



## Activity Report 2016

# 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  
**Paris**

THEME  
**Distributed Systems and middleware**



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## Team MIMOVE

*Creation of the Team: 2014 July 01*

### Keywords:

#### Computer Science and Digital Science:

- 1.2.1. - Dynamic reconfiguration
- 1.2.4. - QoS, performance evaluation
- 1.2.5. - Internet of things
- 1.2.6. - Sensor networks
- 1.2.7. - Cyber-physical systems
- 1.3. - Distributed Systems
- 1.4. - Ubiquitous Systems
- 1.5. - Complex systems
  - 1.5.1. - Systems of systems
  - 1.5.2. - Communicating systems
- 2.5. - Software engineering
- 2.6.2. - Middleware

#### Other Research Topics and Application Domains:

- 6.4. - Internet of things
- 8.2. - Connected city
  - 8.5.1. - Participative democracy

## 1. Members

### Research Scientists

Nikolaos Georgantas [Team leader, Inria, Researcher]  
Valérie Issarny [Inria, Inria@SiliconValley, Senior Researcher, HDR]

### Faculty Member

Françoise Sailhan [CNAM, Associate Professor, *on sabbatical leave (CRCT)*]

### Engineers

Cong Kinh Nguyen [Inria, EIT Digital Env&You project]  
Pierre-Guillaume Raverdy [Inria, SED, from Jun 2016, *part-time*]  
Fadwa Rebhi [Inria, ADT CityLab Platform until Oct 2016; then, EIT Digital Env&You project]

### PhD Students

Amel Belaggoun [CEA, *co-advised PhD, part-time*]  
Georgios Bouloukakis [Inria, UPMC]  
Radha Pallavali [Inria, UPMC, from Nov 2016]

### Post-Doctoral Fellows

Rachit Agarwal [Inria, H2020 FIESTA-IoT project]  
Rafael Angarita Arocha [Inria, EIT Digital CivicBudget project, from May 2016]  
Eya Ben Ahmed [Inria]  
Cristhian Parra Trepowski [Inria, EIT Digital CivicBudget project]

### Visiting Scientist

Garvita Bajaj [Indraprastha Institute of Information Technology, New Delhi, *PhD intern*, from May 2016 until Sept 2016]

#### **Administrative Assistant**

Maryse Desnous [Inria]

#### **Others**

Siddhartha Dutta [Intern, from May 2016 until July 2016]

Christelle Rohaut [Intern, from Mar 2016 until Jun 2016]

## 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 [23], [29]. 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 [28].

- **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 [68], 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 [65]. 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 [82], [46], [79], 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 [32], [59], [60].

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 [72]. 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 [54]. 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 [31], [25], [61], [83].

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 [50], [28], [26]. 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 [48] or the middleware [19], [49], 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 [41] 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 [43], [53]. 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 [42]. 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 [39], [85], [40] with few exceptions [38].

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., [50], [28], [26], [69])?
- How to perceive and model emergent properties in space and in time across volatile compositions of heterogeneous mobile distributed systems (e.g., [43], [53])?
- 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., [38])?

### 3.3. Large-scale mobile sensing and actuation

In the past decade, the increasingly low cost of MEMS<sup>1</sup> 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 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 [76] and re-iterated in [75]: relative resource-poverty in terms of computation and communication, variable

<sup>1</sup>Micro-Electro-Mechanical Systems.



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* [58], [55]. 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 [70]). 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., [81], [45])?
- How to efficiently coordinate the available devices, including resource-poor mobile devices and the more-capable cloud infrastructure (e.g., [68], [36], [74], [64])?
- How to guarantee dependability in a mobile computing environment (e.g., [34], [80], [30])?
- How to ensure that the overhead of sensing does not lead to a degraded performance for the user (e.g., [56], [36])?

### 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 [57]: 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 [55]: 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 [62] 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 [47]. 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 [55], [37], [52], [21], [66]. 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 [63]. 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 [24], [51], [22]. 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 [55]. 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.) [55]. 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 [44]. Ikarus [84] 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., [71])?
- How to guarantee the right level of privacy (e.g., [33], [73])?
- 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 [86], in particular based on the understanding of mobile application usage [78], [77]?
- 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 has 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 <sup>2</sup>. The Inria Project Lab 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

