

Département
D3: Networks, Systems and Services

Équipe Simbiot

SIMulating and Building IOT

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Loria



Laboratoire lorrain de recherche en informatique et ses applications

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En partenariat avec
Inria



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Team Simbiot

Keywords

Cyber-physical systems, IoT networks, UAV, quadruped robots, Co-simulation, Quality of Service, Real-time, Embedded computing, Parallel computing, Numerical simulation, machine learning.

1 Team members, visitors, external collaborators

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- Matthieu Amet [UL, PhD Student, ,]
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2 Overall objectives

The goal of the team is the design and validation of “smart” Cyber-Physical systems. The members of SIMBIOT concentrate their work on the adaptability properties of cyber-physical systems, in terms of calculations and communications, in order to increase their autonomy capacity.

The research program is divided into 3 axes :

- Abstractions and architectures for multi-modelling, modular design, design and validation of cyber-physical systems;
- Efficient distributed and parallel computing algorithms in cyber-physical systems;
- Communications architectures, protocols and Quality of Service (QoS) enhancement to support real-time interactions in cyber-physical systems.

For each scientific challenge, the validation is carried out, among other things, by co-simulation, in-situ experimentation, and formal analysis. This constitutes a challenge orthogonal to the previous ones.

3 Research program

3.1 Abstractions and architectures for multi-modeling

Cosimulation of cyberphysical systems

Most modeling and simulation (M&S) questions about cyber-physical systems (CPS) require expert skills belonging to different scientific fields. The challenges are then to rigorously integrate each domain's tools (formalism and simulation software) within the rigorous framework of M&S process.

To address this issue, we decided to use co-simulation[0]. We propose the specifications in DEVS formalism of a co-simulation framework which enables to interconnect several pre-existing and heterogeneous M&S tool.

From the conceptual and formal perspectives, we developed the previous years a rigorous specification of DEVS wrapping strategy for heterogeneous models/simulators integration implemented in the MECSYCO (www.mecsyco.com) framework.

3.2 Efficient distributed and parallel algorithms in cyber-physical systems

As part of CPS, SIMBIOT team addresses several issues on parallel computing and numerical simulations, as well as on heterogeneous multi-robot systems.

3.2.1 Parallel computing and numerical simulations

In many physical or biological problems, numerical simulations help to understand and predict the evolution of the studied systems. However, such simulations often require very large amount of computation in order to achieve a sufficient accuracy that provides pertinent results.

We focus on developing parallel algorithms that can be used either on a single machine or on a computing cluster to simulate complex phenomena such as radiative transfer or biological neural networks.

Together with F. Aslanaj from LEMTA, we work on a reduced model of gas combustion, based on our simulation code **RAD3D: Radative 3D** that allows to obtain good accuracies while being faster than other existing methods.

Together with L. Buhry from LORIA and J. Gaidamour from IECL, we work on extensions of the biological neural network simulator **SiReNe: Simulation de Reseaux the Neurones** (Neural Networks Simulator). In particular, we focus on several improvements concerning the parallel scheme, as well as including new types of neurons in the models and a GPU support. A GPL version of the first version of the code is available online : <https://sirene.gitlabpages.inria.fr/sirene>

Finally, with N. Fatès from INRIA, we supervise the PhD of Joannès Guichon over the design and implementation of debt netting algorithms in large economic multi-graphs. In particular, this last year we have developed efficient algorithms for integral debt netting. Several useful features have been included such as parallel schemes to reduce the computation time on large graphs, and an upper bound over the available financing.

3.2.2 Heterogeneous multi-robot cyber-physical systems

Mobile robotics (e.g., drones, quadruped and biped robots, autonomous vehicles) is taking an increasingly prominent place in our daily life. How to exploit the complementary functions of those heterogeneous robots rises numerous new research challenges in terms of the coordination and collaboration in real-time. The overall research objective of SIMBIOT team is to design a system of connected robots, viewed as multi-robot Cyber-Physical Systems (CPS), conducting autonomous missions in complex real-world conditions.

3.3 Communications architectures, protocols and Quality of Service

Safety-critical cyber-physical systems such as planes, cars, satellites or power plants require the timely exchange of information and thus rely on time-sensitive networks. While traditional public networks aim at improving the mean service performances (mean ping, mean throughput), time-sensitive networks

provide guarantees for the worst case (e.g. guarantee of a maximal latency, guarantee of a minimal throughput, guarantee of no loss, ...).

Certification of safety-critical cyber-physical systems requires a formal analysis of the underlying time-sensitive networks, which can be challenging due to the wide variety of network systems and the emergent properties of a network.

The SIMBIOT team relies on different mathematical frameworks and develops models and software tools for obtaining formally-proven performance bounds of time-sensitive networks.

For the moment, time-sensitive networks are geographically limited, usually to the size of a car, a plane or a factory. Future challenges include the interconnection of different technologies (5G/TSN/satellite constellations) to support large-scale cyber-physical systems such as distributed factories or distributed power systems.

4 Application domains

Energy is one of the application domains of the Team. Since 2023, we started the Act4IE PEPR project. Integrated in the PEPR SPLEEN, ACT-4-IE is part of the axis focused on the development of tools for the design and management of industries for decarbonization of territories. Thus, this multidisciplinary project aims, through concepts of industrial ecology and more broadly, circular economy, to implement optimisation approaches to pool resource flows between different actors (industrial, territorial, municipalities, individuals).

