparse high bit rate traffics from powerful devices?

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

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

In the perspective of 5G solutions, we are investigating mechanisms that regulate the M2M traffics in order to obtain good performances while keeping a reasonable quality of service (QoS) for human-to-human (H2H) terminals. The idea of piggybacking the M2M data transmission within one of the RA procedure messages is tempting and it is now considered as the best solution for this type of traffic. This means that the M2M data is transmitted on the shared resources of the RACH, and raises questions regarding the capacity of the RACH, which was not designed for these purposes. In this regard, our analysis of the access capacity of LTE-A RACH procedure has to be adapted to multi-class scenarios, in order to understand the competition between M2M and H2H devices. Modeling based on Markov chains provides trends on system scale performances, while event-based simulations enable the analysis of the distribution of the performances over the different kinds of users. Combining both should give enough insights so as to design relevant regulation techniques and strategies. In particular two open questions that have to be tackled can be stated as: When should access resources be opened to M2M traffics without penalizing H2H performances? Does an eNodeB have a detailed enough knowledge of the system and transmit enough information to UE to regulate the traffics? The objective is to go to the analysis of achievable performances to actual protocols that take into account realistic M2M traffic patterns.

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

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

3.3. Network data exploitation

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

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

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

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

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

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

The rational design of an aggregation scheme implies understanding data dynamics (statistical characteristics, information representation), algorithmic optimization (aggregator location, minimizing the number of aggregators toward energy efficiency), and network dynamics (routing, medium sharing policies, node activity). We look for designing a complete aggregation chain including both intra-sensor aggregation and inter-sensor aggregation. For this, we characterize the raw data that are collected in order to understand the dynamic behind several key applications. The goal is to provide a taxonomy of the applications according to the data properties in terms of stationarity, dynamic, etc. Then, we aim to design temporal aggregation functions without knowledge of the network topology and without assumptions about the application data. Such functions should be able to self-adapt to the environment evolution. A related issue is the deployment of aggregators into the wireless network to allow spatial aggregation with respect to the energy consumption minimization, capacity saving maximization and distributed algorithm complexity. We therefore look to define dedicated protocols for each aggregation function family.

4. Application Domains

4.1. Smart Cities

One major characteristic of modern societies is that they are prevalently urban. In coherence, 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. In particular, low cost - small data devices are supposed to be densely deployed in our environment, fostering the interest for a convergence of the traditional wireless networking paradigms.

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

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

5. Highlights of the Year

5.1. Highlights of the Year

- Walid Bechkit holds the PEDR (2017-2021).
- Khaled Boussetta obtained his HDR from the University Paris 13, in December 2018.
- Khaled Boussetta holds the PEDR (2018-2022).
- Khaled Boussetta was promoted MCF *Hors Classe* in September 2018.
- Hervé Rivano holds the PEDR (2017-2021).
- Razvan Stanica holds the PEDR (2016-2020).

- Pascale Vicat Blanc joined Agora as Inria Senior Researcher, in September 2018.

6. New Software and Platforms

6.1. TAPASCologne

Travel and Activity PAtterns Simulation Cologne
KEYWORDS: Mobility - Traces
FUNCTIONAL DESCRIPTION: TAPASCologne is an initiative by the Institute of Transportation Systems at the German Aerospace Center (ITS-DLR), aimed at reproducing, with the highest level of realism possible, car traffic in the greater urban area of the city of Cologne, in Germany.

To that end, different state-of-art data sources and simulation tools are brought together, so to cover all of the specific aspects required for a proper characterization of vehicular traffic:

The street layout of the Cologne urban area is obtained from the OpenStreetMap (OSM) database, The microscopic mobility of vehicles is simulated with the Simulation of Urban Mobility (SUMO) software, The traffic demand information on the macroscopic traffic flows across the Cologne urban area (i.e., the O/D matrix) is derived through the Travel and Activity PAtterns Simulation (TAPAS) methodology, The traffic assignment of the vehicular flows described by the TAPASCologne O/D matrix over the road topology is performed by means of Gawron's dynamic user assignment algorithm.

- Participants: Marco Fiore and Razvan Stanica
- Contact: Marco Fiore
- URL: http://kolntrace.project.citi-lab.fr/#download

6.2. Sense in the City

KEYWORDS: Sensors - Sensors network - Wireless Sensor Networks
FUNCTIONAL DESCRIPTION: Sense in the city is a lightweight experimentation platform for wireless sensor networks in development. The main objective of this platform is to be easily transferable and deployable on the field. It allows a simplified deployment of the code running on the sensors and the collection of logs generated by the instrumentation of the code on a centralized database. In the early stage of the platform, the sensors are powered by small PCs, e.g. Raspberry Pis, but we are investigating the integration of energy harvesting capabilities such as solar panels.

- Participants: Hervé Rivano and Khaled Boussetta
- Contact: Khaled Boussetta

6.3. PrivaMovApp

KEYWORD: Crowd-sensing
FUNCTIONAL DESCRIPTION: Agora is leading the development of an Android application for user data collection purposes. The application is based on the Funf framework, and is currently available on Google Play.

- Participants: Stéphane D'alu, Hervé Rivano, Razvan Stanica and SOLOHAJA RABENJAMINA
- Contact: Razvan Stanica

6.4. WSNet

KEYWORD: Network simulator

FUNCTIONAL DESCRIPTION: WSNet is a modular event-driven simulator targeted to Wireless Sensor Networks. Its main goals are to offer scalabiliy, extensibility and modularity for the integration of new protocols/hardware models and a precise radio medium simulation. We still hope to find the proper resource to make WSNet evolve into a wireless capillary network simulator suitable for conducting simulations at the urban scale.

