



Activity Report 2018

Team INFINE-POST

INFormation NETworks

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).

RESEARCH CENTER
Saclay - Île-de-France

THEME
Networks and Telecommunications

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Team INFINE-POST

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- A3.5.1. - Analysis of large graphs

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- B8.2. - Connected city
- B9.5.1. - Computer science
- B9.6.1. - Psychology
- B9.6.5. - Sociology

1. Team, Visitors, External Collaborators

Research Scientists

- Aline Carneiro Viana [Team leader, Inria, Researcher, HDR]
- Cedric Adjih [Inria, Researcher]
- Emmanuel Baccelli [Inria, Researcher, HDR]

PhD Students

- Licia Amichi [Inria, from Oct 2018]
- Rafael Costa [CAPES, from Jun 2017, co-tutelle]
- Hirah Malik [Inria, from Nov 2017]
- Iman Hmedoush [Inria, from Oct 2018, co-advised with EVA]
- Douglas Teixeira [CAPES, from Apr 2018, co-tutelle]
- Lucas Santos de Oliveira [EMBRACE, from May 2018]
- Joao Batista Borges [EMBRACE, from Oct 2018]
- Loic Dauphin [Inria, until Aug 2018]
- Roni Shigueta [Univ. of Parana, until Jul 2018, co-tutelle]
- Guangshuo Chen [Inria, until Apr 2018]

Technical staff

Francisco Acosta [Inria, until Nov 2018]
Benoit Formet [Inria]
Raul Fuentes Samaniego [Inria, until Jun 2018]
Duc Tuyen Ta [Univ Paris-Sud, from Jul 2018]

Interns

Diego Madariaga Roman [Inria, from Sep 2018 until Nov 2018, on-going]
Panagiota Katsikouli [Inria, from June 2017 until Sep 2017, on-going]
Adriano Di Luzio [Inria, from Jul 2017 until Oct 2017, on-going]
Emanuel Ribeiro Lima [Inria, from Oct 2017 until Dec 2017, on-going]

Administrative Assistant

Laurence Fontana [Inria]

Visiting Scientists

Vinicius Braga [EMBRACE, Mar 2018]
Kléber Cardoso [EMBRACE, Mar 2018]
Sand Luz Correa [EMBRACE, Mar 2018]
Anelise Fonseca [EMBRACE, Feb 2018]
Mauro Fonseca [EMBRACE, Feb 2018]
Parikshit Hegde [Nokia, from May 2018 until Jul 2018]
Akshit Kumar [Nokia, from May 2018 until Jul 2018]
Julinda Stefa [Inria, from Jul 2018 until Sep 2018]

2. Overall Objectives

2.1. Overall Objectives

Our general goal is to develop distributed mechanisms for optimizing the operation of networks both at the logical and physical levels. Despite the massive increases in transmission capacity of the last few years, one has every reason to believe that networks will remain durably congested, driven among other factors by the steadily increasing demand for video content, and the forecasted additional traffic due to machine-to-machine (M2M) communications. There is thus a strong need for smart protocols which transport requested information at the cheapest possible cost on the network.

INFINE team is engaged in research along two main themes: *Human-centric Networking*, and *Internet of Things*. These research activities encompass both theoretical research (on elaboration of models, algorithms, protocols and formal characterization of their performance), and applied research (to validate and/or experiment the proposed concepts against real networking scenarios). INFINE fits in the theme "Networks and Telecommunications" of the research field "Networks, Systems and Services, Distributed Computing" at Inria.

2.2. New challenging demands

Nowadays, the physical context in which we access communication networks has drastically changed. While in the past, Internet was mostly accessed through fixed desktop computers, users are now mobile about 52.2% of their time online ¹. In addition, while communicating machines used to be sparse and wired, with the advent of the Internet of Things we now evolve in a dense, interconnected environment of heterogeneous devices communicating via wireless and/or via wires.

¹ <https://www.statista.com/statistics/241462/global-mobile-phone-website-traffic-share/>

This new context of Internet uses challenges several aspects of currently deployed networks. Some aspects pertain to the physical architecture of the Internet. In particular, at the core of the Internet, a drastic increase in volume of data traffic is anticipated due to the emergence of new applications, generalization of cloud services, or the advent of the Internet of Things (IoT) and Machine-to-Machine (M2M) communications. On the other hand, at the edge of the Internet, user mobility and today's pervasiveness of computing devices with increasingly higher capabilities (i.e., processing, storage, sensing) have a fundamental impact on the adequacy of algorithms and communication mechanisms.

Other aspects concern the logical architecture of the network. For instance, currently deployed protocols at layers above IP must now carry massive publish-subscribe traffic, be human-aware, and support delay tolerant communications and paradigms for which they were not initially designed. While considering physical and logical aspects of networks, the INFINE team will pursue research activities combining theoretical and experimental approaches.

3. Research Program

3.1. Fundamentals

Our general goal is to develop distributed mechanisms for optimizing the operation of networks both at the mentioned logical and physical levels of the architecture. Taking an information- and human-centric perspective, we envision networks as means to convey relevant information to users, while adapting to customary practices (in terms of context, interests, or content demands) of such users.

We now detail further our agenda along two main specific axes, namely Human-Centric Networking and Internet of Things, bearing in mind that we will develop generic solutions relevant to several of these axes wherever possible.

Finally, at the end of this section, we also detail our activities related to standization and open experimental IoT Platforms.

3.1.1. Human-Centric Networking

Cellular and wireless data networks are increasingly relied upon to provide users with Internet access on devices such as smartphones, laptops or tablets. In particular, the proliferation of handheld devices equipped with multiple advanced capabilities (e.g., significant CPU and memory capacities, cameras, voice to text, text to voice, GPS, sensors, wireless communication) has catalyzed a fundamental change in the way people are connected, communicate, generate and exchange data. In this evolving network environment, users' social relations, opportunistic resource availability, and proximity between users' devices are significantly shaping the use and design of future networking protocols.

One consequence of these changes is that mobile data traffic has recently experienced a staggering growth in volume: Cisco has recently foreseen that the mobile data traffic will increase 18-fold within 2016, in front of a mere 9-fold increase in connection speeds. Hence, one can observe today that the inherently centralized and terminal-centric communication paradigm of currently deployed cellular networks cannot cope with the increased traffic demand generated by smartphone users. This mismatch is likely to last because (1) forecasted mobile data traffic demand outgrows the capabilities of planned cellular technological advances such as 4G or LTE, and (2) there is strong skepticism about possible further improvements brought by 5G technology.

Congestion at the Internet's edge is thus here to stay. Solutions to this problem are either to densify infrastructure, or to offload to alternate networks. Densifying infrastructure (with Femtocells for instance) is expensive. Carriers therefore consider other solutions, such as simultaneously leveraging Wi-Fi access points and hot spots. However, the projected increase of mobile data traffic demand pushes towards additional complementary offloading methods. Novel mechanisms are thus needed, which must fit both the new context that Internet users experience now, and their forecasted demands.

