Activity Report 2014

Team MIMOVE

Middleware on the Move

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 [37], [42]. 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 [41].
- **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 and mobile robotics, including by members of the team [80], [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 [78]. 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 [94], [58], [91], 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 [45], [72], [73].

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 [84]. 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 [66]. 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 [44], [39], [74], [95].

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 [62], [41], [40]. 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 [60] or the middleware [34], [61], 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 [53] 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 [55], [65]. 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 [54]. 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 [51], [97], [52] with few exceptions [50].

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., [62], [41], [40], [81])?
- How to perceive and model emergent properties in space and in time across volatile compositions of heterogeneous mobile distributed systems (e.g., [55], [65])?
- 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., [50])?

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 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 [88] and re-iterated in [87]: 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* [71], [67]. 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 [82]). 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., [93], [57])?
- How to efficiently coordinate the available devices, including resource-poor mobile devices and the more-capable cloud infrastructure (e.g., [80], [48], [86], [77])?
- How to guarantee dependability in a mobile computing environment (e.g., [47], [92], [43])?
- How to ensure that the overhead of sensing does not lead to a degraded performance for the user (e.g., [69], [48])?

[1] Micro-Electro-Mechanical Systems.

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 [70]: 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 [67]: 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 [75] 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 [59]. 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 [67], [49], [64], [35], [79]. 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 [76]. 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 [38], [63], [36]. 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 [67]. 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.) [67]. 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 [56]. Ikarus [96] 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., [83])?
- How to guarantee the right level of privacy (e.g., [46], [85])?
- 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 [98], in particular based on the understanding of mobile application usage [90], [89]?
- 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* under creation:

- **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 the effort of creating 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, OAK, SMIS, URBANET and WILLOW. CityLab further involves strong collaboration with Californian 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 on leave 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).

[2] https://citylab.inria.fr

5. New Software and Platforms

5.1. Introduction

In order to validate our research results, our research activities encompass the development of related prototypes as surveyed below.

5.2. iCONNECT: Emergent Middleware Enablers

Participant: Valérie Issarny [correspondent].

As part of our research work on Emergent Middleware, we have implemented Enablers (or Enabler functionalities) that make part of the overall CONNECT architecture realizing Emergent Middleware in practice [4]. The focus of our work is on the: *Discovery enabler* that builds on our extensive background in the area of interoperable pervasive service discovery; and *Synthesis enabler* that synthesizes mediators that allow Networked Systems (NSs) that have compatible functionalities to interact despite mismatching interfaces and/or behaviors.

The Discovery Enabler is the component of the overall CONNECT architecture that handles discovery of networked systems, stores their descriptions (NS models), and performs an initial phase of matchmaking to determine which pairs of systems are likely to be able to interoperate. Such pairs are then passed to the Synthesis Enabler so that mediators can be generated. The Discovery Enabler is written in Java and implements several legacy discovery protocols including DPWS and UPnP.

The Synthesis Enabler assumes semantically-annotated system descriptions *à la* OWL-S, which are made available by the Discovery Enabler, together with a domain ontology, and produces the mediators that enable functionally compatible networked systems to interoperate. The semantically-annotated interfaces of the NSs that need to communicate are processed to compute the semantic mapping between their respective operations using a constraint solver. The resulting mapping serves generating a mediator that coordinates the behaviors of the NSs and guarantees their successful interaction. Only when the mediator includes all the details about the communication of NSs, can interoperability be achieved, which calls for the adequate concretization of synthesized mediators.

The *concretization of mediators* bridges the gap between the application level, which provides the abstraction necessary to reason about interoperability and synthesize mediators, and the middleware-level, which provides the techniques necessary to implement these mediators. Concretization entails the instantiation of the data structures expected by each NS and their delivery according to the interaction pattern defined by the middleware, based on which the NS is implemented. Therefore, we have been developing a mediation engine that, besides executing the data translations specified by the mediator, generates composed parsers and composers, which can process complex messages, by relying on existing libraries associated with standard protocols and state-of-the-art middleware solutions.

The data structures defined within OWL-S system descriptions, that is, the types of the inputs and outputs of the OWL-S atomic process were previously defined manually. As part of the prototype implementation that allows the mediator engine to generate composed parsers and composers, we made an extension that enables the inference of correct data-types [17], relieving developers from the time-consuming task of defining them. This prototype takes the form of a JAVA library that can optionally be used by the Synthesis Enabler whenever abstract data structures are unavailable. This library can be obtained from the iCONNECT GIT repository https://gforge.inria.fr/git/iconnect/iconnect.git (under the subproject `mtc`). While the underlying source code closely follows the formal mechanisms (such as tree automata) and algorithms presented in [17], we further concerned ourselves with making this library usable for non-expert developers by adhering to well-established standards. Specifically, data types, which are internally modeled as top-down tree automata, are transformed both on the input and output to RelaxNG (http://relaxng.org/) or XSD (www.w3.org/TR/xmlschema-1/).

The iCONNECT software has been released in the OW2 open source community (http://forge.ow2.org/projects/iconnect/), as part of FISSi, the Future Internet Software and Services initiative (http://www.ow2.org/view/Future_Internet/). OW2 and FISSi will give to this effort the required visibility in order to attract users and developers of the open source community.

5.3. XSB: eXtensible Service Bus for the Future Internet

Participant: Nikolaos Georgantas [correspondent].

The eXtensible Service Bus (XSB) is a development and runtime environment dedicated to complex distributed applications of the Future Internet. Such applications will be based, to a large extent, on the open integration of extremely heterogeneous systems, such as 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). Such heterogeneous systems are supported by enabling middleware platforms, particularly for their interaction. With regard to middleware-supported interaction, the client-service (CS), publish-subscribe (PS), and tuple space (TS) paradigms are among the most widely employed ones, with numerous related middleware platforms, such as: Web Services, Java RMI for CS; JMS, SIENA for PS; and JavaSpaces, Lime for TS. XSB then provides support for the seamless integration of heterogeneous interaction paradigms (CS, PS and TS).

In a nutshell, our systematic interoperability approach implemented by the proposed XSB is carried out in two stages. First, a middleware platform is abstracted under a corresponding interaction paradigm among the three base ones, i.e., CS, PS and TS. To this aim, we have elicited a connector model for each paradigm, which comprehensively covers its essential semantics. Then, these three models are abstracted further into a single generic application (GA) connector model, which encompasses their common interaction semantics. Based on GA, we build abstract connector converters that enable interconnecting the base interaction paradigms.

Following the above, XSB is an abstract service bus that prescribes only the high-level semantics of the common bus protocol, which is the GA semantics. Furthermore, we provide an implementation of the XSB, building upon existing SOA and ESB realizations. XSB features richer interaction semantics than common ESBs to deal effectively with the increased Future Internet heterogeneity. Moreover, from its very conception, XSB incorporates special consideration for the cross-integration of heterogeneous interaction paradigms. Services relying on different interaction paradigms can be plugged into XSB by employing binding components (BCs) that adapt between their native middleware and the common bus protocol. This adaptation is based on the abstractions, and in particular on the conversion between the native middleware, the corresponding CS/PS/TS abstraction, and the GA abstraction.

Furthermore, we provide a companion implementation, named Light Service Bus (LSB), targeting the Internet of Things (IoT) domain. LSB forms a concrete access solution for IoT systems as it is able to cope with the diversity of the involved interaction protocols and take care of the specifics of IoT services, such as resource constraints, dynamic environments, data orientation, etc. It is implemented to be lightweight in nature and uses REST as the common protocol/bus in place of an ESB solution. In LSB, we confirm the wide use of the aforementioned interaction paradigms (CS/PS/TS) but also underline the existence of an additional paradigm focused on continuous interaction known as Streaming (STR).

Both the XSB and LSB solutions are available for download under open source licenses at http://xsb.inria.fr and http://websvn.ow2.org/listing.php?repname=choreos&path=%2Ftrunk%2Fextensible-service-access%2Flsb%2FLsbBindingComponents%2F respectively.

5.4. MobIoT: Service-oriented Middleware for the Mobile IoT

Participant: Valérie Issarny [correspondent].

MobIoT is a service-oriented middleware aimed at the mobile Internet of Things (IoT), which in particular deals with the ultra-large scale, heterogeneity and dynamics of the target networking environment. MobIoT offers novel probabilistic service discovery and composition approaches, and wraps legacy access protocols to be seamlessly executed by the middleware. The middleware exposes two levels of service abstractions: Thing as a service (on the service provider side); and Things measurements/actions as a service (on the service consumer side).

Key features of MobIoT lie in: (i) the exploitation of ontologies to overcome the heterogeneity of the Things network, (ii) the introduction of probabilistic approaches for both registering and retrieving networked things so as to filter out the ones that are redundant with already known alternatives, and finally, (iii) the exploitation of Thing services composition for responding to user queries asking information about the physical world so as to ease interaction with such a complex and dynamic networking environment.

MobIoT is implemented using Java and the Android platform, and consists of two complementary components: The MobIoT Mobile middleware and the MobIoT Web Service. The MobIoT Mobile middleware is deployed on mobile devices (e.g., smartphones, tablets, sensor devices). It wraps: (i) the Query component that enables the querying of the physical world, (ii) the Registration component that deals with the probabilistic registration of local sensors and actuators, (iii) the domain ontology that allows reasoning about the features of Things, and (iv) the Sensor Access component that enables the sensor data retrieval and exposure. The MobIoT Web Service wraps: (i) the Registry component that keeps tracks of the registered services, (ii) the probabilistic Lookup component that allows retrieving relevant services in a scalable way, and (iii) the Composition & Estimation component to answer queries over the physical world using available Thing services, and finally domain and devices ontologies.

The MobIoT middleware is available for download under an open source license at http://mobiot.ow2.org.

5.5. Srijan: Data-driven Macroprogramming for Sensor Networks

Participant: Animesh Pathak [correspondent].

Macroprogramming is an application development technique for wireless sensor networks (WSNs) where the developer specifies the behavior of the system, as opposed to that of the constituent nodes. As part of our work in this domain, we are working on *Srijan*, a toolkit that enables application development for WSNs in a graphical manner using data-driven macroprogramming.

