Activity Report 2015

Team MIMOVE

Middleware on the Move

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
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THEME
Distributed Systems and middleware

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Team MIMOVE

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2. Overall Objectives

2.1. Overall Objectives

Given the prevalence of global networking and computing infrastructures (such as the Internet and the Cloud), mobile networking environments, powerful hand-held user devices, and physical-world sensing and actuation devices, the possibilities of new mobile distributed systems have reached unprecedented levels. Such systems are dynamically composed of networked resources in the environment, which may span from the immediate neighborhood of the users – as advocated by pervasive computing – up to the entire globe – as envisioned by the Future Internet and one of its major constituents, the Internet of Things. Hence, we can now talk about truly ubiquitous computing.

The resulting ubiquitous systems have a number of unique – individually or in their combination – features, such as dynamicity due to volatile resources and user mobility, heterogeneity due to constituent resources developed and run independently, and context-dependence due to the highly changing characteristics of the execution environment, whether technical, physical or social. The latter two aspects are particularly manifested through the physical but also social sensing and actuation capabilities of mobile devices and their users. More specifically, leveraging the massive adoption of smart phones and other user-controlled mobile devices, besides physical sensing – where a device's sensor passively reports the sensed phenomena – *social sensing/crowd sensing* comes into play, where the user is aware of and indeed aids in the sensing of the environment. In addition, mobile distributed systems are most often characterized by the absence of any centralized control. This results in peer interaction between system entities, ad hoc or opportunistic relations between them, and relations reflecting the social behavior of the systems' users. The above features span the application, middleware and higher network layers of such systems in a cross-layer fashion.

This challenging environment is characterized by high complexity raising key research questions:

- How to deal with the extreme uncertainty, when developing and running mobile distributed systems, resulting from the openness and constant evolution of their execution environment?
- How to manage the ultra large scale and dynamicity resulting from millions or even billions of mobile devices that interact with the physical environment through sensing and actuation?
- How to leverage the social aspects arising out of billions of users carrying personal devices in order to enable powerful, critical-mass social sensing and actuation?

The research questions identified above call for radically new ways in conceiving, developing and running mobile distributed systems. In response to this challenge, MiMove's research aims at enabling next-generation mobile distributed systems that are the focus of the following research topics:

- **Emergent mobile distributed systems.** Uncertainty in the execution environment calls for designing mobile distributed systems that are able to run in a beforehand unknown, ever-changing context. Nevertheless, the complexity of such change cannot be tackled at system design-time. Emergent mobile distributed systems are systems which, due to their automated, dynamic, environment-dependent composition and execution, *emerge* in a possibly non-anticipated way and manifest *emergent properties*, i.e., both systems and their properties take their complete form only at runtime and may evolve

afterwards. This contrasts with the typical software engineering process, where a system is finalized during its design phase [30], [35]. MiMove's research focuses on enabling the emergence of mobile distributed systems while assuring that their required properties are met. This objective builds upon pioneering research effort in the area of *emergent middleware* initiated by members of the team and collaborators [34].

- **Large scale mobile sensing and actuation.** The extremely large scale and dynamicity expected in future mobile sensing and actuation systems lead to the clear need for algorithms and protocols for addressing the resulting challenges. More specifically, since connected devices will have the capability to sense physical phenomena, perform computations to arrive at decisions based on the sensed data, and drive actuation to change the environment, enabling proper coordination among them will be key to unlocking their true potential. Although similar challenges have been addressed in the domain of networked sensing, including by members of the team [72], the specific challenges arising from the *extremely large scale* of mobile devices – a great number of which will be attached to people, with uncontrolled mobility behavior – are expected to require a significant rethink in this domain [70]. MiMove's research investigates techniques for efficient coordination of future mobile sensing and actuation systems with a special focus on their dependability.
- **Mobile social crowd sensing.** While mobile social sensing opens up the ability of sensing phenomena that may be costly or impossible to sense using embedded sensors (e.g., subjective crowdedness causing discomfort or joyfulness, as in a bus or in a concert) and leading to a feeling of being more socially involved for the citizens, there are unique consequent challenges. Specifically, MiMove's research focuses on the problems involved in the combination of the physically sensed data, which are quantitative and objective, with the mostly qualitative and subjective data arising from social sensing. Enabling the latter calls for introducing mechanisms for incentivising user participation and ensuring the privacy of user data, as well as running empirical studies for understanding the complex social behaviors involved. These objectives build upon previous research work by members of the team on mobile social ecosystems and privacy [86], [51], [83], as well as a number of efforts and collaborations in the domain of smart cities and transport that have resulted in novel mobile applications enabling empirical studies of social sensing systems [38], [64], [65].

Outcomes of the three identified research topics are implemented as middleware-level functionalities giving rise to software architectures for mobile distributed systems and enabling practical application and assessment of our research. Furthermore, although our research results can be exploited in numerous application domains, we focus in particular on the domain of smart cities, which is an area of rapidly growing social, economic and technological interest.

3. Research Program

3.1. Introduction

MiMove targets research enabling next-generation mobile distributed systems, from their conception and design to their runtime support. These systems are challenged by their own success and consequent massive growth, as well as by the present and future, fast evolving, global networking and computing environment. This context is well-captured by the Future Internet vision, whose mobile constituents are becoming the norm rather than the exception. MiMove's research topics relate to a number of scientific domains with intensive ongoing research, such as ubiquitous computing, self-adaptive systems, wireless sensor networks, participatory sensing and social networks. In the following, we discuss related state-of-the-art research – in particular work focusing on middleware for mobile systems – and we identify the open research challenges that drive our work.

3.2. Emergent mobile distributed systems

Emergent mobile distributed systems promise to provide solutions to the complexity of the current and future computing and networking environments as well as to the ever higher demand for ubiquitous mobile applications, in particular being a response to the volatile and evolving nature of both the former and the latter. Hence, such systems have gained growing interest in the research literature. Notably, research communities have been formed around *self-adaptive systems* and *autonomic systems*, for which various overlapping definitions exist [76]. Self-adaptive systems are systems that are able to adapt themselves to uncertain execution environments, while autonomic systems have been defined as having one or more characteristics known as *self-** properties, including self-configuring, self-healing, self-optimizing and self-protecting [59]. Self-adaptive or autonomic systems typically include an adaptation loop comprising *modeling*, *monitoring*, *analyzing*, *deciding* and *enactment* processes. The adaptation loop provides feedback about changes in the system and its environment to the system itself, which adjusts itself in response. Current research on emergent distributed systems, including mobile ones, addresses all the dimensions of the adaptation loop [37], [32], [66], [87].