Members of MiMove are co-founders of the Ambiciti start-up (<http://ambiciti.io>) together with the Inria team CLIME, and the NUMTECH and the Civic Engine SMEs. Ambiciti’s technology is a single platform delivering real-time data on street-by-street exposure and risks on multiple environmental pollutants. The platform’s technology leverages open data along with cloud, IoT, mobile and data analytics technologies. Ambiciti collects real-time, street-by-street pollution data and provides urban citizens with a means to personalize their decisions with regard to environmental hazards. The aim is to enable citizens to make more informed choices about their activities, personal behavior and location, and to protect their own health. Ambiciti also supplies businesses with crucial data that allows to better inform consumers and to increase the valuation of services (e.g., real estate). Eventually, Ambiciti supports governments in protecting citizens’ health and in growing cities more sustainably in providing the necessary urban pollution data. Key elements of the Ambiciti platform include the Ambiciti mobile app that leverages mobile phone sensing middleware solutions to monitor the individual and collective exposure of citizens to environmental pollutions in a resource-efficient way (more at <https://www.inria.fr/en/centre/paris/news/ambiciti-an-application-a-start-up>). The first version of the Ambiciti App (successor of SoundCity) deals with noise and air pollution. In particular, Inria and the Paris city council were awarded a *Décibel d’Argent* prize for the App (more at <https://www.inria.fr/en/centre/paris/news/2016-decibel-d-or-golden-decibel-competition-ambiciti-receives-the-decibel-d-argent-silver-decibel-prize-in-the-research-category>).

## 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.

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<sup>2</sup><http://citylab.inria.fr>

## 6.2. VSB: eVolution Service Bus for the Future Internet

**Participants:** Georgios Bouloukakis, Nikolaos Georgantas [contact], Siddhartha Dutta.

**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, Things using CoAP<sup>3</sup>. 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 *GIDL*, 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 GIDL, 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;
- VSB provides support for the client-server, publish/subscribe, tuple space and data streaming interaction paradigms;
- 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: we have developed related tools that support the automated generation of a BC for a service/Thing from its GIDL interface description.

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<sup>3</sup><https://tools.ietf.org/html/rfc7252>

VSB is being developed within the H2020 CHOReVOLUTION project (see § 8.2.1.1). It is also based on previous development carried out in the FP7 CHOReOS project <sup>4</sup>. VSB is available for download under open source license.

### 6.3. Ambiciti App & Platform: Monitoring the Exposure to Environmental Pollution

**Participants:** Valerie Issarny [contact], Cong Kinh Nguyen, Pierre-Guillaume Raverdy, Fadwa Rebhi.

**URL:** <http://ambiciti.io>

Is your exposure to noise too high on certain days? How is air pollution in your street? Will air quality improve in the next hours? Do you want to measure the noise pollution on the way between your home and your office? What pollution levels are considered harmful for your health? Ambiciti (previously SoundCity) provides answers to these questions and many others through dedicated Apps and Platforms that leverage Inria research results in the area of mobile distributed systems (from MiMove team) and data assimilation (from Inria CLIME team). The Ambiciti app is available for download on both the App and the Play stores. Starting December 2016, the Ambiciti software solutions are licensed to the Ambiciti start-up.

**Monitoring exposure to noise pollution:** Noise pollution is a major environmental health problem, with an estimated number of 10,000 premature deaths each year in Europe. The 2002 European environmental noise directive defines a common approach intended to avoid, prevent or reduce the harmful effects of noise. It requires the determination of exposure to environmental noise in major cities, through noise mapping. Until recently, this has been done solely through numerical simulation. Daytime, evening and nighttime averages are generally produced, without distinction between the different days of the year. Also, it is difficult to fill the gap between a noise map and the actual exposure of people where they live and stay. This motivates to monitor noise pollution where and when people are exposed. One promising direction is to make use of the noise sensors that people carry most of the time, i.e., the microphones embedded in their mobile phones.

Ambiciti (previously called SoundCity as it was initially focused on the monitoring of noise pollution) measures the actual noise levels to which individuals are exposed using such an approach, while taking into account the relatively low quality of the collected measurements. Ambiciti can then monitor noise levels throughout the day and inform users about their instantaneous, hourly and daily exposures.

In addition to the monitoring of the individual exposure to the noise pollution using mobile phones, the collective exposure may be derived from crowd-sensing. The adoption rate of mobile phones makes it possible to collect a huge amount of observational data about the noise pollution at the city scale. Recent studies have indeed highlighted the emergence of new environmental monitoring schemes leveraging the combination of mobile phones-embedded sensors and citizen participation. Ambiciti then leverages a mobile phone sensing middleware for collecting noise measurements at the urban scale, which are then assimilated toward the production of real-time pollution maps.

**Monitoring exposure to air pollution:** The Ambiciti app delivers information about the exposure to air pollution, providing hourly air quality maps, which are computed using numerical simulation. Depending on the user's location, the user may have access to hourly air quality maps, at street resolution, in real time and for the next two days. Currently, only Paris (France) and the Bay area enjoy such high resolution maps, but other cities are on the way to be included.