It can be used in various stages of application development, *viz.,*

1. Specification of the application as a task graph,
2. Customization of the auto-generated source files with domain-specific imperative code,
3. Specification of the target system structure,
4. Compilation of the macroprogram into individual customized runtimes for each constituent node of the target system, and finally
5. Deployment of the auto generated node-level code in an over-the-air manner to the nodes in the target system.

The current implementation of *Srijan* targets both the Sun SPOT sensor nodes and larger nodes with J2SE. Most recently, *Srijan* also includes rudimentary support for incorporating Web services in the application being designed.

The software is released under open source license, and available as an Eclipse plug-in at http://code.google.com/p/srijan-toolkit/.

5.6. Dioptase and Spinel: Lightweight Streaming Middleware for the IoT

Participant: Valérie Issarny [correspondent].

Dioptase is a service-oriented middleware for developing stream-based applications which produce, process, store and consume data streams in complex environments such as the Internet of Things (IoT) and Wireless Sensor and Actuator Networks (WSAN). Dioptase leverages a novel service-oriented architecture for continuous processing, in order to deal with the large scale and the heterogeneity of the IoT. Once Dioptase is deployed onto a device, it enables developers to manage it as a generic pool of resources that can execute tasks provided over time. Those tasks are described as compositions of both standard continuous processing operators and customized computations written using a new lightweight stream processing language, called *DiSPL*.

The IoT infrastructure is composed of various devices (sensors, registries, proxies, clusters, etc.), and Dioptase is intended to be deployed onto all of them. To this end, Dioptase is highly modular and can be customized depending on the targeted devices and their roles in the IoT:

- *Dioptase core* is the base version of Dioptase that enables developers to (i) manage embedded sensors and actuators of a device through services and (ii) deploy tasks onto the device at any time.
- *Dioptase task mapper* is a server that implements our research on task mapping and automated deployment. Given a task graph, this server computes where to deploy each task according to the characteristics of tasks and available devices, and then manages the execution of the deployed tasks over time.
- *Dioptase proxy* is a pub/sub broker that enables interactions between Things that can not communicate directly, because of non-compatible networking interfaces/protocols or the use of address translation techniques.
- *Dioptase exchange* is a privacy proxy that manages the data and the services provided by a network of Things. It authenticates outsider Things and users, enabling them to request data streams or services according to access control and data-accuracy policies.

As part of the design of Dioptase, we have been investigating how to open legacy sensors to the future IoT. Toward this end, we propose to take advantage of the multi-modal connectivity as well as the mobility of smartphones, using them as mobile proxies that opportunistically discover close-by static sensors and act as intermediaries between them and the IoT. Spinel is a prototype of such an opportunistic proxy for mobile phones, which monitors the smartphone's mobility and further infers when to discover and register the sensors to an IoT discovery infrastructure, for instance the MobIoT registry(§ 5.4). Spinel collects data from the close-by sensors and pushes the collected data to an IoT stream processing infrastructure, for instance the Dioptase middleware. We will shortly release both Dioptase and Spinel under open source licenses.

5.7. Yarta: Middleware for supporting Mobile Social Applications

Participant: Animesh Pathak [correspondent].

With the increased prevalence of advanced mobile devices (the so-called "smart" phones), interest has grown in *Mobile Social Ecosystems* (MSEs), where users not only access traditional Web-based social networks using their mobile devices, but are also able to use the context information provided by these devices to further enrich their interactions. We are developing a middleware framework for managing mobile social ecosystems, having a multi-layer middleware architecture consisting of modules, which will provide the needed functionalities, including:

- Extraction of social ties from context (both physical and virtual),
- Enforcement of access control to protect social data from arbitrary access,
- A rich set of MSE management functionalities, which can be used to develop mobile social applications.

Our middleware adopts a graph-based model for representing social data, where nodes and arcs describe socially relevant entities and their connections. In particular, we exploit the Resource Description Framework (RDF), a basic Semantic Web standard language that allows representing and reasoning about social vocabulary, and creating an interconnected graph of socially relevant information from different sources.

The current implementation of the Yarta middleware targets both desktop/laptop nodes running Java 2 SE, as well as Android smart phones.

The software is released under open source license at https://gforge.inria.fr/projects/yarta/.

6. New Results

6.1. Introduction

MiMove's research activities in 2014 have focused on a set of areas directly related to the team's research topics. Hence, we have worked on Emergent Middleware (§ 6.3) and Service-oriented Computing in the Future Internet (§ 6.4), in relation to our research topic regarding Emergent Mobile Distributed Systems (§ 3.2). With respect to Large-scale Mobile Sensing & Actuation (§ 3.3), we have developed activities on Service-oriented Middleware for the Mobile Internet of Things (IoT) (§ 6.5), Composing Applications in the IoT (§ 6.6), and Lightweight Streaming Middleware for the IoT (§ 6.7). Last, our effort on Middleware for Mobile Social Networks (§ 6.8) is linked to our research on Mobile Social Crowd-sensing (§ 3.4).

Before presenting our new results in the areas mentioned above, we briefly discuss next the highlights of the year.

6.2. Highlights of the Year

This year has seen the following acknowledgments of the team's contributions:

- Valérie Issarny was distinguished as Chevalier de la Legion d'Honneur for her contributions to science and European scientific cooperation in research and education.
- One of the team's major publication by S. Ben Mokhtar, D. Preuveneers, N. Georgantas, V. Issarny, and Y. Berbers, titled "EASY: Efficient semAntic Service discoverY in pervasive computing environments with QoS and context support" [1], published in the Journal of Systems and Software (Volume 81, Issue 5), is one of the top ten (10) most cited papers among all the papers published by JSS in 2008.

6.3. Emergent Middleware

Participants: Emil Andriescu, Valérie Issarny, Thierry Martinez.

Our previous work on emergent middleware has focused on interconnecting functionally-compatible components, i.e., components that at some high level of abstraction require and provide compatible functionalities, but are unable to interact successfully due to mismatching interfaces and behaviors. To address these differences without changing the components, mediators that systematically enforce interoperability between functionally-compatible components by mapping their interfaces and coordinating their behaviors are required [18]. Our approach for the automated synthesis of mediators is performed through *interface matching*, which identifies the semantic correspondence between the actions required by one component and those provided by the other, followed by the *synthesis of correct-by-construction mediators*. To do so, we analyze the behaviors of components so as to generate the mediator that coordinates the matched actions in a way that guarantees that the two components progress and reach their final states without errors [2]. Our contribution primarily lies in handling interoperability from the application to the middleware layer in an integrated way. The mediators we synthesize act as: (i) translators by ensuring the meaningful exchange of information between components, (ii) controllers by coordinating the behaviors of the components to ensure the absence of errors in their interaction, and (iii) middleware by enabling the interaction of components across the network so that each component receives the data it expects at the right moment and in the right format.

In our latest work, we have particularly focused on item (iii) above. We recognize that modern distributed systems and Systems of Systems (SoS) are built as a composition of existing components and services. As a result, systems communicate (either internally, locally or over networks) using protocol stacks of ever-increasing complexity whose messages need to be translated (i.e., interpreted, generated, analyzed and transformed) by third-party systems. We are particularly interested in the application of message translation to achieve protocol interoperability via protocol mediators. We observe that current approaches are unable to provide an efficient solution towards reusing message translators associated with the message formats composed in protocol stacks. Instead, developers must write ad hoc “glue-code” whenever composing two or more message translators.

Ideally, message translators may be developed by separate parties, using various technologies, while developers should be able to compose them using an easy to use mechanism. However, parsers are monolithic and tightly constructed, which often makes it impossible to combine them, knowing that combining two unambiguous grammars (corresponding to two arbitrary parsers) may result in an ambiguous grammar, and that the ambiguity detection problem for context-free grammars is undecidable in the general case.

In addition to parser composition, the data structures of the parsing output must be manually defined, integrated and harmonized with the target systems (i.e., in this case, the Mediation Engine). As far as we know, the problem of inferring the output schema (or the data type) of an arbitrary tree transformation has not yet been solved, while it is known that, in general, a transformation might not be recognizable by a schema.

Following the challenges above, in [17], we make two major contributions to the issue of systematic message translation for modern distributed systems:

1. Starting from the premise that “off-the-shelf” message translators for individual protocols are readily available in at least an executable form, we propose a solution for the automated composition of message translators. The solution simply requires the specification of a composition rule that is expressed using a subset of the navigational core of the W3C XML query language XPath.
2. We provide a formal mechanism, using tree automata, which based on the aforementioned composition rule, generates an associated AST *data-schema* for the translator composition. This contribution enables the inference of correct data-schemas, relieving developers from the time-consuming task of defining them. On a more general note, the provided method solves the type inference problem for the *substitution* class of tree compositions in linear time on the size of the output. The provided inference algorithm can thus be adapted to a number of applications beyond the scope of this work, such as XML Schema inference for XSLT transformations.

The composition approach that we introduced functions as a purely “black-box” mechanism, thus allowing the use of third-party parsers and message serializers independently of the parsing algorithm they use internally, or the method by which they were implemented/generated. Our solution goes beyond the problem of translator composition by inferring AST data-schemas relative to translator compositions. This feature allows newly generated translators to be seamlessly (or even automatically) integrated with existing systems, and most notably our protocol mediation engine [2].

6.4. Service-oriented Computing in the Future Internet

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

With an increasing number of services and devices interacting in a decentralized manner, *choreographies* represent a scalable framework for the Future Internet. The service oriented architecture inherent to choreographies allows abstracting diverse systems as application components that interact via standard middleware protocols. However, the heterogeneous nature of such systems leads to choreographies that do not only include conventional services, but also sensor-actuator networks, databases and service feeds. We reason about the behavior of such systems by introducing abstract middleware connectors that follow base interaction paradigms, such as client-service (CS), publish-subscribe (PS) and tuple space (TS). These heterogeneous connectors are made interoperable through a service bus connector, the *eXtensible Service Bus* (XSB) [11].