- Participants: Rodrigue Domga Komguem and Fabrice Valois
- Partner: CEA-LETI
- Contact: Guillaume Chelius
- URL: https://gforge.inria.fr/projects/wsnet-3/

6.5. Platforms

6.5.1. 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 LoRa plateforme is: *(i)* research (researchers can use it for studying reliability and capacity problems, privacy related challenges, etc.), and *(ii)* teaching (several courses from INSA, especially in the Telecom department can use this platform as a pedagogical tool).
Part of the software is mutualized with the University of Paris 13, where a LoRaWan testbed project is under deployment at the campus of Villetaneuse. This project, is supported by a local BQR and is leaded by Khaled Boussetta. The mutualization of the software tools will allows us to conduct multi sites experiments, at Lyon and at Paris.

6.5.2. 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 had 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.

7. New Results

7.1. Wireless network deployment

Participants : Walid Bechkit, Amjed Belkhiri, Jad Oueis, Hervé Rivano, Razvan Stanica, Fabrice Valois

7.1.1. UAVs positionning

Mobile base stations mounted on unmanned aerial vehicles (UAVs) provide viable wireless coverage solutions in challenging landscapes and conditions, where cellular/WiFi infrastructure is unavailable. Operating multiple such airborne base stations, to ensure reliable user connectivity, demands intelligent control of UAV movements, as poor signal strength and user outage can be catastrophic to mission critical scenarios. In [17], we propose a deep reinforcement learning based solution to tackle the challenges of base stations mobility control. We design an Asynchronous Advantage Actor-Critic (A3C) algorithm that employs a custom reward function, which incorporates SINR and outage events information, and seeks to provide mobile user coverage with the highest possible signal quality. Preliminary results reveal that our solution converges after 4×10 5 steps of training, after which it outperforms a benchmark gradient-based alternative, as we attain 5dB higher median SINR during an entire test mission of 10,000 steps.

7.1.2. Network functions placement

Emerging mobile network architectures (e.g., aerial networks, disaster relief networks) are disrupting the classical careful planning and deployment of mobile networks by requiring specic self-deployment strategies. Such networks, referred to as self-deployable, are formed by interconnected rapidly deployable base stations that have no dedicated backhaul connection towards a traditional core network. Instead, an entity providing essential core network functionalities is co-located with one of the base stations. In [5], we tackle the problem of placing this core network entity within a self-deployable mobile network, i.e., we determine with which of the base stations it must be co-located. We propose a novel centrality metric, the ow centrality, which measures a node capacity of receiving the total amount of ows in the network. We show that in order to maximize the amount of exchanged trac between the base stations and the core network entity, under certain capacity and load distribution constraints, the latter should be co-located with the base station having the maximum ow centrality. We rst compare our proposed metric to other state of the art centralities. Then, we highlight the signicant trac loss occurring when the core network entity is not placed on the node with the maximum ow centrality, which could reach 55

7.1.3. Mobile edge computing orchestration

Orchestrating network and computing resources in Mobile Edge Computing (MEC) is an important item in the networking research agenda. In [12], we propose a novel algorithmic approach to solve the problem of dynamically assigning base stations to MEC facilities, while taking into consideration multiple time-periods, and computing load switching and access latency costs. In particular, leveraging on an existing state of the art on mobile data analytics, we propose a methodology to integrate arbitrary time-period aggregation methods into a network optimization framework. We notably apply simple consecutive time period aggregation and agglomerative hierarchical clustering. Even if the aggregation and optimization methods represent techniques which are different in nature, and whose aim is partially overlapping, we show that they can be integrated in an efficient way. By simulation on real mobile cellular datasets, we show that, thanks to the clustering, we can scale with the number of time-periods considered, that our approach largely outperforms the case without time-period aggregations in terms of MEC access latency, and at which extent the use of clustering and time aggregation affects computing time and solution quality.

7.1.4. On User Mobility in Dynamic Cloud Radio Access Networks

The development of virtualization techniques enables an architectural shift in mobile networks, where resource allocation, or even signal processing, become software functions hosted in a data center. The centralization of computing resources and the dynamic mapping between baseband processing units (BBUs) and remote antennas (RRHs) provide an increased flexibility to mobile operators, with important reductions of operational costs. Most research efforts on Cloud Radio Access Networks (CRAN) consider indeed an operator perspective and network-side performance indicators. The impact of such new paradigms on user experience has been instead overlooked. In [20], we shift the viewpoint, and show that the dynamic assignment of computing resources enabled by CRAN generates a new class of mobile terminal handover that can impair user quality of service. We then propose an algorithm that mitigates the problem, by optimizing the mapping between BBUs and RRHs on a time-varying graph representation of the system. Furthermore, we show that a practical online BBU-RRH mapping algorithm achieves results similar to an oracle-based scheme with perfect knowledge of future traffic demand. We test our algorithms with two large-scale real-world datasets, where the total number of handovers, compared with the current architectures, is reduced by more than 20%. Moreover, if a small tolerance to dropped calls is allowed, 30% less handovers can be obtained.

7.1.5. Wireless sensor network deployment for environmental monitoring

Air pollution has major negative effects on both human health and environment. Thus, air quality monitoring is a main issue in our days. In [9], we focus on the use of mobile WSN to generate high spatio-temporal resolution air quality maps. We address the sensors' online redeployment problem and we propose three redeployment models allowing to assess, with high precision, the air pollution concentrations. Unlike most of existing movement assisted deployment strategies based on network generic characteristics such as coverage and connectivity, our approaches take into account air pollution properties and dispersion models to offer an efficient air quality estimation. First, we introduce our proposition of an optimal integer linear program based on air pollution dispersion characteristics to minimize estimation errors. Then, we propose a local iterative integer linear programming model and a heuristic technique that offer a lower execution time with acceptable estimation quality. We evaluate our models in terms of execution time and estimation quality using a real data set of Lyon City in France. Finally, we compare our models' performances to existing generic redeployment strategies. Results show that our algorithms outperform the existing generic solutions while reducing the maximum estimation error up to 3 times.

