Activity Report 2015

Team URBANET

Réseaux capillaires urbains

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions).

Table of contents

Creation of the Team: 2012 February 01

Keywords:

Computer Science and Digital Science:

      1.2. - Networks
      1.2.1. - Dynamic reconfiguration
      1.2.2. - Supervision
      1.2.3. - Routing
      1.2.4. - QoS, performance evaluation
      1.2.5. - Internet of things
      1.2.6. - Sensor networks
      1.4. - Ubiquitous Systems
      5.11. - Smart spaces
      5.11.1. - Human activity analysis and recognition
      6.2.6. - Optimization
      7.11. - Performance evaluation
      7.3. - Operations research, optimization, game theory

Other Research Topics and Application Domains:

      6.3.2. - Network protocols
      6.4. - Internet of things
      8. - Smart Cities and Territories
      8.2. - Connected city
      8.5.2. - Crowd sourcing

1. Members

Research Scientist
    Hervé Rivano [Team leader, Inria, Researcher, HdR]

Faculty Members
    Isabelle Auge Blum [INSA Lyon, Associate Professor]
    Walid Bechkit [INSA Lyon, Associate Professor]
    Razvan Stanica [INSA Lyon, Associate Professor]
    Fabrice Valois [INSA Lyon, Professor, HdR]

Engineer
    Stephane d'Alu [INSA Lyon (30%)]

PhD Students
    Yosra Bahri Zguira [University of Sousse, Tunisia government grant, from May 2015]
    Ahmed Boubrima [Inria, from Oct 2015]
    Soukaina Cherkaoui [Inria, ADR Green grant]
    Jin Cui [INSA Lyon, Chinese Scholarship Council grant]
    Rodrigue Domga Komguem [AUF, Cameroon government grant]
    Alexis Duque [Rtone, CIFRE grant, from Oct 2015]
    Guillaume Gaillard [Orange Labs, CIFRE grant]

Leo Le Taro [Univ. Lyon, IMU UrPolSens grant, from Nov 2015]
Trista Lin [Inria, Region ARC7 grant]
Diala Naboulsi [INSA Lyon, MENRT grant, until Sep 2015]
Jad Oueis [INSA Lyon, from Oct 2015]
Mihai-Ioan Popescu [INSA Lyon, Region ARC7 grant, from Nov 2015]
Post-Doctoral Fellows
Angelo Furno [Inria]
Anh Dung Nguyen [Inria, from Oct 2015]
Patrice Raveneau [Univ. Lyon, until Aug 2015]
Visiting Scientists
Khaled Boussetta [Univ. Paris XIII, Associate Professor, from Sep 2014]
Marco Fiore [CNR - IEIIT, Researcher, HdR]
Administrative Assistants
Aude Montillet [Inria (50%), from Dec 2015]
Gaelle Tworkowski [Inria (50%)]

2. Overall Objectives

2.1. Introduction

Team UrbaNet's overall objectives are to study and characterize the architectures of urban capillary wireless networks and to propose mechanisms and protocols that are designed for the specific settings of the urban environment. It requires taking into account constraints on the node deployment, heterogeneous and dynamic wireless connectivity, and requirements yielded by the usage of the city and the societal trends. Our methodology consists in combining formal verification and combinatorial optimization methods with simulation based and analytical performance assessments to guide the development of relevant mechanisms.

3. Research Program

3.1. Capillary networks

The definition of Smart Cities is still constantly redefined and expanded so as to comprehensively describe the future of major urban areas. The Smart City concept mainly refers to granting efficiency and sustainability in densely populated metropolitan areas while enhancing citizens' life and protecting the environment. The Smart City vision can be primarily achieved by 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 digitalized counterpart to a continuum in which digital contents and applications are seamlessly interacting with classical infrastructures and services. The general philosophy of smart cities can also be seen as a paradigm shift combining the Internet of Things (IoT) and Machine-to-Machine (M2M) communication with a citizen-centric model, all together leveraging massive data collected by pervasive sensors, connected mobile or fixed devices, and social applications.

The fast expansion of urban digitalization yields new challenges that span from social issues to technical problems. Therefore, there is a significant joint effort by public authorities, academic research communities and industrial companies to understand and address these challenges. Within that context, the application layer, i.e., the novel services that ICT can bring to digital urban environments, have monopolized the attention. Lower-layer network architectures have gone instead quite overlooked. We believe that this might be a fatal error, since the communication network plays a critical role in supporting advanced services and ultimately in making the Smart City vision a reality. The UrbaNet project deals precisely with that aspect, and the study of network solutions for upcoming Smart Cities represents the core of our work.

Most network-related challenges along the road to real-world Smart Cities deal with efficient mobile data communication, both at the backbone and at the radio access levels. It is on the latter that the UrbaNet project is focused. More precisely, the scope of the project maps to that of capillary networks, an original concept we define next.

The capillary networking concept represents a unifying paradigm for wireless last-mile communication in smart cities. The term we use is reminiscent of the pervasive penetration of different technologies for wireless communication in future digital cities. Indeed, capillary networks represent the very last portion of the data distribution and collection network, bringing Internet connectivity to every endpoint of the urban tissue in the same exact way capillary blood vessels bring oxygen and collect carbon dioxide at tissues in the human body. Capillary networks inherit concepts from the self-configuring, autonomous, ad hoc networks so extensively studied in the past decade, but they do so in a holistic way. Specifically, this implies considering multiple technologies and applications at a time, and doing so by accounting for all the specificities of the urban environment.

3.2. Specific issues and new challenges of capillary networks

Capillary networks are not just a collection of independent wireless technologies that can be abstracted from the urban environment and/or studied separately. That approach has been in fact continued over the last decade, as technologies such as sensor, mesh, vehicular, opportunistic, and – generally speaking – M2M networks have been designed and evaluated in isolation and in presence of unrealistic mobility and physical layer, simplistic deployments, random traffic demands, impractical application use cases and non-existent business models. In addition, the physical context of the network has a significant impact on its performances and cannot be reduced to a simple random variable. Moreover, one of the main element of a network never appears in many studies: the user. To summarize, networks issues should be addressed from a user- and context-centric perspective.

Such abstractions and approximations were necessary for understanding the fundamentals of wireless network protocols. However, real world deployments have shown their limits. The finest protocols are often unreliable and hardly applicable to real contexts. That also partially explains the marginal impact of multi-hop wireless technologies on today's production market. Industrial solutions are mostly single-hop, complex to operate, and expensive to maintain.

In the UrbaNet project we consider the capillary network as an ensemble of strongly intertwined wireless networks that are expected to coexist and possibly co-operate in the context of arising digital cities. This has three major implications:

- Each technology contributing to the overall capillary network should not be studied apart. As a matter of fact, mobile devices integrate today a growing number of sensors (e.g., environment sensing, resource consumption metering, movement, health or pollution monitoring) and multiple radio interfaces (e.g., LTE, WiFi, ZigBee,. . .), and this is becoming a trend also in the case of privately owned cars, public transport vehicles, commercial fleets, and even city bikes. Similarly, access network sites tend to implement heterogeneous communication technologies so as to limit capital expenses. Enabling smart-cities needs a dense sensing of its activities, which cannot be achieved without multi-service sensor networks. Moreover, all these devices are expected to inter-operate so as to make the communication more sustainable and reliable. Thus, the technologies that build up the capillary network shall be studied as a whole in the future.

- The capillary network paradigm necessarily accounts for actual urban mobility flows, city land-use layouts, metropolitan deployment constraints, and expected activity of the citizens. Often, these specificities do not arise from purely networking features, but relate to the study of city topologies and road layouts, social acceptability, transportation systems, energy management, or urban economics. Therefore, addressing capillary network scenarios cannot but rely on strong multidisciplinary interactions.

- Digital and smart cities are often characterized by arising M2M applications. However, a city is, before all, the gathering of citizens, who use digital services and mobile Internet for increasing their quality of life, empowerment, and entertainment opportunities. Some data flows should be gathered to, or distributed from, an information system. Some other should be disseminated to a geographically or time constrained perimeter. Future usage may induce peer-to-peer like traffics. Moreover these services are also an enabler of new usages of the urban environment. Solutions built within the capillary network paradigm have to manage this heterogeneity of traffic requirements and user behaviors.

By following these guidelines, the UrbaNet ambition is to go one step beyond traditional approaches discussed above. The capillary network paradigm for Smart Cities is tightly linked to the specificities of the metropolitan context and the citizens' activity. Our proposal is thus to re-think the way capillary network technologies are developed, considering a broader and more practical perspective.