In this realm, we focus on new approaches leveraging ultra-distributed, user-centric approaches over IP. One approach that is considered in the research community is to leverage spontaneous wireless networks to offload infrastructure-based cellular networks. For example, the delay-tolerant nature of some of the data traffic can be used in conjunction with sequences of opportunistic encounters between users to deliver such data to its destination, without infrastructure access point relaying. However, the full capacity and the achievable information propagation speed in such networks are still barely understood, and in particular, there is a need to refine the characterization of user behaviour and social interaction. Our recent work on leveraging user mobility patterns, contact and inter-contact patterns, content demand patterns will constitute a starting point.

3.1.2. Internet of Things at the Edge

The IoT is indeed expected to massively use this networking paradigm to gradually connect billions of new devices to the Internet, and drastically increase communication without human source or destination – to the point where the amount of such communications will dwarf communications involving humans. Over the last decade, we are witnessing an increasing variety in IoT technologies starting from IoT communication technologies. The main reason for this is the growing diversity of strong requirements (i.e., in terms of bandwidth, latency, energy savings, etc) coming from new varieties of IoT use-cases, which now go far beyond the original wireless sensor networking domain. Besides, such variety of new IoT devices still inherits from the extremely limited capabilities of traditional embedded systems and sensor networks, such as requirements in terms of low power usage, low memory, with today a greater emphasis on interoperability needs.

Large scale user environment automation require communication protocols optimized to efficiently leverage the heterogeneous and unreliable wireless vicinity (the scope of which may vary according to the application). In fact, extreme constraints in terms of cost, CPU, battery and memory capacities are typically experienced on a substantial fraction of IoT devices. We expect that such constraints will not vanish any time soon for two reasons. On one hand the progress made over the last decade concerning the cost/performance ratio for such small devices is quite disappointing. On the other hand, the ultimate goal of the IoT is ubiquitous Internet connectivity between devices as tiny as dust particles. These constraints actually require to redesign not only the network protocol stack running on these devices, but also the software platform powering these machines.

In this context, we will aim at contributing to the design of novel network protocols and software platforms optimized to fit these constraints while remaining compatible with legacy Internet. Our recent work on large IoT testbeds such as FIT and on software platforms such as the RIOT operating system will serve as a starting point to design and conduct large scale experiments that are expected to provide both fruitful feedback to our theoretical analysis, and validation of the protocols we propose in the realm of our standardisation activities. A recent example of this methodology is the publication of RFC6997, the specification of a routing protocol for sensor networks we proposed, which was standardized a few months ago. An example of technique which we plan to explore in this field is the use of network coding. Network coding is ideally suited to such spontaneous wireless networks for increasing communication reliability (while minimizing the traffic load) ; exploiting it fully requires keeping track of the information flows, the central topic of this project proposal. In this domain, we will use as starting point our latest work on practical network coding broadcast.

Information centric networking paradigms emerge to decouple data name and location and organizes pervasive content caching and nearest replica routing, promising performance gains in terms of native multi-homing optimization, content access time and network load, at the price of more complex, more voluminous and volatile state management in routers. In this context, we investigate generic network protocols, that provide a significantly advantageous tradeoff between performance gains and required router state complexity increase on low-end IoT networks.

3.1.3. Open Experimental IoT Platforms

One necessity for research in the domain of IoT is to establish and improve IoT hardware platforms and testbeds, that integrate representative scenarios (such as Smart Energy, Home Automation etc.) and follow the evolution of technology, including radio technologies, and associated experimentation tools. For that, we plan to build upon the IoT-LAB federated testbeds, that we have participated in designing and deploying recently. We plan to further develop IoT-LAB with more heterogeneous, up-to-date IoT hardware and radios that will

provide a usable and realistic experimentation environment. The goal is to provide a tool that enables testing a validation of upcoming software platforms and network stacks targeting concrete IoT deployments.

In parallel, on the software side, IoT hardware available so far made it uneasy for developers to build apps that run across heterogeneous hardware platforms. For instance Linux does not scale down to small, energy-constrained devices, while microcontroller-based OS alternatives were so far rudimentary and yield a steep learning curve and lengthy development life-cycles because they do not support standard programming and debugging tools. As a result, another necessity for research in this domain is to allow the emergence of it more powerful, unifying IOT software platforms, to bridge this gap. For that, we plan to build upon RIOT, a new open source software platform which provides a portable, Linux-like API for heterogeneous IoT hardware. We plan to continue to develop the systems and network stacks aspects of RIOT, within the open source developer community currently emerging around RIOT, which we co-founded together with Freie Universitaet Berlin. The key challenge is to improve usability and add functionalities, while maintaining architectural consistency and a small enough memory footprint. The goal is to provide an IoT software platform that can be used like Linux is used for less constrained machines, both (i) in the context of research and/or teaching, as well as (ii) in industrial contexts. Of course, we plan to use it ourselves for our own experimental research activities in the domain of IoT e.g., as an API to implement novel network protocols running on IoT hardware, to be tested and validated on IoT-LAB testbeds.

3.1.4. *Standardization of Architectures and Efficient Protocols for Internet of Things*

As described before, and by definition, the Internet of Things will integrate not only a massive number of homogeneous devices (e.g., networks of wireless sensors), but also heterogeneous devices using various communication technologies. Most devices will be very constrained resources (memory resources, computational resources, energy). Communicating with (and amongst) such devices is a key challenge that we will focus on. The ability to communicate efficiently, to communicate reliably, or even just to be able to communicate at all, is non-trivial in many IoT scenarios: in this respect, we intend to develop innovative protocols, while following and contributing to standardization in this area. We will focus and base most of our work on standards developed in the context of the IETF, in working groups such as 6lo, CORE, LWIG etc., as well as IRTF research groups such as NWCRG on network coding and ICNRG on Information Centric Networking. We note however that this task goes far beyond protocol design: recently, radical rearchitecturing of the networks with new paradigms such as Information Centric Networking, ICN, (or even in wired networks, software-defined networks), have opened exciting new avenues. One of our direction of research will be to explore these content-centric approaches, and other novel architectures, in the context of IoT.

4. Highlights of the Year

4.1. Highlights of the Year

4.1.1. Awards

Together with his co-authors, Emmanuel Baccelli was awarded the **best demo award** at the 3rd Cloudification of the Internet of Things Conference, in Paris, July 2018, for the demo on **Orchestration of IoT Device and Business Workflow Engine on Cloud** (collaboration with S. Kikuchi, I. Thomas, O. Jallouli, J. Dörr, A. Morgenstern, and K. Schleiser).

RIOT Summit 2018

We successfully organized in September 2018 the thrid RIOT Summit, in Amsterdam. The RIOT Summit 2018 gathered 100+ enthusiastic industrial participants, makers and academics involved in RIOT. Relevant partners such as Ericsson, HERE Technologies, CodeCoup, Wolf SSL, as well as a number of SMEs and startups from various places in Europe gave talks on aspects of IoT communication, use cases IoT hardware, IoT open source community aspects and concepts for future IoT software and networks, as well as hands-on sessions and tutorials. See: <http://summit.riot-os.org>.