Simbiot is involved in the Hy2car and works in the following areas: Data acquisition, physical modelling of the vehicle, and (co-)simulation.

- **Data acquisition:** The acquisition of data from a CAN bus is an essential first step in building up a set of data from which it will be possible to calibrate and validate kinetic and electrical models of the vehicle, and also to apply learning methods. We have developed a set of tools for carrying out semi-automatic measurement campaigns. These data are synchronised with geo-referencing information. Technical and user documentations are currently being finalised.
- **Modelling:** The data acquired is used either to calibrate white or grey box models, or to learn black box models. Based on the data collected, we have developed tools for either calibrating white/grey box models or learning black box models, in terms of the kinetic or electrical behaviour of the car.
- **Co-simulation architecture:** To dimension the future vehicle and/or predict its road and energy behaviour, we have designed a co-simulation architecture. Using Mecsyco, we have developed a multi-model which, on the basis of a journey, calculates the energy required by the electric car.

A part of our research activities are directly linked to mobile robotics. In particular, we have designed and implemented **NAPS: A Nomadic and Accurate Positioning System**. And together with Amaury Saint-Jore, we have embedded the system on SPOT robots (Boston Dynamics) in order to obtain an autonomous exploration system with 3D reconstruction. Also, we have explored the coloring of 3D point clouds by coupling a Lidar with one or more cameras.

5 Social and environmental responsibility

Sylvain Contassot-Vivier has the following roles:

- Elected member of the Loria Counsel
- Elected member of the Counsel of the Faculty of Sciences and Technology
- Member of the directors board of the Explor HPC Center
- Open-science ambassador for the Loria within the University of Lorraine
- Co-manager of the ATER recruitment campaign at Loria: coordination with the teaching departments of the university
- Member of the Mentoring committee at Loria
- Member of the equality workgroup at Loria

6 Highlights of the year

- Project “RÉCITAL” has been accepted in the call for projects of the French National Research Agency (ANR) in the context of the “Appel Générique 2025, JCJC”.
More information here: <https://members.loria.fr/LThomas/recital/>
- Project "CyMove": Simbiot is part of the AMI-CMA CyMoVe project consortium, coordinated by UHA (University of Haute Alsace). It aims to develop research and training programs on the topics of Cybersecurity, Mobility and Electric Vehicle. The project has started since february 2025 for a duration of 5 years.

7 New software, platforms, open data

7.1 Mecsyco

MECSYCO (Multi-agent Environment for Complex System CO-simulation) is a cosimulation software¹. The software is split in 4 main packages:

- MecsycoJava contains the core of the MECSYCO co-simulation middleware written in Java. This is the most supported version.
- MecsycoScholar is a MECSYCO user project that contains tutorials and examples.
- MecsycoCpp is a C++ version of MECSYCO used to interact with ns-3 and OMNeT++.
- MecsycoDsl is an XText project that defines Domain Specific Languages for MECSYCO . They are associated with a description-based development process.

7.2 Saihu

*Saihu*² is a tool for obtaining worst-case performance bounds of communications networks in a wide range of network configurations. Originally developed at EPFL, this macro-tool relies on various software tools, including the *xTFA* software developed by Ludovic Thomas. SIMBIOT continues to work on both *Saihu* and *xTFA* to add new features to the tools and support new types of networks. Both *Saihu* and *xTFA* are open-source projects.

7.3 NAPS embedding on robots

A first embedded prototype of the NAPS positioning system has been released this last year. It has allowed us to perform a series of tests that have validated the feasibility of the aimed autonomous system. Then, we have added several extensions to this system and we have studied the combination of different capture sensors to reconstruct the environment. The technology transfer company SATT Sayens has supported the NAPS project by financing the patent until 2025 and by promoting our technology in the industry and providing pertinent contacts with companies.

7.4 SiReNe extensions

Our simulator of biological neuronal networks has been strongly redesigned these two last years. We have enhanced the parallel schemes, in particular in distributed computing contexts (cluster of machines) and started to develop a GPU support. We continue to develop specific algorithms to enhance performance and memory consumption. In particular, internships are scheduled this year to continue the developments on GPU aspects and models representations. In addition, new neural models with non-spiking neurons, like in the retina, have been added to the simulator. This allows us to simulate a wider range of brain areas and structures.

¹mecsycocom

²<https://github.com/adfee1220/Saihu-TSN-Analysis-Tool-Integration>

7.5 Murene software

In the scope of the PhD thesis of J. Guichon, a new software has been developed to compute integral debt netting on large B2B graphs. This software is currently the subject of a deposit to the APP agency.

7.6 Simsennet and Simsennet-toolbox

Simsennet (SIMbiot SENsor NETwork) is a software platform for raspberry Pi computer. It is made of several linux systemd services allowing the deployment of a network based on wireless communication. The Simsennet is also developed to be resistant at reboot and needs no manual configuration.

The Simsennet-toolbox is a set of installation scripts to build a simsennet network from scratch. Save to this, a new network could be made in few minutes.

7.7 Development on the Microsoft's Library for QUIC

Our merge request³ on `msquic` (Microsoft's open-source library for the QUIC Protocol) has been accepted and is now integrated in `msquic`. It introduces a new flag, `QUIC_SEND_FLAG_DGRAM_CANCEL_ON_BLOCKED`, that allows `msquic` to drop queued datagrams when sending is blocked, reducing excessive delays caused by buffering. The change mirrors UDP's behavior under similar conditions, ensuring more consistent one-way delay.

