RESEARCH CENTRE

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2023 ACTIVITY REPORT

Project-Team MIMOVE

Middleware on the Move

DOMAIN

Networks, Systems and Services, Distributed Computing

THEME

Distributed Systems and middleware

Inria

Contents

Project-Team MIMOVE 1

1 Team members, visitors, external collaborators 2

2 Overall objectives 3

3 Research program 3
3.1 Emergent mobile distributed systems . . . 3
3.2 Large-scale mobile sensing and actuation . . . 3
3.3 Mobile social crowd-sensing . . . 4

4 Application domains 4
4.1 Mobile urban systems for smarter cities . . . 4

5 New software, platforms, open data 5
5.1 New software . . . 5
5.1.1 DeXMS . . . 5
5.1.2 SenseTogether . . . 5
5.1.3 SocialBus . . . 6

6 New results 6
6.1 Collaborative systems for large-scale online citizen participation . . . 6
6.2 Building Online Public Consultation Knowledge Graphs . . . 6
6.3 AutoClass: AutoML for Data Stream Classification . . . 7
6.4 A Service Bus Architecture for Highly Distributed and Dynamic IoT Environments . . . 7
6.5 FaaS for IoT: Evolving Serverless towards Deviceless in I/O clouds . . . 7

7 Partnerships and cooperations 8
7.1 European initiatives . . . 8
7.1.1 Horizon Europe . . . 8
7.2 National initiatives . . . 9

8 Dissemination 10
8.1 Promoting scientific activities . . . 10
8.1.1 Scientific events: selection . . . 10
8.1.2 Invited talks . . . 10
8.1.3 Scientific expertise . . . 10
8.2 Teaching - Supervision - Juries . . . 10
8.2.1 Supervision . . . 11

9 Scientific production 11
9.1 Major publications . . . 11
9.2 Publications of the year . . . 11

Project-Team MIMOVE

Creation of the Project-Team: 2018 February 01

Keywords

Computer sciences and digital sciences

A1.2.1. – Dynamic reconfiguration
A1.2.3. – Routing
A1.2.4. – QoS, performance evaluation
A1.2.5. – Internet of things
A1.2.6. – Sensor networks
A1.2.7. – Cyber-physical systems
A1.3. – Distributed Systems
A1.4. – Ubiquitous Systems
A1.5. – Complex systems
A1.5.1. – Systems of systems
A1.5.2. – Communicating systems
A2.5. – Software engineering
A2.6.2. – Middleware
A3.1.7. – Open data
A3.1.8. – Big data (production, storage, transfer)
A3.3. – Data and knowledge analysis
A3.5. – Social networks

Other research topics and application domains

B6.3. – Network functions
B6.4. – Internet of things
B6.5. – Information systems
B8.2. – Connected city
B8.5.1. – Participative democracy

1 Team members, visitors, external collaborators

Research Scientists

- Nikolaos Georgantas [Team leader, INRIA, Researcher, HDR]
- Maroua Bahri [INRIA, Starting Research Position, from Apr 2023]

Post-Doctoral Fellow

- Maroua Bahri [INRIA, Post-Doctoral Fellow, until Mar 2023]

PhD Students

- Shahin Abdoul Soukour [Sorbonne Université until Sep 2023, then INRIA]
- William Aboucaya [INRIA, until Mar 2023]
- Haidong Zhao [INRIA, from Mar 2023]

Technical Staff

- William Aboucaya [INRIA, Engineer, from Apr 2023]
- Zakaria Benomar [INRIA, Engineer]
- Patient Ntumba Wa Ntumba [INRIA, Engineer, until Jan 2023]

Administrative Assistants

- Nathalie Gaudechoux [INRIA, until Feb 2023]
- Meriem Guemair [INRIA]
- Diana Marino Duarte [INRIA, from Mar 2023]

External Collaborators

- Rachit Agarwal [Merkle Science]
- Rafael Angarita Arocha [Université Paris Nanterre, Associate Professor]
- Georgios Bouloukakis [Télécom SudParis, Associate Professor]
- Vassilis Christophides [ENSEA, Professor]
- Bruno Lefevre [Université Sorbonne Paris Nord]
- Patient Ntumba Wa Ntumba [CNAM, from Feb 2023]
- Françoise Sailhan [IMT-Atlantique, Professor, HDR]

2 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.