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<sup>4</sup><http://www.choreos.eu>

**Mobile app features:** Ambiciti is easy to use, while featuring various functions to meet different levels of user engagement (from passive monitoring to citizen scientists):

- Measuring noise level, anytime on demand or automatically during the day,
- Providing air quality indexes (according to the EU definition), in the past, present and future hours or days, together with pollution levels for nitrogen dioxide, fine particulate matter and ozone,
- Displaying statistics on exposure to pollutions, hourly, daily, during daytime and nighttime, for both noise and air.
- Displaying maps with own's noise measurements and/or hourly NO<sub>2</sub> levels (including street-level resolution for Paris and the San Francisco Bay area)
- Promoting citizen science where communities of users may engage into the intensive measurement of noise in order to analyze a given journey or to map neighborhoods.
- Providing pollution-aware routing.
- Calibration of the smartphone for noise monitoring, automatically with Ambiciti database or manually with a sound level meter,

**Privacy:** The Ambiciti app has been designed with privacy in mind, which especially holds in the case of noise pollution monitoring. It is in particular important to stress that actual sound samples are never stored on the phone or uploaded to the Ambiciti servers. Only the amplitude of the sound in dB(A) is calculated, and uploaded provided the user's permission. An anonymous identifier is further created for each device for distinguishing between the data sent by different users, while no identifying information is collected. Further detail may be found from the App information page.

The Ambiciti platform is developed in collaboration with the Inria CLIME team together with The Civic Engine and the NUMTECH SMEs in the context of CityLab@Inria and Inria@SiliconValley, and with the support of the EIT Digital Env&You activity.

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

**Participants:** Valérie Issarny [contact], Cristhian Parra Trepowski, Rafael Angarita.

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.

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, together with the support of the EIT Digital CivicBudget activity.

## 7. New Results

### 7.1. Introduction

MiMove's research activities in 2016 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 Ambiciti (§ 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). Finally, we have worked on the Fiesta-IoT ontology (§ 7.5) and on the Sarathi platform (§ 7.6), related to our research on both Large-scale Mobile Sensing & Actuation (§ 3.3) and Mobile Social Crowd-sensing (§ 3.4).

### 7.2. QoS for Emergent Mobile Systems

**Participants:** Georgios Bouloukakis, Nikolaos Georgantas, Siddhartha Dutta, Valérie Issarny.

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 [15]. 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 two complementary directions:

- Choreography peers deployed in mobile environments are typically characterized by intermittent connectivity and asynchronous sending/reception of data. In such environments, it is essential to guarantee acceptable levels of timeliness between sending and receiving 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 users sending and receiving data by modeling the intermittent connectivity of mobile users with QNMs.

We utilize the publish/subscribe middleware as the underlying communication infrastructure for the mobile users. To represent the user'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 simulations with real-world workload traces. The deviations between the performance results foreseen by the analytical model and the ones provided by the simulator are shown to be less than 5% for a variety of scenarios [16].

- Based on the QoS models and analyses outlined in the previous paragraph, we go one step further towards realistic QoS modeling and analysis of choreographies integrating heterogeneous interaction paradigms. We introduce QoS modeling patterns that correspond to each one of the interaction paradigms – client-server, publish/subscribe, tuple space and data streaming – and for different interaction styles – one way, two way synchronous, two way asynchronous. Our patterns rely on Queueing Network Models (QNMs) and represent the following characteristics of choreography peers and their middleware protocols: (i) reliable or unreliable interactions supported by the middleware and underlying transport layers; (ii) application-level (user) and middleware-level disconnections; (iii) application-level and middleware-level buffering of messages with finite capacity; (iv) limited lifetime of messages; and (v) timing of synchronous interactions. These QoS patterns enable the analysis and evaluation of the performance and success rates characterizing the modeled interactions. By combining several QoS patterns, we can further evaluate the end-to-end QoS of choreography interactions among heterogeneous peers. Based on our QoS models, we statistically analyze through simulations the effects on QoS when varying the parameters found in (i) to (v). We can also in this way evaluate the interconnection effectiveness, i.e., the degree of mapping of QoS semantics and expectations, when interconnecting heterogeneous choreography peers.

### 7.3. Mobile Phone Sensing Middleware for Urban Pollution Monitoring

**Participants:** Valerie Issarny, Cong Kinh Nguyen, Pierre-Guillaume Raverdy, Fadwa Rebhi.

Mobile Phone Sensing (MPS) is a powerful solution for massive-scale sensing at low cost. The ubiquity of phones together with the rich set of sensors that they increasingly embed make mobile phones the devices of choice to sense our environment. Further, thanks to the – even sometimes unconscious – participation of people, MPS allows for leveraging both quantitative and qualitative sensing. And, still thanks to the participation of people who are moving across space, mobile phones may conveniently act as opportunistic proxies for the sensors in their communication range, which includes the fast developing wearables.