In previous work, we identified and verified the behavioral semantics of the XSB connector derived from the interconnection of base connectors, and introduced a method for constructing protocol converters enabling this interconnection. We implemented our XSB solution into an extensible development and execution platform for application and middleware designers. We also provided a lightweight implementation of the XSB, the *Light Service Bus* (LSB), appropriate for resource-constrained environments and systems. Next, leveraging on the functional interoperability across interaction paradigms offered by the XSB, we initiated our study of end-to-end Quality of Service (QoS) properties of choreographies, where in particular we focus on the effect of middleware interactions on QoS.

Building on the above results, we refine our analysis of QoS on top of the identified interaction paradigms. We have introduced a motivating application scenario inspired from the *2014 D4D Challenge* [3]. More specifically, *Data for Development Senegal* is an innovation challenge on ICT Big Data for the purposes of societal development. Mobile network provider Sonatel (part of the Orange Group) has made anonymous data extracted from the mobile network in Senegal available to international research laboratories, encouraging research related to the development and welfare of the local population.

Our scenario targets the development of an application platform for citywide and countrywide transport information management relying on mobile social crowd-sensing. This takes into account the particular context and constraints in Senegal. More specifically, the local transportation system, although developing, still consists of many unplanned and informal settlements with unreliable services and infrastructure. Additionally, despite wide use of mobile phones in the country, mobile Internet access remains limited, making SMS the only alternative for data access for a large part of the population. Our proposition aims to complement the scarce authoritative transport information coming from structured information sources and compensate for the lack of such information. In particular, in our approach we intend to study and experiment with appropriate interaction paradigms (CS, PS, TS) on top of 3G/2G/SMS data connections, further depending on the specific application and data. We are especially interested in interaction adaptation depending on the network conditions (e.g., switching to SMS-based protocol when the 3G/2G network is unavailable).

We have taken a first step towards enabling such an application platform. This consists in evaluating the publish/subscribe interaction style in a large-scale setting where resources of mobile users are limited, which translates into limited and intermittent connectivity in the system. Additionally, such an application platform must guarantee that the sensing data is processed and delivered to the corresponding mobile users *on-time*, despite the intermittent connectivity of the latter. We have opted for the publish/subscribe paradigm, as it is deemed appropriate for loose spatio-temporal interaction between mobile entities.

In particular, we introduce a queueing network model for the end-to-end interaction within a large-scale mobile publish/subscribe system. We leverage the *D4D dataset* provided by Orange Labs to parametrize this model. We then develop a simulator named *MobileJINQS* [4] that implements our model and uses the dataset traces as realistic input load to the system model over the time span of a whole year. Prior to this, we extensively analyze the D4D dataset in order to identify the data that we are interested in and infer primary results [5]. Based on the results of our simulation-based experiments, we thoroughly evaluate the behavior of the publish/subscribe system and identify ways of tuning the system parameters in order to satisfy certain design requirements. More precisely, we provide results of simulations of our publish/subscribe system with varied incoming loads, service delays and event lifetime periods. We use connection data of various pairs of mobile network antennas to derive realistic traces for both incoming loads and service delays. System or application designers are able to tune the system by selecting appropriate lifetime periods. We demonstrate that varying incoming loads and service delays have a significant effect on response time. By properly setting event lifetime spans, designers can best deal with the tradeoff between freshness of information and information delivery success rates. Still, both of these properties are highly dependent on the dynamic correlation of the event input flow and delivery flow processes, which are intrinsically decoupled.

[3] http://www.d4d.orange.com/en/home
[4] http://xsb.inria.fr/d4d#mobilejinqs
[5] http://xsb.inria.fr/d4d

Our future work includes comparison of the publish/subscribe interaction paradigm with other interaction paradigms (client-server, tuple space), in relation with the network access capacity and the application requirements. Also, we intend to study the response time and success rate for the various combinations of antennas in more fine-grained scales (e.g., check what their evolution is over one day).

6.5. Service-oriented Middleware for the Mobile Internet of Things

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

The Internet of Things (IoT) is characterized by a wide penetration in the regular user's life through an increasing number of Things embedding sensing, actuating, processing, and communication capacities. A considerable portion of those Things will be mobile Things, which come with several advantages yet lead to unprecedented challenges. The most critical challenges, that are directly inherited from, yet amplify, today's Internet issues, lie in handling i) the large scale of users and mobile Things which lead to high communication and computation costs especially with the anticipated large volumes of data to exchange, ii) providing interoperability across the heterogeneous Things which host sensors and actuators providing services and producing data that follow different format/schema specifications, and iii) overcoming the unknown dynamic nature of the environment, due to the mobility of an ultra-large number of Things.

Service-Oriented Architecture (SOA) provides solid basis to address the above challenges as it allows the functionalities of sensors/actuators embedded in Things to be provided as services, while ensuring loose-coupling between those services and their hosts, thus abstracting their heterogeneous nature. In spite of its benefits, SOA has not been designed to address the ultra-large scale of the mobile IoT. Consequently, an alternative is provided within a novel Thing-based Service-Oriented Architecture, that revisits SOA interactions and functionalities, service discovery and composition in particular. Our work on the revisited Thing-based SOA is detailed in [9], [23], [15]. The novel architecture is concretized within MobIoT, a middleware solution that is specifically designed to manage and control the ultra-large number of mobile Things in partaking in IoT-related tasks.

In accordance with SOA, MobIoT comprises Discovery, Composition & Estimation, and Access components, yet modifies their internal functionalities. In more detail, the Discovery component enables Thing-based service registration (for Things to advertise hosted services) and look-up (for Things to retrieve remote services of interest). In order to handle the ultra large number of mobile Things and their services in the IoT, the component revisits the Service-Oriented discovery and introduces probabilistic protocols to provide, not all, but only a sufficient subset of services that can best approximate the result that is being sought after [23], [15] based on a predefined set of requirements such us sensing coverage of the area of interest and the location of the Things. By limiting the participation of Things, the communication costs and volumes of data to process are decreased without jeopardising the quality of the outcome.

Furthermore, the Composition & Estimation component (C&E) provides automatic composition of Thing-based services. This capacity is of interest in the case where no service can perform a required measurement/action task directly (based on its atomic functionalities). To that end, we model our composition specification as mathematical formulas defined semantically within a dedicated ontology. Thing-based service composition executes in three phases: i) expansion, where composition specifications are automatically identified; ii) mapping, where actual service instances (running services) are selected based on their functionalities and the physical attributes of their hosts; and iii) execution, where the services are accessed and the composition specifications are executed. Thing-based service composition revisits Service-Oriented composition by executing seamlessly with no involvement from developers or end users and relying on semantic technologies to identify the most appropriate services to compose.

Last but not least, the Access component provides an easy to use interface for developers to sample sensors/actuators while abstracting sensor/actuator hardware specifications. It revisits Service-Oriented access and leverage semantic technologies by executing access to services transparently and wrapping access functionalities internally. Thus, it alleviates that burden from users, initially in charge of this task. The Access component supports real-time query-based access to remote services and to locally hosted services.

To assess the validity of our proposed architecture, we provide a prototype implementation of MobIoT(§ 5.4) along with a set of extensive evaluations that demonstrate, not only the feasibility of our approach, but also the resulting quality of the discovery approach, along with its scalability, as compared to a regular SOA-based approach.

6.6. Composing Applications in the Internet of Things

Participants: Aness Bajia, Animesh Pathak, Françoise Sailhan.

Resilient computing is defined as the ability of a system to remain dependable when facing changes. To mitigate faults at runtime, dependable systems embark fault tolerance mechanisms such as replication techniques. These mechanisms have to be systematically and rigorously applied in order to guarantee the conformance between the application runtime behavior and its dependability requirements.

Given that devices and networks constituting the IoT are prone to failure and consequent loss of performance, it is natural that IoT applications are expected to encounter and tolerate several classes of faults - something that still largely remains within the purview of low-level-protocol designers. As part of our work on the MURPHY project (§ 7.1.1.1), we are addressing this issue by proposing: i) a set of abstractions that can be used during macroprogramming to express application-level fault tolerance requirements, as well as by developers of fault tolerance protocols to identify the abilities and requirements of their techniques; ii) a runtime system that employs adaptive fault tolerance (AFT) to provide fault tolerance to the networking sensing application; and iii) compilation techniques to instantiate and map tasks as needed to satisfy the requirements of the application for a given deployment. Through our work [26], we demonstrate that our approach provides this much-needed feature to networked sensing applications with negligible development- and minimal performance- overhead.

Complementary to the above, we have proposed task mapping algorithms to satisfy those requirements through a constraint programming approach [24]. Through evaluations on realistic application task graphs, we show that our constraint programming model can effectively capture the end-to-end requirements and efficiently solves the combinatorial problem introduced.

We have been continually incorporating our research results in the above areas into *Srijan* (§ 5.5), which provides an easy-to-use graphical front-end to the various steps involved in developing an application using the ATaG macroprogramming framework.

6.7. Lightweight Streaming Middleware for the Internet of Things

Participants: Benjamin Billet, Valérie Issarny.

The IoT raises many challenges related to its very large scale and high dynamicity, as well as the great heterogeneity of the data and systems involved (e.g., powerful versus resource-constrained devices, mobile versus fixed devices, continuously-powered versus battery-powered devices, etc.). These challenges require new systems and techniques for developing applications that are able to: (i) collect data from the numerous data sources of the IoT, and (ii) interact both with the environment using the actuators and with the users using dedicated GUIs. Given the huge volume of data continuously being produced by sensors (measurements and events), we must consider: (i) data streams as the reference data model for the IoT and, (ii) continuous processing as the reference computation model for processing these data streams. Moreover, knowing that privacy preservation and energy consumption are increasingly critical concerns, we claim that all the Things should be autonomous and work together in restricted areas as close as possible to the users rather than systematically shifting the computation logic into powerful servers or into the cloud.