This challenging context raises key research questions:

- How to deal with heterogeneity and dynamicity, which create runtime uncertainty, when developing and running mobile systems in the open and constantly evolving Internet and IoT environment?
- How to raise human centric crowd-sensing to a reliable means of sensing world phenomena?

3 Research program

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.

3.1 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. 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 [2, 4].

3.2 Large-scale mobile sensing and actuation

The extremely large scale and dynamicity expected in future mobile sensing and actuation systems lead to the clear need for algorithms and protocols for addressing the resulting challenges. More specifically, since connected devices will have the capability to sense physical phenomena, perform computations to arrive at decisions based on the sensed data, and drive actuation to change the environment, enabling proper coordination among them will be key to unlocking their true potential. Although similar challenges have been addressed in the domain of networked sensing, including by members of the team [8], 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. MiMove's research investigates techniques for efficient coordination of future mobile sensing and actuation systems with a special focus on their dependability.

3.3 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, 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.

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

In particular, we concentrate on the following specialized applications:

- **Democratization of urban data for healthy cities.** We integrate the various urban data sources, especially by way of crowd-Xing, to better understand city nuisances. This goes 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).
- **Social applications.** Mobile applications are being considered by sociologists as a major vehicle to actively involve citizens and thereby prompt them to become activists. We study such a vehicle from the ICT perspective and in particular elicit relevant middleware solutions to ease the development of such "*civic apps*".

5 New software, platforms, open data

5.1 New software

5.1.1 DeXMS

Name: Data eXchange Mediator Synthesizer

Keywords: Internet of things, Middleware protocol interoperability, Edge Computing

Functional Description: To deal with the high technology diversity of the IoT solutions landscape, we have introduced a systematic solution to the IoT interoperability problem at the middleware layer. We identify common interaction abstractions across the multitude of existing heterogeneous IoT protocols and model them into the DeX (Data eXchange) API & connector model. We further elicit the DeXIDL (Interface Description) language to describe the application interfaces of Things in a common abstract way. Based on DeX and DeXIDL, we introduce an architecture for mediators that can bridge heterogeneous Things and their protocols. The outcome of our overall effort is the DeXMS (Mediator Synthesizer) development & runtime framework, which supports the automated synthesis, deployment and execution of mediators at the edge.

URL: https://gitlab.inria.fr/DeXMS

Contact: Nikolaos Georgantas

Participants: Georgios Bouloukakis, Nikolaos Georgantas, Patient Ntumba Wa Ntumba, Zakaria Benomar

5.1.2 SenseTogether

Keywords: Mobile Crowdsensing, Sensor Calibration, Context Inference, Edge Computing

Functional Description: Our work aims to raise opportunistic mobile crowdsensing to a reliable means of observing phenomena, focusing on urban environmental monitoring. More specifically, the mobile crowdsensors contribute measurements related to the physical environment (e.g., ambient temperature, air pressure, ambient humidity, ambient light, sound level, magnetic field) using the embedded/connected sensors on smart devices. To this end, we have developed a set of protocols that together support "context-aware collaborative mobile crowdsensing at the edge", by combining the following complementary features:

(i) CalibrateNoiseTogether: Multi-hop, multiparty calibration to ensure the accuracy of sensors embedded in or connected to smartphones. Sensors that are within a relevant sensing and communication range coordinate so that the observations of previously calibrated sensors serve calibrating new sensors.

(ii) ContextSense: Inference of the crowdsensors' physical context so as to characterize the gathered data. Indeed, the relevance of the provided measurements depends on the adequacy of the sensing context with respect to the analyzed phenomena. We introduce an online learning approach to support the local inference of the sensing context that can evolve according to the environment in which it takes place.

(iii) BeTogether: Context-aware grouping of crowdsensors to share the workload and filter out low quality data. We leverage D2D communication and introduce a context-aware and cloudless collaboration strategy in which crowdsensor groups are maintained in an autonomous and distributed way to monitor a physical phenomenon of interest.

(iv) IAM (Interpolation and Aggregation on the Move): Data processing at the edge to enhance the knowledge transferred to the cloud and reduce the data uploading and resource consumption in the cloud. The data interpolation and aggregation is based on opportunistic meetings of the crowdsensors, and the relay decision is made based on the quality of the inferred data.