Associated team - EMBRACE

2018 was the second year of the EMBRACE Associated team. The EMBRACE (IEveraging huMan Behavior for Resource AlloCation and services orchestration modElS) team is composed by members of the INFINE and by three Brazilian teams from three different Brazilian Universities. The EMBRACE project addresses the topic of designing efficient solutions for 5G networks taking into account human behavior, uncertainty, and heterogeneity of networking resources.

More information is available here: <https://team.inria.fr/embrace/>

5. New Results

5.1. IoT Scripting Over-The-Air

Participants: Emmanuel Baccelli, Francisco Acosta.

A large part of the Internet of Things (IoT) will consist of interconnecting low-end devices, whose characteristics include very small memory capacity (a few kBytes) and limited energy consumption (1000 times less than a RaspberryPi). IoT use-cases require the orchestration of different pieces of logic running concurrently on low-end IoT devices and elsewhere on the network (e.g. in the cloud) and communicating with one another. In a number of use-cases, the logic that needs to run on low-end IoT devices is not known upfront, before deploying the device(s). For instance, some part of the logic (e.g. pre-processing of some data) may need to be transferred on demand, from the cloud to the device, for privacy or performance reasons. Another example is the fine-tuning of some parameters of the logic running on some device, which can only be done after the deployment (e.g. the sensitivity of a distributed alarm system on-site). In such context, this paper presents a generic approach to host, run and update IoT application logic on heterogeneous low-end devices, using over-the-air scripting and small containers. Based on RIOT and Javascript, we provide a proof- of-concept implementation of this approach for a building automation IoT scenario, as well as a preliminary evaluation of this implementation running on common off-the-shelf low-end IoT hardware. Our evaluation shows the prototype runs on common off-the-shelf low-end IoT hardware with as little as 32kB of memory. Recent prior work in this domain also proposed Actinium, an approach using small, distributed runtime containers on computers proxying for low-end IoT devices, accessible as Web resources, and hosting JavaScript logic. Compared to Actinium, we eliminate the need for Web resource proxying, as runtime containers are running directly on the low-end IoT devices.

This work was published and presented at the IEEE Percom 2018 conference as "Scripting Over-The-Air: Towards Containers on Low-end Devices in the Internet of Things".

5.2. Information-centric IoT Robotics

Participants: Loic Dauphin, Cedric Adjih, Emmanuel Baccelli.

As IoT emerges, minibots (miniature robots) have appeared on the market. A large community emerged, designing do-it- yourself minibots, and cheap, re-programmable minibots with communication capabilities are now available. For in- stance, small wheeled robots such as the Zoid are based on a small microcontroller (8kB RAM, 64kB ROM) and communicating with a low-power radio in the 2.4 GHz ISM band. Other examples are cheap drones such as the Cheerson CX-10, which has similar hardware characteristics, and which costs under 15\$. Simple robotic arms and legged robots are also available, such as the MetaBot. A current trend bases software embedded in minibots on open source frameworks. The Robot Operating System (ROS) is a software framework for robot application development which has become a de facto standard for most areas in robotics. Other open source robotics frameworks include software suite tailored for drones, some of which provide compatibility with ROS. In fact, we observe that minibots have a number of charac- teristics in common with low-end devices found in the Internet of Things (IoT). Compared to low-end IoT devices, minibots are based on similar hardware and their software follows similar trends. For instance, an IoT-enabled actuator based on a System-on-Chip (SoC) embarking a small microcontroller, and

a radio communicating with a remote server, is very similar to a simple radio-controlled robot. Low-end IoT devices use similar radio modules, and software embedded in IoT devices is more and more based on a variety of open source, lightweight operating systems such as RIOT, FreeRTOS and NuttX, among others. Similarly, as for IoT embedded systems, the network component of minibots represents by itself an important part of the software (in terms of features, code/memory size, and performance). In fact, a wide variety of radio modules and communication protocols are used on minibots. The protocols used by micro-robots for (internal or external) communication range from direct motor control (pulse width modulation PWM, pulse position modulation PPM, or PCM), to serial/bus protocols, and high level protocols such as Real-time Publish-Subscribe Protocol (RTPS). In this work we thus explored the potential of bundling open source robotics software frameworks with IoT software and network architectures, to program and control minibots. To do so, we extend our recent work by designing ROS-ready technology for a minibot based on RIOT and ROS2. We focus primarily on software and networking aspects, targeting ultra-lightweight robots based on a reprogrammable SoC with a microcontroller running at approximately 50 MHz, with 10kB RAM, 100kB Flash, and a low-power radio. Using an information-centric networking paradigm extending NDN, we design and implement the communication primitives required by RIOT-ROS2. Our prototype is able to maintain full compatibility between ROS nodes running on the minibot(s) and ROS nodes running elsewhere on the network without the use of a bridge. We show that RIOT-ROS2 fits on low-end robotics hardware such as a System-on-Chip with an ARM Cortex-M0+ microcontroller. On the software and network performance evaluation side, we illustrate that the latency incurred with our ICN approach is completely acceptable for minibot control, even on constrained radio, based on micro-benchmarks.

This work was published and presented at the IEEE PEMWN 2018 conference as "RIOT-ROS2: Low-Cost Robots in IoT Controlled via Information-Centric Networking".

5.3. Human Mobility completion of Sparse Call Detail Records

Participants: Guangshuo Chen, Aline Carneiro Viana, Marco Fiore [CNR - IEIIT (Italy)], Carlos Sarraute [Grandata Labs].

Mobile phone data are a popular source of positioning information in many recent studies that have largely improved our understanding of human mobility. These data consist of time-stamped and geo-referenced communication events recorded by network operators, on a per-subscriber basis. They allow for unprecedented tracking of populations of millions of individuals over long time periods that span months. Nevertheless, due to the uneven processes that govern mobile communications, the sampling of user locations provided by mobile phone data tends to be sparse and irregular in time, leading to substantial gaps in the resulting trajectory information. In this work, we illustrate the severity of the problem through an empirical study of a large-scale Call Detail Records (CDR) dataset. We then propose two novel and effective techniques to reduce temporal sparsity in CDR that outperform existing ones. The first technique performs completion (1) at nighttime by identifying temporal home boundary and (2) at daytime by inferring temporal boundaries of users, i.e., the time span of the cell position associated with each communication activity. The second technique, named Context-enhanced Trajectory Reconstruction, complete individual CDR-based trajectories that hinges on tensor factorization as a core method by leveraging regularity in human movement patterns. Our approach lets us revisit seminal works in the light of complete mobility data, unveiling potential biases that incomplete trajectories obtained from legacy CDR induce on key results about human mobility laws, trajectory uniqueness, and movement predictability.

These works have been published as invited papers at the ACM CHANTS 2016 workshop (in conjunction with ACM MobiCom 2016), at the IEEE DAWM workshop (in conjunction with IEEE Percom 2017) and at Computer Communication Elsevier journal in 2018. Another journal version (also registered as TR: hal-01675570) is in revision at the EPJ Data Science Journal.