3.3. Characterizing urban networks

Our first objective is to understand and model those properties of real-world urban environments that have an impact on the design, deployment and operation of capillary networks. It means to collect and analyze data from actual deployments and services, as well as testbeds experiments. These data have then to be correlated with urban characteristics, e.g. topography, density of population and activities. The objective is to deduce analytical models, simulations and traces of realistic scenarios that can be leveraged afterward. We structure the axis into three tasks that correspond to the three broad categories of networking aspects affected by the urban context.

- **Topological characteristics**. Nowadays, the way urban wireless network infrastructures are typically represented in the literature is dissatisfying. As an example, wireless links are mostly represented as symmetric, lossless channels whose signal quality depends continuously on the distance between the transmitter and the receiver. No need to say, real-world behaviors are very far from these simplified representations. Another example, topologies are generally modeled according to deterministic (e.g., regular grids and lattices, or perfect hexagonal cell coverages) or stochastic (e.g., random uniform distributions over unbound surfaces) approaches. These make network problems mathematically tractable and simulations easier to set up, but are hardly representative of the layouts encountered in the real world. Employing simplistic models helps understanding some fundamental principles but risks to lead to unreliable results, both from the viewpoint of the network architecture design and from that of its performance evaluation. It is thus our speculation that the actual operations and the real-world topologies of infrastructured capillary networks are key to the successful deployment of these technologies, and, in this task, we aim at characterizing them. To that end, we leverage existing collaborations with device manufacturers (Alcatel-Lucent, HiKob) and operators (Orange), as well as collaboration such as the Sense City project and testbed experiments, in order to provide models that faithfully mimic the behavior of real world network devices. The goal is to understand the important features of the topologies, including, e.g., their overall connectivity level, spatial density, degree distribution, regularity, etc. Building on these results, we try to define network graph models that reproduce such major features and can be employed for the development and evaluation of capillary network solutions.

- **Mobilities**. We aim at understanding and modeling the mobile portion of capillary networks as well as the impact of the human mobility on the network usage. Our definition of "mobile portion" includes traditional mobile users as well as all communication-enabled devices that autonomously interact with Internet-based servers and among themselves. There have been efforts to collect real-world movement traces, to generate synthetic mobility dataset and to derive mobility models. However, real-world traces remain limited to small scenarios or circumstantial subsets of the users (e.g., cabs instead of the whole road traffic). Synthetic traces are instead limited by their scale and by their level of realism, still insufficient. Finally, even the most advanced models cannot but provide a rough representation of user mobility in urban areas, as they do not consider the street layout or

the human activity patterns. In the end, although often deprecated, random or stochastic mobility models (e.g., random walks, exponential inter-arrivals and cell residence times) are still the common practice. We are well aware of the paramount importance of a faithful representation of device and user mobility within capillary networks and, in order to achieve it, we leverage a number of realistic sources, including Call Detail Records (CDR) collected by mobile operators, Open Data initiatives, real-world social network data, and experiments. We collect data and analyze it, so as to infer the critical properties of the underlying mobility patterns.

- **Data traffic patterns**. The characterization of capillary network usages means understanding and modeling when, where and how the wireless access provided by the diverse capillary network technologies is exploited by users and devices. In other words, we are interested in learning which applications are used at different geographical locations and day times, which urban phenomena generate network usage, and which kind of data traffic load they induce on the capillary network. Properly characterizing network usages is as critical as correctly modeling network topology and mobility. Indeed, the capillary networks being the link directly collecting the data from end devices, we cannot count on statistical smoothing which yields regular distributions. Unfortunately, the common practice is to consider, e.g., that each user or device generates a constant data traffic or follows on/off models, that the offered load is uniform over space and does not vary over time, that there is small difference between uplink and downlink behaviors, or that source/destination node pairs are randomly distributed in the network. We plan to go further on the specific scenarios we address, such as smart-parking, floating car data, tele-metering, road traffic management of pollution detection. To that end, we collect real-world data, explore it and derive properties useful to the accurate modeling of content consumption.

3.4. Autonomic networking protocols

While the capillary networks concept covers a large panel of technologies, network architectures, applications and services, common challenges remain, regardless the particular choice of a technology or architecture. Our record of research on spontaneous and multi-hop networks let us think that autonomic networking appears as the main issue: the connectivity to Internet, to cyber-physical systems, to Information Systems should be transparent for the user, context-aware and location-aware. To address these challenges, a capillary network model is required. Unfortunately, very few specific models fit this task today. However, a number of important, specific capillary networks properties can already be inferred from recent experiments: distributed and localized topologies, very high node degree, dynamic network diameter, unstable / asymmetric / non-transitive radio links, concurrent topologies, heterogeneous capabilities, etc. These properties can already be acknowledged in the design of networking solutions, and they are particularly challenging for the functioning of the MAC layer and QoS support. Clearly, capillary networks provide new research opportunities with regard to networking protocols design.

- **Self-* protocols**. In this regard, self-configuration, self-organization and self-healing are some of the major concerns within the context of capillary networks. Solving such issues would allow spontaneous topologies to appear dynamically in order to provide a service depending of the location and the context, while also adapting to the interactions imposed by the urban environment. Moreover, these mechanisms have the capacity to alleviate the management of the network and the deployment engineering rules, and can provide efficient support to the network dynamics due to user mobility, environment modifications, etc. The designed protocols have to be able to react to traffic requests and local node densities. We address such self-adaptive protocols as a transversal solution to several scenarios, e.g. pollution monitoring, smart-services depending on human activities, vehicle to infrastructure communications, etc. In architectures where self-* mechanisms govern the protocol design, both robustness and energy are more than ever essential challenges at the network layer. Solutions such as energy-harvesting can significantly increase the network lifetime in this case, therefore we investigate their impact on the mechanisms at both MAC and network layers.

- **Quality of service issues**. The capillary networks paradigm implies a simultaneous deployment

of multiple wireless technologies, and by different entities (industry, local community, citizens). This means that some applications and services can be provided concurrently by different parts of the capillary network, while others might require the cooperation of multiple parties. The notion of Service Level Agreement (SLA) for traffic differentiation, quality of service support (delay, reliability, etc.) is a requirement in these cases for scalability purposes and resource sharing. We contribute to a proper definition of this notion and the related network mechanisms in the settings of low power wireless devices. Because of the urban context, but also because of the wireless media itself, network connectivity is always temporary, while applications require a delivery ratio close to 100%. We investigate different techniques that can achieve this objective in an urban environment.

- **Data impact**. Capillary networks suffer from low capacity facing the increasing user request. In order to cope with network saturation, a promising strategy is to consider the nature of the transmitted data in the development of the protocols. Data aggregation and data gathering are two concepts with a major role to play in this context of limited capacity. In particular, combining local aggregation and measurement redundancy for improving on data reliability is a promising idea, which can also be important for energy saving purposes. Even if the data flow is well known and regular, e.g. temperature or humidity metering, developing aggregation schemes tailored to the constraints of the urban environment is a challenge we address within the UrbaNet team. Many urban applications generate data which has limited spatial and temporal perimeters of relevance, e.g. smart-parking applications, community information broadcasting, etc. When solely a spatial range of relevance is considered, the underlying mechanisms are denoted "geocasting". We also address these spatio-temporal constraints, which combine geocasting approaches with real-time techniques.

3.5. Optimizing cellular network usage

The capacity of cellular networks, even those that are now being planned, does not seem able to cope with the increasing demands of data users. Moreover, new applications with high bandwidth requirements are also foreseen, for example in the intelligent transportation area, and an exponential growth in signaling traffic is expected in order to enable this data growth. Cumulated with the lack of available new spectrum, this leads to an important challenge for mobile operators, who are looking at both licensed and unlicensed technologies for solutions. The usual strategy consists in a dramatic densification of micro-cells coverage, allowing both to minimize the transmission power of cellular networks as well as to increase the network capacity. However, this solution has obvious physical limits, which we work on determining, and we propose exploiting the capillarity of network interfaces as a complementary solution.

- **Green cellular network**. Increasing the density of micro-cells means multiplying the energy consumption issues. Indeed, the energy consumption of actual LTE eNodeBs and relays, whatever their state, idle, transmitting or receiving, is a major and growing part of the access network energy consumption. For a sustainable deployment of such micro-cell infrastructures and for a significative decrease of the overall energy consumption, an operator needs to be able to switch off cells when they are not absolutely needed. The densification of the cells induces the need for an autonomic control of the on/off state of cells. One solution in this sense can be to adapt the WSN mechanisms to the energy models of micro-cells and to the requirements of a cellular network. The main difficulty here is to be able to adapt and assess the proposed solutions in a realistic environment (in terms of radio propagation, deployment of the cells, user mobility and traffic dynamics).