URL: https://github.com/sensetogether

Contact: Nikolaos Georgantas

Participants: Yifan Du, Francoise Sailhan, Valerie Issarny

5.1.3 SocialBus

Name: Universal Social Network Bus

Keywords: Middleware, Interoperability, Social networks, Software Oriented Service (SOA)

Functional Description: Online social network services (OSNSs) have become an integral part of our daily lives. At the same time, the aggressive market competition has led to the emergence of multiple competing siloed OSNSs that cannot interoperate. As a consequence, people face the burden of creating and managing multiple OSNS accounts and learning how to use them, to stay connected. The goal of the Universal Social Network Bus (USNB) is to relieve users from such a burden, letting them use their favorite applications to communicate.

URL: https://cicamo-re.netlify.app/#socialbus

Contact: Nikolaos Georgantas

Participants: Rafael Angarita Arocha, Lior Diler, William Aboucaya, Valerie Issarny, Nikolaos Georgantas

6 New results

6.1 Collaborative systems for large-scale online citizen participation

Participants: William Aboucaya, Rafael Angarita, Valérie Issarny, Nikolaos Georgantas.

Online participatory platforms have become a common means to involve citizens in public decision-making, allowing for participation at a larger scale than their offline counterparts, both in the number of participants and in the geographical distribution. However, the term “participatory platform” covers a wide range of extremely different systems, implying differences in the problems encountered by platforms administrators and contributors. More precisely, such platforms face specific issues when they aim at allowing citizens to collaborate to produce common contributions or when the number of contributors involved becomes particularly high. This Ph.D. research aims at identifying issues in contemporary online citizen participation platforms and proposing technical means to create participatory platforms more collaborative and suitable for large-scale online participation. My thesis is mainly based on previous works produced in the Computer-Supported Collaborative Work (CSCW) and Natural Language Processing (NLP) fields of computer science research. The contributions of this thesis are: the identification of flaws in a specific citizen participation platform and the recommendation of platform design-oriented alternatives to solve them; the representation of a participatory platform as a knowledge graph and its enrichment using a preexisting external knowledge base; the identification of the different objectives motivating the creation of participatory platforms and of the different types of features for interaction implemented based on a series of interviews; the conception and implementation of a Natural Language Inference-based method to reduce issues faced by online citizen participation when the number of contributors becomes particularly high.

6.2 Building Online Public Consultation Knowledge Graphs

Participants: William Aboucaya, Sonia Guehis, Rafael Angarita.

Online consultation platforms have improved the possibilities for citizens to have an input on public decision making. However, and especially at large scale, identification of the topics discussed and entities evoked has been identified as difficult for both citizens and platform administrators. In this paper, we leverage topic modeling, Named Entity Recognition and Linking and Semantic Textual Similarity to build a knowledge graph representing the different contributions to the République Numérique online citizen consultation in French language. The generated graph links the different proposals to topics identified in the consultation and to relevant DBpedia resources. The model proposed for representation of citizen consultations as knowledge graphs simplifies the retrieval of proposals focused on specific topics or mentioning a given entity. It also allows us to improve contextualization of important words in proposals by linking them to short definitions extracted from Wikipedia.

6.3 AutoClass: AutoML for Data Stream Classification

Participants: Maroua Bahri, Nikolaos Georgantas.

Automated Machine Learning (autoML) is a novel topic that aims to tackle the parameter configuration issue using automatic monitoring models and comprises different machine learning tasks, such as feature selection, model selection, and hyper-parameter tuning. It makes easier use of algorithms for non-ML experts as well as ML experts by automating tasks that rely on expert domain knowledge. Nevertheless, autoML is in its infancy stage and not well explored yet in the offline and stream settings. In this paper, we propose automated Classification (auto-Class) method for automated algorithm selection and configuration for data stream classification. AutoClass consists of training an ensemble of different tuned configurations and selecting the best-performing configuration to do the prediction. We present experiments performed on a diverse set of real and artificial datasets and show how our proposed approach can outperform the performance of competitive state-of-the-art ensemble and single-based methods.

6.4 A Service Bus Architecture for Highly Distributed and Dynamic IoT Environments

Participants: Marco Garofalo, Zakaria Benomar, Francesco Longo, Giovanni Merlino, Nikolaos Georgantas, Antonio Puliafito.