5.4. Adaptive sampling frequency of human mobility

Participants: Panagiota Katsikouli, Aline Carneiro Viana, Marco Fiore [CNR - IEIIT (Italy)], Diego Madariaga.

The problem we address here is the design of a location sampling system for smartphones and handheld devices that reduces the energy consumed by the continuous activation of the GPS, it reduces the space required to store recorded locations, while reliably capturing the movements of the tracked user. The applications here are related to a number of fields relevant to ubiquitous computing, such as energy-efficient mobile computing, location-based service operations, active probing of subscribers' positions in mobile networks and trajectory data compression.

To this end, we propose an adaptive sampling system without the use of any assisting sensors for the activation of GPS, such as accelerometer, or GSM information. Our system captures the mobility of a user with high accuracy and reliably adjusts the sampling frequency depending on the user's movement. During high mobility, our system densely samples the locations of the tracked user, but at a rate at most the usual rate found today in most applications (e.g., 1 sample per minute). During low mobility, we sample sparsely at much lower rate than usual. As a result, the recorded trace contains much less samples than it would contain if we sampled with the fixed pre-defined sampling rate, requiring less storage space and less energy to activate the GPS.

Our first quest for a response led to the discovery of (i) seemingly universal spectral properties of human mobility, and (ii) a linear scaling law of the localization error with respect to the sampling interval. Our findings were based on the analysis of fine-grained GPS trajectories of 119 users worldwide. This work was published at the IEEE Globecom 2017 international conference.

We have improved the published sampling approach by incorporating human behavioral features at the sampling decisions to make it more adaptive. This is an on-going work with Panagiota Katsikouli, who spent 5 months in our team working as an internship and is currently doing a Post-Doc at the AGORA Inria team, and Diego Madariaga who spent 3 months in our team working as an internship and is going to start a PhD in co-tutelle with Aline C. Viana. Diego has implemented an Android application to sample mobility data of users according to our adaptive system described here above. The application is currently under deployment and 8 volunteers are running it in their smartphones. The collected data will allow us validating the correctness and performance of our adaptive sampling system. A patent discussion is also on-going with Inria, currently performing a marked/business study.

5.5. Inference of human personality from mobile phones datasets

Participants: Adriano Di Luzio, Aline Carneiro Viana, Julinda Stefa, Katia Jaffres-Runser [INPT-ENSEEIH - IRIT (Toulouse University)], Alessandro Mei [Sapienza University (Italy) - Dept. of Computer Science].

Related to human behavioral studies, personality prediction research has enjoyed a strong resurgence over the past decade. Due to the recognition that personality is predictive of a wide range of behavioral and social outcomes, the human migration to the digital environment renders also possible to base prediction of individual personality traits on digital records (i.e., datasets) mirroring human behaviors. In psychology, one of the most commonly used personality model is the Big5, based on five crucial traits and commonly abbreviated as OCEAN: Openness (O), Conscientiousness (C), Extroversion (E), Agreeableness (A), and Neuroticism (N). They are relatively stable over time, differ across individuals, and, most importantly, guide our emotions and our reactions to life circumstances. It is so for social and work situations, and even for things as simple as the way we use our smartphone. For instance, a person that is curious and open to new experiences will tend to look continuously for new places to visit and thrills to experience.

This work brings the deepest investigation in the literature on the prediction of human personality (i.e., captured by the Big5 traits) from smartphone data describing daily routines and habits of individuals. We take a ground-breaking step in (i) deeply capturing human habits in terms of movements, visits, wireless connectivity as well as some routinary actions from a crowdsourced mobility dataset and in (ii) better understanding the relationship between personality traits and individual behavior. We do so by leveraging a dataset collecting very detailed routines of individuals originating from different countries located in 2 different continents, who answered the Big Five Inventory and allowed continuous collection of data from their smartphones for research purposes for 3 years. We use this dataset to engineer a set of human-adapted features that capture three aspects of human behavior: Temporal Mobility (e.g. time at home/work or commuting), Spatial Mobility (e.g. number

of most frequent places, maximum distance from home), and the Context of Use (battery charging habits, wireless hotspots availabilities). Then, we use the features that have a statistically significant correlation with the OCEAN traits to predict the personality of a test-set portion of our dataset through cross validation.

Our results attest an accurate prediction of users' personality traits when a 5-level granularity is used per trait. This brings a much higher precision to our predicted results, when compared to the usual 3-level literature granularity. In addition, our prediction methodology carefully takes advantage of engineered features that (1) are more human-adapted and consequently, allow better capturing individuals' habits in terms of movements, visits, connectivity, context, as well as actions (note that contrarily to the literature, neither calls behavior nor data content is leveraged in our analysis), and (2) are designed having in mind the differences and particularities among the Big5 traits of personality. Thus, this work has the potential to impact the way we characterise unique behaviors of individuals as well as quantify how human personality influences lives and actions. Our results show (1) a significant correlation of most of the traits with a small set of mobility-related features and (2) that we are able to predict the individuals' Big5 traits with considerable accuracy (e.g., prediction of the 5 levels of Openness trait shows an F1 score of 0.77), which is significantly outperforming a benchmark approach, when only considering a set of only 3 of our human-adapted features. Finally, we discuss the ethical concerns of our work, its privacy implications, and ways to tradeoff privacy and benefits.

This is an on-going work with Adriano di Luzio, who spent 4 months in our team working as an internship, Julinda Stefa, an invited research visitor at Infine, and two other researchers: Katia Jaffres-Runser and Alessandro Mei. A paper describing this work is under submission at ACM Mobihoc 2018, but a technical report is also registered under the name hal-01954733.

5.6. Data offloading decision via mobile crowdsensing

Participants: Emanuel Lima, Aline Carneiro Viana, Ana Aguiar [FEUP (Portugal) - Dept. of Electrical and Computer Engineering], Paulo Carvalho [FEUP (Portugal) - Dept. of Electrical and Computer Engineering].

According to Cisco forecasts ², mobile data traffic will grow at a compound annual growth rate of 47 % from 2016 to 2021 with smartphones surpassing four-fifths of mobile data traffic. It is known that mobile network operators are struggling to keep up with such traffic demand, and part of the solution is to offload communications to WiFi networks. Mobile data offloading systems can assist mobile devices in the decision making of when and what to offload to WiFi networks. However, due to the limited coverage of a WiFi AP, the expected offloading performance of such a system is linked with the users mobility. Unveiling and understanding human mobility patterns is a crucial issue in supporting decisions and prediction activities for mobile data offloading.

Several studies on the analysis of human mobility patterns have been carried out focusing on the identification and characterization of important locations in users' life in general. We intend to extend these works by studying human mobility from the perspective of mobile data offloading. This brings two major differences compared to the related work. First, high temporal resolution of positioning datasets is needed. In the majority of the related work, important locations have a temporal dimension representing the time spent by a user in that location, which confers its degree of importance. This time is usually in the order of several minutes which is suitable for the case of detecting important locations but not for a mobile data offloading scenario. Here, according to the amount of data traffic that needs to be offloaded, locations with a visiting temporal resolution of few seconds may be enough for data offloading. Thus, we expect to discover additional offloading opportunities, which were not visible with a coarser temporal resolution. Second, while important locations are usually limited in size, offloading locations can have any arbitrary shape and size.