- **Offloading**. Offloading the cellular infrastructure implies taking advantage of the wealth of connectivity provided by capillary networks instead of relying solely on 4G connectivity. Cellular operators usually possess an important ADSL or cable infrastructure for wired services, the development of femtocell solutions thus becomes very popular. However, while femtocells can be an excellent solution in zones with poor coverage, their extensive use in areas with a high density of mobile users leads to serious interference problems that are yet to be solved. Taking advantage of capillarity for offloading cellular data relies on using IEEE 802.11 Wi-Fi (or other similar technologies) access points or direct device-to-device communications. The ubiquity of Wi-Fi access in urban areas

makes this solution particularly interesting, and many studies have focused on its potential. However, these studies fail to take into account the usually low quality of Wi-Fi connections in public areas, and they consider that a certain data rate can be sustained by the Wi-Fi network regardless of the number of contending nodes. In reality, most public Wi-Fi networks are optimized for connectivity, but not for capacity, and more research in this area is needed to correctly assess the potential of this technology. Direct opportunistic communication between mobile users can also be used to offload an important amount of data. This solution raises a number of major problems related to the role of social information and multi-hop communication in the achievable offload capacity. Moreover, in this case the business model is not yet clear, as operators would indeed offload traffic, but also lose revenue as direct ad-hoc communication would be difficult to charge and privacy issues may arise. However, combining hotspot connectivity and multi-hop communications is an appealing answer to broadcasting geo-localized informations efficiently.

4. Application Domains

4.1. Smart urban infrastructure

Unlike the communication infrastructure that went through a continuous development in the last decades, the distribution networks in our cities including water, gas and electricity are still based on 19th century infrastructure. With the introduction of new methods for producing renewable but unpredictable energy and with the increased attention towards environmental problems, modernizing distribution networks became one of the major concerns in the urban world. An essential component of these enhanced systems is their integration with information and communications technology, the result being a smart distribution infrastructure, with improved efficiency and reliability. This evolution is mainly based on the increased deployment of automatic equipment and the use of machine-to-machine and sensor-to-actuator communications that would allow taking into account the behavior and necessities of both consumers and suppliers

Another fundamental urban infrastructure is the transportation system. The progress made in the transportation industry over the last century has been an essential factor in the development of today's urban society, while also triggering the birth and growth of other economic branches. However, the current transportation system has serious difficulties coping with the continuous growth in the number of vehicles, especially in an urban environment. As a major increase in the capacity of a city road infrastructure, already in place for tens or even hundreds of years, would imply dissuasive costs, the more realistic approach is to optimize the use of the existing transportation system. As in the case of distribution networks, the intelligence of the system can be achieved through the integration of information and communication capabilities. However, for smart transportation the challenges are somehow different, because the intelligence is no longer limited to the infrastructure, but propagates to vehicles themselves. Moreover, the degree of automation is reduced in transportation systems, as most actions resulting in reduced road congestion, higher reliability or improved safety must come from the human driver (at least in the foreseeable future)

Finally, smart spaces are becoming an essential component of our cities. The classical architecture tools used to design and shape the urban environment are more and more challenged by the idea of automatically modifying private and public spaces in order to adapt to the requirements and preferences of their users. Among the objectives of this new urban planning current, we can find the transformation of the home in a proactive health care center, fast reconfigurable and customizable workplaces, or the addition of digital content in the public spaces in order to reshape the urban scene. Bringing these changing places in our daily lives is conditioned by a major shift in the construction industry, but it also involves important advancements in digital infrastructure, sensing, and communications

4.2. Urban participatory sensing

Urban sensing can be seen as the same evolution of the environment digitalization as social networking has been for information flows. Indeed, besides dedicated and deployed sensors and actuators, still required for

specific sensing operations such as the real-time monitoring of pollution levels, there is a wide range of relevant urban data that can be collected without the need for new communication infrastructures, leveraging instead on the pervasiveness of smart mobile terminals. With more than 80% of the population owning a mobile phone, the mobile market has a deeper penetration than electricity or safe drinking water. Originally designed for voice transmitted over cellular networks, mobile phones are today complete computing, communication and sensing devices, offering in a handheld device multiple sensors and communication technologies.

Mobile devices such as smartphones or tablets are indeed able to gather a wealth of informations through embedded cameras, GPS receivers, accelerometers, and cellular, WiFi and bluetooth radio interfaces. When collected by a single device, such data may have small value per-se, however its fusion over large scales could prove critical for urban sensing to become an economically viable mainstream paradigm.

This is even more true when less traditional mobile terminals are taken into account: privately-owned cars, public transport means, commercial fleets, and even city bikes are starting to feature communication capabilities and the Floating Car Data (FCD) they generate can bring a dramatic contribution to the cause of urban sensing. Indeed, other than enlarging the sensing scope even further, e.g., through Electronic Control Units (ECUs), these mobile terminals are not burdened by strong energy constraints and can thus significantly increase the granularity of data collection. This data can be used by authorities to improve public services, or by citizens who can integrate it in their choices. However, in order to kindle this hidden information, important problems related to data gathering, aggregation, communication, data mining, or even energy efficiency need to be solved.

4.3. Human-centric networks

Combining location awareness and data recovered from multiple sources like social networks or sensing devices can surface previously unknown characteristics of the urban environment, and enable important new services. As a few examples, one could think of informing citizens about often disobeyed (and thus risky) traffic signs, polluted neighborhoods, or queue waiting times at current exhibitions in the urban area.

Beyond letting their own devices or vehicles autonomously harvest data from the environment through embedded or onboard sensors, mobile users can actively take part in the participatory sensing process because they can, in return, benefit from citizen-centric services which aim at improving their experience of the urban life. Crowdsourcing applications have the potential to turn citizens into both sources of information and interactive actors of the city. It is not a surprise that emerging services built on live mobile user feedback are rapidly meeting a large success. In particular, improving everyone's mobility is probably one of the main services that a smart city shall offer to its inhabitants and visitors. This implies providing, through network broadcast data or urban smart-furniture, an accurate and user-tailored information on where people should head in order to find what they are looking for (from a specific kind of shop to a free parking slot), on their current travel time estimates, on the availability of better alternate means of transport to destination. Depending on the context, such information may need to be provided under hard real-time constraints, e.g., in presence of road accidents, unauthorized public manifestations, or delayed public transport schedules.

In some cases, information can also be provided to mobile users so as to bias or even enforce their mobility: drivers can be alerted of the arrival of an emergency vehicle so that they leave the leftmost lane available, or participants leaving vast public events can be directed out of the event venue through diverse routes displayed on their smartphones so as to dynamically balance the pedestrian flows and reduce their waiting times.

5. Highlights of the Year

5.1. Highlights of the Year

Awards
- The project "Mobile Traffic Signatures in the Urban Landscape" (participants: Angelo Furno, Razvan Stanica, Marco Fiore) was selected among the 10 finalists (from more than 200 submissions) of the Telecom Italia Big Data Challenge- http://www.telecomitalia.com/tit/en/bigdatachallenge/news-social/tim-big-data-challenge-2015-finalisti.html.

6. New Software and Platforms

6.1. PrivaMovApp

FUNCTIONAL DESCRIPTION

UrbaNet 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: Patrice Raveneau, Hervé Rivano, Razvan Stanica.
- Contact: Razvan Stanica
- URL: http://liris.cnrs.fr/privamov/project/

6.2. TAPASCologne

Travel and Activity PAtterns Simulation Cologne
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, Diala Naboulsi and Razvan Stanica.
- Contact: Marco Fiore
- URL: http://kolntrace.project.citi-lab.fr/#download

6.3. Platforms

6.3.1. Sense in the City

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: Khaled Boussetta, Hervé Rivano.
- Contact: Khaled Boussetta

7. New Results

7.1. Characterizing and deploying urban networks

Participants: Ahmed Boubrima, Angelo Furno, Diala Naboulsi, Patrice Raveneau, Walid Bechkit, Marco Fiore, Hervé Rivano, Razvan Stanica.