7.2. Wireless data collection

Participants : Walid Bechkit, Ahmed Boubrima, Alexis Duque, Abdoul-Aziz Mbacke, Hervé Rivano, Razvan Stanica, Yosra Zguira

7.2.1. RFID paradigm

While RFID technology is gaining increased attention from industrial community deploying different RFID-based applications, it still suffers from reading collisions. As such, many proposals were made by the scientific community to try and alleviate that issue using different techniques either centralized or distributed, mono-channel or multi-channels, TDMA or CSMA. However, the wide range of solutions and their diversity make it hard to have a clear and fair overview of the different works. In [4], we propose a survey of the most relevant and recent known state-of-the- art anti-collision for RFID protocols. It provides a classification and performance evaluation taking into consideration different criteria as well as a guide to choose the best protocol for given applications depending on their constraints or requirements but also in regard to their deployment environments.

7.2.2. Anti-collision and routing protocol for RFID

In the midst of Internet of Things development, a first requirement was tracking and identification of those mentioned "things" which could be done thanks to Radio Frequency Identification. However, since then, the development of RFID allowed a new range of applications among which is remote sensing of environmental values. While RFID can be seen as a more efficient solution than traditional Wireless Sensor Networks, two main issues remain: first reading collisions and second proficient data gathering solution. In [18], we examine the implementation of two applications: for industrial IoT and for smart cities, respectively. Both applications, in regards to their requirements and configuration, challenge the operation of a RFID sensing solution combined with a dynamic wireless data gathering over multi-hops. They require the use of both mobile and fixed readers to cover the extent of deployment area and a quick retrieval of tag information. We propose a distributed cross-layer solution for improving the efficiency of the RFID system in terms of collision and throughput but also its proficiency in terms of tag information routing towards one or multiple sinks. Simulation results show that we can achieve high level of throughput while maintaining a low level of collision and a fairness of reader medium access above 95% in situations where readers can be fix and mobile, while tag information is routed with a data rate of 97% at worst and reliable delays for considered applications.

7.2.3. Routing priority information in RFID

Long being used for identification purposes, a new set of applications is now available thanks to the development of RFID technology. One of which is remote sensing of environmental values using passive RFID tags. This leap forward allowed a more energy efficient and cheaper solution for applications like logistics or urban infrastructure monitoring. Nevertheless, serious issues raised with the use of RFID: (i) reading collisions and (ii) gathering of tag information. Indeed, tags information retrieved by readers have to be transmitted towards a base station through a multi-hop scheme which can interfere with neighboring readers activity. In [19], we propose cross-layer solutions meant for both scheduling of readers' activity to avoid collisions, and a multi-hop routing towards base stations, to gather read tag data. This routing is performed with a data priority aware mechanism allowing end-to-end delay reduction of urgent data packets delivery up to 13% faster compared to standard ones. Using fuzzy logic, we combine several observed metrics to reduce the load of forwarding nodes and improve latency as well as data rate. We validate our proposal running simulations on industrial and urban scenarios.

7.2.4. Data collection in DTN networks

Intelligent Transport Systems (ITS) are an essential part of the global world. They play a substantial role for facing many issues such as traffic jams, high accident rates, unhealthy lifestyles, air pollution, etc. Public bike sharing system is one part of ITS and can be used to collect data from mobiles devices. In this paper, we propose an efficient, *Internet of Bikes*, IoB-DTN routing protocol based on data aggregation which applies the Delay Tolerant Network (DTN) paradigm to Internet of Things (IoT) applications running data collection on urban bike sharing system based sensor network. In [6], we propose and evaluate three variants of IoB-DTN: IoB based on spatial aggregation (IoB-SA), IoB based on temporal aggregation (IoB-TA) and IoB based on spatiotemporal aggregation (IoB-STA). The simulation results show that the three variants offer the best performances regarding several metrics, comparing to IoB-DTN without aggregation and the low-power long-range technology, LoRa type. In an urban application, the choice of the type of which variant of IoB should be used depends on the sensed values.

7.2.5. Data sensing in Internet of Bikes

Following the trend of the Internet of Thing, public transport systems are seen as an efficient bearer of mobile devices to generate and collect data in urban environments. Bicycle sharing system is one part of the city's larger transport system. In [23], we study the *Internet of Bikes* IoB-DTN protocol which applies the Delay Tolerant Network (DTN) paradigm to the Internet of Things (IoT) applications running on urban bike sharing system based sensor network. We evaluate the performances of the protocol with respect to the transmission power. Performances are measured in terms of delivery rate, delivery delay, throughput and energy cost. We also compare the multi-hop IoB-DTN protocol to a low-power wide-area network (LPWAN) technology. LPWAN have been designed to provide cost-effective wide area connectivity for small throughput IoT applications: multiyear lifetime and multi-kilometer range for battery-operated mobile devices. This work aims at providing network designers and managers insights on the most relevant technology for their urban applications that could run on bike sharing systems. To the best of our knowledge, this work is the first to provide a detailed performance comparison between multi-hop and long range DTN-like protocol being applied to mobile network IoT devices running a data collection applications in an urban environment.