In this work, offloading regions are defined as spatially aggregated locations where users have mobility suitable to offload. The main contribution of this work are: (a) the identification of offloading regions on an individual basis through unsupervised learning; (b) the characterization of these regions in terms of availability, sojourn, and transition time based on their relevance; (c) the study of the impact of the users mobility on the design of mobile offloading systems. This work was published at ACM CHANTS 2018.

²<https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/mobile-white-paper-c11-520862.html>

We now working on the extension of this work, which will incorporate the mobility prediction of the users. Such prediction is essential to the design of the decision offloading strategy. Such strategy will be used to allow a mobile phone of a user deciding if offload or not her traffic, i.e., when, where (in which offloading region) and how (if the traffic will be offloaded to one or more Access Points). This is an on-going work with the the PhD Emanuel Lima, who spent 4 months as an intern in our team, and his advisors.

5.7. Inferring friends in the crowd in Device-to-Device communication

Participants: Rafael Costa, Aline Carneiro Viana, Leobino Sampaio [UFBA (Brazil) - Institute of Mathematics], Artur Ziviani [National Laboratory for Scientific Computing (Brazil)].

The next generation of mobile phone networks (5G) will have to deal with spectrum bottleneck and other major challenges to serve more users with high-demanding requirements. Among those are higher scalability and data rates, lower latencies and energy consumption plus reliable ubiquitous connectivity. Thus, there is a need for a better spectrum reuse and data offloading in cellular networks while meeting user expectations. According to literature, one of the 10 key enabling technologies for 5G is device-to-device (D2D) communications, an approach based on direct user involvement. Nowadays, mobile devices are attached to human daily life activities, and therefore communication architectures using context and human behavior information are promising for the future. User-centric communication arose as an alternative to increase capillarity and to offload data traffic in cellular networks through opportunistic connections among users. Although having the user as main concern, solutions in the user-centric communication/networking area still do not see the user as an individual, but as a network active element. Hence, these solutions tend to only consider user features that can be measured from the network point of view, ignoring the ones that are intrinsic from human activity (e.g., daily routines, personality traits, etc). In this work, we plan to investigate how human-aspects and behavior can be useful to leverage future device-to-device communication.

This is the PhD thesis subject of Rafael Costa, aiming the design of a methodology to select next-hops in a D2D communication that will be human-aware: i.e., that will consider not only available physical resources at the mobile device of a wireless neighbor, her mobility features and restrictions but also any information allowing to infer how much sharing willing she is. A tutorial paper is under submission to a journal (a TR is in hal-01675445) and a 4h-tutorial was presented at the SBRC 2018 conference ³ (the biggest conference on Computer and Network Science in Brazil).

The next step is then the design of forwarding strategies for data offloading through Device-to-Device (D2D) communication, transforming mobile phone neighbors in service providers. The selection of next hops based on mobility behavior, resource capability as well as collaboration constitute the novelty we plan to exploit.

5.8. Urban Computing Leveraging Location-Based Social Network Data: a Survey

Participants: Thiago H. Silva [UTFPR (Brazil) - Dept. of Computer Science], Aline Carneiro Viana, Antonio Loureiro.

Urban computing is an interdisciplinary area in which urban issues are studied using state-of-the-art computing technologies. This area is at the intersection of a variety of disciplines: sociology, urban planning, civil engineering, computer science, and economics, to name a few. More than half of the world's population today live in cities and, consequently, there is enormous pressure on providing the proper infrastructure to cities, such as transport, housing, water, and energy. To understand and partly tackle these issues, urban computing combines various data sources such as those coming from Internet of Things (IoT) devices; statistical data about cities and its population (e.g., the Census); and data from Location-Based Social Networks (LBSN), sometimes also termed as location-based social media. One fundamental difference between data from LBSNs and data from other sources is that the former offers unprecedented geographic and temporal resolutions: it reflects individual user actions (fine-grained temporal resolution) at the scale of entire world-class cities (global geographic resolution).

³<http://www.sbrc2018.ufscar.br/minicurso-1-mc-1/>

Urban computing with LBSN data has its particularities. For instance, users who share data in Foursquare, a popular LBSN, usually have the goal of showing to their friends where they are while also providing personalized recommendations of places they visit. Nevertheless, when correctly analyzed for knowledge extraction, this data can be used to better understand city dynamics and related social, economic, and cultural aspects. To achieve this purpose, new approaches and techniques are commonly needed to explore that data properly.

In order to better study such needs, we have published at ACM Computing Survey Journal (the ACM journal with highest impact factor) a survey that provides an extensive discussion of the related literature, focusing on major findings and applications. Although its richness concerning knowledge provision, LBSN data presents several challenges, requiring extra attention to its manipulation and usability, which drives future research opportunities in the field of urban computing using LBSN data. Our work is complementary to two existing surveys in the area of urban computing (i.e., by Jiang et al. and by Zheng et al.) since they only mention briefly few studies that explore LBSN data, neglecting key challenges that revolve around LBSNs. We hope that taken together, our effort and these existing ones, provide a broad perspective of urban computing studies and its development through the lens of different data-driven approaches.

5.9. Identifying how places impact each other by means of user mobility

Participants: Lucas Santos, Pedro Olmo [UFMG (Brazil) - Dept. of Computer Science], Aline Carneiro Viana.

The way in which city neighborhoods become popular and how people trajectory impacts the number of visitation is a fundamental area of study in traditional urban studies literature. Many works address this problem by means of user mobility prediction and POI recommendation. In a different approach, other works address the human mobility in terms of social influence which refers to the case when individuals change their behaviors persuaded by others. Nevertheless, fewer works measure influence of POI based on human mobility data.

Different from previous literature, in this work, we are interested in understanding how the neighborhood POI affect each other by means of human mobility using location-based social networks (LBSNs) data source. In other words, how important is this POI for its neighborhood? We proposed thus a framework to measure POI influence by means of LBSN data. First, we modeled the problem using mobility graph approach where each POI is a node and the transitions of users among POI is a weighted vertex. Also, we treat the users' check-in records among POI as a measure of uncertainty, and their strength can be measured by entropy, which enabled to measure direct influence. Second, using same graph, we propose another influence measure taking account the POI importance for its one-hop vicinity in terms of incoming human transition. In addition, this mobility graph can be viewed as a collaborative filtering. We use this collaborative filter for compute the G-causality and evaluate if the transitions among POI has a causal relation and consequently, the influence among POI. Moreover, to the best of our knowledge, we are the first study which investigated POI influence by means of human mobility using LBSN data source.

This work is being prepared for a submission to an international conference.

6. Bilateral Contracts and Grants with Industry

6.1. Bilateral Contracts with Industry

6.1.1. Fujitsu (RunMyProcess):

Participants: Emmanuel Baccelli, Francisco Acosta.