Toward that goal, we have been developing Dioptase [3], a service-oriented middleware for the IoT, which aims to integrate the Things and their streams into today's Web by presenting sensors and actuators as Web services. The research work around the Dioptase middleware consists in designing new service-oriented architectures where services continuously process data streams instead of finite datasets. In this context, new composition mechanisms are investigated in order to provide a way to describe complex fully-distributed stream-based tasks and to deploy them dynamically, at any time, as task graphs, over available Things of the network, including resource-constrained ones. To this end, Dioptase enables task graphs to be composed of Thing-specific tasks (directly implemented on the Thing) and dynamic tasks that communicate using data streams. Dynamic tasks are then described in a lightweight DSL, called *DiSPL*, which is directly interpreted by the middleware and provides specific primitives to manipulate data streams.

As part of the design of such composition mechanisms, we have been investigating the problem of task mapping and automated deployment, which basically consists of mapping a set of tasks onto a set of nodes. Given the specific challenges introduced by the IoT, we worked on a new formalization of the task mapping problem that captures the varying consumption of resources and various constraints (location, capabilities, QoS) in order to compute a mapping that guarantees the lifetime of the concurrent tasks inside the network and the fair allocation of tasks among the nodes (load balancing). This formalization, called *Task Graph to Concrete Actions (TGCA)* [19], results in a binary programming problem for which we provide an efficient heuristic that allows its resolution in polynomial time. Our experiments show that our heuristic: (i) gives solutions that are close to optimal, and (ii) can be implemented on reasonably powerful Things and performed directly within the network without requiring any centralized infrastructure.

6.8. Middleware for Mobile Social Networks

Participants: Animesh Pathak, George Rosca.

As recent trends show, online social networks (OSNs) are increasingly turning mobile and further calling for decentralized social data management. This trend is only going to increase in the near future, based on the increased activity, both by established players like Facebook and new players in the domain such as Google, Instagram, and Pinterest. Modern smart phones can thus be regarded as *social sensors*, collecting data not only passively using, e.g., Bluetooth neighborhoods, but actively in the form of, e.g., “check-in”s by users to locations. The resulting (mobile) social ecosystems are thus an emergent area of interest.

The recent years have seen three major trends in the world of online social networks: *i)* users have begun to care more about the privacy of their data stored by large OSNs such as Facebook, and have won the right (at least in the EU) to remove it completely from the OSN if they want to; *ii)* OSNs are making their presence felt beyond casual, personal interactions to corporate, professional ones as well, starting with LinkedIn, and most recently with the purchase by Microsoft of Yammer, the enterprise social networking startup, and the launch of Google Plus for enterprise customers; and *iii)* users are increasingly using the capabilities of their (multiple) mobile devices to enrich their social interactions, ranging from posting cellphone-camera photos on Instagram to “checking-in” to a GPS location using Foursquare.

In view of the above, we envision that in the near future, the use of ICT to enrich our social interactions will grow (including both personal and professional interactions), both in terms of size and complexity. However current OSNs act mostly like data silos, storing and analyzing their users’ data, while locking in these users to their servers, with non-existent support for federation; this is reminiscent of the early days of email, where one could only email those who had accounts on the same Unix machine. The knee-jerk reaction to this has been to explore completely decentralized social networks, which give the user complete control over and responsibility of their social data, while resorting to peer-to-peer communication protocols to navigate their social networks. Unfortunately, there are few techniques available to reconcile with the fact that the same user might have multiple devices, or that it is extremely resource-consuming to perform complex analysis of social graphs on small mobile devices.

Our view lies somewhere in the middle of the two extremes, taking inspiration from the manner in which users currently use email. While their inboxes contain an immense amount of extremely personal data, most users are happy to entrust it to corporate or personal email providers (or store and manage it individually on their personal email servers) all the while being able to communicate with users on any other email server. The notion of *Federated Social Networks* (FSNs) —already gaining some traction— envisions a similar ecosystem where users are free to choose OSN providers which will provide storage and management of their social information, while allowing customers using different OSN providers to interact socially. Such a federation can be beneficial in three major ways, among others: *i)* it allows users to enjoy properties such as reliability, availability, and computational power of the hosting infrastructure of their choice, while not being locked down in terms of whom they can communicate with; *ii)* much like spam filtering services provided by modern email providers, that are tuned by feedback from their users, FSN users can benefit from the behavior of others sharing the same OSN provider [6]; and *iii)* this fits perfectly with enterprise needs, where ad-hoc teams can be formed across corporate OSN providers of two organizations to work on a joint project.

In [30], we presented a set of requirements, followed by a survey of the state of the art in social networking solutions, with a special focus on their ability to support rich privacy and access control policies in federated settings. Through this extensive analysis we offer a broad vision on existing social networking platforms, protocols involved but also their privacy and access policies. By doing so, we identify the main components of a federated social platform together with presenting the current trends in standards and security paradigms underlying actual open source solutions which offers their implementation, and finally provides recommendations on constructing such systems. Our research is continually being incorporated into the Yarta middleware for mobile social networking(§ 5.7).

7. Partnerships and Cooperations

7.1. National Initiatives

7.1.1. ANR

7.1.1.1. ANR MURPHY

Participant: Animesh Pathak [correspondent].

- **Name:** MURPHY – *Dependability-focused Evaluation of Sensor Networks*
- **URL:** http://cedric.cnam.fr/~sailhanf/murphy/
- **Related activities:** § 6.6
- **Period:** [January 2011 – September 2014]
- **Partners:** CNAM (**Coordinator**), Inria MiMove, LAAS - CNRS, SmartGrains, Univ. Valenciennes.

Murphy aims at easing the development of dependable and pervasive applications built on top of robust wireless sensor networks, thus providing a mean for early detection of possible failures, by estimating dependability metrics. This endeavor is undertaken by providing:

- Fault detection based on in-network event processing;
- Fault injection that attempts to accelerate the occurrence of faults so as to judge the quality of the error handling and hence, facilitate the evaluation of dependability;
- Advanced code dissemination across sensor networks, which is intended to enable the dynamic and distributed insertion of faults and hide from the end user the complexity related to this task; and
- Suitable abstractions to reason on faults, wireless sensor networks, data-centric and event-driven applications.

The aforementioned components enable to detect faults, diagnose possible causes and select appropriate corrective actions, and therefore to consolidate the dependability of sensor applications.

7.1.2. Inria Support

7.1.2.1. Inria ADT iConnect

Participant: Valérie Issarny [correspondent].

- **Name:** iConnect – *Emergent Middleware Enablers*
- **Related activities:** § 6.3 and 6.4
- **Period:** [October 2013 – December 2015]
- **Partners:** Inria MiMove.

[6] This also gives an incentive to commercial OSN providers to provide value-added services.

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.

7.1.2.2. Inria ADT Yarta

Participant: Animesh Pathak [correspondent].

- **Name:** Yarta – *Middleware for mobile social ecosystems*
- **Related activities:** § 6.8
- **Period:** [October 2012 – September 2014]
- **Partners:** Inria MiMove.

Yarta is a middleware for managing mobile social ecosystems, which builds upon existing research in context-awareness in the pervasive computing domain. The work involves development effort in the multi-layer middleware architecture of Yarta, providing the needed functionalities, including: (*i*) Storage of social data in an interoperable format, using semantic technologies such as RDF; (*ii*) Extraction of social ties from context (both physical and virtual); (*iii*) Enforcement of access control to protect social data from arbitrary access; and (*iv*) A rich set of mobile social ecosystem (MSE) management functionalities, using which mobile social applications can be developed. Specifically, the ADT supports the public open source release and evolution of the Yarta middleware, which is currently a research prototype.

7.1.2.3. Inria ADT CityLab Platform

Participant: Animesh Pathak [correspondent].

- **Name:** CityLab Platform – *A Platform for Smarter Cities Promoting Social and Environmental Sustainability*
- **Related activities:** § 6.5
- **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.

7.2. European Initiatives

7.2.1. FP7 & H2020 Projects

We provide below information about the latest FP7 project in which we participated, ICT NoE NESSoS, which ended in 2014. We are currently taking part in two H2020 projects, RIA ICT CHOReVOLUTION and RIA ICT FIESTA, which are starting in 2015 and will appear in next year’s report.

7.2.1.1. FP7 ICT NoE NESSoS

Participants: Valérie Issarny [correspondent], Animesh Pathak [correspondent].

Name: NESSoS – *Network of Excellence on Engineering Secure Future Internet Software Services and Systems*

URL: http://www.nessos-project.eu

Type: COOPERATION (ICT)

Defi: Trustworthy ICT

Instrument: Network of Excellence (NoE)

Related activities: § 6.8

Period: [October 2010 - March 2014]

Partners: Atos Origin (Spain), CNR (Italy) [**coordinator**], ETH Zürich (Switzerland), IMDEA Software (Spain), Inria (teams MiMove, CASSIS, and TRISKELL), KU Leuven (Belgium), LMU München (Germany), Siemens AG (Germany), SINTEF (Norway), University Duisburg-Essen (Germany), Universidad de Malaga (Spain), Università degli studi di Trento (Italy).

The Network of Excellence NESSoS on "Engineering Secure Future Internet Software Services and Systems" aims at constituting and integrating a long lasting research community on engineering secure software-based services and systems. The NESSoS engineering of secure software services is based on the principle of addressing security concerns from the very beginning in system analysis and design, thus contributing to reduce the amount of system and service vulnerabilities and enabling the systematic treatment of security needs through the engineering process. In light of the unique security requirements exposed by the Future Internet, new results are achieved by means of an integrated research, as to improve the necessary assurance level and to address risk and cost during the software development cycle in order to prioritize and manage investments.

7.2.2. Collaborations in European Programs, except FP7

7.2.2.1. EIT ICT Labs 3cixty

Participant: Animesh Pathak [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.

7.3. International Initiatives

7.3.1. 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 conducts her postdoc research in the context of the Inria@Silicon Valley program at UC Berkeley.

7.3.2. Inria Associate Teams

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

Participant: Animesh Pathak [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://mimove.inria.fr/inria-associate-team-sarathi/

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.

