RESEARCH CENTRE

Inria Center
at the University of Lille

2022
ACTIVITY REPORT

Project-Team
FUN

self-organizing Future Ubiquitous Network

DOMAIN

Networks, Systems and Services, Distributed Computing

THEME

Networks and Telecommunications

Inria

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Project-Team FUN

Creation of the Project-Team: 2013 July 01

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1 Team members, visitors, external collaborators

Research Scientists

- Nathalie Mitton [Team leader, INRIA, Senior Researcher, HDR]
- Valeria Loscri [INRIA, Researcher, HDR]

Post-Doctoral Fellows

- Adriana Arteaga Arce [Inria, from Nov 2022]
- Nassima Merabtine [INRIA, from Mar 2022]
- Damien Wohwe Sambo [Inria, from Jun 2022]

PhD Students

- Ildi Alla [Inria, from Oct 2022]
- Hazem Chaabi [Inria, from Dec 2022]
- Jana Koteich [INRIA]
- Meysam Mayahi [INRIA]
- Nina Santi [INRIA]
- Edward Staddon [INRIA]
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- Christiaan Geldenhuys [Stellenbosch University, from Oct 2022]
- Willem Smit [Stellenbosch University, from Sep 2022]

2 Overall objectives

With the foreseen increase of communicating devices around the world, many challenges will arise. Among them, the most predominant ones are certainly the scarcity of the medium, the energy consumption, the lack of interoperability and the security of these devices and their data.

Our objectives are to address these different challenges for the self-organization of these Future Ubiquitous Networks. Our focus will be set on wireless heterogeneous communicating objets that feature different limitations and constraints such as hardware limitations (low computing and memory storage capacities), limited energy, potentially high mobility or hostile environment. By wireless, we mean any communication with no wire. Objects could thus communicate through traditional RF transmissions or any alternative way such as visible light communication (VLC) or molecular technologies. They can

be heterogeneous in terms of hardware processing, mobility patterns (mobility can be undergone or controlled, unknown or predictable), communication technologies, etc. For all these families of devices, we will design holistic communication protocols to allow them to efficiently function and cooperate in a harmonious energy- and data-priority aware fashion. These protocols will focus on low communication layers (PHY, MAC and NET) and combine opportunistically heterogeneous device features to make a global efficient behavior emerge.

The goal of the FUN project team is to leverage the heterogeneity of the new communicating devices to override major rising issues. Heterogeneity and mobility will be seen as opportunities and strengths rather than flaws and exploited. Our protocols will foster the cooperation between devices in a secure, energy efficient and frugal way.

3 Research program

Objectives and methodology

To achieve our main objectives, we will mainly apply the methodology depicted in Figure 1 combining both theoretical analysis and experimental validation. Mathematical tools will allow us to properly dimension a problem, formally define its limitations and needs to provide suitable protocols in response. Then, they will allow us to qualify the outcome solutions before we validate and stress them in real scenarios with regards to applications requirements. For this, we will realize proofs-of-concept with real scenarios and real devices. Differences between results and expectations will be analyzed in return in order to well understand them and integrate them by design for a better protocol self-adaptation capability.

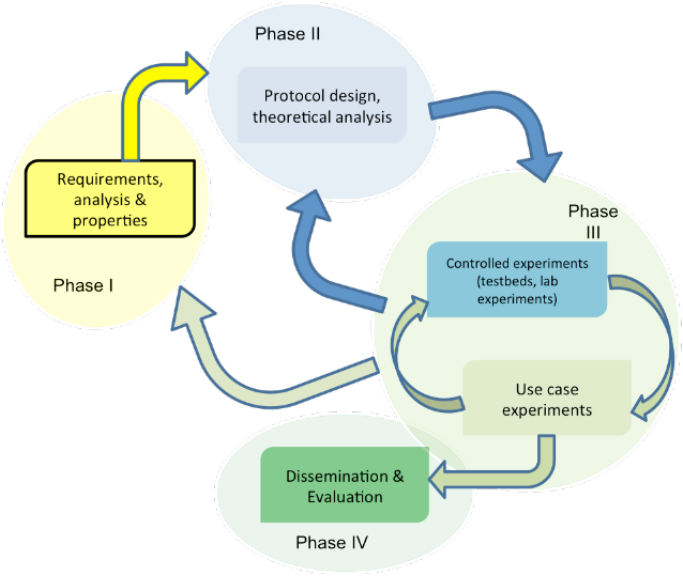

Figure 1: Methodology to be applied in FUN.