However, despite the numerous research work since the end 2000s, MPS keeps raising key challenges among which: How to make MPS resource-efficient? How to mitigate mobile sensing heterogeneities? How to involve and leverage the crowd? How to leverage prior experiences?

Addressing the above MPS challenges primarily lies in taming the high heterogeneity not only of the computing system but also the crowd. The latter introduces a new dimension compared to traditional middleware research that has been concentrating on overcoming the heterogeneities of the computing infrastructure. In order to tackle these two dimensions together, we have been conducting a large scale empirical study in cooperation with the city of Paris (see <http://tinyurl.com/soundcity-paris>). Our experiment revolves around the public release of a MPS app for noise pollution monitoring that is built upon our dedicated mobile crowd-sensing middleware. Building on the Paris experiment, we systematically studied the influence of resource-efficiency and sensing accuracy on the effectiveness of the crowd participation [18]. In a complementary way, we analyzed user participation across time, so as to derive participation patterns that MPS middleware and application design may leverage.

Key take-away for MPS middleware and application design following our analysis includes:

- While contributors exhibit high heterogeneity regarding the accuracy of their sensors, they overall exhibit similar patterns. Location accuracy leads to discard about 60% of the observations and most observations are in the [20 – 50] meters accuracy range. Noise sensing accuracy varies but calibration may be achieved per model rather than per device; calibration may then combine a number of



techniques from comparison using a high-quality reference sensor to automated techniques leveraging assimilation and machine learning. Although our experiment is focused on noise sensing, we may expect similar results for other physical sensors. Overall, MPS allows collecting and assimilating relevant observations/measures. Still, the number of contributed measures by the MPS system needs to be high enough to overcome the low accuracy of the phone sensors.

- Although not specifically related to heterogeneity, energy efficiency is critical for the adoption of MPS. Our study confirms that energy-delay tradeoffs is a valuable approach; hence, the middleware must enable the buffering of the observations while the frequency of the transfers must be tuned by the application. Still, we notice that 30% of the observations reach the server after 2 hours even when observations are not buffered and are sent every 5mns, which indicates long periods of disconnection. Hence, if the timeliness of the observation is critical, then participatory sensing is most likely the approach to follow to ensure that the user is conscious about the sensing and activates appropriate network connection.
- The heterogeneity of the contributing crowd is obvious. However, it turns out to be an asset rather than a shortcoming of MPS. Indeed, the crowd overall exhibits similar contribution patterns across time. However, in the detail, each individual has different contribution patterns. This allows for the collection of complementary contributions over the whole day.
- The users appear to be still most of the time, while the user's activity cannot be qualified for 20% of the observations. This should be accounted for in the design of mobility-dependent MPS.
- One design issue that arises for MPS is whether to promote participatory or opportunistic sensing. It is our belief that a system (and thus supporting app) must support both. This enables to collect as many observations as possible from a large diversity of people, while participatory sensing guarantees contributions of higher quality.

## 7.4. Computer-mediated Social Communication Interoperability

**Participants:** Rafael Angarita, Nikolaos Georgantas, Valerie Issarny, Cristhian Parra Trepowski, Christelle Rohaut.

People increasingly rely on computer-mediated communication for their social interactions. This is a direct consequence of the global reach of the Internet combined with the massive adoption of social media and mobile technologies that make it easy for people to view, create and share information within their communities almost anywhere, anytime. The success of social media has further led – and is still leading – to the introduction of a large diversity of social communication services (e.g., Skype, Facebook, Google Plus, Telegram, Instagram, WhatsApp, Twitter, Slack, ...). These services differ according to the types of communities and interactions they primarily aim at supporting. However, existing services are not orthogonal and users ultimately adopt one service rather than another based on their personal experience. As a result, users who share similar interests from a social perspective may not be able to interact in a computer-mediated social sphere because they adopt different technologies. This is particularly exacerbated by the fact that the latest social media are proprietary services that offer an increasingly rich set of functionalities, and the function of one service does not easily translate -both socially and technically- into the function of another. As an illustration, compare the early and primitive social media that is the Email with the richer social network technology. Protocols associated with the former are rather simple and email communication between any two individuals is now trivial, independent of the mail servers used at both ends. On the other hand, protocols associated with today's social networks involve complex interaction processes, which prevent communication across social networks.