7.3.3. Participation in other International Programs

7.3.3.1. International scientific cooperation program Inria/Brazil – Project M@TURE

Participant: Nikolaos Georgantas [correspondent].

Name: M@TURE – *Models @ runtime for self-adaptive pervasive systems*

Instrument: Inria-Brazil cooperation programme

Period: [October 2012 - September 2014]

Partners: Institute of Informatics of Federal University of Goias (Brazil), Inria MiMove.

The overall goal of the M@TURE project is to design, implement and evaluate a novel approach and architecture - comprising conceptual foundations, engineering techniques, and supporting middleware infrastructure - for self-adaptive pervasive systems by building on the notion of Models@run.time. Models@run.time extends the applicability of models and abstractions to the runtime environment. In contrast to design-time models, runtime models are used to reason about the running system taking into account its operating environment, and thus these models enable automating runtime decisions and actions regarding the creation, configuration, and evolution of the system. We in particular focus on the following dimensions and related models: (i) Requirements models making a system requirements-aware at runtime; (ii) Application- and middleware-level interoperability models exposing to an external observer the technological and business features of a system; and (iii) End-user and system engineer models modeling the internal elements of a system at two different abstraction levels. These models are considered both independently and, more importantly, in synergy in order to introduce a comprehensive conceptual and architectural solution for self-adaptive pervasive systems.

7.4. International Research Visitors

7.4.1. 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. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific events organisation

8.1.1.1. Member of organizing committee

- Valérie Issarny is member of the Steering Committee of the ESEC/FSE conference.

8.1.1.2. Chair of technical program committee

- Rachit Agarwal is co-chair of the “Advanced and Trusted Internet of Things and Smart City" track in the 12th IEEE International Conference on Advanced and Trusted Computing (ATC 2015);
- Valérie Issarny is co-programme chair of “New Ideas Track" at ESEC/FSE'15 international conference;
- Animesh Pathak is co-chair of the systems track of the IC3'2015 international conference.

8.1.1.3. Member of technical program committee

- Nikolaos Georgantas is PC member of the following international conferences: AmI'14, DATA'14&'15, ICSOFT-EA'14&'15, ICSOFT-PT'14&'15, ANT'14&'15, SOSE'14&'15, HPCC'14, WETICE'15, CBSE'15, ComPAS'15, Projects Showcase event at STAF'15;

- Nikolaos Georgantas is PC member of the following international workshops: MW4NG'14, ARM'14, OrChor'14, SESoS'14&'15, SERENE'14&'15;
- Raphael De Aquino Gomes is PC member of the following international conferences: CSE'14, and CISIS'15;
- Valérie Issarny is PC member of the following international conferences: CBSE'14, Coordination'14&15, ESSOS'14, FASE'15&16, FSE'14, ICDCS'15, ICSE-SEIP Track'14&15, IFIPTM'15, ISPN'15, Middleware'14&15, SEAMS'14;
- Animesh Pathak is PC member of the following international conferences: HPCC'14, EWSN'14, S-Cube'14, and Sensornets'14.

8.1.2. Journal

8.1.2.1. 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.

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

Master: Nikolaos Georgantas, "Pervasive Service Oriented Computing" as part of "Services Web et Architectures à bases de services" (SWAS), 18 hours (équivalent TD), niveau M2, University of Versailles Saint-Quentin en Yvelines, France;

Master: Animesh Pathak co-taught a M2 COSY level course on "Web sémantique, contenus et usages" at University of Versailles Saint-Quentin-en-Yvelines in Spring 2014; and

Master: Animesh Pathak gave two three-hour guest lectures at CNAM, Paris as part of a M2 level course on embedded systems in Spring 2014.

8.2.2. Supervision

In 2014, the following students successfully defended their PhD:

Sara Hachem, *Service-Oriented Middleware for the Large-Scale Mobile Internet of Things*, UVSQ-EDSTV, defended in February 2014, advised by A. Pathak and V. Issarny.

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

Emil Andriescu, *Synthèse et déploiement dynamiques de protocoles de médiation pour l'interopérabilité dans les environnements collaboratifs nomades*, started October 2012, UPMC-EDITE, CIFRE Inria-Ambientic, advised by Valérie Issarny and Roberto Speicys-Cardoso (Ambientic).

Benjamin Billet, *Self-adaptive Streaming Middleware for the Internet of Things*, started October 2012, UVSQ-EDSTV, advised by Valérie Issarny

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.

8.3. Popularization

- Benjamin Billet was invited to speak at a one-day Android tutorial event organized by the ARAMIS business network at Lyon.

8.4. Other Academic Services

8.4.1. Institutional Commitment

- Nikolaos Georgantas is member of the PhD monitoring committee at Inria Paris-Rocquencourt;
- Nikolaos Georgantas is member of the Inria PhD scholarship selection committee at Inria Paris-Rocquencourt;
- Valérie Issarny is elected member of the *Commission d'Evaluation Inria*;
- Valérie Issarny is scientific coordinator of Inria@Silicon Valley;
- Animesh Pathak served on the Inria assistant selection committee for Lille and Rennes centers.

8.4.2. Collective Responsibilities outside Inria

- Valérie Issarny and Nikolaos Georgantas are members of the IFIP Working Group 2.14/6.12/8.10 on Services-oriented Systems;
- Valérie Issarny is member of the IFSTTAR Scientific Council & "Commission d'évaluation des chercheurs";
- Valérie Issarny is member of the GDR GPL scientific council.

9. Bibliography

Major publications by the team in recent years

[1] S. BEN MOKHTAR, D. PREUVENEERS, N. GEORGANTAS, V. ISSARNY, Y. BERBERS. *EASY: Efficient SemAntic Service DiscoverY in Pervasive Computing Environments with QoS and Context Support*, in "Journal of Systems and Software, Special Issue on Web Services Modelling and Testing", 2008, vol. 81, n^{o} 5, pp. 785-808

[2] A. BENNACEUR, V. ISSARNY. *Automated Synthesis of Mediators to Support Component Interoperability*, in "IEEE Transactions on Software Engineering", 2014, 22 p. , https://hal.inria.fr/hal-01076176

[3] B. BILLET, V. ISSARNY. *Dioptase: a distributed data streaming middleware for the future web of things*, in "Journal of Internet Services and Applications", 2014, vol. 5, n^{o} 1, 28 p. [*DOI :* 10.1186/S13174-014-0013-1], https://hal.inria.fr/hal-01081738

[4] G. BLAIR, A. BENNACEUR, N. GEORGANTAS, P. GRACE, V. ISSARNY, V. NUNDLOLL, M. PAOLUCCI. *The Role of Ontologies in Emergent Middleware: Supporting Interoperability in Complex Distributed Systems*, in "Big Ideas track of ACM/IFIP/USENIX 12th International Middleware Conference", Lisbon, Portugal, 2011, http://hal.inria.fr/inria-00629059/en

[5] M. CAPORUSCIO, P.-G. RAVERDY, V. ISSARNY. *ubiSOAP: A Service Oriented Middleware for Ubiquitous Networking*, in "IEEE Transactions on Services Computing", 2012, vol. 99 [*DOI :* 10.1109/TSC.2010.60], http://hal.inria.fr/inria-00519577

[6] S. HACHEM, A. PATHAK, V. ISSARNY. *Service-Oriented Middleware for Large-Scale Mobile Participatory Sensing*, in "Pervasive and Mobile Computing", 2014, http://hal.inria.fr/hal-00872407

[7] V. ISSARNY, M. CAPORUSCIO, N. GEORGANTAS. *A Perspective on the Future of Middleware-based Software Engineering*, in "FOSE '07: 2007 Future of Software Engineering", Washington, DC, USA, IEEE Computer Society, 2007, pp. 244–258, http://dx.doi.org/10.1109/FOSE.2007.2

[8] V. ISSARNY, N. GEORGANTAS, S. HACHEM, A. ZARRAS, P. VASSILIADIS, M. AUTILI, M. A. GEROSA, A. BEN HAMIDA. *Service-Oriented Middleware for the Future Internet: State of the Art and Research Directions*, in "Journal of Internet Services and Applications", May 2011, vol. 2, n^o^ 1, pp. 23-45 [*DOI :* 10.1007/S13174-011-0021-3], http://hal.inria.fr/inria-00588753/en

Publications of the year

Doctoral Dissertations and Habilitation Theses

[9] S. HACHEM. *Service-Oriented Middleware for the Large-Scale Mobile Internet of Things*, Université de Versailles-Saint Quentin en Yvelines, February 2014, https://tel.archives-ouvertes.fr/tel-00960026

Articles in International Peer-Reviewed Journals

[10] R. AGARWAL, V. GAUTHIER, M. BECKER, T. TOUKABRI, H. AFIFI. *Large Scale Model for Information Dissemination with Device to Device Communication using Call Details Records*, in "Computer Communications", January 2015, forthcoming, https://hal.inria.fr/hal-01111385

[11] D. ATHANASOPOULOS, M. AUTILI, N. GEORGANTAS, V. ISSARNY, M. TIVOLI, A. ZARRAS. *An Architectural Style for the Development of Choreographies in the Future Internet*, in "Global Journal of Advanced Software Engineering (GJASE)", December 2014, vol. 1, n^o^ 1, pp. 14-28, https://hal.inria.fr/hal-01110502

[12] A. BENNACEUR, V. ISSARNY. *Automated Synthesis of Mediators to Support Component Interoperability*, in "IEEE Transactions on Software Engineering", 2014, 22 p. , https://hal.inria.fr/hal-01076176

[13] A. BENVENISTE, C. JARD, A. KATTEPUR, S. ROSARIO, J. A. THYWISSEN. *QoS-Aware Management of Monotonic Service Orchestrations*, in "Formal Methods in System Design", February 2014, vol. 44, n^o^ 1, pp. 1-43 [*DOI :* 10.1007/S10703-013-0191-7], https://hal.archives-ouvertes.fr/hal-00840362

[14] B. BILLET, V. ISSARNY. *Dioptase: a distributed data streaming middleware for the future web of things*, in "Journal of Internet Services and Applications", 2014, vol. 5, n^o^ 1, 28 p. [*DOI :* 10.1186/S13174-014-0013-1], https://hal.inria.fr/hal-01081738