7.1.1. *Collection and Analysis of Mobile Phone Data*

Cellular communications are undergoing significant evolutions in order to accommodate the load generated by increasingly pervasive smart mobile devices. At the same time, recent generations of mobile phones, embedding a wide variety of sensors, have fostered the development of open sensing applications, while cellular operators are looking for new services they can provide using the data collected on their side, in the access or the core network.

The analysis of operator-side data is a recently emerged research field, and, apart a few outliers, relevant works cover the period from 2005 to date, with a sensible densification over the last three years. In [9], we provided a thorough review of the multidisciplinary activities that rely on mobile traffic datasets, identifying major categories and sub-categories in the literature, so as to outline a hierarchical classification of research lines and proposing a complete introductory guide to the research based on mobile traffic analysis. The usage of these datasets in the design of new networking solutions, in order to achieve the so-called *cognitive networking* paradigm, is discussed in detail in the PhD thesis of Diala Naboulsi [2], where the examples of green networking and virtualized radio access networks are given.

When constructing a social network from interactions among people (e.g., phone calls, encounters), a crucial task is to define the threshold that separates social from random (or casual) relationships. The ability to accurately identify social relationships becomes essential to applications that rely on a precise description of human routines, such as recommendation systems, forwarding strategies and opportunistic dissemination protocols. We thus proposed a strategy to analyze users' interactions in dynamic networks where entities act according to their interests and activity dynamics [10]. Our strategy allows classifying users interactions, separating random ties from social ones, and unveils significant differences among the dynamics of users' wireless interactions in the datasets.

Furthermore, mobile traffic data has been recently used to characterize the urban environment in terms of urban fabric profiles. While showing promising results, the existing urban fabric detection solutions are built without a clear understanding of the detection process chain. In [16], we distinguished and analyzed the different steps common to all urban profiling techniques. By evaluating the impact of each step of the process, we were able to propose a new solution that outperforms the state of the art techniques. Our approach uses the weekly periodicity of human activities, as well as a median-based filtering technique, resulting in a better clustering in terms of both coverage and entropy, as shown by results obtained on two large scale mobile traffic datasets covering the urban areas of Milan and Turin, in Italy. The solution proposed in this work was selected among the 10 finalists of the Telecom Italia Big Data challenge.

A second source of mobile data is the smartphone itself. In the context of the PrivaMov project, funded by the Labex IMU, we developed and deployed a data collection platform on more than 100 Android devices. A first step in the study of this enormous dataset (more than 50 Gb have been collected to date) was presented in [21], with a focus on the extraction of user mobility information and Wi-Fi mapping. This led us to the study of Wi-Fi tracking, a method relying on signals emitted by portable devices to track individuals for commercial, security or surveillance purposes. Wi-Fi tracking has the potential to passively track a large fraction of the population and is therefore an ideal population surveillance technology and a serious privacy threat. In [19], we argue that Wi-Fi routers make an ideal building block to create a large scale Wi-Fi tracking system, showing how they can be easily turned into Wi-Fi tracking devices through software modification. We provided a first evaluation of the tracking capabilities of an hypothetical Wi-Fi tracking system through a set of simulations based on real-world datasets. Results showed that the spatial distribution of Wi-Fi routers is such that compromising even a small fraction of Wi-Fi routers is sufficient to track people for a large fraction of the time.

Preservation of user privacy is therefore paramount in the publication of datasets that contain fine-grained information about individuals. The problem is especially critical in the case of mobile traffic datasets collected by cellular operators, as discussed above, as they feature high subscriber trajectory uniqueness and they are resistant to anonymization through spatiotemporal generalization. In [17], we first unveiled the reasons behind such undesirable features of mobile traffic datasets, by leveraging an original measure of the

anonymizability of users' mobile fingerprints. Building on such findings, we proposed GLOVE, an algorithm that grants k-anonymity of trajectories through specialized generalization. We evaluated our methodology on two nationwide mobile traffic datasets, and show that it achieves k-anonymity while preserving a substantial level of accuracy in the data.

7.1.2. Deployment of Wireless Sensor Networks for Pollution Monitoring

Recently, air pollution monitoring emerged as one of the main services of smart cities because of the increasing industrialization and the massive urbanization. Wireless Sensor Networks are a suitable technology for this purpose, thanks to their substantial benefits including low cost and autonomy. Minimizing the deployment cost is one of the major challenges in the design of such networks, therefore sensors positions have to be carefully determined. In [13], we proposed two integer linear programming formulations based on real pollutants dispersion modeling to deal with the minimum cost sensor network deployment for air pollution monitoring. We illustrated the concept by applying our models on real world data, namely the Nottingham City street lights. We compared the two models in terms of execution time and showed that the second flow-based formulation is much better. We finally conducted extensive simulations to study the impact of some parameters and derive some guidelines for efficient urban sensor deployment for air pollution monitoring.

7.2. Technology specific solutions

Participants: Jin Cui, Walid Bechkit, Khaled Boussetta, Hervé Rivano, Fabrice Valois.

7.2.1. Temperature-Aware Algorithms for Wireless Sensor Networks

Temperature variations have a significant effect on low power wireless sensor networks as wireless communication links drastically deteriorate when temperature increases. A reliable deployment should take temperature into account to avoid network connectivity problems resulting from poor wireless links when temperature increases. A good deployment needs also to adapt its operation and save resources when temperature decreases and wireless links improve. Taking into account the probabilistic nature of the wireless communication channel, in [12] we investigated the effect of temperature on percolation-based connectivity in large scale wireless sensor networks and showed that more energy can be saved by allowing some nodes to go to deep sleep mode when temperature decreases and links improve. Based on this result, we proposed a simple, yet efficient, Temperature-Aware MAC plugin (TA-MAC), which can be potentially used with any MAC protocol, enabling it to dynamically adapt the network effective density in order to allow further energy savings, while maintaining network connectivity. We carried out simulations and demonstrated that sate of the art protocols augmented with the TA-MAC plugin allow a significant energy efficiency improvement.

Going one step further, we developed a mathematical model that provides the most energy efficient deployment in function of temperature without compromising the correct operation of the network by preserving both connectivity and coverage [3]. We used our model to design three temperature-aware algorithms that seek to save energy (i) by putting some nodes in hibernate mode as in the SO (Stop-Operate) algorithm in TA-MAC, or (ii) by using transmission power control as in PC (Power-Control), or (iii) by doing both techniques as in SOPC (Stop-Operate Power-Control). All proposed algorithms are fully distributed and solely rely on temperature readings without any information exchange between neighbors, which makes them low overhead and robust. Our results identified the optimal operation of each algorithm and showed that a significant amount of energy can be saved by taking temperature into account.

7.2.2. Resilience in Wireless Sensor Networks

The concept of resilience for routing protocols in wireless sensor networks has been proposed and developed in the team in the last few years. In our previous works, a general overview of the resilience, including definition, metric and resilient techniques based on random behavior and data replication have been proposed. Following these previous methods, in [6] we proposed a new resilient solution based on network coding techniques, to improve resilience in wireless sensor networks for smart metering applications. More precisely, using our resilience metric based on a performance surface, we compared several variants of a well-known gradient based routing protocol with the previous methods (random routing and packet replications) and the

new proposed methods (two network coding techniques). The proposed methods outperformed the previous methods in terms of data delivery success even in the presence of high attack intensity.

We also continued to study the resilience of routing protocols against malicious insiders willing to disrupt network communications. Previously, the simulation results showed that introducing randomness in routing protocols increases uncertainty for an adversary, making the protocols unpredictable. When combined with data replication, it permits route diversification between a source and a destination, thus enhancing the resilience. In [15], we proposed a theoretical framework to quantify analytically the performance of random protocols against attacks based on biased random walks on a torus lattice. The objective is to evaluate analytically the influence of bias and data replication introduced to random walks. The bias allows to decrease the route length by directing random walks toward the destination, thus reducing the probability of a data packet to meet a malicious insider along the route; however, it decreases also the degree of randomness (entropy). When random protocols are combined with data replication, the reliability is improved thanks to route diversity despite an additional overhead in terms of energy consumption.

7.2.3. *Data aggregation in Wireless Sensor Networks*

Aggregation functions are intended to save energy and capacity in Wireless Sensor Networks, by avoiding unnecessary transmissions. Aggregation functions take benefit from spatial and/or temporal correlations to forecast or to compress the real data which are collected. Although several works have focused on data aggregation in Wireless Sensor Networks, there is a lack of a formal unified framework that can compare several aggregation functions suitable for a given network topology, a given application and a target accuracy. In [14], we address this question by proposing a Markov Decision Process that can help to evaluate the performances of aggregation functions. The performances are expressed using two new proposed metrics, which can assess the energy and capacity savings of aggregation functions. As illustrative examples, we use our Markov Decision Process to evaluate and analyze the performances of basic aggregation functions (e.g. average) and more complex ones (time series, polynomial functions).