7.8 Heterogeneous Multi-Agent Systems

This open source project aims to design a generic, decentralized, and interoperable system via the ROS 2 middleware, enabling autonomous missions in complex real-world environments, with interaction and collaboration between robots and human operators. Two original approaches to real-time 3D localization are proposed: a RTK GNSS solution for outdoor use and the NAPS nomadic system for indoor use, both offering robust centimeter-level accuracy and suitable for multi-agent systems. A role-based trust model is also introduced to monitor agent behaviors, detect anomalies, and enhance system resilience. All these contributions, integrated into ROS 2, were tested on a real HMAS combining ground and aerial mobile robots. It is available on github [[saintjore:hal-05285843v1](https://github.com/saintjore:hal-05285843v1)].

7.9 Open data

In the context of I.Hamdioui PhD thesis and in collaboration with UIR (Rabat,Morocco), a comprehensive dataset was created using real-world data collected from the Renault Kangoo ZE electric vehicle via the On-Board Diagnostics (OBD) protocol.

The dataset was obtained from ten real-world driving sessions conducted across a range of weather conditions, spanning warm to cold climates.

Each trip contains approximately 10,000 data points capturing key parameters related to vehicle dynamics and battery performance. All trips were recorded using the same lithium-battery electric vehicle and an identical sensor configuration.

The objective of this dataset is to support research and development in:

- Electric vehicle performance analysis
- Battery behavior modeling

The dataset has been deposited in Mendeley Data under embargo and will be made publicly available upon publication of the accompanying manuscript. A DOI has been reserved for this dataset [0].

³<https://github.com/microsoft/msquic/pull/4320>

8 New results

8.1 Abstractions and architectures for multi-modeling

Participants: Vincent Chevrier, Ikram Hamdioui, Diego Vega.

8.1.1 Cosimulation based optimization

Simulation-based engineering has become a cornerstone when designing new systems or products. This approach is coupled with an optimization phase in which the engineering result is tailored to optimize different design aspects (sizing components, minimizing cost, etc.). In the case of complex systems, such as cyber-physical systems, their modeling and simulation call for multi-domain expertise. As a consequence, a simulation-based approach that integrates different simulators is needed; this is called co-simulation. This PhD thesis is motivated by the increasing presence of complex system problems being solved with co-simulation combined with optimization techniques; this combined method is not yet established as a structured tool to study complex systems. The objective of the thesis is to consolidate the existing applications found in the literature into a generalized framework that can define co-simulation-based optimization as a reference method that is validated with any further application, rather than scattered ad-hoc applications, for this reason, we highlighted the necessity for a co-simulation-based optimization state-of-the-art survey, since there is no such survey in the literature, we submitted the survey to the ACM Computer survey journal (journal ranked Q1 in computed science), which is currently in the second stage review. The results obtained from the state-of-the-art survey are: the presence of many applications of the combined method with different strategies, a lack of a general framework, and finally, some key characteristics are repeated within the many frameworks found. These findings constitute the basis for the main contribution of this thesis, which is the proposal of a general framework that implements all the key characteristics identified in the literature review (modularity, flexibility, extensibility, interface generalization, and the pre-processing stage); to showcase the presence and advantages of these characteristics, we implemented the framework in the co-simulation software MECSYCO and developed 3 study cases combined with 3 optimization algorithms to challenge the proposed framework. This thesis work was finished and successfully defended on December 9th in Loria.

8.1.2 Building an AI-Based Digital Twin for Electric Vehicles

As part of the LIA (International Associated Laboratory) DataNet, joint between UL and UIR (International Universities of Rabat), TICLab and LORIA started a joint PhD supervision on the theme of digital technology for mobility, and more precisely that of the digital twin which combines digital modeling with the integration of data from the target system as well as the possibility of acting in return on the latter. Over the past year, we progressed on the following aspects:

State Estimation The first focus area was the estimation of the battery state, which involved:

- **Data Collection:** A comprehensive dataset was created using real-world data collected from the Renault Kangoo ZE electric vehicle via the On-Board Diagnostics (OBD) protocol.
- **Machine Learning Model Development:** Utilizing the collected data, various machine learning algorithms were employed to predict critical battery parameters, such as State of Charge (SoC), using parameters like battery current, voltage, and temperature.
- **Results:** The predicted SoC curve closely matches the actual SoC, validating the effectiveness of the developed models.
- **Publication:** A paper summarizing the findings has been completed and submitted in 2025.

Battery Thermal Management System With a focus on the battery's thermal behavior, the following efforts were undertaken:

- **System Modeling:** A thermal management system was modeled to regulate battery temperature during different driving cycles.
- **Importance:** Managing temperature is crucial to prevent degradation and ensure optimal performance and longevity of lithium-ion batteries.
- **Thermal Management Methods:** The battery thermal management system maintains the battery within its optimal operating temperature range by selectively activating heating or cooling systems as required during vehicle operation, thereby ensuring efficient performance, safety, and extended battery life.
- **Simulations:** Different driving conditions and their impact on battery temperature and performance are being analyzed.

Co-simulation framework This step involved integrating the individually modeled subsystems developed in this thesis, along with existing models available in the LORIA and the TIClab, into a unified co-simulation framework toward the development of an electric vehicle digital twin.

- **Case Study:** A first case study was then conducted to evaluate the impact of driving style on energy consumption and on the prediction of the battery's state of charge (SoC).
- **Publication:** A paper presents the first case study and demonstrates the potential of the co-simulation framework. It was accepted and presented at the IEEE ETFA International Conference in Porto in September 2025.