[15] S. HACHEM, A. PATHAK, V. ISSARNY. *Service-Oriented Middleware for Large-Scale Mobile Participatory Sensing*, in "Pervasive and Mobile Computing", 2014, vol. 10, pp. 66-82 [*DOI :* 10.1016/J.PMCJ.2013.10.010], https://hal.inria.fr/hal-00872407

[16] J. LU, S. ROSENBLUM DAVID, T. BULTAN, V. ISSARNY, S. DUSTDAR, M.-A. STOREY, D. ZHANG. *Roundtable on "The Future of Software Engineering for Internet Computing"*, in "IEEE Software", January 2015, vol. 32, n^o^ 1, pp. 91-97, https://hal.inria.fr/hal-01110877

International Conferences with Proceedings

[17] E. - M. ANDRIESCU, T. MARTINEZ, V. ISSARNY. *Composing Message Translators and Inferring their Data Types using Tree Automata*, in "18th International Conference on Fundamental Approaches to Software Engineering (FASE)", London, United Kingdom, April 2015, https://hal.inria.fr/hal-01097389

[18] A. BENNACEUR, V. ISSARNY. *Layered Connectors: Revisiting the Formal Basis of Architectural Connection for Complex Distributed Systems*, in "ECSA'14 - The 8th European Conference on Software Architecture", Vienna, Austria, Springer, August 2014, https://hal.inria.fr/hal-01015897

[19] B. BILLET, V. ISSARNY. *From Task Graphs to Concrete Actions: A New Task Mapping Algorithm for the Future Internet of Things*, in "MASS - 11th IEEE International Conference on Mobile Ad hoc and Sensor Systems", Philadelphia, United States, October 2014, https://hal.inria.fr/hal-01069838

[20] R. GOMES, F. COSTA, R. DA ROCHA, N. GEORGANTAS. *A Middleware-based Approach for QoS-aware Deployment of Service Choreography in the Cloud*, in "Proceedings of the 11th Middleware Doctoral Symposium", Bordeaux, France, December 2014, pp. 2:1–2:4 [*DOI :* 10.1145/2684080.2684082], https://hal.inria.fr/hal-01110861

[21] S. HACHEM, V. MALLET, V. RAPHAËL, P.-G. RAVERDY, A. PATHAK, V. ISSARNY, R. BHATIA. *Monitoring Noise Pollution Using The Urban Civics Middleware*, in "IEEE BigDataService 2015", San Francisco, United States, March 2015, https://hal.inria.fr/hal-01109321

[22] S. HACHEM, G. MATHIOUDAKIS, A. PATHAK, V. ISSARNY, R. BHATIA. *Sense2Health: A Quantified Self Application for Monitoring Personal Exposure to Environmental Pollution*, in "SENSORNETS 2015", Angers, France, February 2015, https://hal.inria.fr/hal-01102275

[23] S. HACHEM, A. PATHAK, V. ISSARNY. *Service-Oriented Middleware for the Mobile Internet of Things: A Scalable Solution*, in "IEEE GLOBECOM: Global Communications Conference (Accepted)", Austin, United States, December 2014, https://hal.inria.fr/hal-01057530

[24] F. HASSANI BIJARBOONEH, A. PATHAK, J. PEARSON, V. ISSARNY, B. JONSSON. *A constraint programming approach for managing end-to-end requirements in sensor network macroprogramming*, in "SENSORNETS 2014 - 3rd International Conference on Sensor Networks", Lisbon, Portugal, January 2014, https://hal.inria.fr/hal-00927148

[25] A. PATHAK, V. ISSARNY, J. HOLSTON. *AppCivist - A Service-oriented Software Platform for Socially Sustainable Activism*, in "International Conference on Software Engineering (ICSE), Software Engineering in Society (SEIS) Track", Florence, Italy, May 2015, https://hal.inria.fr/hal-01109314

[26] M. STOICESCU, J.-C. FABRE, M. ROY, A. PATHAK. *From Resilient Computing Architectural Concepts to Wireless Sensor Network-based Applications*, in "EDCC 2014 - Tenth European Dependable Computing Conference", Newcastle upon Tyne, United Kingdom, IEEE, May 2014, pp. 46 - 49 [*DOI :* 10.1109/EDCC.2014.23], https://hal.inria.fr/hal-00938389

Scientific Books (or Scientific Book chapters)

[27] A. BENNACEUR, R. FRANCE, G. TAMBURRELLI, T. VOGEL, P. J. MOSTERMAN, W. CAZZOLA, F. M. COSTA, A. PIERANTONIO, M. TICHY, M. AKŞIT, P. EMMANUELSON, H. GANG, N. GEORGANTAS, D. REDLICH. *Mechanisms for Leveraging Models at Runtime in Self-adaptive Software*, in "Models@run.time", N. BENCOMO, R. B. FRANCE, B. H. CHENG, U. ASSMANN (editors), Lecture Notes in Computer Science, Springer, 2014, vol. 8378, pp. 19-46 [*DOI :* 10.1007/978-3-319-08915-7_2], https://hal.inria.fr/hal-01018734

[28] G. BOULOUKAKIS, I. BASDEKIS, C. STEPHANIDIS. *Supporting Accessible User Interfaces using Web Services*, in "Human-Computer Interfaces and Interactivity: Emergent Research and Applications", P. ISAÍAS, K. BLASHKI (editors), IGI Global, June 2014, vol. 8, https://hal.inria.fr/hal-01001839

[29] M. CAPORUSCIO, M. FUNARO, C. GHEZZI, V. ISSARNY. *ubiREST: A RESTful Service-oriented Middleware for Ubiquitous Networking*, in "Advanced Web Services", A. BOUGUETTAYA, Q. SHENG, F. DANIEL (editors), Springer, 2014, vol. III, pp. 475-500 [*DOI :* 10.1007/978-1-4614-7535-4_20], https://hal.inria.fr/hal-00927085

[30] A. PATHAK, G. ROSCA, V. ISSARNY, M. DECAT, B. LAGAISSE. *Privacy and Access Control in Federated Social Networks*, in "Advances in Engineering Secure Future Internet Services and Systems", M. HEISEL, W. JOOSEN, J. LOPEZ, F. MARTINELLI (editors), LNCS - Lecture Notes in Computer Science, Springer, June 2014, vol. 8431, pp. 162-181, https://hal.inria.fr/hal-00989726

Scientific Popularization

[31] S. HACHEM, V. ISSARNY, A. POZDNOUKHOV, R. BHATIA. *Urban Civics - Democratizing Urban Data for Healthy Smart Cities*, in "ERCIM News", July 2014, vol. 2014, n^{o} 98, pp. 10-11, https://hal.inria.fr/hal-01112023

[32] J. HOLSTON, R. OCHIGAME, A. PATHAK. *AppCivist - A Service-oriented Software Platform for Social Activism*, in "ERCIM News", July 2014, vol. 2014, n^{o} 98, pp. 12-13, https://hal.inria.fr/hal-01112026

[33] V. ISSARNY. *CityLab@Inria - A Lab on Smart Cities fostering Environmental and Social Sustainability*, in "ERCIM News", July 2014, vol. 2014, n^{o} 98, pp. 13-14, https://hal.inria.fr/hal-01112029

References in notes

[34] L. ALDRED, W. M. P. VAN DER AALST, M. DUMAS, A. H. M. TER HOFSTEDE. *Dimensions of Coupling in Middleware*, in "Concurrency and Computation: Practice and Experience", 2009, vol. 21, n^{o} 18, pp. 2233–2269, http://eprints.qut.edu.au/40797/

[35] B. BALAJI, J. XU, A. NWOKAFOR, R. GUPTA, Y. AGARWAL. *Sentinel: Occupancy Based HVAC Actuation Using Existing WiFi Infrastructure Within Commercial Buildings*, in "Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems", New York, NY, USA, SenSys '13, ACM, 2013, pp. 17:1–17:14, http://doi.acm.org/10.1145/2517351.2517370

[36] M. V. BARBERA, A. EPASTO, A. MEI, V. C. PERTA, J. STEFA. *Signals from the Crowd: Uncovering Social Relationships Through Smartphone Probes*, in "Proceedings of the 2013 Conference on Internet Measurement Conference", New York, NY, USA, IMC '13, ACM, 2013, pp. 265–276, http://doi.acm.org/10.1145/2504730.2504742

[37] L. BARESI, C. GHEZZI. *The Disappearing Boundary Between Development-time and Run-time*, in "Proceedings of the FSE/SDP Workshop on Future of Software Engineering Research", New York, NY, USA, FoSER '10, ACM, 2010, pp. 17–22, http://doi.acm.org/10.1145/1882362.1882367

[38] A. BEACH, M. GARTRELL, S. AKKALA, J. ELSTON, J. KELLEY, K. NISHIMOTO, B. RAY, S. RAZGULIN, K. SUNDARESAN, B. SURENDAR, M. TERADA, R. HAN. *Whozthat? Evolving an ecosystem for context-aware mobile social networks*, in "IEEE Xplore", 2008, vol. 22, n^{o} 4, pp. 50–55

[39] N. BENCOMO, A. BELAGGOUN, V. ISSARNY. *Dynamic Decision Networks for Decision-making in Self-adaptive Systems: A Case Study*, in "Proceedings of the 8th International Symposium on Software Engineering for Adaptive and Self-Managing Systems", Piscataway, NJ, USA, SEAMS '13, IEEE Press, 2013, pp. 113–122, http://dl.acm.org/citation.cfm?id=2487336.2487355

[40] A. BENNACEUR. *Synthèse dynamique de médiateurs dans les environnements ubiquitaires*, Université Pierre et Marie Curie - Paris VI, July 2013, http://hal.inria.fr/tel-00849402