In our previous work, we introduced the paradigm of *emergent middleware*, which enables networked systems with heterogeneous behaviors to coordinate through adequate interaction protocols that emerge in an automated way [55], [34], [33]. A key point of that work is the combined study of the application- and middleware-layer behaviors, while current efforts in the literature tend to look only at one layer, either the application [53] or the middleware [27], [54], and take the other for granted (i.e., homogeneous, allowing direct coordination). Furthermore, the uncertainty of the computing and networking environments that is intrinsic to emergent mobile distributed systems [46] calls for taking into account also the underlying network and computational resources in a cross-layer fashion. In another line of work, we studied cross-integration of heterogeneous interaction paradigms at the middleware layer (message passing versus event-based and data sharing), where we investigate functional and QoS semantics of paradigms across their interconnections [48], [58]. Our focus there is to grasp the relation between individual and end-to-end semantics when bridging heterogeneous interaction protocols. In contrast, existing research efforts typically focus on emergent or evolving properties in homogeneous settings [47]. Last but not least, integrating heterogeneous mobile distributed systems into emergent compositions raises the question of dependability. More specifically, the overall correctness of the composition with respect to the individual requirements of the constituent systems can be particularly hard to ensure due to their heterogeneity. Again, current approaches typically deal with homogeneous constraints for dependability [44], [89], [45] with few exceptions [43].

As evident from the above, there is considerable interest and intensive research on emergent mobile distributed systems, while at the same time there are key research questions that remain open despite initial relevant work, including ours, which are summarized in the following:

- How to effectively deal with the combined impact on emergent properties of the different functional layers of mobile distributed systems (e.g., [55], [34], [33], [73])?
- How to perceive and model emergent properties in space and in time across volatile compositions of heterogeneous mobile distributed systems (e.g., [48], [58])?
- How to produce dependable emergent mobile distributed systems, i.e., systems that correctly meet their requirements, despite uncertainty in their emergence and execution exacerbated by heterogeneity (e.g., [43])?

3.3. Large-scale mobile sensing and actuation

In the past decade, the increasingly low cost of MEMS [1] devices and low-power microprocessors has led to a significant amount of research into mobile sensing and actuation. The results of this are now reaching the general public, going beyond the largely static use of sensors in scenarios such as agriculture and waste-water management, into increasingly *mobile* systems. These include sensor-equipped smartphones and personal wearable devices focused on the idea of a “quantified self", gathering data about a user’s daily habits in order

[1] Micro-Electro-Mechanical Systems.

to enable them to improve their well-being. However, in spite of significant advances, the key challenges of these systems arise from largely the same attributes as those of early envisioned mobile systems, introduced in [80] and re-iterated in [79]: relative resource-poverty in terms of computation and communication, variable and unreliable connectivity, and limitations imposed by a finite energy source. These remain true even though modern mobile devices are significantly more powerful compared to their ancestors; the work we expect them to do has increased, and the computation and storage abilities available through fixed infrastructure such as the cloud are larger by order of magnitudes than any single mobile device. The design of algorithms and protocols to efficiently coordinate the sensing, processing, and actuation capabilities of the large number of mobile devices in future systems is a core area of MiMove's research.

Precisely, the focus of MiMove's research interests lies mostly in the systems resulting from the increased popularity of sensor-equipped smart devices that are carried by people, which has led to the promising field of *mobile phone sensing* or *mobile crowd-sensing* [63], [60]. The paradigm is powerful, as it allows overcoming the inherent limitation of traditional sensing techniques that require the deployment of dedicated fixed sensors (e.g., see work on noise mapping using the microphones in users' telephones [74]). Specifically, we are interested in the challenges below, noting that initial work to address them already exists, including that by team members:

- How to efficiently manage the large scale that will come to the fore when millions, even billions of devices will need to be managed and queried simultaneously (e.g., [85], [50])?
- How to efficiently coordinate the available devices, including resource-poor mobile devices and the more-capable cloud infrastructure (e.g., [72], [41], [78], [69])?
- How to guarantee dependability in a mobile computing environment (e.g., [40], [84], [36])?
- How to ensure that the overhead of sensing does not lead to a degraded performance for the user (e.g., [61], [41])?

3.4. Mobile social crowd-sensing

Mobile crowd-sensing as introduced in Section 3.3 is further undergoing a transformation due to the widespread adoption of social networking. The resulting mobile *social* crowd-sensing may be qualified as "*people-centric sensing*" and roughly subdivides into two categories [62]: i) *participatory sensing*, and ii) *opportunistic sensing*. Participatory sensing entails direct involvement of humans controlling the mobile devices, while opportunistic sensing requires the mobile device itself to determine whether or not to perform the sensing task. Orthogonally to the above categorization, mobile sensing can be [60]: i) *personal sensing*, mostly to monitor a person's context and well-being; ii) *social sensing*, where updates are about the social and emotional statuses of individuals; or iii) *urban (public) sensing*, where public data is generated by the public and for the public to exploit. Personal sensing is aimed towards personal monitoring and involves one or just a few devices in direct relationship with their custodian. For instance, SoundSense [67] is a system that enables each person's mobile device to learn the types of sounds the owner encounters through unsupervised learning. Another application example relates to the sensing-based detection of the users' transportation mode by using their smartphones [52]. In social sensing, the mobile device or its owner decides what social information to share about the owner or the owner's environment, with an individual or group of friends [60], [42], [57], [28], [71]. Social sensing is mostly participatory. Therefore, it is the custodian of the device who determines when and where data should be generated. Social participatory sensing is closely related to social networking [68]. On the other hand, within opportunistic social sensing, the underlying system is in charge of acquiring needed data through relevant probes, as opposed to having the end-user providing them explicitly [31], [56], [29]. In urban sensing, also known as public sensing, data can be generated by everyone (or their devices) and exploited by everyone for public knowledge, including environment monitoring, or traffic updates [60]. In participatory urban sensing, users participate in providing information about the environment by exploiting the sensors/actuators embedded in their devices (which can be smartphones, vehicles, tablets, etc.) [60]. However data is only generated according to the owner's willingness to participate. Participatory urban sensing is especially characterized by scale issues at the data level, where data is generated by numerous individuals

and should be processed and aggregated for knowledge to be inferred, involving adequate data scaling approaches [49]. Ikarus [88] is an example of participatory sensing, where data is collected by a large number of paragliders throughout their flights. The focus is on aggregating the data and rendering the results on a thermal map.

As outlined above, mobile social crowd-sensing has been a very active field of research for the last few years with various applications being targeted. However, effectively enabling mobile social crowd-sensing still raises a number of challenges, for which some early work may be identified:

- How to ensure that the system delivers the right quality of service, e.g., in terms of user-perceived delay, in spite of the resource constraints of mobile systems (e.g., [75])?
- How to guarantee the right level of privacy (e.g., [39], [77])?
- How to ensure the right level of participation from end-users so that mobile sensing indeed becomes a relevant source of accurate knowledge, which relates to eliciting adequate incentive mechanisms [90], in particular based on the understanding of mobile application usage [82], [81]?
- How to enrich sensor-generated content that is quantitative with user-generated one, thereby raising the issue of leveraging highly unstructured data while benefiting from a rich source of knowledge (e.g., sensing the crowdedness of a place combined with the feeling of people about the crowdedness, which may hint on the place's popularity as much as on discomfort)?