8.2 Efficient distributed and parallel algorithms in cyber-physical systems

Participants: Sylvain Contassot-Vivier, Joannès Guichon, Laurent Ciarletta, Ye-Qiong Song, Amaury Saint-Jore, Benjamin Phan.

8.2.1 Radiation model

As mentioned before, together with F. Asllanaj from LEMTA, we have obtained a new gas radiation model of high accuracy that is based on the principle of weighted sum of gray gases [asllanaj:hal-04375649, 0]. These results are based on our simulation code **RAD3D: Radative 3D**. S. Contassot-Vivier is involved in the scientific co-supervision of the PhD Thesis of Bowen Wang that has started in 2024 on this subject. In this context, we have obtained an improved model last year and our results are to be published soon in the International Journal of Heat and Mass Transfer.

8.2.2 Large multi-graphs analysis and processing

Together with N. Fatès from INRIA we co-supervise the PhD Thesis of J. Guichon since 2023. During his first year, he has conducted a deep statistical analysis of the structure of debt networks. These networks take the form of multi-graphs, i.e. one vertex may have several edges towards another vertex.

During his second PhD year, we have focused on developing debt netting algorithms and assessing their performance under various parameter settings, guided by specific economic constraints and expectations [0]. In parallel, we began exploring techniques to optimise graph partitioning in order to speed up computations in these algorithms without compromising their efficiency [0].

During the last year, we have focused on improving the integral debt netting algorithms. We were able to improve the computation time by more than an order of magnitude while maintaining nearly the same result quality. An additional useful feature has been added to the algorithms by introducing the possibility of limiting the available financing, allowing simulations to be closer to realistic scenarios.

Several papers, either presenting the algorithmic parts or economic effects, are currently under review for publication in academic journals. These articles are collaborative efforts with Massimo Amato, professor in economy at the Bocconi University in Milan.

8.2.3 HMAS for heterogeneous multi-robot cyber-physical systems

For addressing the integration issue of the heterogeneous mobile robots, in the PhD work of A. Saint-Jore [0], a heterogeneous multi-agent systems (HMAS) framework has been designed based on the use of the Robot Operating System (ROS 2) middleware. This HMAS framework ensures the interoperability by structuring hardware and software layers around embedded sensors and computing boards through ROS 2.

As the precise localization of agents is of prime importance, we have developed a solution for both outdoor and indoor environments using RTK GNSS and NAPS (Nomadic and Precise Positioning System) positioning systems. Our contributions consist of integrating both systems into our HMAS via ROS 2.

Real-time data exchange is another key function for ensuring the efficient multi-robotic operations. This data sharing is based on the abstract communication layer DDS (Data Distribution Service) in ROS 2. However, the QoS of the underlying networks (e.g., WiFi, LTE) is not yet supported. As a first step toward a systematic QoS mapping between DDS and the underlying network protocols, we have evaluated the network performance of our HMAS and propose solutions to optimize data transfers, enhance scalability, and enable large-scale deployment through DDS.

Trustworthiness is another important issue that we have addressed. In fact, an HMAS offering multiple services between heterogeneous agents requires a trust management mechanism for real-time evaluation and supervision of their behaviors to prevent undesirable activities caused by compromised components. We have introduced a role-based trust model, enabling the identification of these deviant behaviors. This model was implemented and validated in an HMAS using ROS 2, demonstrating its feasibility and ability to detect different types of attacks or failures.

8.2.4 Multi-agent reinforcement learning algorithms for heterogeneous multi-robotic cyber-physical systems

For providing efficient heterogeneous multi-robot coordination and collaboration, as part of a new PhD work of B. Phan started in June 2025 and in collaboration with ANDRA (French National Agency for Radioactive Waste Management), we have made a comprehensive survey of the existing multi-agent reinforcement learning (MARL) algorithms. It allowed us to identify the interests but also the current limitations in MARL when they are used in heterogeneous collaborative robots.

8.2.5 Deep reinforcement learning in case of complex environment

In an industrial context, we apply deep reinforcement learning (DRL) to a simulator of an unmanned underwater vehicle (UUV) [0]. This UUV is moving in a complex environment, that needs to compute acoustic propagation in very different scenarios. Consequently, the simulation time per time step varies greatly due to the complexity of the acoustic situation and the variation in the number of elements simulated. Therefore, we use an asynchronous actor-learner parallelization scheme to avoid any loss of computational resource efficiency. However, this variability in computation time is strongly correlated with the current state of the environment. The classical benchmarks in the DRL are not representative of the considered environment slowdowns, whether in magnitude nor in their correlation with the current observation. The aim of this paper is therefore to investigate the possible existence of a bias that could be induced by an observation-correlated slowdown in the case of a DRL algorithm using an asynchronous architecture. Through numerous simulations, we provide empirical evidence of the existence of such a bias on a modified version of the Cartpole environment. We then study the evolution of this bias as a function of several parameters: the number of parallel environments, the exploration and the positioning of slowdowns. Results show that the bias is highly dependent on the capacity of the policy to find trajectories that avoid the slowdown areas

8.3 Communications architectures, protocols, Real-time Quality of Service, Trust management and applications

Participants: Ye-Qiong Song, Emmanuel Nataf, Laurent Ciarletta, Enrico Natalizio, Ludovic Thomas, Théo Docquier, Runbo Su, Matthieu Amet

8.3.1 IoT sensor network for air quality measurement

During the year 2024, our IoT network has been used in real use cases. We measured air quality in a surgical operating theatre during patient anaesthesia procedures. The network was also used in a marble factory where the use of marble cutting machines generates a lot of particles. The network has finally been used by unqualified personnel following the procedures we provide.