[41] G. BLAIR, A. BENNACEUR, N. GEORGANTAS, P. GRACE, V. ISSARNY, V. NUNDLOLL, M. PAOLUCCI. *The Role of Ontologies in Emergent Middleware: Supporting Interoperability in Complex Distributed Systems*, in "Big Ideas track of ACM/IFIP/USENIX 12th International Middleware Conference", Lisbon, Portugal, 2011, http://hal.inria.fr/inria-00629059/en

[42] B. BOEHM. *A View of 20th and 21st Century Software Engineering*, in "Proceedings of the 28th International Conference on Software Engineering", New York, NY, USA, ICSE '06, ACM, 2006, pp. 12–29, http://doi.acm.org/10.1145/1134285.1134288

[43] Z. BOUZID, M. G. POTOP-BUTUCARU, S. TIXEUIL. *Optimal Byzantine-resilient Convergence in Uni-dimensional Robot Networks*, in "Theor. Comput. Sci.", July 2010, vol. 411, n^{o} 34-36, pp. 3154–3168, http://dx.doi.org/10.1016/j.tcs.2010.05.006

[44] R. CALINESCU, C. GHEZZI, M. KWIATKOWSKA, R. MIRANDOLA. *Self-adaptive Software Needs Quantitative Verification at Runtime*, in "Commun. ACM", September 2012, vol. 55, n^{o} 9, pp. 69–77, http://doi.acm.org/10.1145/2330667.2330686

[45] L. CAPRA, P. CHÂTEL, A. PATHAK, R. SPEICYS CARDOSO. *TravelDashboard – a Framework for the Delivery of Personalized Mobility Services to Urban Travellers*, in "ERCIM News", April 2013, vol. 2013, n^{o} 93, http://hal.inria.fr/hal-00939031

[46] D. CHRISTIN, C. ROSSKOPF, M. HOLLICK. *uSafe: A privacy-aware and participative mobile application for citizen safety in urban environments*, in "Pervasive and Mobile Computing", 2013, vol. 9, n^{o} 5, pp. 695-707, http://dblp.uni-trier.de/db/journals/percom/percom9.html#ChristinRH13

[47] V. CICIRELLO, M. PEYSAKHOV, G. ANDERSON, G. NAIK, K. TSANG, W. REGLI, M. KAM. *Designing dependable agent systems for mobile wireless networks*, in "Intelligent Systems, IEEE", 2004, vol. 19, n^{o} 5, pp. 39–45

[48] E. CUERVO, A. BALASUBRAMANIAN, D.-K. CHO, A. WOLMAN, S. SAROIU, R. CHANDRA, P. BAHL. *MAUI: Making Smartphones Last Longer with Code Offload*, in "Proceedings of the 8th International Conference on Mobile Systems, Applications, and Services", New York, NY, USA, MobiSys '10, ACM, 2010, pp. 49–62, http://doi.acm.org/10.1145/1814433.1814441

[49] M. DEMIRBAS, M. BAYIR, C. AKCORA, Y. YILMAZ, H. FERHATOSMANOGLU. *Crowd-sourced sensing and collaboration using Twitter*, in "World of Wireless Mobile and Multimedia Networks (WoWMoM), 2010 IEEE International Symposium on a", June 2010, http://dx.doi.org/10.1109/WOWMOM.2010.5534910

[50] F. DI GIANDOMENICO, A. BERTOLINO, A. CALABRÒ, N. NOSTRO. *An approach to adaptive dependability assessment in dynamic and evolving connected systems*, in "International Journal of Adaptive, Resilient and Autonomic Systems (IJARAS)", March 2013, vol. Volume 4, n^{o} 1, pp. 1-25

[*DOI :* 10.4018/JARAS.2013010101], http://www.igi-global.com/article/approach-adaptive-dependability-assessment-dynamic/75547

[51] M. DIXIT, A. CASIMIRO, P. LOLLINI, A. BONDAVALLI, P. VERISSIMO. *Adaptare: Supporting Automatic and Dependable Adaptation in Dynamic Environments*, in "ACM Trans. Auton. Adapt. Syst.", July 2012, vol. 7, n^o 2, pp. 18:1–18:25, http://doi.acm.org/10.1145/2240166.2240168

[52] I. EPIFANI, C. GHEZZI, G. TAMBURRELLI. *Change-point Detection for Black-box Services*, in "Proceedings of the Eighteenth ACM SIGSOFT International Symposium on Foundations of Software Engineering", New York, NY, USA, FSE '10, ACM, 2010, pp. 227–236, http://doi.acm.org/10.1145/1882291.1882326

[53] N. ESFAHANI, S. MALEK. *Uncertainty in Self-Adaptive Software Systems*, in "Software Engineering for Self-Adaptive Systems II", R. LEMOS, H. GIESE, H. A. MULLER, M. SHAW (editors), Lecture Notes in Computer Science, Springer Berlin Heidelberg, 2013, vol. 7475, pp. 214-238, http://dx.doi.org/10.1007/978-3-642-35813-5_9

[54] A. FILIERI, C. GHEZZI, G. TAMBURRELLI. *A Formal Approach to Adaptive Software: Continuous Assurance of Non-functional Requirements*, in "Form. Asp. Comput.", March 2012, vol. 24, n^o 2, pp. 163–186, http://dx.doi.org/10.1007/s00165-011-0207-2

[55] N. GEORGANTAS, G. BOULOUKAKIS, S. BEAUCHE, V. ISSARNY. *Service-oriented Distributed Applications in the Future Internet: The Case for Interaction Paradigm Interoperability*, in "ESOCC 2013 - European Conference on Service-Oriented and Cloud Computing", Malaga, Spain, K.-K. LAU, W. LAMERSDORF, E. PIMENTEL (editors), Lecture Notes in Computer Science, Springer, July 2013, vol. 8135, pp. 134-148 [*DOI :* 10.1007/978-3-642-40651-5_11], http://hal.inria.fr/hal-00841332

[56] S. HACHEM. *Service-oriented middleware for the large-scale mobile Internet of Things*, Université de Versailles Saint Quentin en Yvelines, February 2014

[57] S. HACHEM, A. PATHAK, V. ISSARNY. *Probabilistic Registration for Large-Scale Mobile Participatory Sensing*, in "Proceedings of the 11th IEEE International Conference on Pervasive Computing and Communications, (PerCom)", Mar. 2013

[58] S. HACHEM, A. TONINELLI, A. PATHAK, V. ISSARNY. *Policy-based Access Control in Mobile Social Ecosystems*, in "IEEE International Symposium on Policies for Distributed Systems and Networks", Pisa, Italie, IEEE computer society, 2011, http://hal.inria.fr/inria-00608201

[59] S. HEMMINKI, P. NURMI, S. TARKOMA. *Accelerometer-based Transportation Mode Detection on Smartphones*, in "Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems", New York, NY, USA, SenSys '13, ACM, 2013, pp. 13:1–13:14, http://doi.acm.org/10.1145/2517351.2517367

[60] P. INVERARDI, M. TIVOLI. *Automatic Synthesis of Modular Connectors via Composition of Protocol Mediation Patterns*, in "Proceedings of the 2013 International Conference on Software Engineering", Piscataway, NJ, USA, ICSE '13, IEEE Press, 2013, pp. 3–12, http://dl.acm.org/citation.cfm?id=2486788.2486790

[61] V. ISSARNY, A. BENNACEUR, Y.-D. BROMBERG. *Middleware-layer Connector Synthesis: Beyond State of the Art in Middleware Interoperability*, in "11th International School on Formal Methods for the Design of Computer, Communication and Software Systems: Connectors for Eternal Networked Software Systems", M.

BERNARDO, V. ISSARNY (editors), Lecture notes in computer science, Springer, 2011, vol. 6659, pp. 217-255 [*DOI :* 10.1007/978-3-642-21455-4], http://hal.inria.fr/inria-00586630

[62] V. ISSARNY, A. BENNACEUR. *Composing Distributed Systems: Overcoming the Interoperability Challenge*, in "FMCO 2012", F. DE BOER, M. BONSANGUE, E. GIACHINO, R. HAHNLE (editors), Lecture Notes in Computer Science, Springer, 2013, pp. 168-196 [*DOI :* 10.1007/978-3-642-40615-7_6], http://hal.inria.fr/hal-00828801

[63] J. JUN, Y. GU, L. CHENG, B. LU, J. SUN, T. ZHU, J. NIU. *Social-Loc: Improving Indoor Localization with Social Sensing*, in "Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems", New York, NY, USA, SenSys '13, ACM, 2013, pp. 14:1–14:14, http://doi.acm.org/10.1145/2517351.2517352

[64] C. KAISER, A. POZDNOUKHOV. *Enabling real-time city sensing with kernel stream oracles and MapReduce*, in "Pervasive and Mobile Computing", 2013, vol. 9, n^{o} 5, pp. 708-721, http://dblp.uni-trier.de/db/journals/percom/percom9.html#KaiserP13

[65] A. KATTEPUR, N. GEORGANTAS, V. ISSARNY. *QoS Analysis in Heterogeneous Choreography Interactions*, in "11th International Conference on Service Oriented Computing (ICSOC)", Berlin, Germany, December 2013, http://hal.inria.fr/hal-00866190

[66] J. O. KEPHART, D. M. CHESS. *The Vision of Autonomic Computing*, in "Computer", January 2003, vol. 36, n^{o} 1, pp. 41–50, http://dx.doi.org/10.1109/MC.2003.1160055

[67] W. Z. KHAN, Y. XIANG, M. Y. AALSALEM, Q. ARSHAD. *Mobile Phone Sensing Systems: A Survey*, in "IEEE Communications Surveys Tutorials", 2013, vol. 15, n^{o} 1, pp. 402-427

[68] A. LAMANI, M. G. POTOP-BUTUCARU, S. TIXEUIL. *Optimal deterministic ring exploration with oblivious asynchronous robots*, in "Structural Information and Communication Complexity", Springer, 2010, pp. 183–196

[69] N. D. LANE, Y. CHON, L. ZHOU, Y. ZHANG, F. LI, D. KIM, G. DING, F. ZHAO, H. CHA. *Piggyback CrowdSensing (PCS): Energy Efficient Crowdsourcing of Mobile Sensor Data by Exploiting Smartphone App Opportunities*, in "Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems", New York, NY, USA, SenSys '13, ACM, 2013, pp. 7:1–7:14, http://doi.acm.org/10.1145/2517351.2517372