The above issue is no different than the long-standing issue of interoperability in distributed computing systems, which require to mediate (or translate) the protocols run by the interacting parties for them to be able to exchange meaningful messages and coordinate. And, while interoperability in the early days of distributed systems was essentially relying on the definition of standards, the increasing complexity and diversity of networked systems has led to the introduction of various interoperability solutions, among which the (Enterprise) Service Bus paradigm.

In the above context, we have specifically introduced the "*social communication bus*" paradigm so as to allow interoperability across computer-mediated social communication protocols. Our work is motivated by our research effort within the AppCivist project. AppCivist provides a software platform for participatory democracy that leverages the reach of the Internet and the powers of computation to enhance the experience and efficacy of civic participation. Its first instance, AppCivist-PB, targets participatory budgeting, an exemplary process of participatory democracy that let citizens prepare and select projects to be implemented with public funds by their cities [17]. For city-wide engagement, AppCivist-PB must enable citizens to participate with the Internet-based communication services they are the most comfortable with. The need for interoperability in this context is indeed paramount since the idea is to include people in the participatory processes without leaving anyone behind. This has led us to revisit the service bus paradigm for the sake of social communication across communities, so as to gather together the many communities of our cities.

Our contributions span:

- *Social communication paradigm*: Based on the survey of the various forms of computer-mediated social communication supported by today's software services and tools, we have derived how the approaches to middleware interoperability may apply to social communication interoperability.
- *Social Communication Bus architecture*: We leverage the VSB bus (see § 6.2) that supports interoperability across interaction paradigms as opposed to interoperability across heterogeneous middleware protocols implementing the same paradigm. The proposed bus architecture features the traditional concepts of bus protocols and binding components, but those are customized for the sake of social interaction whose coupling differs along the social and presence dimensions.
- *Social Communication Bus instance for participatory democracy*: We have refined our bus architecture, introducing the Social-MQ implementation that leverages the RabbitMQ message broker. The resulting implementation has been integrated within the AppCivist-PB platform for evaluation.

In order to inform the further study of the "Social Communication Bus" paradigm, we have analyzed existing practices and supporting technologies promoting citizen collaboration. In relation with our work on the AppCivist-PB platform, our study has concentrated on Participatory Budgeting (PB) campaigns, with a special focus on US-related initiatives, as a mean to understand the current and future design space of ICT for participatory democracy. We then derived new design opportunities for ICT to facilitate citizen collaboration in the PB process, and by extension, to reflect on how these technologies could better foster deliberative decision-making at a scale that is both small and large.

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.

## 7.5. FIESTA-IoT Ontology: Semantic Model for Federation & Interoperability among Platforms

**Participants:** Rachit Agarwal, Valérie Issarny, Nikolaos Georgantas.

Plethora of heterogeneous data is being generated and made available by diverse platforms. Such platforms can be those that are formed by the use of mobile application that act as interface between sensing devices and storage or between users and storage. The diversity and openness in the data generated isolate platforms and lead to interoperability issues between platforms, where much work has to be done in order to ensure compatibility. One has to understand the other's format, parse different data formats, and create the mapping between different data formats. One method to accomplish this interoperability is by attaching semantics to this data. Semantics provides meaning to the data and helps in (a) achieving common understanding and (b) performing analysis and reasoning. Many IoT-related semantic models<sup>5</sup> propose interoperability but have many issues like: observation graph is missing, are highly domain specific, and do not follow best practices. In order to address the above, we focused our research on: the identification of a unified semantic model that addresses the above, creation of a prototype application, and identification of guidelines for storing semantic data [13]. We report our following key results:

<sup>5</sup><http://sensormeasurement.appspot.com/?p=ontologies>

- *State of art survey of semantic models that are available in literature in the domain of the Internet of Things*: This survey gave us required knowledge needed for the semantic model from which concepts can be reused to create a unified ontology. This helps the semantic community by not overloading the domain with concepts similar to already existing concepts, and allows us to reuse concepts as much as possible. We identified that recent trends show more and more use of the SSN [35] and oneM2M [67] ontologies. However, these models are currently far from being able to address observation-related issues and lack domain taxonomy.
- *Unified semantic model for enabling interoperability and federation of testbeds*: Based on the analysis of the concepts from various ontologies identified, we unify specific concepts from these identified ontologies into one ontology. These ontologies being: SSN, oneM2M, IoT-lite [27], WGS84<sup>6</sup>, DUL<sup>7</sup>, TIME<sup>8</sup> and M3-lite taxonomy (created as a part of this research). Such unification gives our ontology the power to define meta data about the sensor that is producing the observation and the observation itself. The federation is achieved by the use of the taxonomy that each platform should follow.
- *Best practices to publish data based on the unified model*: In order to enable full interoperability, federation and usage of data, it is essential that best practices are followed while storing the data based on the unified model. We identify various best practices which form our recommendations to the platform owners towards annotating the data with respect to the ontology. This is supported by a reference annotator that also acts as a guide for developers to publish data.