These experiments enabled us to correct anomalies in the code and improve it. Some new uses were suggested for future collaboration (planned for 2025), such as the use of a centralized server to store and manage the data captured by our network. The addition of a new type of sensor (specialized in CO₂) and the possibility of defining a threshold associated with a visual alarm are also envisaged.

8.3.2 Zero-Knowledge Performance Validation and Blockchain Management of Time-Sensitive Networks

We developed a framework for the management and verification of deterministic service agreements in large-scale, multi-domain, time-sensitive networks. This framework relies on zero-knowledge proofs (ZKPs) to disclose only the minimum amount of information necessary to participating entities. These ZKPs enable the verification that network flows traversing a time-sensitive network can meet their guaranteed performance constraints.

To generate these proofs, we use Risc Zero, a verifiable virtual machine capable of executing code whose correctness can be proven, together with a blockchain-based application embedding a proof verifier. Within this environment, we implemented the Total Flow Analysis (TFA) algorithm, a network calculus-based algorithm that determines whether flow guarantees can be satisfied, and executed it inside the Risc Zero VM.

In addition, we developed a smart contract that operates alongside the Risc Zero verifier to orchestrate payments based on the proof submitted by the network operator and the outputs of the TFA algorithm. Overall, this framework enables the assessment of whether flows requiring deterministic guarantees can be supported by a given network topology, while allowing mutually untrusted parties to verify, via cryptographic proofs, that such guarantees can indeed be met.

This work was described in a conference paper submitted to INFOCOM 2026, which has been accepted and will appear in 2026.

As future work, we plan to verify that a given configuration is effectively enforced on specific devices using Linux Security Modules (LSMs) and the Trusted Platform Module (TPM). This extension will be integrated into our existing framework so that, after proving the existence of a configuration capable of meeting flow guarantees, the network is required to commit to that configuration. The solution relies on a program instantiated on each device, whose integrity is ensured via LSMs. This program generates a cryptographic fingerprint of the device configuration and commits it to the TPM. Any verifier can then quote the TPM to check that the stored value matches the configuration agreed upon in the first part of our framework. We plan to deploy and evaluate this approach using the Mininet emulator, Linux traffic control mechanisms, and a blockchain to verify the configuration fingerprints.

8.3.3 QoS in 5G and V2X networks

As part of ANR COMMITS project, we have investigated the QoS of 5G for V2X communications, especially in the use-case of URBANLOOP transportation system. In [0], we first introduced the core principles of the Urbanloop system and then examined the necessity of 5G integration by analyzing how communication QoS impacts system safety and performance. Using Veins-Simu5G, we evaluated the effects of packet

loss and latency under various communication and mobility scenarios, and the related impacts on safety distance and pod deployment density. Finally, we validated our simulation findings through preliminary real-world testing with the OAIBOX platform, built upon the OpenAirInterface framework, confirming the practical relevance of our results for future deployments.

9 Bilateral contracts and grants with industry

9.0.1 ANDRA (Agence nationale pour la gestion des déchets radioactifs)

Participants: Ye-Qiong Song, Laurent Ciarletta, Benjamin Phan.

Company : ANDRA Duration: 3 years

Title: Heterogeneous collaborative robots on new generation networks: exploration and measurement of environments.

Context: ANDRA-UL contract for the PhD thesis of Benjamin Phan (June 2025 - May 2028).

Abstract: The aim of this PhD work is to build a multi-agent based solution for heterogeneous multi-robot collaboration on new-generation wireless networks. These agents will be autonomous mobile systems (e.g., quadruped/multipod robots, aerial drones, hybrids, and may evolve as equipment becomes available during the thesis) linked by wireless networks (such as private 5G or WiFi 6E to start with, and WiFi 7 mesh later). This enables them to exchange state and context information, and their intentions in real time, and to build and collaborate to form a multi-agent system. They are equipped with on-board computers, giving them computing autonomy, but also with edge computing capabilities (Fog/Edge), increasing their resources for intensive AI algorithm computing needs (e.g., navigation, image processing, reinforcement learning). These objectives are to be achieved in a coordinated but decentralized way, involving monitoring missions, specific actions and scientific measurement campaigns in various target zones of the ANDRA laboratory, prefiguring the final storage environment at the Bure site.

10 Partnerships and cooperations

10.1 International initiatives

The PhD thesis of Ikram Hamdioui is in cotutelle with TICLab of UIR founded through LUE.

Simbiot has hosted Yuya Onogawa, PhD student from Osaka Metropolitan University, for a three-months research stay working on developing TSN over WiFi 6 for real-time QoS support.

10.2 National initiatives

10.2.1 ACT4IE, a projet from the SPLEEN PEPR

Simbiot is part of the ACT4IE project consortium, coordinated by LGC (Toulouse INP / CNRS / University of Toulouse) and involving GEPEA (IMT Atlantique / Oniris / Nantes University / CNRS), G2Elab (Grenoble INP / University Grenoble Alpes / CNRS), and IFPEN.