[70] N. D. LANE, S. B. EISENMAN, M. MUSOLESI, E. MILUZZO, A. T. CAMPBELL. *Urban sensing systems: opportunistic or participatory?*, in "Proceedings of the 9th workshop on Mobile computing systems and applications", ACM, 2008, pp. 11–16

[71] N. D. LANE, E. MILUZZO, H. LU, D. PEEBLES, T. CHOUDHURY, A. T. CAMPBELL. *A survey of mobile phone sensing*, in "Communications Magazine, IEEE", 2010, vol. 48, n^{o} 9, pp. 140–150

[72] LE PARISIEN. *Comment ne plus jamais être en retard*, Oct 2013, Article in "Le parisien : Comment ne plus jamais être en retard", Public article on the neverBLate app developed by team members, http://www.leparisien.fr/espace-premium/seine-et-marne-77/comment-ne-plus-jamais-etre-en-retard-23-10-2013-3250205.php

[73] LE PARISIEN. *Fuyez les rames bondées*, Oct 2013, Article in "Le Parisien : fuyez les rames bondées, Public article on the Boîte à Sardines app developed by team members, http://www.leparisien.fr/espace-premium/paris-75/fuyez-les-rames-bondees-23-10-2013-3249981.php

[74] X. LIU, A. BOUGUETTAYA, X. WU, L. ZHOU. *Ev-LCS: A System for the Evolution of Long-Term Composed Services*, in "IEEE Trans. Serv. Comput.", January 2013, vol. 6, n^{o} 1, pp. 102–115, http://dx.doi.org/10.1109/TSC.2011.40

[75] H. LU, W. PAN, N. D. LANE, T. CHOUDHURY, A. T. CAMPBELL. *SoundSense: Scalable sound sensing for people-centric applications on mobile phones*, in "Proceedings of the 7th International conference on Mobile systems, applications, and services", New York, NY, USA, 2009, pp. 165–178

[76] E. MILUZZO, N. D. LANE, S. B. EISENMAN, A. T. CAMPBELL. *CenceMe – injecting sensing presence into social networking applications*, in "Smart Sensing and Context", Springer, 2007, pp. 1–28

[77] N. MITTON, S. PAPAVASSILIOU, A. PULIAFITO, K. S. TRIVEDI. *Combining Cloud and sensors in a smart city environment*, in "EURASIP Journal on Wireless Communications and Networking", 2012, vol. 2012, n^{o} 1, pp. 1–10

[78] L. MOTTOLA, G. P. PICCO. *Programming wireless sensor networks: Fundamental concepts and state of the art*, in "ACM Computing Surveys (CSUR)", 2011, vol. 43, n^{o} 3, 19 p.

[79] A. J. OLINER, A. P. IYER, I. STOICA, E. LAGERSPETZ, S. TARKOMA. *Carat: Collaborative Energy Diagnosis for Mobile Devices*, in "Proceedings of the 11th ACM Conference on Embedded Networked Sensor Systems", New York, NY, USA, SenSys '13, ACM, 2013, pp. 10:1–10:14, http://doi.acm.org/10.1145/2517351.2517354

[80] A. PATHAK, V. K. PRASANNA. *Energy-efficient task mapping for data-driven sensor network macroprogramming*, in "Computers, IEEE Transactions on", 2010, vol. 59, n^{o} 7, pp. 955–968

[81] R. POPESCU, A. STAIKOPOULOS, A. BROGI, P. LIU, S. CLARKE. *A Formalized, Taxonomy-driven Approach to Cross-layer Application Adaptation*, in "ACM Trans. Auton. Adapt. Syst.", May 2012, vol. 7, n^{o} 1, pp. 7:1–7:30, http://doi.acm.org/10.1145/2168260.2168267

[82] R. K. RANA, C. T. CHOU, S. S. KANHERE, N. BULUSU, W. HU. *Ear-phone: An End-to-end Participatory Urban Noise Mapping System*, in "Proceedings of the 9th ACM/IEEE International Conference on Information Processing in Sensor Networks", New York, NY, USA, IPSN '10, ACM, 2010, pp. 105–116, http://doi.acm.org/10.1145/1791212.1791226

[83] L. RAVINDRANATH, J. PADHYE, R. MAHAJAN, H. BALAKRISHNAN. *Timecard: Controlling User-perceived Delays in Server-based Mobile Applications*, in "Proceedings of the Twenty-Fourth ACM Symposium on Operating Systems Principles", New York, NY, USA, SOSP '13, ACM, 2013, pp. 85–100, http://doi.acm.org/10.1145/2517349.2522717

[84] M. SALEHIE, L. TAHVILDARI. *Self-adaptive Software: Landscape and Research Challenges*, in "ACM Trans. Auton. Adapt. Syst.", May 2009, vol. 4, n^{o} 2, pp. 14:1–14:42, http://doi.acm.org/10.1145/1516533.1516538

[85] G. SANTUCCI. *Privacy in the Digital Economy: Requiem or Renaissance? An Essay on the Future of Privacy*, 2013, Privacy Surgeon, http://www.privacysurgeon.org/blog/wp-content/uploads/2013/09/Privacy-in-the-Digital-Economy-final.pdf

[86] M. SATYANARAYANAN, P. BAHL, R. CACERES, N. DAVIES. *The case for VM-based cloudlets in mobile computing*, in "Pervasive Computing, IEEE", 2009, vol. 8, n^{o} 4, pp. 14–23

[87] M. SATYANARAYANAN. *Mobile computing: The next decade*, in "ACM SIGMOBILE Mobile Computing and Communications Review", 2011, vol. 15, n^{o} 2, pp. 2–10

[88] M. SATYANARAYANAN. *Fundamental challenges in mobile computing*, in "Proceedings of the fifteenth annual ACM symposium on Principles of distributed computing", ACM, 1996, pp. 1–7

[89] I. SCHWEIZER, C. MEURISCH, J. GEDEON, R. BÄRTL, M. MÜHLHÄUSER. *NoiseMap: Multi-tier Incentive Mechanisms for Participative Urban Sensing*, in "Proceedings of the Third International Workshop on Sensing Applications on Mobile Phones", New York, NY, USA, PhoneSense'12, ACM, 2012, pp. 9:1–9:5, http://doi.acm.org/10.1145/2389148.2389157

[90] C. SHIN, J.-H. HONG, A. K. DEY. *Understanding and Prediction of Mobile Application Usage for Smart Phones*, in "Proceedings of the 2012 ACM Conference on Ubiquitous Computing", New York, NY, USA, UbiComp '12, ACM, 2012, pp. 173–182, http://doi.acm.org/10.1145/2370216.2370243

[91] R. SPEICYS CARDOSO, V. ISSARNY. *Architecting Pervasive Computing Systems for Privacy: A Survey*, in "Sixth Working IEEE/IFIP Conference on Software Architecture : WICSA 2007", Mumbai, Maharashtra, Inde, 2007, 26 p. , http://hal.inria.fr/inria-00415925

[92] M.-O. STEHR, C. TALCOTT, J. RUSHBY, P. LINCOLN, M. KIM, S. CHEUNG, A. POGGIO. *Fractionated software for networked cyber-physical systems: Research directions and long-term vision*, in "Formal Modeling: Actors, Open Systems, Biological Systems", Springer, 2011, pp. 110–143

[93] T. TEIXEIRA, S. HACHEM, V. ISSARNY, N. GEORGANTAS. *Service Oriented Middleware for the Internet of Things: A Perspective*, in "ServiceWave", Poznan, Pologne, Springer-Verlag, 2011, pp. 220-229, http://hal.inria.fr/inria-00632794

[94] A. TONINELLI, A. PATHAK, V. ISSARNY. *Yarta: A Middleware for Managing Mobile Social Ecosystems*, in "GPC 2011 : International Conference on Grid and Pervasive Computing", Oulu, Finlande, J. RIEKKI, M. YLIANTTILA, M. GUO (editors), Lecture notes in computer science, Springer, May 2011, vol. 6646, pp. 209-220 [*DOI :* 10.1007/978-3-642-20754-9_22], http://hal.inria.fr/hal-00723794

[95] S. VANSYCKEL, D. SCHAFER, V. MAJUNTKE, C. KRUPITZER, G. SCHIELE, C. BECKER. *COMITY: A framework for adaptation coordination in multi-platform pervasive systems*, in "Pervasive and Mobile Computing", 2014, vol. 10, Part A, pp. 51 - 65, Selected Papers from the Eleventh Annual {IEEE} International Conference on Pervasive Computing and Communications (PerCom 2013) [*DOI :* 10.1016/J.PMCJ.2013.10.006], http://www.sciencedirect.com/science/article/pii/S1574119213001302

[96] M. VON KAENEL, P. SOMMER, R. WATTENHOFER. *Ikarus: Large-scale Participatory Sensing at High Altitudes*, in "Proceedings of the 12th Workshop on Mobile Computing Systems and Applications", ACM, 2011, pp. 63–68

[97] C. XU, W. YANG, X. MA, C. CAO, J. LU. *Environment Rematching: Toward Dependability Improvement for Self-Adaptive Applications*, in "Automated Software Engineering (ASE), 2013 IEEE/ACM 28th International Conference on", Nov 2013, pp. 592-597, http://dx.doi.org/10.1109/ASE.2013.6693118

[98] J. ZIMMERMAN, A. TOMASIC, C. GARROD, D. YOO, C. HIRUNCHAROENVATE, R. AZIZ, N. R. THIRUVENGADAM, Y. HUANG, A. STEINFELD. *Field Trial of Tiramisu: Crowd-sourcing Bus Arrival Times to Spur*

Co-design, in "Proceedings of the SIGCHI Conference on Human Factors in Computing Systems", New York, NY, USA, CHI '11, ACM, 2011, pp. 1677–1686, http://doi.acm.org/10.1145/1978942.1979187