7.2.4. *Data Gathering in Mesh Networks*

In the gathering problem in mesh networks, a particular node in a graph, the base station, aims at receiving messages from some nodes in the graph. At each step, a node can send one message to one of its neighbors (such an action is called a call). However, a node cannot send and receive a message during the same step. Moreover, the communication is subject to interference constraints, more precisely, two calls interfere in a step, if one sender is at distance at most d_I from the other receiver. Given a graph with a base station and a set of nodes having some messages, the goal of the gathering problem is to compute a schedule of calls for the base station to receive all messages as fast as possible, i.e., minimizing the number of steps (called makespan). The gathering problem is equivalent to the personalized broadcasting problem where the base station has to send messages to some nodes in the graph, with same transmission constraints.

In [5], we focused on the gathering and personalized broadcasting problem in grids. Moreover, we considered the non-buffering model: when a node receives a message at some step, it must transmit it during the next step. In this setting, though the problem of determining the complexity of computing the optimal makespan in a grid is still open, we presented linear (in the number of messages) algorithms that compute schedules for gathering with $d_I \in 0, 1, 2$. In particular, we presented an algorithm that achieves the optimal makespan up to an additive constant 2 when $d_I = 0$. If no messages are "close" to the axes (the base station being the origin), our algorithms achieve the optimal makespan up to an additive constant 1 when $d_I = 0$, 4 when $d_I = 2$, and 3 when both $d_I = 1$ and the base station is in a corner.

7.3. Capillary Network Solutions

Participants: Patrice Raveneau, Trista Lin, Marco Fiore, Hervé Rivano, Razvan Stanica.

7.3.1. Connected Vehicles

Managing user mobility is historically one of the most critical issues in cellular radio access networks (RANs). That task will become an even greater challenge due to cellular users on-board vehicles and networked cars that autonomously access Internet-based services, whose number is expected to grow dramatically in the next few years. There is thus a need to characterize RAN access from/by vehicles in a similar way to what has been done for traditional pedestrian access. In [11], we proposed a first study of the macroscopic and microscopic features of pervasive vehicular access in a case-study large-scale urban environment, in presence of realistic datasets of the road traffic and RAN deployment. We found that pervasive vehicular access is characterized by unique temporal and spatial variability in the urban region, such that it may require a dedicated RAN capacity planning: the presence of stable vehicular access load patterns and mobility flows can help to that end. Also, we identified the theoretical distributions that best fit key metrics for RAN planning, i.e., the vehicular users' inter-arrival and residence times at cells, and discuss how their parameters vary over time and space.

Smart parking, allowing drivers to access parking information through their smart-phone, is another important service for vehicular users, which can be provided not only through cellular networks, but also by using metropolitan wireless networks, whose deployment strategy needs to be guided by efficiency and functionality. In [8], we introduced and studied a deployment strategy for wireless on-street parking sensor networks. We defined a multiple-objective problem in our analysis, and solved it with two real-world street parking maps. We presented the results on the tradeoff among minimum energy consumption, sensing information delay and the amount of deployed mesh routers and Internet gateways, i.e., the cost of city infrastructure. We also analyzed these tradeoffs to see how different urban layouts affect the optimal solutions. The overall smart parking architecture and services made the object of the PhD thesis of Trista Lin [1], where the analysis of the entire system can be found, including results on the wireless sensor networks used to collect data from parking places and the Publish-Subscribe service used to disseminate this information to users.

7.3.2. Offloading Cellular Networks

Offloading is a promising technique for alleviating the ever-growing traffic load from infrastructure-based networks such as the Internet. Offloading consists in using alternative methods of transmission as a cost-effective solution for network operators to extend their transport capacity. Wi-Fi offloading is one of the most effective approaches to relieve the cellular radio access from part of the burgeoning mobile demand. To date, Wi-Fi offloading has been mainly leveraged in limited contexts, such as home, office or campus environments. In [18], we investigated the scaling properties of Wi-Fi offloading, by studying how it would perform on a much larger scope than those considered today. To that end, we considered a real-world citywide scenario, built on data about actual infrastructure deployments and mobile traffic demand, and observed which amount of traffic could be accommodated by the existing pervasive Wi-Fi access infrastructure, were it opened to mobile users. We found that more than 80% of the mobile traffic demand in a large urban area may be easily served by Wi-Fi access points, under a wide range of system settings.

A new offloading technique was introduced in [20] and further detailed in [4], where we advocate the use of conventional vehicles equipped with storage devices as data carriers whilst being driven for daily routine journeys. The road network can be turned into a large-capacity transmission system to offload bulk transfers of delay-tolerant data from the Internet. The challenges we addressed include how to assign data to flows of vehicles and while coping with the complexity of the road network. We proposed an embedding algorithm that computes an offloading overlay where each logical link spans over multiple stretches of road from the underlying road infrastructure. We then formulated the data transfer assignment problem as a novel linear programming model we solve to determine the optimal logical paths matching the performance requirements of a data transfer. We evaluated our road traffic allocation scheme using actual road traffic counts in France. The numerical results show that 20% of vehicles in circulation in France equipped with only one Terabyte of storage can offload Petabyte transfers in a week.

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

- 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 some industrial partners on the subject of smart casing. However, these contracts are under non disclosure agreements and cannot be mentioned here.

- We have contracted bilateral cooperation with industrial and academic partners in the context of the PSPC Fed4PMR project (2015-2018). In this context, we will be working on the design of new professional mobile radio solutions, compatible with 4G and 5G standards.

8.2. Bilateral Grants with Industry

- Common Laboratory Inria/Alcatel-Lucent Bell Labs - ADR Green.
  UrbaNet is part of the ADR Green of the common laboratory Inria/Alcatel-Lucent Bell Labs. This ADR provides the PhD grant of Soukaina Cherkaoui on the channel access capacity evaluation in 5G networks.

9. Partnerships and Cooperations

9.1. Regional Initiatives

- BQR INSA CROME 12/2013-12/2016
  Participants: Fabrice Valois
  The partners in this project are the CITI DynaMid team and LIRIS. The project studies the coordination of a fleet of mobile robots for the multi-view analysis of complex scenes.

- Labex IMU Priva'Mov 10/2013-10/2016
  Participants: Patrice Raveneau, Hervé Rivano, Razvan Stanica
  The partners in this project are DRIM LIRIS, Inria Privatics, INSA EVS, and LET ENTPE. The aim of this project is to develop and deploy a crowdsensing platform to collect mobility traces from a sample of real users equipped with android devices, while carrying research on privacy preservation issues. Our contribution consists on developing the platform and using the collected data to analyze cellular network offloading strategies.

- Labex IMU UrPolSens 10/2015-10/2018
  Participants: Ahmed Boubrima, Leo Le Taro, Walid Bechkit, Hervé Rivano
  The partners in this project are Ifsttar, LMFA, EVS, and TUBA, with Inria Urbanet 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.

9.2. National Initiatives

9.2.1. ANR

- ANR ABCD 10/2013-04/2017.
  Participants: Diala Naboulsi, Marco Fiore, Razvan Stanica
  The partners in the ANR ABCD project are: Orange Labs, Ucopia, Inria UrbaNet, UPMC LIP6
  PHARE, Telecom ParisTech. The objective of ABCD is to characterize large-scale user mobility and
  content consumption in urban areas via mobile data mining, so as to achieve efficient deployment
  and management of cloud resources via virtual machines. Our contribution in the project consists on
  the characterization of human mobility and service consumption at a city scale, and the design of
  appropriate resource allocation techniques at the cellular network level.
- ANR IDEFIX 10/2013-04/2017.
  Participants: Soukaina Cherkaoui, Hervé Rivano, Fabrice Valois
  The partners in the ANR IDEFIX project are: Orange Labs, Alcatel Lucent - Bell Labs, Telecom
  Paris Tech, Inria UrbaNet, Socrate and Dyogene.

9.2.2. 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.

9.2.3. 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.
  Urbanet will have the opportunity to tests some of its capillary networking solutions in a very realistic
  but controlled urban environment. The first deployment is scheduled early 2015.

9.2.4. Inria Project lab

- CityLab
  Urbanet is involved in the CityLab Inria Project Lab lead by Valérie Issarny. Within this project,
  Hervé Rivano is the networking referent for the PhD thesis of Raphael Ventura, advised by Vivien
  Mallet, in the Clime Inria team.