In 2018 we have worked with Fujitsu RIOT enhancements to demonstrate dynamic application software loading and execution on top of RIOT running on Arduino-like hardware, managed remotely from Fujitsu's RMP Cloud component. The results of this work were published in several conferences in 2018, and a prototype was demonstrated.

6.1.2. *Thalès:*

Participant: Cedric Adjih.

In 2018, studies were made with Thalès (TRT) on IoT systems.

6.1.3. *GranData:*

Participants: Guangshuo Chen, Adriano Di Luzio, Aline Carneiro Viana.

Since June 2014, we have a collaboration with GranData (<http://grandata.com/>), Buenos Aires, Argentina on traffic vs mobility modeling of smartphone users. GranData is a small company that integrates first-party and telco partner data to understand key market trends, to predict customer behavior, and to deliver business results. For the time being, the collaboration with Grandata has generated knowledge transfer. From both directions, (1) from myself to GranData, I have been transferring my knowledge in modeling and analysing human behavior in terms of mobility, encounters, and content demand, (2) from them to myself, they have advised me on issues related to machine learning and statistical methods to be used. It describes **an industrial partner's collaboration having the outcomes of our works impacting their products** (e.g., GranData data mining algorithms can be improved based on the better understanding on mobility and content consumption of mobile users) **or research/business decisions** (e.g., proved strong correlations between mobility and data traffic consumption can open new perspectives of services to telecom operators, i.e., clients of GranData).

Part of the thesis of Guangshuo Chen (ended April 2018) and of Eduardo Mucelli (ended in 2015) on data traffic analysis used telco traces provided by GranData.

7. Partnerships and Cooperations

7.1. National Initiatives

7.1.1. *Equipex FIT:*

Participants: Cedric Adjih, Emmanuel Baccelli, Alexandre Abadie [SED - Inria], Ichrak Amdouni [Ecole Nationale d'Ingénieurs de Sousse & CRISTAL].

Partners: Inria (Lille, Sophia-Antipolis, Grenoble), INSA, UPMC, Institut Telecom Paris, Institut Télécom Evry, LSIT Strasbourg.

FIT (Future Internet of Things) aims to develop an experimental facility, a federated and competitive infrastructure with international visibility and a broad panel of customers. It provides this facility with a set of complementary components that enable experimentation on innovative services for academic and industrial users. The project gives french internet stakeholders a means to experiment on mobile wireless communications at the network and application layers thereby accelerating the design of advanced networking technologies for the future internet. FIT was one of 52 winning projects from the first wave of the French Ministry of Higher Education and Research's "Équipements d'Excellence" (Equipex) research grant program, in 2011.

One component of the FIT platform is the sets of IoT-LAB testbeds (see [the IoT-LAB web site](#)). These were motivated by the observation that the world is moving towards an "Internet of Things", in which most communication over networks will be between objects rather than people.

The Infine team is more specifically managing the FIT IoT-LAB site formerly at Rocquencourt, which recently moved to Saclay (on-going re-deployment), and is participating in the deployment of an additional IoT-lab testbed in Berlin (at Freie Universitaet Berlin).

7.1.2. *ANR*

The team has submitted three PRC ANR projects: two projects for the CE25, i.e., on "Réseaux de communication multi-usages, infrastructures de hautes performances, sciences et technologies logicielles" and one for the CE35, i.e., on "Révolution numérique : rapports au savoir et à la culture".

7.2. European Initiatives

7.2.1. H2020 Projects

7.2.2. AGILE (H2020 project)

Participants: Emmanuel Baccelli, Cedric Adjih.

Program: H2020 ICT-30-2015 Topic: Internet of Things and Platforms for Connected Smart Objects

Project acronym: AGILE

Project title: Adoptive Gateways for dIverse muLtiiple Environments

Duration: 2015-2018

Coordinator: Emmanuel Baccelli

Other partners: Canonical (UK), Eclipse IoT Foundation (IE), Mobistar (BE), Libelium (ES), Startupbootcamp IoT (SP), CREATE-NET (IT), iMinds (BE), Atos (SP), Rulemotion (UK), Jolocom (DE), Passau University (DE), Sky-Watch (DN), BioAssist (GR), Graz Technical University (AT), Eurotech (IT), IoTango (US).

Abstract: The AGILE project is a 3-year H2020 project started in January 2016, which will deliver an integrated framework of open source tools and platforms that interoperate for enabling the delivery of adaptive, self-configurable and secure IoT elements (both software and hardware) that can be utilized in a variety of scenarios. Such tools target actors with heterogeneous skills, including entrepreneurs, researchers, and individuals, aiming to enable the realization of IoT applications respecting user privacy and data ownership.

7.3. International Initiatives

7.3.1. Inria Associate Teams Not Involved in an Inria International Labs

7.3.1.1. EMBRACE

Title: Leveraging Human Behavior and Uncertainty in 5G Networks to Build Robust Resource Allocation and Services Orchestration Models

International Partners (Institution - Laboratory - Researcher):

UTFPR (Brazil) - Departamento Acadêmico de Informática (DAINF) Curso de Pós-Graduação em Engenharia Elétrica e Informática Industrial (CPGEI) - Anelise Munaretto

UFG (Brazil) - Institute of Computational Mathematics and Scientific / Engineering Computing - Kleber Vieira Cardoso

UFMG (Brazil) - Dpt of Statistics - Antonio A. F. Loureiro

Start year: 2017

See also: <https://team.inria.fr/embrace/>

Abstract: EMBRACE propose une architecture novatrice pour gérer des ressources et des services opérationnels hétérogènes. EMBRACE se concentre sur les défis scientifiques liés des ensembles de données collectées dans le monde réel et décrivant le comportement du réseau des utilisateurs. En particulier, EMBRACE exploite la modélisation du comportement humain en termes de mobilité, de demande de contenu, d'intérêts communs et des interactions entre-utilisateurs. En construisant des modèles d'allocation des ressources tenant compte de l'utilisateur, EMBRACE a pour objectif de diminuer l'incertitude et mieux cerner les profils humains dans les réseaux 5G. La communication D2D sera également utilisée comme service opérationnel pour gérer la croissance du trafic mobile en libérant des ressources des réseaux cellulaires, sans augmenter les coûts. La nouveauté de l'architecture réside dans les algorithmes conçus qui exploiteront les caractérisations tirés de l'analyse du comportement des utilisateurs, l'hétérogénéité du réseau, et de l'incertitude. L'évaluation par simulation et l'émulation sera également l'un des thèmes clés. Enfin, les équipes concernées (Inria Infine, UFMG, UFG, UTFPR) ont un long historique de coopération sur ces thèmes.

7.3.2. Inria International Partners

7.3.2.1. Declared Inria International Partners

1. Renewed IOTPUSH collaboration with Freie Universitaet Berlin around the long-term stay of Emmanuel Baccelli in Berlin, on research topics about the Internet of Things, RIOT and Information-Centric Networking.