The Internet of Things (IoT) impacts numerous application domains nowadays, including smart cities, smart factories, and intelligent transportation, to name a few. However, leveraging the IoT within software applications raises tremendous challenges from the networking up to the application layer due to the ultra-large-scale, extreme heterogeneity, and dynamics of IoT. This paper explores how the service-oriented architecture paradigm may be revisited to address communication challenges posed by the IoT for the development of distributed applications in the IoT realm.

6.5 FaaS for IoT: Evolving Serverless towards Deviceless in I/O clouds

Participants: Giovanni Merlino, Giuseppe Tricomi, Luca D'Agati, Zakaria Benomar, Francesco Longo, Antonio Puliafito.

The burgeoning paradigms of Fog and Edge computing propose delegating Cloud-related tasks to the network's periphery, thus placing computational resources closer to data producers. This shift promises to boost the performance of IoT-based services, providing swift response times while conserving bandwidth. Despite their potential, the current Edge/Fog computing platforms must provide the required flexibility for dynamic service orchestration within a data-oriented context. Addressing this gap, the Function-as-a-Service (FaaS) model emerges as an exceptional strategy for Edge/Fog deployments. Its ability

to manage an ever-expanding ecosystem of devices with remarkable flexibility and efficiency holds considerable promise. This paper articulates a novel approach to enhancing the adaptability of IoT Edge/Fog deployments. We propose an innovative extension to OpenStack, an open-source Cloud management system, which pushes its functionality towards the network Edge. Our approach empowers OpenStack to facilitate FaaS services within a distributed IoT infrastructure, thus infusing unprecedented adaptability and efficiency into the Edge/Fog computing paradigms.

7 Partnerships and cooperations

7.1 European initiatives

7.1.1 Horizon Europe

SEDIMARK

Participants: Nikolaos Georgantas, Maroua Bahri.

SEDIMARK project on cordis.europa.eu

Title: SEcure Decentralised Intelligent Data MARKetplace

Duration: From October 1, 2022 to September 30, 2025

Partners:

- INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET AUTOMATIQUE (INRIA), France
- WINGS ICT SOLUTIONS TECHNOLOGIES PLIROFORIKIS KAI EPIKOINONION ANONYMI ETAIREIA (WINGS ICT SOLUTIONS AE), Greece
- UNIVERSITY COLLEGE DUBLIN, NATIONAL UNIVERSITY OF IRELAND, DUBLIN (NUID UCD), Ireland
- FORUM VIRIUM HELSINKI OY (RADIO- JATELEVISIOTEKNIIKAN TUTKIMUS RTT), Finland
- SIEMENS SRL, Romania
- ATOS SPAIN SA, Spain
- AYUNTAMIENTO DE SANTANDER, Spain
- MYTILINAIOS ANONIMI ETAIREIA (MYTILINEOS), Greece
- UNIVERSIDAD DE CANTABRIA (UC), Spain
- FONDAZIONE LINKS - LEADING INNOVATION & KNOWLEDGE FOR SOCIETY (FONDAZIONE LINKS), Italy
- ATOS IT SOLUTIONS AND SERVICES IBERIA SL (ATOS IT), Spain
- UNIVERSITY OF SURREY (SURREY), United Kingdom
- EASY GLOBAL MARKET SAS (EGLOBALMARK), France

Inria contact: Nikolaos Georgantas

Coordinator: ATOS SPAIN SA, Spain

Summary: The EU data economy has grown tremendously, with forecasts predicting to reach 800Billion Euros in 2025. Data are becoming the new currency, being exchanged as products or services in marketplaces. Data markets are predicted to reach a size of 100 Billion Euros in 2025. Existing data marketplaces are centralised, store the data on the cloud, provide limited to no guarantees about data quality and they are governed by single entities that make the rules. SEDIMARK merges

the expertise of a large team of experts to build a secure, trusted and intelligent decentralised data and services marketplace, based on Distributed Ledger Technology and Artificial Intelligence. SEDIMARK enables distributed heterogeneous data within the EU to be easily and seamlessly linked, shared and exploited for diverse business and research scenarios. SEDIMARK builds upon the concept of FAIR data, ensuring that data are of the highest quality, unbiased, enriched and annotated, so that they can be discovered, accessed, and easily reused. SEDIMARK includes a distributed registry of resources (data/services) stored on edge systems, close to where they are generated and where the data are cleaned, labelled, validated and anonymised. Security is applied with strong access control, privacy techniques for data minimisation and purpose limitation, exploiting blockchain for enforcing trust, decentralised identities, and data verification. Energy efficient AI techniques will be used for automated data quality management, labelling and classification of data as well as for providing (distributed) analytics and advanced services on top of the data. Semantic interoperability based on common ontologies and data models will allow the easy and efficient discovery, sharing and federation of heterogeneous data from multiple sources. The system is built on top of existing platforms of the consortium, starting from TRL5 and will be tested and demonstrated in four real world scenarios, reaching TRL-8.