9.3. International Initiatives

9.3.1. Inria International Partners

9.3.1.1. Declared Inria International Partners

- DTN for IOT - Bilateral contract with III Taiwan 2015.
  This collaboration, funded by III, focuses on the feasibility to implement Delay Tolerant Network
  protocols within the Internet Of Things context. The motivation for using generic protocols able to
  handle the constraints of the Intenet of Things is highlighted with the choice of the Bundle Protocol.
  A study of existing implementations of this protocol is realized within a sensor context and a tailored
  implementation is proposed. This collaboration has partially funded the postdoc of Patrice Raveneau.

9.3.1.2. Informal International Partners

- **Ecole Polytechnique de Montréal, QC, Canada**. Cooperation on subjects related to mobile
  networks with the group of Prof. Samuel Pierre.
- **University of Waterloo, ON, Canada**. Joint publications and visits to/from the group of Prof.
  Catherine Rosenberg.

9.4. International Research Visitors

9.4.1. Visits of International Scientists

- Dennis Chen,Research Engineer, III, Taiwan: one week visit (June 2015).
- Ling-Jyh Chen, Associate Research Fellow, Academia Sinica, Taiwan: one week visit (December 2015).
- Mario Gerla, Professor, UCLA, USA: one day visit (March 2015).
- Roch Glitho, Associate Professor, Concordia University, Montreal, Canada: one week visit (September 2015).
- Catherine Rosenberg, Professor, University of Waterloo, Canada: two days visit (July 2015).

9.4.1.1. Internships

- F. Bernardo Duarte, intern, University of Lisbon, Portugal: Comfortable workplace using sensor motes (3 months).
- A. Boubrima, MS thesis, ESI Algiers, Algeria: Optimal deployment of wireless sensor networks for air pollution monitoring (6 months).
- A. Dobre, intern,Polytechnic University of Bucharest, Romanial: Comfortable workplace using sensor motes (3 months).
- A. Hanganu, intern, Polytechnic University of Bucharest, Romania: Comfortable workplace using sensor motes (3 months).
- J. Lallana, intern, Universidad Politécnica de Madrid, Spain: Performance evaluation of RPL resiliency using Cooja (5 months)
- D. Martella, intern, Politecnico di Torino, Italy: Coordination of robots fleet (6 months).
- M. Iliushkina, intern, University of Saint Petersburg, Russia: Comfortable workplace using sensor motes (3 months).
- Z. Plokhovska, intern, University of Pittsburgh, PA, USA: Combining DSRC and VLC in Safety Vehicular Networks (3 months).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

10.1.1.1. General chair, scientific chair

- Hervé Rivano was general co-chair of the ResCom Summer School "Smart Cities", held in Lyon in June 2015.

10.1.1.2. Member of the organizing committees

- Razvan Stanica was in the organizing committee of the ResCom Summer School "Smart Cities", held in Lyon in June 2015.

10.1.2. Scientific events selection

10.1.2.1. Member of the conference program committees

- Walid Bechkit was TPC member for the following conferences: IEEE ICC, IEEE CCNC, ACS/IEEE AICCSA, IWCMC and ISPS.
- Marco Fiore was TPC member for IEEE INFOCOM, IEEE WoWMoM, IEEE ICC, IEEE VNC, IEEE VTC, IEEE/IFIP WONS, IEEE WF-IoT, MobiArch, ExtremeCom, IEEE/IFIP Wireless Days, IEEE UIC, IEEE WiMob, and a number of international workshops.

- Razvan Stanica was in the TPC of the following conferences: IEEE ICC, IEEE GlobeCom, IEEE VTC Fall, IEEE CCNC, ISNCC, WSC, ICCVE, GIIS, IOV, MobiArch, MobiApps, WF-IoT, INT-GAST, AlgoTel.
- Fabrice Valois was in the TPC of the following confrences: IEEE ICC, IEEE AINA, IEEE Globecom, IWCMC, IEEE VTC Spring, IEEE WCNC.

10.1.3. Journal

10.1.3.1. Member of the editorial boards

- Marco Fiore is Technical Committee member for Elsevier Computer Communications.
- Marco Fiore and Razvan Stanica were Guest Editors for the Elsevier Computer Communication special issue on Mobile Traffic Analytics.

10.1.3.2. Reviewer - Reviewing activities

- Walid Bechkit was a reviewer for the following journals: Elsevier Ad-Hoc Networks, Telecommunication Systems and Journal of Network and Computer Applications.
- Marco Fiore served as a reviewer for a number of international journals, including IEEE Transactions on Mobile Computing, IEEE Journal on Selected Areas in Communications, IEEE Transactions on Vehicular Technology, IEEE Transactions on Wireless Communications, IEEE Transactions on Communications, IEEE Transactions on Industrial Informatics, IEEE Communications Magazine, IEEE Vehicular Technology Magazine, Elsevier Ad-hoc Networks, Elsevier Computer Communications, Elsevier Vehicular Communications.
- Razvan Stanica was a reviewer for the following journals: IEEE Communications Magazine, Elsevier Ad-Hoc Networks, Elsevier Computer Communications, Elsevier Vehicular Communications, Springer Annals of Telecommunications, IEEE Sensors Journal, Sensors, Procedia Engineering, Journal of Advanced Transportation, Frontiers of Information Technology & Electronic Engineering.

10.1.4. Invited talks

- Marco Fiore gave an invited talk "Mobile Traffic Data Analytics for 5G Cognitive Networking" at the 1st GdR MaDICS Workshop on Big Data for the 5G RAN, Paris, November 2015.
- Marco Fiore gave an invited lecture on "Mining cellular traffic collected at mobile operator network probes" at the Networks and Data Mining Summer School, Luchon, June 2015.
- Marco Fiore gave an invited talk "Road traffic modeling with an eye to networking applications" atTelecom Sud Paris, Paris, June 2015.
- Hervé Rivano gave an invited talk and a demo entitled "Capteurs pour la route intelligente" at the inauguration conference of the Sense City EquipEx, Marne la Vallée, March 2015.
- Hervé Rivano gave an invited talk entitled "Issues of urban capillary networks" in the Japan-France workshop on Cyber security, French Embassy, Tokyo, April 2015.
- Hervé Rivano gave an invited talk entitled "Urban networks for Smarter Cities" in the Aristote association workshop on Smart Cities, Ecole Polytechnique, April 2015.
- Hervé Rivano gave an invited talk entitled "Networking for Smarter Cities" in the Berkeley-Inria-Stanford workshop of Inria@SiliconValley, Berkeley, May 2015.
- Hervé Rivano gave an invited talk and a demo entitled "Sensors for smart roads" in the Global Metropolitan Lab of the World Bank, Marne la Vallée, June 2015.
- Hervé Rivano gave an invited talk entitled "Including citizens in the design of Smart Cities – Needs, results and challenges of interdisciplinarity" in the CNRS Lamsade/NSF-Dimacs Citizens Science workshop, Paris, December 2015.
- Razvan Stanica gave an invited talk entitled "Véhicules connectés : Pourquoi nos voitures apprennent à parler?" in the Connected Objects workshop organized in the context of the 28th Jacques Cartier Meetings, Lyon, December 2015.

- Fabrice Valois gave an invited talk entitled "Capillary networks for Smart Cities" in the Ecole d'été ResCom, GDR CNRS, Lyon, June 2015.

10.1.5. *Leadership within the scientific community*

- Hervé Rivano has been named in the working group of Rhone Alpes region and Caisse des Dépôts et Consignations on "Territoires Augmentés", Lyon, November 2015.
- Fabrice Valois has been named as a member of the Scientific Council of the LIMOS-UMR6158 laboratory, Clermont Ferrand, in January 2015.

10.1.6. *Scientific expertise*

- Marco Fiore was a reviewer for the following calls: MiSe FCS (Italy), MiSe DA (Italy), ANR appel générique (France).
- Hervé Rivano has done a scientific expertise for the Aquitaine Province, April 2015.
- Hervé Rivano is involved in the "Villes et territoires innovants" working group of the Conseil National de l'Information Géographique.