4. Application Domains

4.1. Mobile urban systems for smarter cities

With the massive scale adoption of mobile devices and further expected significant growth in relation with the Internet of Things, mobile computing is impacting most -if not all- the ICT application domains. However, given the importance of conducting empirical studies to assess and nurture our research, we focus on one application area that is the one of "*smart cities*". The smart city vision anticipates that the whole urban space, including buildings, power lines, gas lines, roadways, transport networks, and cell phones, can all be wired together and monitored. Detailed information about the functioning of the city then becomes available to both city dwellers and businesses, thus enabling better understanding and consequently management of the city's infrastructure and resources. This raises the prospect that cities will become more sustainable environments, ultimately enhancing the citizens' well being. There is the further promise of enabling radically new ways of living in, regulating, operating and managing cities, through the increasing active involvement of citizens by ways of crowd-sourcing/sensing and social networking.

Still, the vision of what smart cities should be about is evolving at a fast pace in close concert with the latest technology trends. It is notably worth highlighting how mobile and social network use have reignited citizen engagement, thereby opening new perspectives for smart cities beyond data analytics that have been initially one of the core foci for smart cities technologies. Similarly, open data programs foster the engagement of citizens in the city operation and overall contribute to make our cities more sustainable. The unprecedented democratization of urban data fueled by open data channels, social networks and crowd sourcing enables not only the monitoring of the activities of the city but also the assessment of their nuisances based on their impact on the citizens, thereby prompting social and political actions. However, the comprehensive integration of urban data sources for the sake of sustainability remains largely unexplored. This is an application domain that we intend to focus on, further leveraging our research on emergent mobile distributed systems, large-scale mobile sensing & actuation, and mobile social crowd-sensing.

In a first step, we concentrate on the following specialized applications, which we investigate in close collaboration with other researchers, in particular as part of the dedicated Inria Project Lab *CityLab@Inria*:

- **Democratization of urban data for healthy cities.** The objective here is to integrate the various urban data sources, especially by way of crowd-Xing, to better understand city nuisances from raw pollution sensing (e.g., sensing noise) to the sensing of its impact on citizens (e.g., how people react to urban noise and how this affects their health).
- **Socially-aware urban mobility.** Mobility within mega-cities is known as one of the major challenges to face urgently due to the fact that today's mobility patterns do not scale and to the negative effect on the environment and health. It is our belief that mobile social and physical sensing may significantly help in promoting the use of public transport, which we have started to investigate through empirical study based on the development and release of dedicated apps.
- **Social applications.** Mobile applications are being considered by sociologists as a major vehicle to actively involve citizens and thereby prompt them to become activists. This is especially studied with the Social Apps Lab at UC Berkeley. Our objective is to study such a vehicle from the ICT perspective and in particular elicit relevant middleware solutions to ease the development and development of such "*civic apps*".

Acknowledging the need for collaborative research in the application domain of smart cities, MiMove is heavily involved and actually leading CityLab@Inria [2]. CityLab is focused on the study of ICT solutions promoting social sustainability in smart cities, and involves the following Inria project-teams in addition to MiMove: CLIME, DICE, FUN, MYRIADS, SMIS, URBANET and WILLOW. CityLab further involves strong collaboration with California universities affiliated with CITRIS (Center for Information Technology Research in the Interest of Society) and especially UC Berkeley, in relation with the *Inria@SiliconValley* program. We note that Valérie Issarny acts as scientific manager of Inria@SiliconValley and is currently visiting scholar at CITRIS at UC Berkeley. In this context, MiMove researchers are working closely with colleagues of UC Berkeley, including researchers from various disciplines interested in smart cities (most notably sociologists).

5. Highlights of the Year

5.1. Highlights of the Year

On Wednesday July 8, 2015, Inria announced the launch of SoundCity, a mobile application to measure your personal exposure to noise pollution. The project is developed in the context of CityLab@Inria by the MiMove and CLIME teams, further involving collaboration with French and California startups. The project is supported by the City of Paris smart city initiative and Bernard Jomier, deputy mayor responsible for health, disability, and relations with Paris public hospital system. Noise pollution, which lowers quality of life and harms health, is a serious environmental challenge in almost every major city. The noise levels found in most cities today can interfere with memory and learning, disturb sleep, and contribute to heart disease. In Paris, the urban ecology agency and the Bruitparif association [3] currently rely on monitoring stations and computer simulations to understand noise exposure of citizens. SoundCity aims to complement these data with personal sound level exposure measurements collected with smartphones. SoundCity will also help citizens be more aware and engaged with noise in their environments. More at http://www.inria.fr/en/centre/paris/news/launch-of-soundcity-mobile-application.

6. New Software and Platforms

6.1. Introduction

In order to validate our research results and, in certain cases, make them available to specific communities or to the public, our research activities encompass the development of related software as surveyed below.

[2] https://citylab.inria.fr
[3] http://www.bruitparif.fr

6.2. VSB: eVolution Service Bus for the Future Internet

Participants: Georgios Bouloukakis, Nikolaos Georgantas [contact], Maël Besson.

URL: https://tuleap.ow2.org/plugins/git/chorevolution/evolution-service-bus

The *eVolution Service Bus (VSB)* is a development and runtime environment dedicated to complex distributed applications of the Future Internet. Such applications are open, dynamic choreographies of extremely heterogeneous services and Things, including lightweight embedded systems (e.g., sensors, actuators and networks of them), mobile systems (e.g., smartphone applications), and resource-rich IT systems (e.g., systems hosted on enterprise servers and Cloud infrastructures). VSB's objective is to seamlessly interconnect, inside choreographies, services and Things that employ heterogeneous interaction protocols at the middleware level, e.g., SOAP Web services, REST Web services, and Things using CoAP (https://tools.ietf.org/html/rfc7252). This is based on runtime conversions between such protocols, with respect to their primitives and data type systems, while properly mapping between their semantics. This also includes mapping between the public interfaces of services/Things, regarding their operations and data, from the viewpoint of the middleware: the latter means that operations and data are converted based on their middleware-level semantics, while their business semantics remains transparent to the conversion.

VSB follows the well-known Enterprise Service Bus (ESB) paradigm. In this paradigm, a common intermediate bus protocol is used to facilitate interconnection between multiple heterogeneous middleware protocols. Conversion of each protocol to the common bus protocol is done by a component associated to the service/Thing in question and its middleware, called a Binding Component (BC), as it binds the service/Thing to the service bus. We introduce a generic architecture for VSB, which relies on the notion of *Generic Middleware (GM)* connector. GM abstracts interactions among peer components that employ the same middleware protocol through generic *post* and *get* operations, in a unifying fashion for any middleware protocol. We propose an API (application programming interface) for GM and a related generic interface description, which we call *GM-IDL*, for application components that (abstractly) employ GM. Concrete middleware protocols and related interface descriptions of application components that employ these middleware protocols can be mapped to GM API and GM-IDL, respectively. Based on these abstractions, we elaborate a generic architecture for BCs, as well as a related method for BC synthesis and refinement for a concrete choreography that includes services/Things with heterogeneous middleware protocols.