These above-mentioned results are currently applied in the frame of the EU funded H2020 FIESTA-IoT project (see § 8.2.1.2).

## 7.6. Sarathi: A Platform for Personalized Mobility Service for Urban Travellers

**Participants:** Rachit Agarwal, Garvita Bajaj, Georgios Bouloukakis, Valérie Issarny, Nikolaos Georgantas.

Thanks to the increased abundance of mobile phones, the recent field of mobile participatory sensing could be leveraged towards providing a more fine-grained and up-to-date view of a city's transportation system. Thus, in order to address problems like dynamicity (unexpected faults, stoppages, etc.) and unexpected load (number of people using the transportation), etc., in different societal contexts of France and India, we aimed to produce a middleware platform called "Sarathi" that is enriched with personalized mobility services for urban travelers and is evaluated via real-life demonstrators. Towards this, the key results include:

- *Identification of System Architecture* [14]: We first identify requirements for our system that would satisfy the objectives. The identified requirements are then mapped to specific components that would carry out specific tasks. A client-server system architecture is then created by connecting the identified components. Some components that we identified are: UI component that would run at the client side, recommendation system and knowledgebase component that would run at the server, and a communication component that would ensure communication of the client with the server. To realise these components, we also identify tools and techniques that would ensure best runtime performance.
- *Modeling Passenger convenience in Metro transit* [20]: This effort builds upon existing research in the area, studied during our joint survey of related work, and applies the work to the context of the Paris and New Delhi metro system. This work captures 'personalized' experience of passengers during a multi-leg journey and models the convenience for commuters. A leg in a journey is defined as a segment of a journey traveled on a metro line. The work proposes a mathematical model for commuter convenience and validates it using data collected from metro commuters. The convenience model uses 3 convenience measures namely *seat availability*, *wait time* and *comfort*. The work

<sup>6</sup><https://www.w3.org/2003/01/geo/>

<sup>7</sup><http://www.ontologydesignpatterns.org/ont/dul/DUL.owl>

<sup>8</sup><https://www.w3.org/TR/owl-time/>

also aims to identify the best mobile interaction paradigm for enabling timely data collection and dissemination and outlines a middleware architecture to achieve this (aiming at acceptable response times for mobile apps).

- *Mobile Application*: An Android application called *MetroCognition* for gathering commuters convenience rating during their metro transit based on the three above described measures has been developed, deployed and made available on Google Play Store <sup>9</sup> for beta testing.

## 8. Partnerships and Cooperations

### 8.1. National Initiatives

#### 8.1.1. Inria Support

##### 8.1.1.1. Inria IPL CityLab@Inria

**Participants:** Valérie Issarny [correspondent], Fadwa Rebhi.

- **Name:** CityLab@Inria – *Overcoming the Smart City Challenge – Toward Environmental and Social Sustainability*
- **Related activities:** § 7.3 and § 6.3
- **Period:** [January 2014 – December 2018]
- **Inria teams:** CLIME, DICE, FUN, MIMOVE, MYRIADS, SMIS, URBANET, WILLOW
- **URL:** <http://citylab.inria.fr>

The Inria Project Lab (IPL) CityLab@Inria studies ICT solutions toward smart cities that promote both social and environmental sustainability. A strong emphasis of the Lab is on the undertaking of a multi-disciplinary research program through the integration of relevant scientific and technology studies, from sensing up to analytics and advanced applications, so as to actually enact the foreseen smart city Systems of Systems. Obviously, running experiments is a central concern of the Lab, so that we are able to confront proposed approaches to actual settings.

##### 8.1.1.2. Inria ADT CityLab Platform

**Participants:** Valérie Issarny [correspondent], Fadwa Rebhi.

- **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. The ADT is more specifically focused on the development of a middleware platform supporting mobile crowd-Xing for environmental pollution monitoring through user-led observations.

<sup>9</sup><https://play.google.com/apps/testing/edu.sarathi.metroCognition>

## 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-IoT

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

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

**URL:** <http://fiesta-iot.eu>

**Type:** Research & Innovation Action (ICT)

**Topic:** FIRE+ (Future Internet Research & Experimentation)

**Related activities:** § 7.5

**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 Digital Env&You

**Participant:** Valérie Issarny [correspondent].

**Name:** Env&You – *Personalizing environmental science for your home, your neighborhood and your life*

**URL:** <http://ambiciti.io>

**Related activities:** § 7.3 and § 6.3

**Period:** [January 2016 - December 2016]

**Partners:** Ambientic (F), CapDigital (F), Forum Virium Helsinki (FI), Inria CLIME, Inria MIMOVE [coordinator], NumTech (F), TheCivicEngine (USA).