7.2 National initiatives

BPI – France Relance – 5G Events Labs

Participants: Nikolaos Georgantas, Patient Ntumba, Zakaria Benomar, William Aboucaya, Shahin Abdoul Soukour.

Partner Institutions:

- Orange
- Ericsson
- INRIA
- CEA - Centre de Saclay

Duration: 2021 - 2024

Additional info: The 5G Events Labs project aims to boost the economic activity of the events, culture and sports sectors, around ten major sites in France where Orange and its partners will offer 5G coverage, technological platforms and adapted support enabling companies to leverage these technologies and incubate innovations in the areas of services for attendees and organizers. MIMOVE brings expertise in middleware solutions for the IoT that support intelligent spaces and applications across the mobile-edge-cloud continuum.

BPI – France Relance – Cloud Platform For Smart City (CP4SC)

Participants: Nikolaos Georgantas, Zakaria Benomar, William Aboucaya.

Partner Institutions:

- ATOS
- Ericsson
- INRIA
- INRAE
- IFPEN

- Oslandia
- Vertical M2M

Duration: 2023 - 2024

Additional info: The objective of the CP4SC platform is to help governments implement ambitious policies towards carbon neutrality by ingesting data from different verticals such as mobility, energy management and earth and environmental observation. MIMOVE brings expertise in middleware solutions for the IoT that support communication protocol and application data exchange interoperability.

8 Dissemination

8.1 Promoting scientific activities

8.1.1 Scientific events: selection

Member of the conference program committees

- Nikolaos Georgantas, member of the TPC of the following international conferences: ACM SAC'23, IEEE SOSE'23, IEEE SMARTCOMP'23, SEAMS'23, IEEE MetaCom'23.
- Maroua Bahri, member of the TPC of the following international conferences: IJCAI'23, PAKDD'23, SAC'23.
- Nikolaos Georgantas, member of the TPC of the following international workshop: MRT'23.

8.1.2 Invited talks

- Maroua Bahri, "Efficient data stream mining", Université Paris 8, Feb 2023.
- Maroua Bahri, "Data stream mining", LRI-LaHDAK team, CentraleSupélec, Oct 2023.
- Zakaria Benomar, "A middleware-based approach for enabling interoperable IoT-to-Edge-to-Cloud environments", INRIA Brasil Workshop @ São Paulo, April 10th - 11th, University of São Paulo.
- Zakaria Benomar, "Interoperability in the IoT-to-Edge-to-Cloud continuum", International Workshop on Information Technology and Communication for a Smart City (IWITIC'23), Gustave Eiffel University, May 2023.

8.1.3 Scientific expertise

- Maroua Bahri, Reviewer for a CEFIPRA Indo-French call for project proposals, Nov 2023.

8.2 Teaching - Supervision - Juries

- Maroua Bahri, "Databases", for 2nd year engineering students (12h, 107 students), lecturer at Télécom Paris.
- Maroua Bahri, "Data stream mining", for 2nd year master students (3h), lecturer at Télécom Paris.
- Maroua Bahri, "Data stream mining", for specialized master students (14h, 6 students), lecturer at Université Paris-Cité.

8.2.1 Supervision

- PhD defense: William Aboucaya, "Collaborative systems for large-scale online citizen participation", Sorbonne Université, Nov 30, 2023, Valérie Issarny, Rafael Angarita, Nikolaos Georgantas.
- PhDs in progress:
  - Shahin Abdoul Soukour (from October 2020): "Leveraging domain knowledge in requirements engineering for IoT applications", Sorbonne University, Nikolaos Georgantas.
  - Haidong Zhao (from March 2023): "Edge Inference Serving System for Industrial Monitoring", Sorbonne Université, Nikolaos Georgantas.