The eVolution Service Bus (VSB) presents a significant rethinking of the architecture and the implementation of a service bus destined to serve dynamic choreographies of services but also Things as first-class entities. More specifically, VSB presents the following advancements:

- VSB is a unified interoperability solution for both services and Things participating in choreographies;
- VSB is flexible and lightweight: it is a completely decentralized network of BCs that are deployed as necessary; hence, no BC is needed when a service/Thing employs the same middleware protocol as the one used as common bus protocol;
- Besides the client-server, publish/subscribe and tuple space paradigms, VSB also provides support for the data streaming paradigm;
- Different protocols can be introduced as VSB's common bus protocol with the same easiness as for integrating support for a new middleware protocol of a service/Thing; additionally, there is no need for relying on and/or providing a full-fledged ESB platform;
- While very modular, VSB's architecture includes only few levels of indirection in the processing of primitives when converting between protocols; this makes it simple, lightweight and fast;
- In VSB, mapping between a concrete middleware protocol and the GM paradigm can be performed in different ways, thus enabling to cover all possible interaction cases; there is no unique, fixed mapping limiting the applicability of the solution;
- BC synthesis follows a systematic method allowing for its automation.

VSB is being developed within the H2020 CHOReVOLUTION project (see § 8.2.1.1) with additional support from the iCONNECT Inria ADT (see § 8.1.1.1). It is also based on previous development carried out in the FP7 CHOReOS project (http://www.choreos.eu). VSB is available for download under open source license.

6.3. SoundCity: Urban-scale Noise Monitoring using the Urban Civics Middleware

Participants: Valérie Issarny [contact], Fadwa Rebhi, Animesh Pathak, Sara Hachem.

URL: http://urbancivics.com/soundcity_app.html

The interest in noise pollution and its effects, especially in terms of its influence on citizens' health, has been increasing throughout the years, as illustrated by the plethora of available research and health studies. Traditionally, cities perform periodic noise monitoring to assess the noisiness of neighborhoods and update their city planning policies accordingly. However, in its current state, noise monitoring for city planning takes place once every several years and leverages only a few static sensors (e.g., BruitParif activity, http://www.bruitparif.fr). Additionally, the outcome is not representative of citizens' personal exposure to noise as it is coarse grained and requires preplanning to determine where and when the sensing should take place. It is worth mentioning that, even if we assume that the city administration is able to use applications running on the smart phones of the city employees, gathering data by following a pre-determined spatio-temporal schedule – although an excellent strategy in terms of the quality of data gathered – would be expensive and cumbersome to organize.

Noise sensing is also complemented by data modeling approaches to generate maps that allow citizens and governments to visualize the distribution of noise over a region of interest. Those techniques range from basic data plotting to data assimilation techniques that leverage large scale data analytics further enabling the simulation and estimation of missing noise values. However, assimilation techniques are usually restricted to static sensing with predetermined locations and sensing times. This approach limits the capacity of assimilation models to provide estimates with high accuracy.

A solution to the above issues is through mobile participatory sensing, where noise monitoring is no longer restricted to a few expensive sensors. Participatory sensed data can be then leveraged, along with data provided from static sensors, by the assimilation techniques to further reduce the errors in the simulated maps. Toward that goal, we have been building the Urban Civics middleware, which we have further customized for noise monitoring [20]. The refined Urban Civics comprises middleware solutions for noise sensing, crowd-sourcing and data assimilation with the data assimilation component being more specifically developed by the Inria CLIME team. The noise-sensing itself is performed through existing dedicated applications, integrated with our middleware. Such approach enables us to alleviate the burden of domain-specific development and exploit the knowledge of domain experts.

SoundCity and supporting Urban Civics middleware are developed in collaboration with the Inria CLIME team, Ambientic (FR) and the Civic Engine at Berkeley (USA) in the context of CityLab@Inria and Inria@SiliconValley.

6.4. AppCivist-PB: A Platform for Democratic Assembly Customized for Participatory Budgeting

Participants: Valérie Issarny [contact], Cristhian Parra Trepowski, Animesh Pathak.

Participatory budgeting processes are among the most illustrative, real-life experiences of participatory democracy. Participatory Budgeting (PB) has its beginnings in the late 1980s, when some Brazilian cities started to experiment with processes of citizen participation in decisions about how to better allocate part of the city's budget. Although PB takes different forms, they can all be considered as refining the following base process: residents of a city propose spending ideas, volunteers or delegates develop those ideas into proposals, residents then vote on the proposals, and the government finally implements the winning projects. Since the 1980s, PB processes have spread around the world as a set of administrative reforms and, more recently, as a "best practice" in mainstream international development.

Although a large array of ICT tools exist to support citizens' engagement, their use in PB is still limited and scattered. Mostly, ICT have been leveraged for communication for promotion purposes (through multiple channels such as TV, radio and social media) and for facilitating voting for citizens (usually, with custom-made web sites or SMS).

With AppCivist-PB, we want to enable city governments to configure the software assemblies that best match the requirements of the kind of PB campaign they want to support, while leveraging existing software services and components. However, from the overall perspective of participatory democracy, our goal is primarily to facilitate the elaboration of proposals by citizen assemblies that form according to the citizen interests. In other words, we want to support a process that emphasizes collaborative contribution making at all stages of the elaboration of proposals by diverse citizen assemblies, which are primarily created by and for citizens. The collaborative process must in particular facilitate the assembly of groups (or sub-assemblies) on the basis of commonalities among the proposals, which is essential if one wants to sustain city-scale participation and be inclusive of citizen contributions.

AppCivist-PB helps users assemble proposal making and selection workflows, using service-oriented architecture (SOA) principles. The composition principles of SOA allow for various implementations and instances of these workflows, including the possibility of integrating and linking different workflows for the same PB campaign. For example, a city might create and manage its own workflow to receive proposals and facilitate deliberation and voting by registered residents; at the same time, citizen groups (typically activists) can create their own, independent, workflows to co-create, develop, and promote proposals for the city, following their own collaboration practices. Compared to traditional SOA, AppCivist-PB distinguishes itself by enabling the assembly of software services dedicated to the support of online-facilitated participatory democracy by and for relevant citizen assemblies.

The AppCivist-PB platform is developed in collaboration with the Social Apps Labs at CITRIS at University of California Berkeley (USA) in the context of CityLab@Inria and Inria@SiliconValley.

7. New Results

7.1. Introduction

MiMove's research activities in 2015 have focused on a set of areas directly related to the team's research topics. Hence, we have worked on QoS for Emergent Mobile Systems (§ 7.2) in relation to our research topic regarding Emergent Mobile Distributed Systems (§ 3.2). Furthermore, our effort on SoundCity (§ 7.3) is linked to our research on Mobile Social Crowd-sensing (§ 3.4). Still in the context of Mobile Social Crowd-sensing (§ 3.4), we have developed AppCivist-PB (§ 7.4) related to our interest in social applications aiming to actively involve citizens (see § 4.1); this is further linked to our research on composition of Emergent Mobile Distributed Systems (§ 3.2).

7.2. QoS for Emergent Mobile Systems

Participants: Georgios Bouloukakis, Nikolaos Georgantas, Rachit Agarwal, Valérie Issarny, Raphael de Aquino Gomes.