7.3.2.2. Informal International Partners

1. On-going collaboration with Freie Universitaet Berlin and Hamburg University of Applied Science around RIOT.
2. Informal collaborations with UIUC and UMass.
3. Informal collaborations with ENSI Tunis and Sesame Tunis.
4. On-going strong collaboration with Sapienza University of Rome, Italy.
5. On-going strong collaboration with CNR Torino, Italy.
6. On-going collaboration with University of Porto, Portugal.
7. On-going collaboration with ENSAE/CNRS, France.
8. On-going collaboration with University of Edinburgh, UK.
9. On-going collaboration with Boston University, US.

7.3.3. Participation in Other International Programs

7.3.3.1. Indo-French project

The Inria teams Infine and Eva are part of the "D2D Communication for LTE Advanced Cellular Network" , a project funded by the Indo-French Centre for the Promotion of Advanced Research (CEFIPRA). With industrial partners, and also with Indian partners, this project is focusing on the evolution of cellular networks towards 5G: this includes exploration of device-to-device (D2D) communication, and more generally IoT communication in a cellular context. Research directions include efficient access for IoT devices (massive numbers of devices with low volume communication); combination of random access protocols/error coding/physical layer ; efficient neighbor discovery,

7.3.3.2. STIC AmSud MOTIf 2017

Participant: Aline Carneiro Viana.

Program: STIC AmSud

Project title: Mobile phone sensing of human dynamics in techno-social environment

Duration: 2017-2019

Coordinators: Marton Karsai (ENS/Inria) and Jussara M. Almeida (UFMG) and Alejo Salles (Univ. of Buenos Aires)

Abstract: Information and Communication Technology (ICT) is becoming increasingly social, as demonstrated by the multitude of emerging technologies and technology platforms that facilitate social interactions, taking place as communication via telephone, text message, email, online social networks etc. At the same time, our social activities are increasingly embedded in the ICT environments that enable and enhance our ability to transact, share experiences, and maintain social relationships. One of the best ways to explore these developments is through the mining and analysis of data, which are collected through mobile phones and allow us to investigate how individuals act when embedded in a technology-enabled environment. The MOTIf project builds on the analysis and modeling of geo-localized temporally detailed but fully anonymised mobile phone call networks. These datasets allow us to address the two scientific objectives about spatiotemporal patterns of service usage of anonymised individuals to learn when, where, and what people are doing; and about the fine-grained sociodemographic structure of society and its effect on the the individual social behaviour. In other words our goal in general is to understand how individuals behave in a dynamic techno-social environment.

7.4. International Research Visitors

7.4.1. Visits of International Scientists

Prof. Antonio F. Loureiro is a Visiting Researcher at Infine for 3 months, under the *DigiCosme Visiting Professor* funding. He worked with Aline C. Viana and the internship Joao Batista Borges on the inference of motifs from daily human mobility. He is also the Brazilian coordinator of the EMBRACE Inria associate team. He will give a series of lectures on “*What can a mobility trace tell us?*”.

7.4.1.1. Internships

Joao Batista Borges visited us for 2 weeks on October 2018 and will return on January 2019. The visits enter in the context of EMBRACE associated team. He work with Aline C. Viana and Antonio Loureiro on the extraction of motifs of mobility patterns of individuals that, when merged together, describe their daily motion and can be used to enhance mobility prediction.

Diego Madariaga Roman did an internship of 3 months at our team (Sep-Nov 2018). He work with Aline C. Viana, Marco Fiore and Panagiota Katsikouli on adaptive sampling frequency of human mobility.

Lucas Santos did an internship of 5 months at our team (May-Nov 2018), in the context of EMBRACE associated team. He work with Aline C. Viana and Pedro Olmo on the investigation of causalities in habits of human visits.

7.4.2. Visits to International Teams

7.4.2.1. Research Stays Abroad

Emmanuel Baccelli is Visiting Professor at Freie Universitaet (FU) Berlin, within the context of the formal collaboration IOTPUSH with this university on research topics about the Internet of Things, RIOT and Information-Centric Networking.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific Events Organisation

8.1.1.1. Member of the Organizing Committees

1. **Aline C. Viana** is Publicity co-Chair of: IEEE PICom 2018; IEEE MiSeNet 2018 (jointly with IEEE Infocom 2018); DCOSS 2018; DCOSS 2019; CoUrb 2019 (jointly with DCOSS 2019).
2. **Aline C. Viana** is Student Travel Grant co-chair of IEEE Infocom 2019.

8.1.2. Scientific Events Selection

8.1.2.1. Chair of Conference Program Committees

1. **Emmanuel Baccelli** was chair of the RIOT Summit 2018.

8.1.2.2. Member of the Conference Program Committees

1. **Aline C. Viana** is/was TPC member of: Altotel 2018; Algotel 2019; NTMS 2018; LADaS 2018.

8.1.3. Journal

8.1.3.1. Member of the Editorial Boards

1. **Aline C. Viana** is an Editorial Board member of Urban Computing Spring book series (<http://www.springer.com/series/15552>), since Feb. 2018; an Associate Editor of ACM SIGCOMM Computer Communication Review (ACM CCR), since May 2014; an Editorial Board member of Wireless Communications and Mobile Computing Open Access Journal of John Wiley&Sons and Hindawi since 2016.

8.1.3.2. Reviewer - Reviewing Activities

1. in 2018, **Emmanuel Baccelli** reviewed for ACM Transactions on IoT, ACM ICN, IEEE Transactions on Cloud Computing, IEEE Journal on Internet of Things, JSAC, PEMWN.
2. **Aline C. Viana** reviewed papers for ACM SIGCOMM CCR Journal, elsevier Pervasive and Mobile Computing Journal and Computer Communication Elsevier Journal, IEEE Trans. on Network and Service Management, on IEEE Internet Computing.

8.1.4. Standardization

1. **Emmanuel Baccelli and Cedric Adjih** have participated at several working groups at IETF during 2018.
2. **Emmanuel Baccelli and Cedric Adjih** have participated at several IETF hackathons during 2018.

8.1.5. Invited Talks

1. in 2018, **Emmanuel Baccelli** gave invited talks as EPO in Berlin, at Paris Open Source Summit, at the 2018 French-Japanese Workshop on Cybersecurity in Tokyo, and at OSIS 2018 in Paris.
2. in 2018, **Cedric Adjih** presented FIT IoT-LAB at the IoT Tunisia Forum 2018, described ICN IoT challenges at IoT Tunisia Workshop 2018, and in december, at a scientific seminar in University Paris 13.
3. **Aline C. Viana** was invited to give a talk at (1) LNCC, Petrópolis, Brazil, workshop on Urban Computing and Society in November 2018; (2) Univ. de la Rochelle, workshop CoFaBras 2018 in October 2018
4. **Aline C. Viana** was the keynote speaker of the CoUrb 2018 Workshop jointly organized with SBRC 2018, Brazil in May 2018. She will be a keynote at the GDR RSD Winter School in February 2019.