7.2.6. Reducing IoT traffic through data aggregation mechanisms

Intelligent Transport Systems (ITS) are an essential part of the global world. They play a substantial role for facing many issues such as traffic jams, high accident rates, unhealthy lifestyles, air pollution, etc. Public bike sharing system is one part of ITS and can be used to collect data from mobiles devices. In this paper, we propose an efficient, " Internet of Bikes " , IoB-DTN routing protocol based on data aggregation which applies the Delay Tolerant Network (DTN) paradigm to Internet of Things (IoT) applications running data collection on urban bike sharing system based sensor network. In [6], we propose and evaluate three variants of IoB-DTN: IoB based on spatial aggregation (IoB-SA), IoB based on temporal aggregation (IoB-TA) and IoB based on spatiotemporal aggregation (IoB-STA). The simulation results show that the three variants offer the best performances regarding several metrics, comparing to IoB-DTN without aggregation and the low-power long-range technology, LoRa type. In an urban application, the choice of the type of which variant of IoB should be used depends on the sensed values.

7.2.7. Environmental modeling

Wireless sensor networks (WSN) are widely used in environmental applications where the aim is to sense a physical parameter such as temperature, humidity, air pollution, etc. Most existing WSN-based environmental monitoring systems use data interpolation based on sensor measurements in order to construct the spatiotemporal field of physical parameters. However, these fields can be also approximated using physical models which simulate the dynamics of physical phenomena. In [11], we focus on the use of wireless sensor networks for the aim of correcting the physical model errors rather than interpolating sensor measurements. We tackle the activity scheduling problem and design an optimization model and a heuristic algorithm in order to select the sensor nodes that should be turned off to extend the lifetime of the network. Our approach is based on data assimilation which allows us to use both measurements and the physical model outputs in the estimation of the spatiotemporal field. We evaluate our approach in the context of air pollution monitoring while using a dataset from the Lyon city, France and considering the characteristics of a monitoring system developed in our lab. We analyze the impact of the nodes' characteristics on the network lifetime and derive guidelines on the optimal scheduling of air pollution sensors.

7.2.8. Multi-robot routing for evolving missions

In [22], we propose Dynamic Multi Robot-Routing (DMRR), as a continuous adaptation of the multi-robot target allocation process (MRTA) to new discovered targets. There are few works addressing dynamic target allocation. Existing methods are lacking the continuous integration of new targets, handling its progressive effects, but also lacking dynamic support (e.g. parallel allocations, participation of new robots). This work proposes a framework for dynamically adapting the existing robot missions to new discovered targets. Missions accumulate targets continuously, so the case of a saturation bound for the mission costs is also considered. Dynamic saturation-based auctioning (DSAT) is proposed for allocating targets, providing lower time complexities (due to parallelism in allocation). Comparison is made with algorithms ranging from greedy to auction-based methods with provable sub-optimality. The algorithms are tested on exhaustive sets of inputs, with random configurations of targets (for DMRR with and without a mission saturation bound). The results for DSAT show that it outperforms state-of-the-art methods, like standard sequential single-item auctioning (SSI) or SSI with regret clearing.

7.2.9. Measuring information using VLC

The use of visible light for bidirectional communication between regular smartphones and the small LEDs integrated in most consumer electronics nowadays raises new challenges. In [13], we enhance the state of the art with an efficient image processing algorithm to accurately detect the LEDs and decode their signal in real time. We propose an efficient decoding algorithm, which can detect the LED position, process and decode the signal on average in 18.4 ms, for each frame, on a Nexus 5 unrooted smartphone. Thus, this implementation is convenient for low latency indoor localization or real-time transmission with a moving receiver. Also, as the ROI detection is the most complex step of the algorithm, scenarios with several transmitters can be envisaged, enabling MIMO-like transmissions. We also present smart mechanisms and protocols to build a robust flash-to-LED communications channel using off- the-shelf smartphones and small LEDs. Our experimental evaluation shows a throughput of 30 bit/s, which is suitable for feedback, wake-up or even some limited communication purposes. We believe that such bidirectional VLC communication system will be a great opportunity for smart and connected consumer electronic products, providing bidirectional smartphone- to-device communication at lower cost.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

- We have contracted a first bilateral contract with Total (2018-2019) 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 et evaluated by LQA.
- We have contracted bilateral cooperation with Rtone, an SME focusing on the connected objects area. This collaboration is associated with the CIFRE PhD grant for Alexis Duque, on the subject of Visible Light Communication.
- We have contracted bilateral cooperation with industrial and academic partners in the context of the PSPC Fed4PMR project (2015-2019). In this context, we are working on the design of new professional mobile radio solutions, compatible with 4G and 5G standards. This collaboration funds the PhD thesis of Jad Oueis, the PhD thesis of Romain Pujol, and a part of the PhD thesis of Abderrahman Ben Khalifa.

8.2. Bilateral Grants with Industry

- Common Laboratory Inria/Nokia Bell Labs - ADR Network Information Theory.
  Agora is part of the ADR Network Information Theory of the common laboratory Inria/Nokia Bell Labs.
- Spie - INSA Lyon IoT Chaire.
  Agora is involved in the SPIE INSA Lyon IoT Chaire, launched in November 2016. The IoT Chaire partially funds the PhD thesis of Abderrahman Ben Khalifa. The PhD thesis work of Alexis Duque and Amjed Belkhiri are also contributing in this structure.
- Volvo - INSA Lyon Chaire.
  Agora is involved in the Volvo Chaire at INSA Lyon, on the area of autonomous electrical distribution vehicle in urban environments. Razvan Stanica is a member in the steering committee of this structure.