With the emergence of Future Internet applications that connect web services, sensor-actuator networks and service feeds into open, dynamic, mobile choreographies, heterogeneity support of interaction paradigms is of critical importance. Heterogeneous interactions can be abstractly represented by client-server, publish/subscribe, tuple space and data streaming middleware connectors that are interconnected via bridging mechanisms providing interoperability among the choreography peers. We make use of the *eVolution Service Bus (VSB)* (see § 6.2) as the connector enabling interoperability among heterogeneous choreography participants. VSB models interactions among peers through generic *post* and *get* operations that represent peer behavior with varying time/space coupling.

Within this context, we study end-to-end Quality of Service (QoS) properties of choreographies, where in particular we focus on the effect of middleware interactions on QoS. We consider both homogeneous and heterogeneous (via VSB) interactions. We report in the following our results in three complementary directions:

- While VSB ensures functional interoperability of heterogeneous choreography interactions, differences in timing requirements and constraints of such interactions can severely affect their latencies and success rates. To model timeliness, we introduce the *lease* and *timeout* parameters. The former captures data availability and validity in time, while the latter represents intermittent availability of data recipients due to mobility and disconnection. By precisely studying the related timing thresholds using timed automata models, we verify conditions for successful interactions with VSB connectors. Furthermore, we statistically analyze through simulations, the effect of varying lease and timeout periods to ensure higher probabilities of successful interactions. Simulation experiments are compared with experiments run on the VSB implementation testbed to evaluate the accuracy of results. This work can provide application developers with precise design time information when setting these timing thresholds in order to ensure accurate runtime behavior [23].
- Choreography peers deployed in mobile environments are typically characterized by intermittent connectivity and asynchronous reception of data. In such environments, it is essential to guarantee acceptable levels of timeliness between the data sources and mobile users. In order to provide QoS guarantees in different application scenarios and contexts, it is necessary to model the system performance by incorporating the intermittent connectivity. Queueing Network Models (QNMs) offer a simple modeling environment, which can be used to represent various application scenarios, and provide accurate analytical solutions for performance metrics, such as system response time. We provide an analytical solution regarding the end-to-end response time between the users and the data sources by modeling the intermittent connectivity of mobile users with product-form QNMs. We utilize the publish/subscribe middleware as the underlying communication infrastructure for the mobile users. To represent the subscriber's connections/disconnections, we model and solve analytically an ON/OFF queueing system by applying a mean value approach. Finally, we validate our model using both simulations with real-world workload traces and comparison with an actual implementation of a Java Messaging Service middleware. The deviations between the performance results foreseen by the analytical model and the ones provided by the simulator and the prototype implementation of a real system are shown to be less than 5% for a variety of scenarios.
- Large-scale mobile environments are characterized by, among others, a large number of mobile users, intermittent connectivity and non-homogeneous arrival rate of data to the users, depending on the region's context. Multiple application scenarios in major cities need to address the above situation for the creation of robust mobile systems. Towards this, it is fundamental to enable system designers to tune a communication infrastructure using various parameters depending on the specific context. We take a first step towards enabling an application platform for large-scale information management relying on mobile social crowd-sourcing [26]. To inform the stakeholders of expected loads and costs, we model a large-scale mobile pub/sub system as a queueing network. We introduce additional timing constraints such as (i) mobile user's intermittent connectivity period; and (ii) data validity lifetime period (e.g. that of sensor data). Using our MobileJINQS simulator (http://xsb.inria.fr/d4d#mobilejinqs), we parameterize our model with realistic input loads derived from the D4D CDR (Call Detail Record) dataset (http://www.d4d.orange.com/en/home) and varied lifetime periods in order to analyze the effect on response time. This work provides system designers with coarse grain design time information when setting realistic loads and time constraints [18].

7.3. Urban Civics: An IoT Middleware for Democratizing Crowdsensed Data in Smart Societies

Participants: Valérie Issarny, Fadwa Rebhi, Animesh Pathak, Sara Hachem.

The growth of our cities comes along with the aggravation of urban nuisances (e.g., air pollution), which significantly alters the citizens' quality of life and especially their health. It then becomes essential to ensure the growth of cities is both environmentally and socially sustainable. As computer scientists, it is our vision that ICT shall play a key role in achieving the above sustainability requirements, as already put forward by the smart city/society concept. However, smart cities have mostly emphasized the big data dimension and related knowledge engineering to ease the management of the city's infrastructure and resources. While this is an important part of smart cities, we believe that ICT should be leveraged to promote participatory democracy so that citizens and government can communicate openly about the issues facing their societies as much as about their solutions. Toward that goal, we have introduced the Urban Civics middleware, which addresses three complementary research questions underlying participatory democracy from an ICT perspective [20], [21]:

(RQ1) How to leverage the richness of urban sensors of the new digital era that features the Internet of Things, open data, social networking, and mobile computing to serve both citizens and government with better insights? Our answer lies in connecting those various data sources where probabilistic protocols combined with semantic technology allow for an urban-scale middleware solution.

(RQ2) How to assimilate urban data so as to generate explanatory city models to inform urban problem solving? Our solution leverages data assimilation (developed by the Inria CLIME team) that has proven successful in geosciences and paves the way to the comprehensive integration of heterogeneous data sources whose accuracy may vary significantly.

(RQ3) How to integrate the solutions to the above into a scalable urban middleware and further ensure citizen participation? Building on our past experience in developing middleware solutions for the mobile environment and especially the – mobile – Internet of Things, we have conceived and introduced the architecture of Urban Civics, a novel IoT middleware solution for democratizing crowd-sensed data in smart societie. We are in particular confident that, in addition to leveraging existing incentive mechanisms, the citizen participation will also be prompted by the very nature of participatory democracy. However, such an assumption needs to be validated through actual experiments at an urban scale for which we deploy use cases in the Paris and San Francisco Bay areas.

7.4. AppCivist: Engineering Software Assemblies for Participatory Democracy

Participants: Valérie Issarny, Cristhian Parra Trepowski, Animesh Pathak.

Information and communication technologies (ICT) are profoundly changing the nature of human social and environmental interactions. One such change concerns innovations in the way that citizens both interact with government institutions and engage in greater self-government through democratic assembly and collective action. Our research focuses on this transformation of politics, asking how new social media can contribute to new forms of democracy. The pervasive use of ICT suggests that they present an unprecedented opportunity to rethink the constraints of time and space that are generally thought to make the exercise of a more direct and engaging democracy at a large scale practically impossible. In effect, ICT challenge the assumption that citizens of large political units must be content with systems of representative democracy that typically produce a more passive and legalistic citizenship than an active and participatory one.

To consider this challenge, we undertake a pragmatic and modest investigation of how ICT and more precisely software systems can contribute to enabling direct democracy at a large scale. Our research has two immediate objectives. One is to engineer software that leverages the reach of the Internet and the powers of computation to enhance the experience and efficacy of civic participation. The second is to use the ICT software platform to induce the associational forms of a new digitally-inspired citizenship among residents.