The fight against climate change requires a reduction in greenhouse gas emissions. In France, the industrial sector is responsible for about 20% of the emissions. Territorial symbioses (development of circularity and optimization of flows across a territory) are a rapid first reduction lever. The ACT-4-IE project aims to adopt a systemic approach to develop a methodology dedicated to the assessment, diagnosis, and optimization of resources. It is a lever for rapid reduction, but it is currently implemented in an ad-hoc manner, specific to a situation, without a structured process, and in a way that is difficult to generalize. The ACT4IE project aims to adopt a systemic approach dedicated to the assessment, diagnosis, and optimization of resources in industrial zones, and to develop a methodological framework intended

to transform economic zones. Simbiot's expertise in multimodeling and co-simulation will contribute to the development of a model integrating various flows, taking into account variations in temporal and spatial scales, and to the evaluation of strategies for centralized versus decentralized management.

In the context of this partnership, a research engineer contract started in September 2025 to define the decarbonization methodology to be offered to territories. The engineer joins the project mid-way, which means that the first stage was the revision of the progress of the project to highlight and capitalize the contributions of the work done so far, then the development of the methodology starts with an Agile approach (short cycles of requirements-development-reviewing) based on Sprints that generate functional results for each cycle. The initial approach is to collect the scientific contributions of the project into an integrated optimization model. We use the published works such as [0], [0], and [0] to propose the integrated model that will be iteratively improved towards the final product for the client (the territory).

10.2.2 ANR COMMITS

Simbiot participates to ANR COMMITS project (2024-2028) that is coordinated by LORIA RESIST team. The main objective is to develop a communication system for Urbanloop transport system supporting real-time QoS.

10.3 New National Partnerships

10.3.1 CyMoVe, a project from AMI-CMA France 2030

Simbiot is part of the AMI-CMA CyMoVe project consortium, coordinated by UHA (University of Haute Alsace). It aims to develop research and training programs on the topics of Cybersecurity, Mobility and Electric Vehicle. The project has started since february 2025 for a duration of 5 years.

10.4 Regional initiatives

10.4.1 Collaboration with the INRS

This year, the collaboration with the INRS (Institut National de la Recherche en Sécurité du travail) has been pursued. A Bachelor of Technology student, Mr Adrien MANGIN has lead to news solutions for the communication inside the sensor network [0].

The complete description of the work done with the INRS is now available in [nataf:hal-05486317]. And the source code is now stored by the APP agency under the number :

IDDN.FR.001.050042.000.S.C.2026.000.10100
(deposit 01-29-2026)

The collaboration with the INRS will be starting again with new projects for 2026. bo

11 Dissemination

11.1 Promoting scientific activities

11.1.1 Scientific events: organisation

Member of the organizing committees Vincent Chevrier co-organized with Amine El Hamri (LIS-AMU), the "Journées d'étude sur la mobilité durable : défis et solutions", the 10-11 June, at A Marseille <https://amu.hal.science/hal-05377957v1>

11.1.2 Scientific events: selection

Chair of conference program committees

Enrico Natalizio was ICCCN 2025, Track chair and IEEE VTC 2025 Spring, Track Chair.

Member of the conference program committees

Vincent Chevrier was member of the JFSMA program committee.

Ye-Qiong Song was member of the following program committees: IEEE WFCS, RTNS, ITC.

Ludovic Thomas is member of the following program committee: RTNS, the ETR summer school.

Enrico Natalizio was member of IEEE Infocom.

Member of other events committees

Sylvain Contassot-Vivier was mentor and member of the jury of the scientific Game Jam 2026 organized by Université de Lorraine at the Fêru des sciences museum.

11.1.3 Journal

Member of the editorial boards

- Ye-Qiong Song is Associate Editor of Springer Nature Real-time systems Journal.
- Enrico Natalizio is Associate Editor with Elsevier Computer Networks.

11.1.4 Invited talks

- Enrico Natalizio gave the following invited talk: "Networked Robotics for Future Mobility Systems", in 14th Workshop and Industry Panel on Cooperative Automated Driving and Future Mobility Systems, in conjunction with 36th IEEE INTELLIGENT VEHICLES SYMPOSIUM, June 2025.
- Sylvain Contassot-Vivier gave the following talk: "Réalité matérielle du numérique" (material resources behind digital technologies) at the Printemps de la Donnée 2025.

11.1.5 Scientific expertise

- Ludovic Thomas performs an expertise for ONERA and Airbus.
- Sylvain Contassot-Vivier is in the scientific counsel of Isart Digital, a private school in Video Game and Animation creation.
Also, he has performed an expertise for the PIQ Inria Quadrant program.
- Ye-Qiong Song performed an expertise for PIQ (Programme Inria Quadrant).

11.1.6 Research administration

Ye-Qiong Song was member of the HCERES committee of LAAS Toulouse.

Ye-Qiong Song is member of the scientific advisory board of IRIMAS lab of Université de Haute Alsace.

11.2 Teaching - Supervision - Juries

11.2.1 Teaching

As most of the permanent staff of the team are university employees, they teach many domains of computer science in different formations (bachelor, master, engineers). The team members delivered more than 1350 hours of classes.