9. Partnerships and Cooperations

9.1. Regional Initiatives

- FIL Grant, 2018
  Participants: Hervé Rivano
  The partners of this project, supported by the *Fédération d'Informatique de Lyon*, are: CITI, LIP.
  The goal is to use crow-sensing applications with data collection of Wi-Fi networks which are available in the neighborhood in order *i)* to build a map of the wireless network in terms of performance for the application and *ii)* to optimize the wireless network configuration.
- Labex IMU UrPolSens,10/2015-10/2018
  Participants: Walid Bechkit, Amjed Belkhiri, Ahmed Boubrima, Hervé Rivano
  The partners in this project are Ifsttar, LMFA, EVS, TUBA, and Air Rhone-Alpes, with Inria Agora leading the project.
  UrPolSens deals with the monitoring of air pollution using low-cost sensors interconnected by a wireless networks. Although they are less accurate than the high-end sensors used today, low-cost autonomous air quality sensors allow to achieve a denser spatial granularity and, hopefully, a better monitoring of air pollution. The main objectives of this project are to improve the modeling of air pollution dispersion; propose efficient models to optimize the deployment the sensors while considering the pollution dispersion and the impact of urban environment on communications; deploy a small-scale network for pollution monitoring as a proof of concept; compare the measured and estimated levels of exposure; study the spatial disparities in exposure between urban areas.
- Labex IMU 3M'Air 2018-2021
  Participants: Walid Beckhit, Ahmed Boubrima, Manoel Dahan, Mohamed Anis Fekih, Ichrak Mokhtari, Hervé Rivano.
  The partners in this project are: EVS, LMFA, Métropole de Lyon, Ville de Lyon , Atmo AURA, Météo France, Lyon Météo. Inria Agora is the leader of this project.
  The 3M'Air project explore the potential of participatory sensing to improve local knowledge of air quality and urban heat islands. The main aim of this project is therefore to equip citizens with low-cost mobile sensors and then ensure an efficient real-time data collection and analysis. This allows to obtain a finer spatiotemporal granularity of measurements with lighter installation and operational costs while involving citizens.

- ARC6 Robot fleet mobility under communication constraints, 10/2016-09/2019.
  Participant : Fabrice Valois.
  This work is a joint project with the Inria Chroma research group. Considering a fleet of drones moving in a 3D area, looking for a given target, we focus on how to maintain the wireless connectivity of the network of drones while the drones patrol autonomously. The other partners in this project are University of Grenoble and Viameca.
- Labex IMU Veleval, 10/2017-10/2019
  Participant: Hervé Rivano.
  The partners in this project are: EVS, LIRIS, LLSETI and CITI, with LAET leading the project.
  The goal of this pluridisciplinary project is to study, understand and model the behavior of cyclists in an urban environment with a methodology combining quantitative measurements of mobility traces and image analysis with qualitative informations from reactivation interviews. In particular the input of Agora is to provide crowdsourcing tools for gathering mobility data that are optimized for the practice of urban cycling.

9.2. National Initiatives

9.2.1. ANR

- ANR CANCAN 2019 - 2022 (accepted in 2018, kickoff in February 2019)
  Participants: Solohaja Rabenjamina, Razvan Stanica.
  The partners in this project are: CEDRIC, Inria, Orange Labs, with Thalès Communications & Security leading the project.
  The ANR CANCAN (Content and context based adaptation in mobile networks) targets the following objectives: *i)* collecting novel measurement datasets that describe mobile network data traffic at unprecedented spatial and temporal accuracy levels, and for different mobile services separately. The datasets will be gathered in an operational nationwide network, *ii)* evaluating existing analytics for classification, prediction and anomaly detection within real-world high-detail per-service mobile network data, and tailoring them to the specifications of the management of resources at different network levels, and *iii)* demonstrating the integration of data analytics within next-generation cognitive network architectures in several practical case studies.
- ANR MAESTRO 5G 2019 - 2022 (accepted in 2018, kickoff in February 2019)
  Participants: Hervé Rivano, Razvan Stanica.
  The partners in this project are: CEDRIC, Inria, L2S, LIA, Nokia Bell Labs, TSP, with Orange Labs leading the project.
  The ANR MAESTRO 5G (Management of slices int he radio access of 5G networks) is expected to provide: *i)* a resource allocation framework for slices, integrating heterogeneous QoS requirements and spanning on multiple resources including radio, backhauling/fronthauling and processing resources in the RAN, *ii)* acomplete slice management architecture including provisioning and re-optimization modules and their integration with NFV and SDN strata, *iii)* a business layer for slicing in 5G, *iv)* a demonstrator showing the practical feasibility as well as integration of the major functions and mechanisms proposed by the project, on a 5G Cloud RAN platform. The enhanced platform is expected to support the different 5G services.
- ANR CoWorkWorlds 01/2018 - 12/2020.
  Participants: Solohaja Rabenjamina, Razvan Stanica.
  The ANR CoWorkWorlds (Sustainability and spatiality in co-workers' mobility practices) project is lead by ENTPE. Its focus is on the study of co-working environments, and more precisely on the mobility behaviour of users of such spaces. Our role in the project is to collect and analyse mobility data from a set of users, using the PrivaMov smartphone application.

9.2.2. DGA

- DGA CLOTHO 10/2016-10/2018.
  Participants: Junaid Khan, Romain Pujol, Razvan Stanica, Fabrice Valois
  The partners in the DGA CLOTHO project are Traqueur and Sigfox. The objective of the project is to reduce the energy consumption of the device tracking functionality, by taking profit of short-range communications between the tracked objects.

9.2.3. PIA

- PIA ADAGE 07/2016-06/2018.
  Particpants: Elli Zavou, Razvan Stanica
  The partners in the PIA ADAGE project are Orange, LAAS-CNRS and Inria Privatics. The objective of the ADAGE project is to design and evaluate anonymization algorithms for the specific case of mobile traffic data. Our role in the project is focused on evaluating whether the anonymized data is still usable for adaptive networking mechanisms.

9.2.4. Pôle ResCom

- Ongoing participation (since 2006)
  Communication networks, working groups of GDR ASR/RSD, CNRS (http://rescom.inrialpes.fr). Hervé Rivano is member of the scientific committee of ResCom.