10.1.7. *Research administration*

- Walid Bechkit is responsible for seminar organization and scientific animation within the CITI laboratory.
- Hervé Rivano is responsible with the Economic and Strategic Intelligence affairs of the CITI research laboratory, in charge with setting up ZRRs withing the lab.
- Hervé Rivano is member of the Administration Council of the EquipEx Sense City as representative of Inria.
- Hervé Rivano is member of the Steering Committee of the ResCom axis of the ASR CNRS GdR.
- Hervé Rivano and Razvan Stanica are members in the CITI laboratory council.
- Razvan Stanica is the CITI laboratory correspondent with the Labex IMU.
- Fabrice Valois is director of the CITI research laboratory of INSA Lyon.

10.2. Teaching - Supervision - Juries

10.2.1. *Teaching*

Licence : Isabelle Augé-Blum, Operating Systems, 70h, L3, Telecom. Dpt. INSA Lyon.

Licence : Walid Bechkit, IP Networks, 40h, L3, Telecom. Dpt. INSA Lyon.

Licence : Hervé Rivano, IP Networks, 20h, L3, Telecom. Dpt. INSA Lyon.

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

Licence : Razvan Stanica, Advanced Wireless Networks, 20h, L3, IST / Telecom. Dpt. INSA Lyon (lectures given in english).

Licence : Fabrice Valois, IP Networks, 100h, L3, Telecom. Dpt. INSA Lyon.

Licence : Fabrice Valois, IP Networks, 20h, L3, IST / Telecom. Dpt. INSA Lyon (lectures given in english).

Master : Isabelle Augé-Blum, Innovation project, 30h, M1, Telecom. Dpt. INSA Lyon.

Master : Isabelle Augé-Blum, Bibliographical study, 30h, M1, Telecom. Dpt. INSA Lyon.

Master : Isabelle Augé-Blum, Real-Time Networks, 25h, M2, Telecom. Dpt. INSA Lyon.

Master : Isabelle Augé-Blum, Networks of the Future, 10h, M2, University of Lyon.

Master : Walid Bechkit, Network architectures, protocols and services, 12h, M1, Telecom. Dpt. INSA Lyon.

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

Master : Walid Bechkit, Wireless multihop networks, 10h, M2, University of Lyon.

Master : Walid Bechkit, Wireless networks: architecture and security, 18h, M2, INSA Lyon.

Master: Hervé Rivano, Wireless multihop networks, 10h, M2, University of Lyon.

Master: Hervé Rivano, Smart Cities, 4h, M2, Polytech Perpignan.

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

Master : Fabrice Valois, Mobile Networks, 30h, M1, Telecom. Dpt. INSA Lyon.

Master : Fabrice Valois, Wireless Sensor Networks, 6h, M2, University of Grenoble.

Isabelle Augé-Blum is in charge of the foreign affairs of the Telecommunications department at INSA Lyon, coordinating all incoming and outgoing student exchange programs.

Razvan Stanica is responsible for the administrative part related to all Master projects prepared by INSA Lyon Telecommunications department students.

Fabrice Valois is responsible of the networking teaching team in the Telecommunications department at INSA Lyon, coordinating all the courses in the networking domain.

Since 2006, Fabrice Valois is the head of an international teaching program focused on Internet of Things, established between INSA Lyon and Shanghai Jiao Tong University.

Fabrice Valois and Walid Bechkit are elected members of the Telecommunications Department Council at INSA Lyon.

E-learning

MOOC : Hervé Rivano, Villes intelligentes et technologies nume´riques, with the Inria Project Lab « Smart Cities », FUN platform.

10.2.2. Supervision

PhD : Diala Naboulsi, Analysis and exploitation of mobile traffic datasets, INSA Lyon, 09/2015. Advisors: Marco Fiore, Razvan Stanica, Fabrice Valois.

PhD : Trista Lin, Smart parking: network, infrastructure and urban service, INSA Lyon, 12/2015. Advisors: Frédéric Le Mouel (CITI DynaMid), Hervé Rivano.

PhD in progress : Yosra Bahri Zguira, DTN for IoT, since 05/2015. Advisors: Aref Meddeb (Univ. Sousse, Tunisia), Hervé Rivano.

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 : Soukaina Cherkaoui, Energy-saving strategies for backhaul networks, since 11/2013. Advisor: Hervé Rivano.

PhD in progress : Jin Cui, Aggregation: From data dynamics to network dynamics, since 11/2012. Advisor: Fabrice Valois.

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 : Alexis Duque, Use of visible light communication in a smart city context, since 10/2015. Advisors: Hervé Rivano, Razvan Stanica.

PhD in progress : Guillaume Gaillard, SLA pour réseaux de capteurs multi-services, since 12/2012. Advisor: Fabrice Valois.

PhD in progress : Leo Le Taro, Recalibration of wireless sensors for pollution monitoring, since 11/2015. Advisor: Hervé Rivano.

PhD in progress: Jad Oueis, Systèmes PMR très haut débit fédérateurs, since 10/2015. Advisors: Razvan Stanica, Fabrice Valois.

PhD in progress: Mihai Popescu, Mobilité au sein de flottes de robots sous contrainte de maintien de la connectivité, since 11/2015. Advisors: Olivier Simonin (Inria CHROMA), Anne Spalanzanni (Inria CHROMA), Fabrice Valois.

MS thesis: S. Bouchareb, INSA Lyon, Capacity Limits in Cloud RAN, 09/2015. Advisors: Samir Perlaza (Inria Socrate), Razvan Stanica.

MS thesis: A. Merabtene, Univ. Lyon 1, Usage-Mobility Correlation in Mobile Phone Data, 07/2015. Advisor: Razvan Stanica.

MS thesis: J. Oueis, INSA Lyon, Energy Harvesting in Wireless Sensor Networks, 07/2015. Advisors: Razvan Stanica, Fabrice Valois.

MS thesis: B. Saves, INSA Lyon, Mobile data collection in wireless sensor networks for air pollution monitoring, 09/2015. Advisors: Walid Bechkit, Hervé Rivano.

MS thesis: J. Wang, INSA Lyon, Wi-Fi based Localization in Urban Spaces, 09/2015. Advisors: Patrice Raveneau, Razvan Stanica.

10.2.3. Juries

- Marco Fiore was external reviewer in the following PhD defense committees:
  - E. Mucelli, From Human Routine to more Efficient Mobile Networks, École Polytechnique, Paris, 03/2015.
  - F. Mezghani, Dissemination de contenus dans les reseaux vehiculaires, INP Toulouse, 10/2015.
- Hervé Rivano was external reviewer in the following PhD defense committees:
  - H. Xiang, Quasi-Optimal Mobile Crowdsensing : Cadre de conception et algorithmes, Télécom SudParis, Université Pierre et Marie Curie, 01/2015.
  - G. Artero Gallardo, Qualité de service dans de environnements réseaux mobiles, hétérogènes et contraints, IRIT, INP Toulouse, 03/2015.
  - R. Dagher, Sur la radionavigation dans les villes intelligentes du futur. Le cas des re´seaux de capteurs sans fils, Inria, Université de Lille 1, 10/2015.
- Hervé Rivano was member in the following PhD defense committees:
  - F. Zahra Moataz, Vers des Re´seaux Optiques Efficaces et Tole´rants aux Pannes : Complexite´ et Algorithmes, I3S, Université de Nice-Sophia Antipolis, 10/2015.
- Fabrice Valois was external reviewer in the following PhD defense committees:
  - G. Romanielleo, Energy Efficient Protocols for Harvested Wireless Sensor Networks, LIG, Université de Grenoble, 03/2015.
  - D. Carvin, Mécanismes de supervision distribués pour la gestion des réseaux dynamiques, LAAS, INSA Toulouse, 07/2015.
  - C. Cobarzan, Internet of Highly Mobile Things, I-Cube, Université de Strasbourg, 09/2015.
  - N. Guzzo, Facing the real challenges in wireless sensor network-based applications : an adaptative cross-layer self- organization WSN protocol, Inria, Université de Lille 1, 12/2015.
- Fabrice Valois was member in the following PhD defense committees:
  - T. Antignac, Méthodes formelles pour le respect de la vie privée par construction, CITI, INSA Lyon, 02/2015.
  - Y. Chen, Routing Algorithm Dedicated to Environmental Data Collection: Precision Agriculture, LIMOS, Université Blaise Pascal, Clermont-Ferrand, 04/2015.

    – M. Vucinic, Architectures and Protocols for Secure and Energy-Efficient Integration of Wireless Sensor Networks with the Internet of Things, LIG, Université de Grenoble, 11/2015.

    – T. Lin, Smart Parking : Network, Infrastructure and Urban Service, CITI, INSA Lyon, 12/2015.