8.1.6. Research Administration

1. **Aline C. Viana** is the President of the Scientific Commission at Inria Saclay, responsible for the selection of candidates for the CORDI-S, Post-Doc and Delegation campaigns.
2. **Aline C. Viana** is the international coordinator of the EMBRACE associated team of Inria.
3. Together with the members of the team, **Aline C. Viana** has submitted the short proposal of the new team as well as has presented it at the BCEP and CEP. The long versio of the team proposal will be sent by next week.

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

- Master : Emmanuel Baccelli, “IoT & Security”, summer semester seminar, Freie Universitaet Berlin.
- Master : Emmanuel Baccelli, “IoT & Security”, winter semester seminar, Freie Universitaet Berlin.
- Master : Emmanuel Baccelli, “Operating Systems for Small Connected Devices in the Internet of Things”, 3h cours magistral, Formation PESTO Corps des Mines, Telecom ParisTech, Paris France
- Engineering School: Cédric Adjih, “Internet of Thing”, 3h practical courses, Telecom SudParis
- Engineering School: Cédric Adjih, “Internet of Thing”, 6h practical courses, ENSEA
- Lectures to under-graduation, masters and PhD students at foreign Universities: “Complete trajectory reconstruction from sparse mobile phone data”, 1h, Nov. 2018, LNCC, Petrópolis, Brazil
- Short-courses at conference: “Humans in the communication loop: enablers of next generation networks”, 4h, May 2017, SBRC 2018 conference, Brazil <http://www.sbrc2018.ufscar.br/minicurso-1-mc-1/>.

8.2.2. Supervision

- PHD Guangshuo Chen has defended his PhD in April 2018. *Thesis title*: Human Habits Investigation: from Mobility Reconstruction to Mobile Traffic Prediction. Ecole Polytechnique/ ED STIC Univ. Paris Saclay. Advisor: Aline C. Viana
- Roni Shigueta has defended his PhD in July 2018. *Thesis title*: Channel resource allocation of wireless interfaces of mobile devices. Co-tutelle: PUC-PR and Ecole Polytechnique/ ED STIC Univ. Paris Saclay. Advisors: Aline C. Viana and Mauro Fonseca (UTFPR, Brazil)
- PhD in progress: Licia Amichi, “Modelling exploration factor of human beings”, since Sep. 2018.
- PhD in progress: Lucas Santos, “Investigating causalities in habits of human visits”, since May 2018.
- PhD in progress: Douglas Teixeira, “Context-enhanced human predictability in short-term datasets with high spatial resolution”, since April 2018.
- PhD in progress: Joao B. Borges, “Revealing motifs in human mobility”, since Nov. 2018.
- PhD in progress: Rafael Costa, “Human-enhanced forwarding strategies for Device-to-Device (D2D) communication”, since Sep 2017.

8.2.3. Juries

- **Reviewer for PhD thesis committee:** Aline Viana was reviewer for the following PhDs: H. Chelle (INP/Univ. de Toulouse, Dec. 2018); Y. Zhou (CentraleSupélec, Jui.2018); F. Coriat (UPMC, Dec. 2018);
- **Examiner for PhD thesis committee:** Aline Viana was examiner for the committees of the following PhDs: A. Boubrima (INSA-Lyon/AGORA, Feb. 2019); L. Pajević (KTH, Nov. 2018);
- **Mid-term Examiner PhD thesis committee:** Emmanuel Baccelli was mid-term reviewer for the PhD of Benjamin Beurdouche (Inria, June 2018). Aline Viana was mid-term examiner for the following PhDs: M. Sardara (Cisco/TPT, Jun. 2018); M. Charfi and I. D. Adamou (CentraleSupélec, Jun. 2018); C. Bertier (Thales/UPMC, Avr. 2018);

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Doctoral Dissertations and Habilitation Theses

- [1] G. CHEN. *Human Habits Investigation : from Mobility Reconstruction to Mobile Traffic Prediction*, Université Paris-Saclay, April 2018, <https://pastel.archives-ouvertes.fr/tel-01784503>

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- [2] I. AMDOUNI, C. ADJIH, N. AITSAADI, P. MUHLETHALER. *Extensive Experimentations on Opportunistic Routing in Wireless Sensor Networks*, in "Sensors", September 2018, vol. 18, n^o 9, 3031 p. , <https://hal.inria.fr/hal-01961054>
- [3] G. CHEN, S. HOTEIT, A. CARNEIRO VIANA, M. FIORE, C. SARRAUTE. *Enriching sparse mobility information in Call Detail Records*, in "Computer Communications", 2018, vol. 122, pp. 44-58 [DOI : 10.1016/J.COMCOM.2018.03.012], <https://hal.archives-ouvertes.fr/hal-01756120>

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- [4] G. CHEN, A. CARNEIRO VIANA, M. FIORE. *Takeaways in Large-scale Human Mobility Data Mining*, in "IEEE International Symposium on Local and Metropolitan Area Networks", Washington, United States, June 2018, <https://hal.inria.fr/hal-01795633>

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- [5] E. BACCELLI, J. DOERR, O. JALLOULI, S. KIKUCHI, A. MORGENSTERN, F. A. PADILLA, K. SCHLEISER, I. THOMAS. *Reprogramming Low-end IoT Devices from the Cloud*, in "The 3rd Cloudification of the Internet of Things Conference (CIoT 2018)", Paris, France, July 2018, <https://hal.inria.fr/hal-01960405>
- [6] E. BACCELLI, J. DOERR, S. KIKUCHI, F. A. PADILLA, K. SCHLEISER, I. THOMAS. *Scripting Over-The-Air: Towards Containers on Low-end Devices in the Internet of Things*, in "IEEE PerCom 2018", Athens, Greece, March 2018, pp. 1-4, <https://hal.inria.fr/hal-01766610>
- [7] L. DAUPHIN, E. BACCELLI, C. ADJIH. *RIOT-ROS2: Low-Cost Robots in IoT Controlled via Information-Centric Networking*, in "7th IFIP/IEEE International Conference on Performance Evaluation and Modeling in Wired and Wireless Networks (PEMWN 2018)", Toulouse, France, September 2018, <https://hal.inria.fr/hal-01898889>

Conferences without Proceedings

- [8] P. KATSIKOULI, A. CARNEIRO VIANA, M. FIORE, A. TARABLE. *L' étude de la fréquence d' échantillonnage des mouvements des humains*, in "CORES 2018 - Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication", Roscoff, France, May 2018, pp. 1-4, <https://hal.archives-ouvertes.fr/hal-01784475>

Other Publications

- [9] B. ADAMSON, C. ADJIH, J. BILBAO, V. FIROIU, F. FITZEK, G. A. M. SAMAH, E. LOCHIN, A. MASUCCI, M.-J. MONTPETIT, M. V. PEDERSEN, G. PERALTA, V. ROCA, P. SAXENA, S. SIVAKUMAR. *Taxonomy of Coding Techniques for Efficient Network Communications*, June 2018, Internet Research Task Force, Request For Comments (RFC) 8406, <https://datatracker.ietf.org/doc/rfc8406/>, <https://hal.inria.fr/hal-00998506>
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