9.2.5. EquipEx

- SenseCity
  We have coordinated the participation of several Inria teams to the SenseCity EquipEx. Within the SenseCity project, several small reproduction of 1/3rd scale city surroundings will be built under a climatically controlled environment. Micro and nano sensors will be deployed to experiment on smart cities scenarios, with a particular focus on pollution detection and intelligent transport services. Agora will have the opportunity to tests some of its capillary networking solutions in a very realistic but controlled urban environment. A proof of concept test site has been built in 2015. We have deployed an experiment on low cost sensor network for vehicle detection and one on atmospheric pollution sensor calibration. The operational site is build, the information system is being finalized and the equipment will be inaugurated in April 2018.

9.2.6. Inria Project lab

- CityLab
  Agora is involved in the CityLab Inria Project Lab lead by Valérie Issarny. Within this project, Hervé Rivano co-advises, with Nathalie Mitton (FUN team, Inria Lille-Nord-Europe), the PhD thesis of Abdoul Aziz Mbacke on “Data gathering in sensor and passive RFID with energy harvesting for urban infrastructure monitoring”.

9.3. European Initiatives

9.3.1. Collaborations in European Programs, Except FP7 & H2020

Program: Interreg Med

Project acronym: ESMARTCITY

Project title: Enabling Smarter City in the MED Area through Networking

Duration: 02/2018 - 07/2020

Coordinator: Abruzzo Region, Italy

Other partners: ARIC and RWG (Greece), APEGR (Spain), RAIS (Bosnia and Herzegovina), ENA (Portugal), MCM and PoliMi (Italy), Capergies (France)

Abstract: The project has its primary objective in improving the innovation capacity of MED cities by creating innovation ecosystems, which involve actors of the quadruple helix (Citizens, Businesses Operators, Research, Universities and Public Authorities) , and in applying the Smart City concept, which utilizes digital and energy saving technologies to allow better services for the citizen with less impact on the environment, producing furthermore new employability and living scenarios. To achieve this goal, the project envisages the pilot testing of the Smart City concept to provide specific services to citizens in the field of intelligent urban districts, energy efficiency of buildings and smarter public lighting.

9.4. International Initiatives

9.4.1. Inria International Partners

9.4.1.1. Informal International Partners

- **University of Waterloo, ON, Canada**. Joint publications and visits to/from the group of Prof. Catherine Rosenberg.
- **Nimbus Centre, Cork, Ireland**. Collaboration around LoRa experiments with Dr. Ramona Marfievici.
- **CNR-IEIIT, Turin, Italy**. Joint publications and projects with Dr. Marco Fiore.
- **Trento University, Italy**. Collaboration around routing for IoT networks with the group of Prof. Gian Pietro Picco.
- **University of Edinburgh, UK**. Joint publications and visits to/from the group of Dr. Paul Patras.

9.4.2. Participation in Other International Programs

9.4.2.1. PHC Campus France

- **University of Cluj-Napoca, Romania**. PHC DRONEM (2017-2019) on Monitoring using connected fleet of drones, a collaboration with the group of Prof. Gabriela Czibula.

9.5. International Research Visitors

9.5.1. Visits of International Scientists

- Abdelmalik Bachir, Professor, Biskra University, Algeria: invited professor at INSA Lyon (July, 2018)
- Josep Paradells Aspas, Professor, Universitat Politecnica de Catalunya, Barcelona, Spain: invited professor at INSA Lyon (October 2018)
- Rui Li, PhD student, University of Edinburgh, Scotland, UK: visiting PhD student (March, 2018)

9.5.1.1. Research Stays Abroad

- Ahmed Boubrima visited the group of Prof. Azzedine Boukerche, University of Ottawa, Canada.
- Mihai Popescu visited the group of Prof. Gabriela Czibula, at University of Cluj-Napoca, Romania (3 periods of 1 month duration: April, June and November 2018).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific Events Organisation

10.1.1.1. General Chair, Scientific Chair

- Khaled Boussetta was co-track chair of Wireless Models and Simulations in the 10th IFIP Wireless Days 2018, April, 2018, Dubai, UAE.

10.1.1.2. Member of the Organizing Committees

- Khaled Boussetta was on the Organizing Committee of 2018 IEEE SOCA/SC2/IOV, 19-22 November, 2018, Paris.

10.1.1.3. Member of the Conference Program Committees

- Walid Bechkit was in the TPC of the followinf conference: IEEE ICC.
- Khaled Boussetta was in the TPC of the following conferences: IEEE CCNC, IEEE GlobeCom, IEEE ICC, Med-Hoc-Net, Wireless Days.
- Oana Iova was in the TPC of the following conferences: IEEE Globecom, ACM AINTEC, AdHoc-Now, EWSN 2018 (track Poster and Demos).
- Razvan Stanica was in the TPC of the following conferences: IEEE ICC, IEEE CCNC, ICIN.
- Fabrice Valois was in the TPC of the following conferences: IEEE ICC, ICT, IEEE Globecom, IEEE VTC Spring, WiSARN.

10.1.1.4. Reviewer

- Oana Iova was a reviewer for the following conferences: IEEE ICC, IEEE WCNC.

10.1.2. Journal

10.1.2.1. Reviewer - Reviewing Activities

- Oana Iova was a reviewer for the following journals: ACM TOSN, Elsevier Ad Hoc Networks, Elsevier Computer Networks, IEEE Transactions on Communications, IEEE Access, Springer Wireless Networks.
- Razvan Stanica was a reviewer for the following journals: IEEE Transactions on Mobile Computing, IEEE Transactions on Intelligent Transportation Systems, IEEE Communications Letters, Pervasive and Mobile Computing, IEEE Access, EURASIP Journal on Wireless Communications and Networking, IET Intelligent Transport Systems.