11.2.2 Supervision

Interns

- Adrien Mangin, 2025-02-17 → 2025-04-25, *Etude et réalisation d'une architecture MQTT*
- Jénaël Pelmard, 2025-05-05 → 2025-06-13, *Métrologie réseau, systèmes multi-agents hétérogènes*
- Evan Berger, 2025-05-05 → 2025-06-1, *Métrologie réseau, systèmes multi-agents hétérogènes*
- Florian Delage, 2025-05-05 → 2025-06-13, *Optimisation d'un algorithme de calcul de bornes de latences pour accélérer la génération de preuves*

- Rafael Buard, 2025-05-05 → 2025-06-27, *Routage dans les Réseaux sous Contraintes de Latence*
- Adam Lamy, 2025-06-02 → 2025-07-25, *Accélération GPU d'une simulation de réseaux de neurones biologiques*
- Emeline Gehanno, 2025-06-02 → 2025-07-25, *Génération procédurale de toits*
- Douae El Ghazouali, 2025-06-16 → 2025-08-13, *Collaborations et actions d'agents dans un système robotique*
- Yassine Akremi, 2025-06-16 → 2025-08-14, *Collaborations et actions d'agents dans un système robotique*
- Axel Humbert, 2025-06-16 → 2025-08-29, *Création d'une interface web et d'un orchestrateur pour DNaaS (Deterministic Networks as a Service)*
- Vinicius Kamiya Svierk, 2025-06-02 → 2025-08-2, *Bridging Co-simulation and Optimization in Complex Systems via the Interface Component*
- Donatien Edy, 2025-06-25 → 2025-12-24, *Contrôle d'un robot quadrupède par approches d'IA et via ROS 2*
- Paul RIGAUULT-ROOS, 2025-09-08 → 2025-12-31, *Robotique CAO*
- Abel Jourdain De Muizon, 2025-09-08 → 2026-02-20, *robotique multi-agent aerospace*

11.2.3 Juries

The team members are regularly involved in HDR and PhD Committees. Also, they participate as experts to different projects evaluation committees.

Vincent Chevrier was member of the following Phd committees: Florian Condette (30/4/25, reviewer), Mathias Dehais (24/11/25, chair).

Sylvain Contassot-Vivier was member of the following PhD and HdR committees: Sheikh Shah Mohammad Motiur RAHMAN at IUT Belfort (president), Arun Thangamani at Strasbourg University (president), Radhouane Jilani at Lorraine University (president), Pierre-Frédéric Villard at Lorraine University (president).

Ye-Qiong Song was member of the following Phd and HdR committees: Matthias Houssin (17/12/2025, reviewer), Amine Brahmia (HdR, examiner).

Enrico Natalizio was member of the following Phd and HdR committees: HDR: Malisa Vucinic, PSL Université Paris, 27/10/2025 and thesis :Ahmad Merei, Université du Québec à Chicoutimi, Canada, 20/11/2025 ; Theotime Balaguer, INSA Lyon, 25/11/2025; Pravallika Katragunta, Carleton University, Canada, 18/4/2025 and Alvarado Marin, Sorbonne Université, 16/5/2025.

11.3 Popularization

11.3.1 Internal or external responsibilities

Ye-Qiong Song was member of the CNRS national committee (CoNRS section 06) until June 2025.

11.3.2 Education

Virginie Galtier developed a serious game used during work-experience placements on the Metz campus to introduce Grade 8–9 pupils to the history of computer science.

12 Scientific production

12.1 Major publications

- [0] I. Abdallah, L. Ciarletta, P. Henaff, J. Champagne and M. Bonavent. ‘Effect of a slowdown correlated to the current state of the environment on an asynchronous learning architecture’. In: *Reinforcement Learning Journal* 6 (2025), pp. 384–398. URL: <https://hal.science/hal-05294363>.
- [0] F. Asllanaj, S. Contassot-Vivier, F. Pascale, R. J. da Fonseca, G. C. Fraga and F. H. França. ‘Unified gas radiation model over the entire temperature range based on WSGG’. In: *International Journal of Heat and Mass Transfer* 241 (May 2025), p. 126713. DOI: [10.1016/j.ijheatmasstransfer.2025.126713](https://doi.org/10.1016/j.ijheatmasstransfer.2025.126713). URL: <https://hal.science/hal-04912190>.
- [0] J. Guichon, S. Contassot-Vivier and N. Fatès. ‘Integral B2B Debt Netting: Model and Static Algorithm’. In: *FRCCS 2025*. Bordeaux, France: Springer-Nature, May 2025. DOI: [10.1007/978-3-032-00206-8](https://doi.org/10.1007/978-3-032-00206-8). URL: <https://hal.science/hal-04947742>.

12.2 Publications of the year

International journals

- [0] W. Alkendi, F. Gechter, L. Heyberger and C. Guyeux. ‘Optimized Data Structuring and Preprocessing Techniques for Belfort Civil Registers of Birth Transcription’. In: *SN Computer Science* 6.5 (16th June 2025), p. 550. DOI: [10.1007/s42979-025-03987-2](https://doi.org/10.1007/s42979-025-03987-2). URL: <https://hal.science/hal-05404468>.