Our research is multi-disciplinary in nature, bringing together anthropologists and computer scientists to coinvestigate how to build software systems that promote the development of such digital democratic assemblies and citizens. Our initiative is further rooted in the principles of social activism in that we want to provide citizens with new software systems that help them articulate projects, deliberate directly among

themselves, and mobilize activities. A number of digital tools and in particular social networks and web-based content management systems already support aspects of social activism. However, these tools need to be customized as much as composed to become really useful for activists. To that end, we have set the principles of the AppCivist service-oriented software platform in [24]. AppCivist is built around the vision of letting activist users compose their own applications, called Assemblies, using relevant Internet-based components that enable various aspects of democratic assembly and collective action. Starting from a social science perspective, we identified the following high-level categories of functions for AppCivist Assemblies: Mobilizing people, Co-creating proposals, Acting collectively, and Communicating.

Following, we have concentrated on developing the first instance of AppCivist for Participatory Budgeting (PB), as a representative use case of participatory democracy. As a result, we are able to account for various initiatives in citizen participation, including lessons learned from existing PB campaigns worldwide since their emergence in Brazil in the late 1980s. Research contributions more specifically relate to [22]:

- *State of the art survey and analysis of software systems that contribute to enabling participatory democracy*, which lacks an adequate bottom-up approach to digital proposal making. Such an approach would allow groups of citizens to self-assemble on the basis of common interests and enable the resulting citizen assemblies to initiate ideas and elaborate on them using convenient assemblies of software services.
- *State of the art survey and analysis of digital tools oriented towards Participatory Budgeting*, where leveraging ICT to enable truly urban-scale participation in PB campaigns remains unrealized. AppCivist-PB utilizes the concepts of *citizen assembly* and *software assembly* to address this challenge.
- *AppCivist-PB software architecture* enabling citizen and software assemblies, which following the design of AppCivist introduced in [24] strictly adheres to the principles of service orientation. In that framework, citizen assemblies allow registered users and groups of users to self assemble into higher-level groups to coordinate idea generation and to elaborate proposals through versioning. In a complementary way, software assemblies adhere to the well-known principle of service composition, configuring software services and components oriented towards the implementation of functions supporting participatory democracy.
- *AppCivist-PB prototype* permits an early assessment of the effectiveness of AppCivist-PB in supporting actual urban-scale PB campaigns, such as the one of Paris in 2015. In addition, the prototype provides an opportunity to experiment with developing service wrappers to integrate third-party services (e.g., Etherpad.org) into its software assemblies. In the near future, we intend to automate this integration as much as possible, building on our background in the synthesis of mediators [13], [12].

This research is carried out in collaboration with the Social Apps Lab at CITRIS at UC Berkeley in the context of CityLab@Inria and Inria@SiliconValley.

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. Inria Support

8.1.1.1. Inria ADT iCONNECT

Participant: Nikolaos Georgantas [correspondent].

- **Name:** iConnect – *Emergent Middleware Enablers*
- **Related activities:** § 6.2
- **Period:** [October 2013 – December 2015]
- **Partners:** Inria MiMove.

The pervasive computing vision is hampered by the extreme level of heterogeneity in the underlying infrastructure, which impacts on the ability to seamlessly interoperate. Further, the fast pace at which technology evolves at all abstraction layers increasingly challenges the lifetime of networked systems in the digital environment.

Overcoming the interoperability challenge in pervasive computing systems has been at the heart of the FP7 FET IP CONNECT project (http://www.connect-forever.eu/), which ran from 2009 to 2012, and was coordinated by Inria ARLES (MiMove's predecessor team). Specifically, CONNECT has been investigating the paradigm of *Emergent middleware*, where protocol mediators are dynamically synthesized so as to allow networked systems that provide complementary functionalities to successfully coordinate. The CONNECT project has in particular delivered prototype implementation of key enablers for emergent middleware, spanning discovery, protocol learning, and mediator synthesis and deployment. Further, while CONNECT focused on learning and reconciling interaction protocols at the application layer, the FP7 project CHOReOS (http://www.choreos.eu) to which ARLES contributed as well, investigated a complementary enabler that supports interoperability across systems implementing heterogeneous interaction paradigms (i.e., client-service, event-based and shared memory). The proposed enabler introduces the concept of XSB - eXtensible Service Bus, which revisits the notion of Enterprise Service Bus and features an end-to-end interaction protocol that preserves the interaction paradigms of the individual components, while still allowing interoperability.

The objective of the Inria iConnect ADT is to leverage and integrate the above complementary results, packaging and further enhancing enabler prototypes, for take-up of the results by the relevant open source community. The work will involve development effort focused on the following core enablers:

- Universal discovery of resources composing legacy discovery protocols,
- Dynamic synthesis and deployment of mediators specified as enhanced labelled transition systems,
- XSB as underlying run-time support for mediators so as to support interoperability across systems based on heterogeneous interaction paradigms,
- Experiment in the area of federated social networking.

We are releasing the software prototypes through the OW2 open source initiative FISSi (Future Internet Software and Services initiative – http://www.ow2.org/view/Future_Internet/), as our solutions are of direct relevance to sustaining interoperability in the Future Internet.

8.1.1.2. Inria ADT CityLab Platform

Participant: Valérie Issarny [correspondent].

- **Name:** CityLab Platform – *A Platform for Smarter Cities Promoting Social and Environmental Sustainability*
- **Related activities:** § 7.3 and § 6.3
- **Period:** [November 2014 – October 2016]
- **Partners:** Inria MiMove, Inria CLIME.

The CityLab Platform ADT is part of the CityLab Inria Project Lab focused on the study of ICT-based smart city systems from supporting "sensing" systems up to advanced data analytics and new services for the citizens. While the topic is broad, the lab leverages relevant effort within Inria project-teams that is further revisited as well as integrated to meet the challenges of smart cities

There is the promise of enabling radically new ways of living in, regulating, operating and managing cities through the increasing active involvement of citizens. The latest technology trends of crowd- sourcing/sensing (crowd-Xing) and location-based social networking have reignited citizen engagement, opening new perspectives for cost-effective ways of making local communities and cities more sustainable. However, this requires investigating supporting systems of systems from advanced sensing systems up to integrated data management and associated data analytics. This is specifically the objective of the CityLab Inria ProjectLab, where the related ADT is focused on the development and maintenance of the CityLab Platform. The platform integrates the software prototypes developed as part of the undertaken research and will be made available under open source license. It is further the objective of the ADT to deploy and experiment with the platform within cities.

8.2. European Initiatives

8.2.1. FP7 & H2020 Projects

8.2.1.1. H2020 ICT CHOReVOLUTION

Participants: Nikolaos Georgantas [correspondent], Valérie Issarny [correspondent].

Name: CHOReVOLUTION – *Automated Synthesis of Dynamic and Secured Choreographies for the Future Internet*

URL: http://www.chorevolution.eu

Type: Research & Innovation Action (ICT)

Topic: Tools and Methods for Software Development

Related activities: § 7.2 and § 6.2

Period: [January 2015 - December 2017]

Partners: CEFRIEL (Italy), Inria MiMove, OW2 Consortium (France), Thales Communications S.A. (France) [**coordinator**], Università degli Studi dell'Aquila (Italy) [**scientific leader**], Softeco Sismat SrL (Italy), Tirasa (Italy), Viktoria Swedish ICT (Sweden).