10.1.3. Invited Talks

- Walid Bechkit was invited speaker at the 1st Winter School on Information Theory and Signal Processing for Internet of Things, Villeurbanne, France.
- Walid Bechkit was invited speaker at the CESER (conseil économique, social et environnemental régional).
- Oana Iova was invited panelist at: 1st Winter School on Information Theory and Signal Processing for Internet of Things, Villeurbanne, France.
- Hervé Rivano was invited speaker at *La Nuit des idées*, Maison de France, Sfax, Tunisia.
- Hervé Rivano was invited speaker at La Myne, Lyon, France.
- Hervé Rivano was invited speaker Conseil de Développement de la Métropole/Amis de l'Université, Lyon, France.
- Hervé Rivano was invited speaker IMERIR, Perpignan, France.
- Hervé Rivano was invited speaker Salon Internet des Objets (SidO), Lyon, France.
- Hervé Rivano was invited speaker réseau ARAMIS, Lyon, France.
- Hervé Rivano was invited speaker at CIVIC Conference, University Constantine III, Algeria.
- Hervé Rivano was invited speaker at TokyoTech, Japan.
- Hervé Rivano was panel organizer on Smart Cities, POP Science Forum, Lyon, France.

10.1.4. Leadership within the Scientific Community

- Walid Bechkit was co-representative of the Labex IMU at the Smart City Expo World Congres (Barcelona).
- Walid Bechkit is a nominated member in the scientific committee of the Fédération d'Informatique de Lyon (FR 2000 CNRS).
- Hervé Rivano is member of the steering committee of the ResCom axis of the RSD CNRS GdR.
- Hervé Rivano is a member of the Scientific Council of TUBA Lyon.
- Hervé Rivano is member ot the steering committee of Ecole Urbaine de Lyon, in charge of Smart and Learning Cities.
- Fabrice Valois is a member of the Scientific Council of the LIMOS-UMR6158 laboratory, Clermont Ferrand.
- Fabrice Valois is member of the Scientific Council of the Labex IMU (Intelligence des Mondes Urbains).

10.1.5. Scientific Expertise

- Khaled Boussetta was reviewer for ANR generic call for projects 2018.
- Hervé Rivano is member of the Metropole de Lyon [R] Challenge, board of scientific experts.
- Hervé Rivano is member of the Scientific Committee of the Digital League Regional Cluster.
- Fabrice Valois was a member in the recruitment committee of a Full Professor in Computer Science at INSA Lyon.
- Fabrice Valois was a member in the recruitment committee of a Full Professor in Computer Science at Université d'Auvergne.

10.1.6. Research Administration

- Walid Bechkit is responsible for seminar organization and scientific animation within the CITI laboratory.
- Khaled Boussetta is member of the steering committee of the MathStic federation at University Paris 13.
- Hervé Rivano is member of the Administration Council of the EquipEx Sense City as representative of Inria.
- Hervé Rivano is president of the CITI laboratory council.
- Razvan Stanica is the CITI laboratory correspondent with the Labex IMU.
- Razvan Stanica is member of the steering committee of the Volvo Chaire at INSA Lyon.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

Licence : Walid Bechkit, IP Networks, 30h, L3, Telecom. Dpt. INSA Lyon.

Licence : Oana Iova, IP Networks, 30h, L3, Telecom. Dpt. INSA Lyon.

Licence : Oana Iova, Medium Access Control, 8h, L3, Telecom. Dpt. INSA Lyon.

Licence : Oana Iova, Network and System Programming, 82h, L3, Telecom. Dpt. INSA Lyon.

Licence : Hervé Rivano, Networking Fundamentals, 2h, L3, Telecom. Dpt. INSA Lyon.

Licence : Hervé Rivano, Algorithms and programming, 165h, L1 - L2, INSA Lyon.

Licence : Hervé Rivano, Sensors data engineering project, 34h, L2, INSA Lyon.

Licence : Razvan Stanica, Network Programming, 90h, L3, Telecom. Dpt. INSA Lyon.

Licence : Fabrice Valois, IP Networks, 42h, L3, Telecom. Dpt. INSA Lyon.

Master : Walid Bechkit, Introduction to wireless sensor networks, 50h, L2, INSA Lyon.

Master : Walid Bechkit, Performance evaluation of telecom networks, 100h, M1, Telecom. Dpt. INSA Lyon.

Master : Walid Bechkit, Cryptography and communication security, 30h, M1, Telecom. Dpt., INSA Lyon.

Master : Walid Bechkit, Wireless networks: architecture and security, 30h, M2, INSA Lyon.

Master : Master : Walid Bechkit, Network Acces Control, 6h, M2, Telecom. Dpt. INSA Lyon.

Master : Oana Iova, Network Routing Protocols, 40h, M1, Telecom. Dpt. INSA Lyon.

Master : Oana Iova, Long Range Networks, 10h , M2, Telecom. Dpt. INSA Lyon

Master : Hervé Rivano, Smart Cities and IoT, 44h, M2, Telecom. Dpt. INSA Lyon.

Master : Razvan Stanica, Mobile Networks, 30h, M1, Telecom. Dpt. INSA Lyon.

Master : Razvan Stanica, Network Science, 10h, M2, Telecom. Dpt. INSA Lyon.

Master : Fabrice Valois, Mobile Networks, 16h, M1, Telecom. Dpt. INSA Lyon.

MOOC : Hervé Rivano, Razvan Stanica, Fabrice Valois, Connectez à Internet vos Objets Intelligents, production started in the context of the ANR Connect-IO project.

Walid Bechkit is in charge of the admission service of the Telecommunication department at INSA Lyon.