3.1 Research axes

To reach this overall objective, we will develop our research around the three following axes: *i)* Frugality and opportunism, *ii)* Security and *iii)* Interconnectivity. Note that these axes are not completely independent nor hermetic. A transversal axis will be the deployment and set up of experimental testbeds.

3.1.1 Frugality and opportunism

As the objects we consider are resource-limited and that they use a rare resource to communicate (wireless medium), all our solutions must be frugal and use as little resources as possible. A way to alleviate the energy consumption and the medium utilization is to reduce the data to send and/or to smartly decide when to send it, by what mean and to whom without jeopardizing the accuracy and completeness of the data. When to send a data can indeed impact the resource utilization since in a dynamic environment, some interference could appear at different times; in a mobile environment, a data could be carried rather than transmitted; in an energy-harvesting network, the amount of available energy could grow. We thus intend to closely analyse and understand interference impacts on different environments and contexts on one hand (as the research initiated in LumiCar, EthiCam, AgriNET) and to exploit them in the design of our protocols.

Deciding what data to send allows for a data reduction and resource savings. To do so, we will use machine learning techniques (e.g. Thompson sampling, Bayesian approaches, linear approaches, ARMA, Pearson sampling etc) that we will adapt to fit the specific context of the applications. The idea is to propose predictive algorithms to "guess" a data rather than transmitting it. This is among others what we are investigating in the AgriNET project.

In case of the availability of multiple communication technologies, the choice of this technology will impact the global system since all technologies do not provide the same QoS performances (delays, throughputs, etc) with different energy consumptions and do not face interferences the same way depending on the environment. We will thus analyse and understand all these specificities to combine them to get the best performances.

In all above mentioned cases, we will try to provide time and space depend protocols as frugal as possible but still meeting the application requirements and expectations. This will be done by opportunistically leveraging network particularities (multiple technologies, mobility, energy-harvesting, etc) based on experimental-driven behavioral analysis, as initiated with the collaboration with Sencrop.

3.1.2 Security

Security of wireless transmissions is a rising issue that gains importance with the increase of wireless devices. Our team has just started research work in security but we will pursue our efforts. Our goal will be to secure the wireless communications in different ways. Indeed, traditional security techniques (cryptography, firewalls, etc) cannot be applied in FUN because of their pervasive feature and limited resources. In terms of Security, we will focus on the lowest layers of the communication stack in order to first identify attacks that may appear at these levels and proposes *i)* recovering and healing solutions and *ii)* new solutions that are robust by design.

At the MAC layer, we will for instance investigate denial of sleep-like attacks that aim to make nodes deplete their energy quickly. At NET layer, we will investigate different routing protocols that are able to detect an abnormal behavior of a neighbor node to then exclude it from any network operation. This has obviously to be done locally and in a distributed way. In all cases, the same methodology will be apply: observe, understand and model, to then identify the threat or the malicious entity and finally heal. In some case, we can leverage the characteristics of the communication technology to reinforce the security aspect, such as VLC that may allow Line-of-Sight (LOS) communications and for which certain types of attacks that can be effective for "traditional" wireless systems (i.e., jamming attacks) cannot be easily applied. The works initiated in the framework of the H2020 CyberSANE project, in the DGA grant and in DEPOSIA project, fall within this perspective.

3.1.3 Interconnectivity

Another challenge faced by FUN is their interconnectivity to traditional networks such as Internet and the data offloading. Because of their limited capacity, FUN devices may need to call for remote services. These latter are usually hosted in the cloud. But being served by the cloud implies sometimes long latency and uselessly congest the wired network. We will thus investigate how to get these services closer to the FUN devices to alleviate the energy consumption, reduce latency and network congestion. This will go from edge and mobile edge deployments to service distribution over more powerful heterogeneous devices. Our research will analyse devices needs and estimate in time and space the services to be

deployed. When the service is expected to be temporary, mobile edge services could be deployed and so our investigations will include the self-deployment techniques. When some already deployed wireless devices feature more capacity, we can leverage this node heterogeneity to distribute the services over these nodes. The research conducted towards this third objective will call for adaptation of machine learning techniques to predict needs, to mobility modeling and cross-layer communication protocols. This has been initiated in the DRUID-NET project.