10.3. Popularization

- Hervé Rivano gave a popularization talk entitled "Réseaux de capteurs urbains" in the Tuba X-pert session of February 2015.
- Hervé Rivano participated to a TV Show on "IoT and Smart Cities", Tele Grenoble, April 2015.
- Razvan Stanica gave a popularization talk entitled "Teaching Our Cars How to Speak: Communications for Intelligent Transportation Systems" in the internal meeting of the Transportation Group of the Spie company.

11. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] T. LIN. *Smart Parking: Network, Infrastructure and Urban Service*, INSA Lyon, December 2015, https://hal.archives-ouvertes.fr/tel-01249062

[2] D. NABOULSI. *Analysis and exploitation of mobile traffic datasets*, INSA Lyon, September 2015, https://hal.archives-ouvertes.fr/tel-01235304

Articles in International Peer-Reviewed Journals

[3] A. BACHIR, W. BECHKIT, Y. CHALLAL, A. BOUABDALLAH. *Joint Connectivity-Coverage Temperature-Aware Algorithms for Wireless Sensor Networks*, in "IEEE Transactions on Parallel and Distributed Systems", July 2015, vol. 26, n° 07, pp. 1923-1936 [*DOI : 10.1109/TPDS.2014.2331063*], https://hal.archives-ouvertes.fr/hal-01006039

[4] B. BARON, P. SPATHIS, H. RIVANO, M. DIAS DE AMORIM. *Offloading Massive Data onto Passenger Vehicles: Topology Simplification and Traffic Assignment*, in "IEEE/ACM Transactions on Networking", December 2015, http://hal.upmc.fr/hal-01247713

[5] J.-C. BERMOND, B. LI, N. NISSE, H. RIVANO, M.-L. YU. *Data gathering and personalized broadcasting in radio grids with interference*, in "Journal of Theoretical Computer Science (TCS)", 2015, vol. 562, pp. 453-475 [*DOI : 10.1016/J.TCS.2014.10.029*], https://hal.inria.fr/hal-01084996

[6] P. BRUNISHOLZ, O. ERDENE-OCHIR, M. ABDALLAH, K. QARAQE, M. MINIER, F. VALOIS. *Network Coding versus Replication Based Resilient Techniques to Mitigate Insider Attacks for Smart Metering*, in "International Journal of Distributed Sensor Networks", 2015, vol. 2015, n^o Article ID 737269, 11 p. [*DOI : 10.1155/2015/737269*], https://hal.archives-ouvertes.fr/hal-01199787

[7] A. FARSI, N. N. A. ACHIR, ·. KHALED BOUSSETTA. *WLAN planning: Separate and joint optimization of both access point placement and channel assignment*, in "annals of telecommunications - annales des télécommunications", January 2016, vol. 70, n° 5-6, pp. 263–274 [*DOI : 10.1007/S12243-014-0447-2*], https://hal.inria.fr/hal-01251971

[8] T. LIN, H. RIVANO, F. LE MOUËL. *Urban Infrastructure Deployment for Wireless On-Street Parking Sensor Networks*, in "Procedia Engineering", 2015, vol. 115, pp. 29-36 [*DOI :* 10.1016/J.PROENG.2015.07.351], https://hal.inria.fr/hal-01170754

[9] D. NABOULSI, M. FIORE, S. RIBOT, R. STANICA. *Large-scale Mobile Traffic Analysis: a Survey*, in "Communications Surveys and Tutorials, IEEE Communications Society", October 2015 [*DOI :* 10.1109/COMST.2015.2491361], https://hal.inria.fr/hal-01132385

[10] P. OLMO VAZ DE MELO, A. CARNEIRO VIANA, M. FIORE, K. JAFFRÈS-RUNSER, F. LE MOUËL, A. A. F. LOUREIRO, L. ADDEPALLI, C. GUANGSHUO. *RECAST: Telling Apart Social and Random Relationships in Dynamic Networks*, in "Performance Evaluation", March 2015, vol. 87, n° 19-36 [*DOI :* 10.1016/J.PEVA.2015.01.005], https://hal.inria.fr/hal-01109969

[11] S. UPPOOR, M. FIORE. *Characterizing pervasive vehicular access to the cellular RAN infrastructure: an urban case study*, in "IEEE Transactions on Vehicular Technology", June 2015, vol. 64, n° 6, pp. 2603-2614 [*DOI :* 10.1109/TVT.2014.2343651], https://hal.inria.fr/hal-01237022

International Conferences with Proceedings

[12] W. BECHKIT, Y. CHALLAL, A. BACHIR, A. BOUABDALLAH. *Temperature MAC Plug-in for Large Scale WSN*, in "ICC 2015 - IEEE International Conference on Communications", London, United Kingdom, June 2015, https://hal.archives-ouvertes.fr/hal-01149317

[13] A. BOUBRIMA, F. MATIGOT, W. BECHKIT, H. RIVANO, A. RUAS. *Optimal Deployment of Wireless Sensor Networks for Air Pollution Monitoring*, in "ICCCN 2015 - 24th International Conference on Computer Communication and Networks", Las Vegas, United States, August 2015, https://hal.archives-ouvertes.fr/hal-01171765

[14] J. CUI, K. BOUSSETTA, F. VALOIS. *Performance Evaluation of Data Aggregation Functions using Markov Decision Processes*, in "The Twelve ACM International Symposium on Performance Evaluation of Wireless Ad Hoc, Sensor, and Ubiquitous Networks", Cancun, Mexico, Proceeding of ACM MSWIM, ACM, November 2015, https://hal.inria.fr/hal-01251687

[15] O. ERDENE-OCHIR, M. ABDALLAH, K. QARAQE, M. MINIER, F. VALOIS. *A theoretical framework of resilience: Biased random walk routing against insider attacks*, in "WCNC 2015 - IEEE Wireless Communications and Networking Conference", New Orleans, United States, IEEE, March 2015, pp. 1602–1607, https://hal.archives-ouvertes.fr/hal-01199222

[16] A. FURNO, R. STANICA, M. FIORE. *A Comparative Evaluation of Urban Fabric Detection Techniques Based on Mobile Traffic Data*, in "ASONAM 2015 - IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining", Paris, France, August 2015, https://hal.inria.fr/hal-01246620

[17] M. GRAMAGLIA, M. FIORE. *Hiding Mobile Traffic Fingerprints with GLOVE*, in "CoNEXT 2015 - ACM 11th International Conference on emerging Networking EXperiments and Technologies", Heidelberg, Germany, December 2015, https://hal.inria.fr/hal-01237032

[18] P. RAVENEAU, R. STANICA, M. FIORE, S. UPPOOR, M. CUNCHE, H. RIVANO, Z. SMOREDA. *Urban-scale Cellular Offloading through Wi-Fi Access Points: a Measurement-based Case Study*, in "RTSI 2015 - 1st

International Forum on Research and Technologies for Society and Industry", Turin, Italy, September 2015, https://hal.archives-ouvertes.fr/hal-01201719

[19] P. ROUVEYROL, P. RAVENEAU, M. CUNCHE. *Large Scale Wi-Fi tracking using a Botnet of Wireless Routers*, in "SAT 2015 - Workshop on Surveillance & Technology", Philadelphia, United States, June 2015, https://hal.inria.fr/hal-01151446

Conferences without Proceedings

[20] B. BARON, P. SPATHIS, H. RIVANO, M. DIAS DE AMORIM. *Étude de l'intermodalité pour le délestage des réseaux d'infrastructure*, in "ALGOTEL 2015 — 17èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Beaune, France, June 2015, https://hal.archives-ouvertes.fr/hal-01148427

[21] P. RAVENEAU, A. CABALLERO, R. STANICA, H. RIVANO. *Privamov : Suivi d'utilisateurs mobiles et reconstruction de trajectoires*, in "ALGOTEL 2015 — 17èmes Rencontres Francophones sur les Aspects Algorithmiques des Télécommunications", Beaune, France, June 2015, https://hal.archives-ouvertes.fr/hal-01147217

Research Reports

[22] D. COUDERT, S. PÉRENNES, H. RIVANO, M.-E. VOGE. *Combinatorial optimization in networks with Shared Risk Link Groups*, Inria, October 2015, 24 p. , https://hal.inria.fr/hal-01053859

[23] P. RAVENEAU, H. RIVANO. *Tests Scenario on DTN for IOT III Urbanet collaboration*, Inria - Research Centre Grenoble – Rhône-Alpes ; Inria, August 2015, n⁰ RT-465, https://hal.inria.fr/hal-01187114