The Future Internet (FI) represents an age of unprecedented opportunities for social, economic, and business growth thanks to the global scale connectivity of the virtual as well as of the physical world. This indeed opens up a wealth of innovative and revolutionary real-life scenarios, as for instance illustrated by the smarter cities perspectives where envisioned scenarios significantly ease daily human activities and give support for the growth of new markets and employment opportunities. However, leveraging the FI for the development of innovative software applications remain a challenging task even though major enablers are readily available by ways of service-oriented and cloud computing. It is in particular our vision that enabling the choreography of FI services shall play a significant role in the provisioning of innovative applications. However, existing choreography-based service composition approaches are rather static and are poorly suited to the need of the FI that is a highly dynamic networking environment, further bringing together highly heterogeneous services ranging from Thing- to Business-based services that span different security domains. As a result, the technology is not mature enough for market take-up. CHOReVOLUTION elevates the Readiness Level of existing choreography technologies in order to drop the dynamism and cross-organization security barriers via the automated synthesis of dynamic and secured choreographies in the FI. To meet its objectives, CHOReVOLUTION undertakes both research and innovation tasks. The former concentrates on choreography modelling, synthesis, adaptation, service bus, security, and cloud; the latter focus on industrial validation, development support and integration platform, and the establishment of a CHOReVOLUTION community and market take- up. Last but not least CHOReVOLUTION outcomes are assessed by experimenting with new applications in the field of Intelligent Transportation Systems.

8.2.1.2. H2020 ICT FIESTA

Participants: Valérie Issarny [correspondent], Nikolaos Georgantas [correspondent].

Name: FIESTA – *Federated Interoperable Semantic IoT/cloud Testbeds and Applications*

URL: *Under construction*

Type: Research & Innovation Action (ICT)

Topic: FIRE+ (Future Internet Research & Experimentation)

Related activities: § 7.3 and § 6.3

Period: [February 2015 - January 2018]

Partners: Fraunhofer FOKUS (Germany) [**coordinator**], INSIGHT @ National University of Galway (Ireland) [**co-coordinator**], University of Southampton IT Innovation Centre (UK), Inria MiMove, University of Surrey (UK), Unparallel Innovation Lda (Portugal), Easy Global Market (France), NEC Europe Ltd (UK), University of Cantabria (Spain), Com4innov (France), Athens Information Technology (Greece), SOCIEDAD PARA EL DESARROLLO REGIONAL DE CANTABRIA (Spain), Ayuntamiento de Santander (Spain), Korea Electronics Technology Institute (Korea).

Despite the proliferation of IoT and smart cities testbeds, there is still no easy way to conduct large scale experiments that leverage data and resources from multiple geographically and administratively distributed IoT platforms. Recent advances in IoT semantic interoperability provide a sound basis for implementing novel cloud-based infrastructures that could allow testbed-agnostic access to IoT data and resources. FIESTA will open new horizons in IoT experimentation at a global scale, based on the interconnection and interoperability of diverse IoT testbeds. FIESTA will produce a first-of-a-kind blueprint experimental infrastructure (tools, techniques and best practices) enabling testbed operators to interconnect their facilities in an interoperable way, while at the same time facilitating researchers in deploying integrated experiments, which seamlessly transcend the boundaries of multiple IoT platforms. FIESTA will be validated and evaluated based on the interconnection of four testbeds (in Spain, UK, France and Korea), as well as based on the execution of novel experiments in the areas of mobile crowd-sensing, IoT applications portability, and dynamic intelligent discovery of IoT resources. In order to achieve global outreach and maximum impact, FIESTA will integrate an additional testbed and experiments from Korea, while it will also collaborate with IoT experts from USA. The participation of a Korean partner (based its own funding) will maximize FIESTA's value for EC money. Moreover, the project will take advantage of open calls processes towards attracting third-parties that will engage in the integration of their platforms within FIESTA or in the conduction of added-value experiments. As part of its sustainability strategy, FIESTA will establish a global market confidence programme for IoT interoperability, which will enable innovative platform providers and solution integrators to ensure/certify the openness and interoperability of their developments.

8.2.2. Collaborations in European Programs, except FP7 & H2020

8.2.2.1. EIT ICT Labs 3cixty

Participants: Animesh Pathak [correspondent], Rachit Agarwal [correspondent].

Name: 3cixty – *A Platform for Apps and Services that Offer Comprehensive Views of a City*
URL: http://www.3cixty.com/
Period: [January 2014 - December 2015]
Partners: Ambientic (F), CEFRIEL (IT), DFKI (DE) [**coordinator**], Eurecom (F) [**associate leader**], Fondazione Politechnico di Milano (IT), Innovalor (NL), Inria MiMove [**associate leader**], LocaliData (ES), Mobidot (NL), Politechnico di Milano (IT), Telecom Italia (IT) [**associate leader**], Thales (F), TU Delft (NL), UC London (UK).

3cixty is a platform, well motivated in business terms, for developing apps for city visitors that makes it easy for application developers to access and process comprehensive heterogeneous information about a city; and a Showcase App using the platform that demonstrates its added value. The project will result new opportunities to enable city visitors to exploit the transportation, business, cultural, and touristic opportunities offered by a city more fully and in a more personally and environmentally appropriate way, thereby benefiting cities, their visitors, and application and service developers.

8.3. International Initiatives

8.3.1. Inria International Labs

Valérie Issarny acts as scientific manager of the Inria@Silicon Valley program (https://project.inria.fr/inria-siliconvalley/) since summer 2013; she is visiting scholar at CITRIS, EECS, University of California, Berkeley.

Sara Hachem and Cristhian Parra have been carrying out their postdoc research at UC Berkeley in the context of the Inria@Silicon Valley program and CityLab@Inria.

8.3.2. Inria Associate Teams not involved in an Inria International Lab

8.3.2.1. Inria DRI/DST-CEFIPRA Associate Team: SARATHI

Participants: Animesh Pathak [correspondent], Nikolaos Georgantas [correspondent].

Name: SARATHI – *Personalized Mobility Services for Urban Travelers*
Instrument: Inria DRI/DST-CEFIPRA Associate Team
Period: [January 2014 - December 2016]
Partners: Indraprastha Institute of Information Technology (IIIT), Delhi (India), Inria MiMove.
Website: https://saarthiproject.wordpress.com/

The focus of the *Sarathi* project is on creating a personalized mobility service platform for urban travelers. The proposed work would require work on large scale mobile participatory sensing, urban transportation, location-aware services, machine learning, and software engineering. The individual strength of MiMove and IIIT provide complementary technical benefits for the project. MiMove leverages its work on large scale mobile participatory sensing (so far focused on EU-based transit contexts) addressing challenges brought to the fore by dynamic large scale systems in India; IIIT will build up on their previous work on mobile based system to provide route information and work on learning and mining techniques for inferring events of interest in transport systems.

Besides the complementary technical benefits, the collaboration will also help the project in evaluating the proposed solution in context of both developing and developed countries with different societal structure and preferences. Since personalized services are an integral part of the solution, the variety in social structures of India and France will help in developing solutions that are valid across continents. A deployment of the proposed solution in India will also test scalability and robustness of the solution in resource-constrained environments (e.g. intermittent network connectivity, low bandwidth) and will help in developing solutions that can be deployed in different working environments. Similarly, France (with already an advanced transit system) offers opportunities in verifying the requirements of a successful sustainable transport system.