4 Application domains

The FUN research can be applied in various applications. We only cite here the ones on which we currently focus.

- **Smart Agriculture:** Wireless sensors are more and more deployed in remote fields and livestock for an accurate monitoring. This generates new challenges in terms of reliability, energy consumption and range as investigated in the D4SC and Agrinet projects.
- **Vehicular networks:** vehicles become smarter and smarter, providing new useful services. But communications between vehicles on one hand and between vehicles and road infrastructures on the other hand raise a lot of challenges as investigated in the CONCESE project.
- **Smart infrastructures:** FUN research can also apply to different urban and civil infrastructure like road monitoring (as in the DEFI with CEREMA) or Smart Grids.
- **Logistic and traceability:** RFID and IoT are the key technologies to enable large scale traceability. They are for instance investigated in the GoodFloow project.
- **Post disaster recovery:** New services of different kinds (communications, processing, context analysis) need to be deployed quickly and efficiently after a disaster in order to support rescue operations. This requires adaptable and flexible resource deployment such as investigated in NEPHELE and DRUID-NET projects.

5 Highlights of the year

5.1 Awards

Nathalie Mitton has been nominated among the 100 personalities in 2022 who are driving tech and innovation in the Hauts de France by The French Tech Lille.

6 New results

6.1 Security

Participants: Emilie Bout, Valeria Loscri, Nassima Merabtine, Nathalie Mitton, Edward Staddon.

Internet of things (IoT) devices have become the new privileged targets for cyberattackers these recent years. This is in part due to the amount of sensitive data they provide. In parallel, the security systems are becoming more and more robust with the help of Machine Learning (ML) algorithms. However, this advance can also benefit malicious people. In recent years, ML-based smart attacks have emerged and are significantly changing the threat landscape. We are focusing on new approaches, combining ML approaches and cyber attacks, in order to improve their effectiveness, minimize their detection and make them efficient in terms of energy [2, 13, 6]. In [1] we play the role of the attacker. We have designed a new attack framework based on Markov chain theory. The goal of this latter is to maximize the success probability of attacks while minimizing energy consumption. We tested this framework on both passive

and active jamming attacks, thus exhibiting the effectiveness of our approach when compared against basic eavesdropping and jamming attacks. We show that this new type of attack can cut by half the energy consumption of an eavesdropping attack, while maintaining an 88% attack efficiency.

From another point of view, attacks are becoming increasingly sophisticated and attempt to evade basic detection methods. Consequently, there is a real need to evaluate this new type of attack to improve the robustness of the detection and mitigation methods. A simulating tool to assess the impact of jamming attacks on wireless networks has become essential to gain effectiveness against attackers. In [14, 15] we have proposed a module of jamming attack for the discrete network simulator 3 (ns-3). This module, adaptable to any type of jamming attack strategy, provides a set of essential metrics allowing their evaluation. We evaluate the module by comparing the impacts of different types of jamming attacks already carried out in a real environment.

Malicious nodes can infiltrate the network and cause disruptions during routing. In [19, 11], we grant nodes the ability to evaluate the behaviour of their neighbours and, through consensus inspired from blockchain's miners, agree on the credibility of each node. The resulting metric is expressed as a node's reputation allowing, in the case of a malicious node, to isolate it from network operations. By illustrating this in an AODV-like multi-hop routing protocol, we can influence route selection no longer based solely upon the shortest number of hops, but also the highest overall reputation.

6.2 Visible Light Communication

Participants: Valeria Loscri, Meysam Mayahi.