International peer-reviewed conferences

- [0] L. Ciarletta, J. Cotton, G. Hermand, G. Pernot and L. Briot. ‘Leveraging advanced AI robotics for monitoring radioactive waste repositories: a review of current technologies, use cases and future trends’. In: *Waste Management Symposia*. Phoenix (AZ), United States, 9th Mar. 2025. URL: <https://hal.science/hal-04812096>.
- [0] I. Hamdioui, V. Chevrier, M. Faqir, O. Karrakchou and M. Ghogho. ‘A Co-Simulation Framework for Assessing the Impact of Driving Styles on Energy Consumption and SOC Prediction in EVs’. In: *International Conference on Emerging Technologies and Factory Automation (ETFA)*. 2025 IEEE 30th International Conference on Emerging Technologies and Factory Automation (ETFA). Porto, Portugal, 9th Sept. 2025, pp. 1–4. DOI: [10.1109/ETFA65518.2025.11205778](https://doi.org/10.1109/ETFA65518.2025.11205778). URL: <https://inria.hal.science/hal-05396593>.
- [0] J. Hansert, P. Offermann and F. Gechter. ‘Solving the Lunar Lander Problem with Spiking Neural Networks and One-Hot Encoding’. In: *Artificial Intelligence Applications and Innovations. AIAI 2025*. IFIP International Conference on Artificial Intelligence Applications and Innovations (AIAI). Vol. 755. IFIP Advances in Information and Communication Technology. Limassol (Chypre), Cyprus: Springer Nature Switzerland, 22nd June 2025, pp. 29–42. DOI: [10.1007/978-3-031-96239-4_3](https://doi.org/10.1007/978-3-031-96239-4_3). URL: <https://hal.science/hal-05404764>.
- [0] S. K. Idrees, R. Couturier, J. Azar, A. K. Idrees and F. Gechter. ‘Efficient lightweight image compression approach for Multimedia Internet of Things’. In: *2025 5th IEEE Middle East and North Africa Communications Conference (MENACOMM)*. 2025 5th IEEE Middle East and North Africa Communications Conference (MENACOMM). Byblos, France: IEEE, 22nd Feb. 2025, pp. 1–6. DOI: [10.1109/MENACOMM62946.2025.10910969](https://doi.org/10.1109/MENACOMM62946.2025.10910969). URL: <https://hal.science/hal-05404492>.
- [0] R. Su, A. Lahmadi, Y.-Q. Song and J.-P. Mangeot. ‘Assessing 5G Connectivity for Urbanloop: a Pod-based Autonomous Railway Transport System’. In: *2025 IEEE 102nd Vehicular Technology Conference*. Chengdu, China, 2025. URL: <https://hal.science/hal-05157729>.

Conferences without proceedings

- [0] S. Contassot-Vivier. ‘Réalité matérielle du numérique’. In: *Printemps de la Donnée 2025*. Rennes, France, 20th Mar. 2025. URL: <https://hal.inrae.fr/hal-05018444>.

- [0] J. Guichon, S. Contassot-Vivier and N. Fatès. ‘A divide-and-conquer approach for B2B integral debt netting’. In: *Conférence 2025 du chapitre local de la Complex Systems Society*. Paris, France, 23rd June 2025. URL: <https://hal.science/hal-04994717>.
- [0] A. Picard, Y. Mualla and F. Gechter. ‘Explaining in Natural Language: A Discussion on Leveraging the Reasoning Capabilities of LLMs for XAI ★’. In: *xAI 2025 Late-breaking Work, Demos and Doctoral Consortium*, 3rd World Conference on eXplainable Artificial Intelligence (xAI 2025). Istanbul, Turkey, 11th July 2025. URL: <https://hal.science/hal-05404748>.

Edition (books, proceedings, special issue of a journal)

- [0] M. E. A. Hamri and V. Chevrier, eds. *Actes des journées d'étude sur la mobilité durable : défis et solutions*. Actes des journées d'étude sur la mobilité durable : défis et solutions. MARSEILLE, France, 2025. URL: <https://amu.hal.science/hal-05377957>.
- [0] M. E. A. Hamri and V. Chevrier, eds. *Actes des journées d'étude sur la mobilité durable : défis et solutions*. Journées d'étude sur la mobilité durable : défis et solutions. Marseille, France, 2025. URL: <https://amu.hal.science/hal-05454394>.

Doctoral dissertations and habilitation theses

- [0] A. Saint-Jore. ‘Heterogeneous multi-agent systems applied to interconnected collaborative mobile robotics’. Université de Lorraine, 26th Nov. 2025. URL: <https://theses.hal.science/tel-05538139>.

Reports & preprints

- [0] M. Amato, S. Contassot-Vivier, N. Fatès, L. Gobbi and J. Guichon. *Reducing B2B Liquidity Needs With Integral Netting, A Systemic Solution*. 5th Nov. 2025. URL: <https://hal.science/hal-05348629>.
- [0] J. Guichon, S. Contassot-Vivier and N. Fatès. *Optimization heuristic for large-scale B2B integral debt netting*. 24th Nov. 2025. URL: <https://hal.science/hal-05379834>.
- [0] J. Guichon, S. Contassot-Vivier, N. Fatès and M. Amato. *Temporal B2B Debt Netting: Finite Lifespans and Reimbursements of the Financer*. 11th Mar. 2025. URL: <https://hal.science/hal-04987059>.

Other scientific publications

- [0] A. Mangin. ‘Étude et réalisation d'une architecture MQTT’. Université de Lorraine, 10th Apr. 2025. URL: <https://inria.hal.science/hal-05486292>.

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- [0] I. Hamdioui, V. Chevrier, M. Faqir, O. Karrakchou and M. Ghogho. *WeatherDrive: A Real-World Driving Dataset Collected Under Diverse Weather Conditions*. 2025. DOI: [10.17632/92cvzj65ky.1](https://doi.org/10.17632/92cvzj65ky.1).
- [0] S. Thomas, M. Boix and S. Negny. ‘A generic modular multiobjective optimization model for industrial symbioses’. In: *Available at SSRN 5668094* ().
- [0] J. Wenger, M.-C. Alvarez-Herault and B. Lacarriere. ‘Integrated multi energy optimization for sector coupling decarbonation’. In: *CIREN 2025 Conference*. 2025.