8.3.3. Inria International Partners

8.3.3.1. Informal International Partners

We have a lasting collaboration with Prof. Fabio Costa at the Federal University of Goias (UFG), Brazil, on self-adaptive ubiquitous and cloud-based systems. This collaboration was funded by the Inria-Brazil International Scientific Cooperation Program during the period 2012-2014. In 2015, Raphael de Aquino Gomes, UFG PhD student, conducted an 1-year PhD internship with MiMove, funded by a scholarship of the CAPES/CNPq Brazilian Science without Borders program. A collaborative project proposal by Inria MiMove and UFG was submitted at the "Associate Teams with Brazil Program" 2016 Call, co-funded by Inria and the Brazilian Research Foundations (FAPs). The project was successfully evaluated and will be funded for three years, enabling further fruitful exchanges between UFG and Inria MiMove.

8.4. International Research Visitors

8.4.1. Visits of International Scientists

8.4.1.1. Internships

Raphael de Aquino Gomes (from Sep. 2014 until Aug. 2015)

PhD internship funded by a visitor PhD student scholarship of the Brazilian Science without Borders program provided by CAPES and CNPq.

Subject: *Self-Adaptive Use of Cloud Resources for Heterogeneous Dynamic Service Choreographies*

Institution: Federal University of Goias - UFG (Brazil)

8.4.2. Visits to International Teams

8.4.2.1. Research stays abroad

Valérie Issarny is visiting scholar at CITRIS at UC Berkeley, in the context of which she carries out collaborative research in the area of smart cities and acts as scientific coordinator of the Inria@SiliconValley program.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific events organisation

9.1.1.1. General chair, scientific chair

Valérie Issarny of co-chair of the BIS'15 workshop, which is the yearly workshop organized by Inria@SiliconValley to present the state of scientific collaborations and to work on proposals for future ambitious joint projects. BIS'2015 in particular featured a one-day International Conference on Digital Assets, Data Philanthropy and Public Benefit, entitled "Who Owns the Data", which was co-organized with CITRIS, with the support of EIT Digital.

9.1.1.2. Chair of technical program committee

- Nikolaos Georgantas is co-chair of the ARM'15 international workshop.
- Valérie Issarny is co-PC chair of the New Idea track of ESEC/FSE'15.

9.1.1.3. Member of technical program committee

- Nikolaos Georgantas is PC member of the following international conferences: 3PGCIC'15, AmI'15, SOSE'15, DATA'15, ICSOFT-EA'15, ICSOFT-PT'15, ANT'15, WETICE'15, CBSE'15, SAC'16;
- Nikolaos Georgantas is PC member of the following international workshops: SCART'15, Projects Showcase event at STAF'15, SERENE'15, SESoS'15;
- Valérie Issarny is PC member of the following international conferences: Coordination'15&16, ESSOS'14, FASE'15-17, FSE'14, ICDCS'15-16, IFIPTM'15, ISPN'15, Middleware'15&16, SEAMS'14.

9.1.2. Journal

9.1.2.1. Member of editorial board

- Nikolaos Georgantas is associate editor of the International Journal of Ambient Computing and Intelligence (IJACI);
- Valérie Issarny is associate editor of the Springer JISA Journal of Internet Services and Applications.

9.1.2.2. Guest editor of special issue

- Nikolaos Georgantas is co-guest editor of the Thematic Series on the Internet of Things of the Springer JISA Journal of Internet Services and Applications.

9.1.3. Invited talks

- Valérie Issarny gave a keynote at Formal Methods 2015.

9.1.4. Scientific expertise

- Valérie Issarny is member of the IFSTTAR Scientific Council & "Commission d'évaluation des chercheurs";
- Valérie Issarny is member of the GDR GPL scientific council;
- Valérie Issarny is elected member of the *Commission d'Evaluation Inria*;
- Nikolaos Georgantas is member of the Inria PhD scholarship, Inria postdoc scholarship and Inria professor leave *(Délégation)* scholarship selection committees at Inria Paris-Rocquencourt.

9.1.5. Research administration

- Valérie Issarny is scientific coordinator of Inria@Silicon Valley and CityLab@Inria;
- Nikolaos Georgantas is member of the PhD monitoring committee at Inria Paris-Rocquencourt.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

E-learning

Valérie Issarny is co-author and coordinator, and Animesh Pathak is co-author, of the MOOC entitled "Smart Cities: Technology and Societal Challenges", which is provided via the FUN platform. The MOOC (in French) provides a high-level introduction to digital technologies underlaying the design and development of smart cities. The course is composed of 5 weeks, each featuring from 5 to 8 sequences. Valérie Issarny and Animesh Pathak are authors of 5 and 4 sequences, respectively. The first edition of the MOOC is played in January 2016.

Class teaching

Master: Nikolaos Georgantas, "Pervasive Service Oriented Computing" as part of "Architectures orientées services", 9 hours (équivalent TD), niveau M2, University of Versailles Saint-Quentin en Yvelines, France.

9.2.2. Supervision

In 2015 and beginning 2016, the following students successfully defended their PhD:

Benjamin Billet, *Data Stream Management System for the Future Internet of Things*, defended in March 2015, UVSQ-EDSTV, advised by Valérie Issarny;

Emil Andriescu, *Synthèse et déploiement dynamiques de protocoles de médiation pour l'interopérabilité dans les environnements collaboratifs nomades*, defended in February 2016, UPMC-EDITE, CIFRE Inria-Ambientic, advised by Valérie Issarny and Roberto Speicys-Cardoso (Ambientic).

Additionally, the following PhD thesis is currently in progress at the MiMove team:

Georgios Bouloukakis, *Runtime adaptation of middleware connectors for emergent mobile systems*, started October 2013, UPMC-EDITE, advised by Nikolaos Georgantas and Valérie Issarny.

Also, Valérie Issarny is co-advising with Ansgar Radermacher from CEA-LISE, the PhD thesis of Amel Belaggoun on *Adaptabilité et reconfiguration des systèmes temps-réel embarquées*; this is a PhD from UPMC-EDITE with the research being undertaken at CEA-LISE.

9.2.3. Juries

Nikolaos Georgantas was external reviewer for the PhD thesis of Amleto Di Salle, *Automated Synthesis of Service Choreographies*, defended in April 2015, Univ. of L'Aquila, Italy, advised by Prof. Paola Inverardi and Dr. Marco Autili;

Nikolaos Georgantas was examiner for the PhD thesis of Mourad Amziani, *Modeling, Evaluation and Provisioning of Elastic Service-based Business Processes in the Cloud*, defended in June 2015, Télécom SudParis and Université d'Evry Val Essonne, France, advised by Prof. Samir Tata and Dr. Tarek Melliti.

Valérie Issarny was reviewer for the PhD thesis of Dimitrios Miloris, *Trend Detection and Information Propagation in Dynamic Social Networks*, defended in April 2015, Ecole Polytechnique, France, advised by Philippe Jacquet and Paul Mühlethaler.

10. Bibliography

Major publications by the team in recent years

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