Visible Light Communication (VLC) is recognized as a complement communication technology that meets many hurdles of Radio Frequency (RF) systems. For example, VLC overcomes the limited RF spectrum resources for mobile users, even though its application demands an effective mechanism to handover among the different devices, in order to keep the connectivity consistent. In [17, 18], a new handover mechanism is introduced for mobile VLC nodes, based on a real time evaluation of the Interference-to-Noise Ratio (INR). This mechanism is coupled with four adaptive modulation schemes to further enhance the data rate. The communication system is evaluated at 0.15 mps and 0.3 mps velocities for different parameters i.e., handover rate, delivered data per handover and handover delay ratio, through an extensive simulated campaign. An experimental validation carried out through software-defined approach, considering a small-scale scenario and low power Light Emitting Diodes (LEDs). When outdoor scenarios are considered, we need to account for effects such as saturation and non-linearity of the signal [16]. Saturation of optical receivers, caused by sunlight, represents a major issue in outdoor VLC system design for vehicular applications. This effect reduces maximum communication range, causing performance degradation when transmitter and receiver are in strict proximity. In addition, when saturation phenomena occur, only a fraction of total transmitted power is really exploited by the receiver, resulting in a significant waste of energy. The aim of this work, is to provide a novel analytical perspective, properly validated by experimental tests, in which the effects of saturation are related to the performance of outdoor VLC systems, in terms of signal to noise ratio (SNR). Another important aspect of wireless communication systems, is the synchronization, that we have considered in [9, 12], with a specific focus on VLC. Synchronization is a big deal in all the wireless communication systems and the key features of VLC paradigm make the synchronization techniques existing for RF not suitable for VLC. A novel technique, OSCI-LIGHT based on Andronov-Hopf oscillators, is proposed in order to realize an effective synchronization mechanism in a VLC system. In particular, phase alignment and robustness towards noise have been tested through both numerical simulation and experimental results and a comparison with widely employed synchronization techniques, based on Phase Locked Loop (PLL), has been provided. Experimental results show that our technique outperforms PLL techniques in terms of noise robustness, showing a proper steady state phase delay and a lower Synchronization Error Rate, even in presence of highly noisy environmental conditions.

6.3 Emerging Communication Technologies

Participants: Valeria Loscri, Carola Rizza.

The interference in wireless communication systems is paramount and it still more important for reprogrammable environment, as those based on the new paradigm Reconfigurable Intelligent Surfaces (IRS). In [10], a wireless system in outdoor environment including a reconfigurable intelligent metasurface designed to perform beam-steering is presented. The metasurface unit-cell has been designed to work in the range 37-40 GHz and the designed meta-atom is insensitive to the angle of incidence until 30°. We model and evaluate the effect of interferers on the tracking performances. In particular, we model the channel including interferers and we consider the effect of interferers for different signal powers and different directions on the radiation pattern generated by the metasurface. In general, we notice that the sidelobe level increases when the number of scatterers and their power increase and also when the angle of incidence of the signals scattered from the cluster is increased. Interestingly, for certain configurations, e.g. at 225°, the radiation pattern at 50°is better than at 30°, showing that the behavior is not linear.

6.4 Cooperative UAV

Participants: Valeria Loscri, Nassima Merabtine.

UAVs are offering many global industry sectors the opportunity to adopt more sustainable business models. By offering innovative ways of managing resources, and newer opportunities to address key challenges in many areas, UAVs are expected to play a relevant role in the upcoming 6G networks scenario. As an example of their deployment, in smartagriculture, UAVs are used to collect data such as weather and soil moisture, enabling more effective land management. They can also be applied to the inspection of infrastructure projects or equipment such as onshore and offshore wind turbines, reducing the need for potentially dangerous human inspection, or, finally, for the distribution businesses and services. All these new applications tend to require the cooperation of groups, namely "swarms" of UAVs, in order to provide collaborative sensing and processing solutions. New requirements are then imposed in terms of safety, coordination, and operation management. In [3], we provide an overview of some of the technical challenges that multirotor UAVs are still facing in terms of aerial coordination and interaction. In this regard, we focus on recent developments available in literature and present some contributions we realized during the past few years that address UAV interaction to achieve collision-free flights and swarm-based missions. Based on the analysis provided in this work, we eventually provide an insight on the challenges still open that need to be solved in order to enable effective UAVbased solutions to support sustainable aerial services. In [7], we highlight several novel 6G enabling technologies, and present the detailed study and evaluation of communication technology candidates from the perspective of aerial communication networks, key design considerations and technical challenges.

6.5 New services based on prediction methods

Participants: Jana Koteich, Nathalie Mitton, Nina Santi.

Nowadays, to improve animal well-being in livestock farming applications, a wireless video sensor network (WVSN) can be deployed for surveillance and livestock monitoring to early detect injury or Asian hornets attacks. They are composed of small embedded video and camera motes that capture video frames periodically and send them to a specific node called a sink. Sending all the captured images to the sink consumes a lot of energy on every sensor and may cause a bottleneck at the sink level. Energy consumption and bandwidth limitation are two important challenges in WVSNs because of the limited energy of nodes and the medium scarcity. In [8], we exploit prediction to reduce the quantity of data to be sent. We leverage the Spatio-temporal correlation between neighboring nodes to reduce the number

of captured frames. For that purpose, Synchronization with Frame Rate Adaptation SFRA algorithm is introduced where overlapping nodes capture frames in a synchronized fashion every N-1 period, where N is the number of overlapping sensor nodes. The results show more than 90% data reduction, surpassing other techniques in the literature at the level of the number of sensed frames by 20% at least.