9 Scientific production

9.1 Major publications

[1] R. Angarita, B. Lefèvre, S. Ahvar, E. Ahvar, N. Georgantas and V. Issarny. 'Universal Social Network Bus: Towards the Federation of Heterogeneous Online Social Network Services'. In: *ACM Transactions on Internet Technology* (2019). DOI: 10.1145/3323333. URL: https://hal.inria.fr/hal-02072544.

[2] A. Bennaceur and V. Issarny. 'Automated Synthesis of Mediators to Support Component Interoperability'. In: *IEEE Transactions on Software Engineering* (2015), p. 22. URL: https://hal.inria.fr/hal-01076176.

[3] B. Billet and V. Issarny. 'Spinel: An Opportunistic Proxy for Connecting Sensors to the Internet of Things'. In: *ACM Transactions on Internet Technology* 17.2 (Mar. 2017), pp. 1–21. DOI: 10.1145/3041025. URL: https://hal.inria.fr/hal-01505879.

[4] G. Blair, A. Bennaceur, N. Georgantas, P. Grace, V. Issarny, V. Nundloll and 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. URL: http://hal.inria.fr/inria-00629059/en.

[5] G. Bouloukakis, N. Georgantas, P. Ntumba and V. Issarny. 'Automated synthesis of mediators for middleware-layer protocol interoperability in the IoT'. In: *Future Generation Computer Systems* 101 (Dec. 2019), pp. 1271–1294. DOI: 10.1016/j.future.2019.05.064. URL: https://hal.inria.fr/hal-02304074.

[6] M. Caporuscio, P.-G. Raverdy and V. Issarny. 'ubiSOAP: A Service Oriented Middleware for Ubiquitous Networking'. In: *IEEE Transactions on Services Computing* 99 (2012). DOI: \url{http://doi.ieeecomputersociety.org/10.1109/TSC.2010.60}. URL: http://hal.inria.fr/inria-00519577.

[7] Y. Du, F. Sailhan and V. Issarny. 'Let Opportunistic Crowdsensors Work Together for Resource-efficient, Quality-aware Observations'. In: *PerCom 2020: IEEE International Conference on Pervasive Computing and Communications*. Austin / Virtual, United States, Mar. 2020. DOI: 10.1109/PerCom45495.2020.9127391. URL: https://hal.archives-ouvertes.fr/hal-02463610.

[8] S. Hachem, A. Pathak and V. Issarny. 'Service-Oriented Middleware for Large-Scale Mobile Participatory Sensing'. In: *Pervasive and Mobile Computing* (2014). URL: http://hal.inria.fr/hal-00872407.

9.2 Publications of the year

International journals

[9] G. Merlino, G. Tricomi, L. D'Agati, Z. Benomar, F. Longo and A. Puliafito. 'FaaS for IoT: Evolving Serverless towards Deviceless in I/Oclouds'. In: *Future Generation Computer Systems* (2nd Jan. 2024). DOI: 10.1016/j.future.2023.12.029. URL: https://hal.science/hal-04405277.

International peer-reviewed conferences

[10] S. Abdoul Soukour, W. Aboucaya and N. Georgantas. 'Leveraging Knowledge Graphs for Goal Model Generation'. In: 7th Workshop on Natural Language Processing for Requirements Engineering (NLP4RE) in conjuction with the 30th International Woking Conference on Requirements Engineering: Foundation for Software Quality (REFSQ 2024). Winterthur, Switzerland, 8th Apr. 2024. URL: https://inria.hal.science/hal-04486653.

[11] W. Aboucaya, S. Guehis and R. Angarita. 'Building Online Public Consultation Knowledge Graphs'. In: Text2KG 2023: International Workshop on Knowledge Graph Generation from Text, Co-located with the ESWC 2023. Hersonissos (Crete), Greece, 28th May 2023, p. 12. URL: https://inria.hal.science/hal-04076743.

[12] M. Bahri and N. Georgantas. 'AutoClass: AutoML for Data Stream Classification'. In: 8th Workshop on Real-time Stream Analytics, Stream Mining, CER/CEP & Stream Data Management in Big Data in conjunction with the IEEE International Conference on Big Data 2023. Sorrento, Italy, 18th Nov. 2023. URL: https://inria.hal.science/hal-04338637.

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National peer-reviewed Conferences

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