There is a clear, and probably increasing, desire from the citizens to better know their individual exposure to pollution. Partial solutions exist to the exposure data problem but each focuses on one or another domain of information – crowdsourcing exposure, translating government open data to usable consumer information, harnessing social media information, harnessing biometrics – what is unique about Env&You is that we assimilate a multi-dimensional picture of exposure and provide the integrated information to citizen, government, and business use (spanning: B2G, B2B and B2C business cases).

### 8.2.2.2. EIT Digital CivicBudget

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

**Name:** CivicBudget – *Software platform supporting Internet-based participatory budgeting campaigns*

**Related activities:** § 7.4 and § 6.4

**Period:** [January 2016 - December 2016]

**Partners:** CITRIS (USA), Inria MIMOVE, MissionsPubliques (F) [coordinator], Nexus (DE), and TU Berlin (DE).

Many cities in Europe and the U.S.A, and around the world, commit a percentage of their annual budget (often 5%) to implement citizen-proposed projects through a process called Participatory Budgeting (PB). However, supporting urban-scale participatory budgeting campaigns is greatly challenged as it still principally relies on physical meetings. CivicBudget addresses this challenge by leveraging latest ICT so as to promote urban-scale inclusion. CivicBudget fosters a new and inclusive urban public sphere of citizenship. It is especially designed for community groups and activists who want to participate in the PB process. City governments will also be able to promote its use. CivicBudget will facilitate the mobilization of residents both to promote their proposals and to monitor their progress through the PB process to implementation.

## 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 the EECS Department of University of California, Berkeley, and hosted by CITRIS.

### 8.3.2. Inria Associate Teams Not Involved in an Inria International Labs

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

**Participant:** Rachit Agarwal [correspondent].

**Name:** SARATHI – *Personalized Mobility Services for Urban Travelers*

**Instrument:** Inria DRI/DST-CEFIPRA Associate Team

**Related activities:** § 7.6

**Period:** [January 2014 - December 2016]

**Partners:** Indraprastha Institute of Information Technology (IIIT) Delhi (India), Inria MiMove.

**Website:** <http://sarathi.gitlab.io/web/>

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.

#### 8.3.2.2. Inria/Brazil Associate Team: ACHOR

**Participant:** Nikolaos Georgantas [correspondent].

**Name:** ACHOR – *Adaptive enactment of service choreographies*

**Instrument:** Inria/Brazil Associate Team

**Related activities:** § 7.2 and § 6.2

**Period:** [January 2016 - December 2018]

**Partners:** Universidade Federal de Goiás (UFG), Brazil, Inria MiMove.

**Website:** <http://www.inf.ufg.br/projects/achor>

Service choreographies are distributed compositions of services (e.g., Web services) that coordinate their execution and interactions without centralized control. Due to this decentralized coordination and the ability to compose third-party services, choreographies have shown great potential as an approach to automate the construction of large-scale, on-demand, distributed applications. Technologies to enable this approach are reaching maturity level, such as modeling languages for choreography specification and engines that operate the deployment of services and enactment of choreographies at Future Internet scales. Nevertheless, a number of problems remain open on the way to fully realize the approach, among them: (i) Deployment of multiple choreographies on top of a collection of shared services (considering service sharing as an effective way to increase the utilization of resources); (ii) Dynamic adaptation of functional and non-functional properties due to runtime changes in the environment and user requirements (adapting the set of services and/or the resources used to run the services in order to add/remove/change functions and maintain QoS properties, respectively); and (iii) Seamless and dynamic integration of mobile services (e.g., smartphone apps, sensors and actuators on handhelds and wearables) and cloud-based services (including the need to consider: mobility of both devices and services, resource constraints of mobile devices, temporary disconnection, interoperability between different interaction paradigms (message-passing, event-based, data-sharing) at the middleware layer, and effect of these paradigms on end-to-end QoS).

The overall goal of the project is to design an architecture for adaptive middleware to support service choreographies in large-scale scenarios that involve dynamicity and diversity in terms of application requirements, service interaction protocols, and the use of shared local, mobile and cloud resources.

## 8.4. International Research Visitors

### 8.4.1. Visits of International Scientists

#### 8.4.1.1. Internships

Garvita Bajaj (from May 2016 until Sept 2016)

PhD internship funded by Associate Team Sarathi and H2020 FIESTA-IoT project.