Internet of Things (IoT) devices generate a tremendous amount of time series data that is extremely dynamic, heterogeneous and time dependent. Such types of data introduce significant challenges for the real-time prediction of QoS metrics of IoT applications with different traffic characteristics. To this end, in this paper, we propose a temporal transformer model and a unified system to predict several QoS metrics of heterogeneous IoT applications when they communicate with the Edge [5] of the network. The transformer model also leverages an attention module to provide a solution for both short-term and long-term sequence prediction of QoS metrics that allows to better extract any time dependencies. In particular, in our framework [4], we firstly generate a set of datasets containing real-time traffic information of five different IoT applications such as Heating, Ventilation, and Air Conditioning (HVAC), lighting, Voice over Internet Protocol (VoIP), surveillance and emergency response using the 802.15.4 access technology and the RPL routing protocol. Following, we perform the data cleaning, downsampling and pre-processing of the datasets and we construct the QoS datasets, which include four QoS metrics, namely throughput, packet delivery ratio, packet loss ratio and latency. Finally, we evaluate the transformer model through extensive experimentation using both short-term and long-term dependencies and we show that our model can guarantee a robust performance and accurate QoS prediction.

6.6 Digital agriculture

Participants: Nathalie Mitton.

Digital technologies are spreading in agriculture as they do in other economic sectors. Facing this wave, two major french research institutes dedicated to agriculture (INRAE) and digital sciences (INRIA) address the following question « how can digital technologies be designed to accelerate the transition towards more sustainable and resilient food systems, including agroecology, climate-change resilient agriculture and adaptation to food transitions ? » in a White Book, published in 2022 [20, 21]. The approach has been to review the opportunities offered by the state of the art of digital technologies and the risks linked to these technologies, and to confront them in order to design research avenues that enable us to take advantage of the opportunities while mitigating risks. Opportunities have been found in 3 directions : better agricultural production, better inclusion in value chains and networks, and better knowledge sharing. Risks are economical (cost, power control), social (digital divide, deskilling), technical (cybersecurity, complexity), ecological (ICT footprint...) and also linked to sovereignity regarding data. Eventually, research avenues have been built in four areas : (1) digital technologies for creating and sharing data and knowledge, (2) digital technologies for helping farmers in farm management, (3) digital technologies for accompanying the collective management of territories and (4) digital technologies for better inclusion in the value chains. These areas of research are crossed by four transversal challenges, that will guide research : (1) developping holistic approaches, (2) searching resilience and not optimum, (3) looking for frugal solutions (green IT) and (4) ensuring confidence of the users (security, transparency). Last, four final messages will be delivered to pave the way to future research for a responsible digital agriculture, in France and abroad.

7 Bilateral contracts and grants with industry

Dotdot

Participants: Valeria Loscri, Nathalie Mitton *(contact person)*.

This collaboration aims to investigate a smart communication network enabled by vehicles.

8 Partnerships and cooperations

8.1 International initiatives

8.1.1 Associate Teams in the framework of an Inria International Lab or in the framework of an Inria International Program

AGRINET

Title: Wireless accurate monitoring for a smarter agriculture

Duration: 2020 -> 2024

Coordinator: Riaan Wolhuter (wolhuter@sun.ac.za)

Partners:

- Stellenbosch University (Afrique du Sud)