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.

Khaled Boussetta is the studies director of Apprenticeship Education Program Specialty in Computer Science and Network at Sup'Galilée Engineering School (University Paris 13).

Hervé Rivano is responsible for the coordination of all courses in the Smart Cities and IoT option at the INSA Lyon Telecommunications department.

Herve´ Rivano is referent DSI in the FIMI Dpt., INSA Lyon.

Razvan Stanica is responsible of the research option at the Telecommunications department of INSA Lyon.

Razvan Stanica is vice dean of the Telecommunications department of INSA Lyon, in charge of education related affairs.

10.2.2. Supervision

PhD in progress: Abderrahman Ben Khalifa, Cognitive mechanisms for IoT networks, since 11/2016. Advisors: Hervé Rivano, Razvan Stanica.

PhD in progress: Ahmed Boubrima, Optimal deployment of wireless sensor networks for air pollution monitoring, since 10/2015. Advisors: Walid Bechkit, Hervé Rivano.

PhD in progress : Rodrigue Domga Komguem, Autonomous WSN architectures for road traffic applications, since 11/2012. Advisors: Razvan Stanica, Maurice Tchuente (Univ. Yaoundé, Cameroun), Fabrice Valois.

PhD in progress: Mohamed Anis Fekih, Urban pollution using wireless sensor networks, since 11/2018.Advisors: Walid Bechkit, Hervé Rivano.

PhD in progress: Mihai Popescu, Connectivity constrained mobility in fleets of robots, since 11/2015. Advisors: Olivier Simonin (Inria CHROMA), Anne Spalanzanni (Inria CHROMA), Fabrice Valois.

PhD in progress: Romain Pujol, Data collection in dynamic wireless networks, since 11/2018. Advisors: Razvan Stanica, Fabrice Valois.

PhD in progress: Solohaja Rabenjamnia, Data analysis of cellular trafic, since 11/2018. Advisors: Hervé Rivano, Razvan Stanica.

10.2.3. Juries

- Hervé Rivano was a reviewer in the following PhD defense committee:
  - V. Quintuna Rodriguez, Nouvelle commande réseau IP : Performance des fonctions virtualisées pour une infrastructure programmable, LIP6, Université Pierre et Marie Curie, Paris VI
  - Y. Couble, Optimisation de la gestion des ressources de la voie retour, IRIT, Université de Toulouse
  - L. Molina, Metrics and non-intrusive techniques to characterize Wi-Fi networks, IRISA, Université de Bretagne-Pays de la Loire
  - H. Tall, Load balancing in multichannel data collection wireless sensor networks, LIMOS, Université de Clermont Auvergne
  - H. Pimenta Moraes Junior, A contribution to data sharing in vehicular networks, Heudiasyc, Université Technologique de Compiègne
- Hervé Rivano was a reviewer in the following HDR defense committee:
  - F. Giroire, Nouvelle commande réseau IP : Performance des fonctions virtualisées pour une infrastructure programmable, I3S, Université de Nice Sophia Antipolis
- Fabrice Valois was a reviewer in the following PhD defense committee:
  - E. Morin, Intéroperabilité de protocoles de communication adaptatifs basse consommation pour des réseaux de capteurs, LIG, Université Grenoble Alpes
- Fabrice Valois was a member in the following PhD defense committee:
  - D. Alshamaa, Indoor localization of sensors: application to dependent elderly people, UTT
  - H. Chelle, Contrôle de charge des réseaux IoT : D'une étude théorique à une implantation réelle, IRIT, ENSHEEIT
- Fabrice Valois was a reviewer in the following HDR defense committee:
  - P. Berthou, Vers la dématérialisation des Réseaux Hybrides satellites et terrestre, LAAS, Université Paul Sabatier
- Fabrice Valois was a member in the following HDR defense committee:
  - T. Begin, Contributions to the Performance Modeling of Computer Networks, LIP, Université de Lyon 1
  - K. Boussetta, Dimensionnement, adaptation et placement de fonctionnalités réseaux pour des applications sensibles aux délais, L2TI, Université Paris XIII

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[1] A. DUQUE. *Bidirectional Visible Light Communications for the Internet of Things*, Université de Lyon - INSA Lyon, October 2018, https://hal.inria.fr/tel-01940002

[2] A. A. MBACKÉ. *Collection and multi-hop forwarding of RFID data for the monitoring of urban infrastructures*, Université de Lille, October 2018, https://hal.inria.fr/tel-01901740

[3] J. OUEIS. *Radio Access and Core Functionalities in Self-deployable Mobile Networks*, Université de Lyon - INSA Lyon, November 2018, https://hal.inria.fr/tel-01950198

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[4] A. A. MBACKÉ, N. MITTON, H. RIVANO. *A survey of RFID readers anticollision protocols*, in "IEEE Journal of Radio Frequency Identification", March 2018, vol. 2, n^o 1, 11 p. [*DOI :* 10.1109/JRFID.2018.2828094], https://hal.inria.fr/hal-01767311

[5] J. OUEIS, V. CONAN, D. LAVAUX, H. RIVANO, R. STANICA, F. VALOIS. *Core Network Function Placement in Self-Deployable Mobile Networks*, in "Computer Communications", January 2019, vol. 133, pp. 12-23 [*DOI :* 10.1016/J.COMCOM.2018.10.009], https://hal.inria.fr/hal-01928552

[6] Y. ZGUIRA, H. RIVANO, A. MEDDEB. *Internet of Bikes: A DTN Protocol with Data Aggregation for Urban Data Collection*, in "Sensors", August 2018, vol. 19, n^o 8, pp. 1-39 [*DOI :* 10.3390/S18092819], https://hal.inria.fr/hal-01862155

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