Subject: *Extending current FIESTA-IoT Ontology*

Institution: Indraprastha Institute of Information Technology (IIIT) Delhi (India)

### 8.4.2. Visits to International Teams

#### 8.4.2.1. Research Stays Abroad

Valérie Issarny is visiting scholar at the EECS Department at UC Berkeley; she is hosted by CITRIS 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 is co-chair of the BIS'16 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.



### 9.1.2. Scientific Events Selection

#### 9.1.2.1. Chair of Conference Program Committees

- Valérie Issarny is PC co-chair of ICSE-SEIS'2018 - The Software Engineering in Society Track of the ICSE'18 conference.

#### 9.1.2.2. Member of the Conference Program Committees

- Valérie Issarny is PC member of the following International Conferences: COORDINATION'2016, FASE'2016 & 2017 & 2018, ICDCS'2016, ICSE-SEIS'2016 & 2017, ICSE'2018, InterIoT'2016, ISEC'2017, Middleware'2016, MOBILESoft'2017, SEAMS'17, EUROSYS'2017.
- Nikolaos Georgantas is PC member of the following international conferences: SOSE'16&'17, WETICE'16&'17, SAC'16 &'17, Aml'17, ICSE'17 Poster Track, ANT'16.
- Nikolaos Georgantas is PC member of the following international workshops: MRT'16, SERENE'16, ARM'16, IoT-ASAP'17.

### 9.1.3. Journal

#### 9.1.3.1. Member of the Editorial Boards

- 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.

### 9.1.4. Invited Talks

- Valérie Issarny, *Monitoring Urban Pollution using Mobile Crowd Sensing: The SoundCity Use Case*, Keynote at - UIC - The 13th International Conference on Ubiquitous Intelligence and Computing, July 19, 2016; Toulouse, France.
- Valérie Issarny, *Revisiting Service-oriented Architecture for the IoT: A Middleware Perspective*, Keynote at - ICSOC - The 14th International Conference on Service-Oriented Computing, October 12, 2016; Banff, Alberta, Canada.

### 9.1.5. Scientific Expertise

- 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.

### 9.1.6. 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.

## 9.2. Teaching - Supervision - Juries

### 9.2.1. Teaching

#### E-learning

Valérie Issarny, MOOC *Villes intelligentes : défis technologiques et sociétaux*  
<https://www.fun-mooc.fr/courses/inria/41009/session01/about>

#### Class teaching

Master: Rachit Agarwal, "Urban data democratization and its application to access urban concepts" as part of "Gestion de données ambiantes et Internet des objets", 9 hours (équivalent TD), niveau M2, University of Versailles Saint-Quentin en Yvelines, France.

### 9.2.2. Supervision

In 2016, the following PhD thesis was successfully defended:

Emil Andriescu, *Dynamic Data Adaptation for the Synthesis and Deployment of Protocol Mediators*, defended in February 2016, UPMC-EDITE, CIFRE Inria-Ambientic, advised by Valérie Issarny and Roberto Speicys-Cardoso (Ambientic).

Additionally, the following PhD theses are currently in progress at the MiMove team:

Georgios Bouloukakis, *Enabling Emergent Mobile Systems in the IoT: from Middleware-layer Communication Interoperability to Associated QoS Analysis*, started October 2013, UPMC-EDITE, advised by Nikolaos Georgantas and Valérie Issarny.

Radha Pallavali, *Dynamic adaptation of middleware-layer protocols for emergent mobile systems*, started November 2016, 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 examiner for the PhD thesis of Fatiha Houacine, *Architecture Orientée Service pour le Mobile Cloud Computing*, defended in November 2016, Conservatoire National des Arts et Métiers, France, advised by Ass. Prof. Samia Bouzeffrane.

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### Major publications by the team in recent years

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## Publications of the year

### Doctoral Dissertations and Habilitation Theses

- [9] E.-M. ANDRIESCU. *Dynamic Data Adaptation for the Synthesis and Deployment of Protocol Mediators*, Université Pierre et Marie Curie - Paris VI, February 2016, <https://tel.archives-ouvertes.fr/tel-01402011>

### Articles in International Peer-Reviewed Journals

- [10] N. BEN MABROUK, N. GEORGANTAS, V. ISSARNY. *Multi-Objective Service Composition in Ubiquitous Environments with Service Dependencies*, in "International Journal of Services Computing (IJSC)", April 2016, vol. 4, <https://hal.inria.fr/hal-01403750>

### Invited Conferences

- [11] A. BELAGGOUN, V. ISSARNY. *Towards adaptive autosar : a system-level approach*, in "FISITA 2016 World Automotive Congress", Busan, South Korea, September 2016, <https://hal.inria.fr/hal-01416879>
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