Inria contact: Nathalie Mitton

Summary: The proposed research entails the development of a flexible, rapidly deployable, biological data acquisition platform to create advanced agricultural monitoring and management techniques for better natural resource management and smart farming decision making. This platform will involve a wireless sensor network and a machine-learning based decision making tools. Sensors will be spread over the fields to sense information on soil water and nitrate concentration, temperature etc, and remotely communicate this data in a wireless way to the server which will provide decision making tools according to the kind of culture. A first objective is to create an advanced, flexible wireless sensor network for wide area agricultural data measurement, with an adaptable dynamic routing strategy including the considerations of various factors such as network availability, node positioning, message priority and resource availability (typically battery capacity) in order to optimize data transmission reliability and utilize communication resources optimally. This particular topology is proposed to enhance the total network coverage and to compensate for propagation problems that are certain to occur due to the variable crop-, climatic- and vineyard topography. A second objective to be achieved in parallel is to adapt current machine learning and pattern recognition algorithms to obtain an area wide and in depth view of crop and soil conditions to identify and enable optimal crop management and harvest conditions. In AgriNet, multiple inputs from multiple nodes will be integrated into a machine learning based classification framework. Complementary and inter-dependent data input will enable and enhance the detection of converging patterns, providing a completely new level of confidence in terms of early warning strategies and sensing accuracy. This could be of enormous value in presenting early warning signs of disease and other unwanted conditions for cost efficiency and increase in crop yield and quality. A third objective is the integration of the final system (wireless sensor network and machine learning based system) in a complete agriculture-oriented prototype. Pilot projects will be deployed during the last year in both France and South Africa focusing on two main cultures: potato crops and vineyards in order to stress and evaluate the AgriNet prototype.

8.1.2 Visits of international scientists

Participants: Christiaan Geldenhuys, Willem Smit.

In the framework of the AGRINET associated team, Christiaan and Willem visited us for a few weeks in fall 2022 to discuss common work with Stellenbosch University on vineyard monitoring.

8.1.3 Visits to international teams

Research stays abroad

Participants: Carola Rizza.

Carola spent two months at the Friedrich-Alexander-Universität Faculty of Engineering under the supervision of Robert Schober.

8.2 European initiatives

8.2.1 Horizon Europe

NEPHELE

Participants: Adriana Arteaga Arce, Hazem Chaabi, Nathalie Mitton.

NEPHELE project

Title: A LIGHTWEIGHT SOFTWARE STACK AND SYNERGETIC META-ORCHESTRATION FRAMEWORK FOR THE NEXT GENERATION COMPUTE CONTINUUM

Duration: From September 1, 2022 to August 31, 2025

Inria contact: Nathalie Mitton

Coordinator: Symeon Papvassiliou, NTUA

Summary: The vision of NEPHELE is to enable the efficient, reliable and secure end-to-end orchestration of hyper-distributed applications over programmable infrastructure that is spanning across the compute continuum from Cloud-to-Edge-to-IoT, removing existing openness and interoperability barriers in the convergence of IoT technologies against cloud and edge computing orchestration platforms, and introducing automation and decentralized intelligence mechanisms powered by 5G and distributed AI technologies. The NEPHELE project aims to introduce two core innovations, namely: (i) an IoT and edge computing software stack for leveraging virtualization of IoT devices at the edge part of the infrastructure and supporting openness and interoperability aspects in a device-independent way. Through this software stack, management of a wide range of IoT devices and platforms can be realised in a unified way, avoiding the usage of middleware platforms, while edge computing functionalities can be offered on demand to efficiently support IoT applications' operations.

(ii) a synergetic meta-orchestration framework for managing the coordination between cloud and edge computing orchestration platforms, through high-level scheduling supervision and definition, based on the adoption of a "system of systems" approach.

The NEPHELE outcomes are going to be demonstrated, validated and evaluated in a set of use cases across various vertical industries, including areas such as disaster management, logistic operations in ports, energy management in smart buildings and remote healthcare services. Two successive open calls will also take place, while a wide open-source community is envisaged to be created for supporting the NEPHELE outcomes.

SLICES-PP

Participants: Nathalie Mitton.

SLICES-PP project

Title: Scientific Large-scale Infrastructure for Computing/Communication Experimental Studies - Preparatory Phase

Duration: From September 1, 2022 to December 31, 2025

Inria contact: Nathalie Mitton

Coordinator: Nathalie Mitton

Summary: The digital infrastructures research community continues to face numerous new challenges towards the design of the Next Generation Internet. This is an extremely complex ecosystem encompassing communication, networking, data-management and data-intelligence issues, supported by established and emerging technologies such as IoT, 5/6G, cloud-to-edge computing. Coupled with the enormous amount of data generated and exchanged over the network, this calls for incremental as well as radically new design paradigms. Experimentally-driven research is becoming worldwide a de-facto standard, which has to be supported by large-scale research infrastructures to make results trusted, repeatable and accessible to the research communities.

SLICES-RI (Research Infrastructure), which was recently included in the 2021 ESFRI roadmap, aims to answer these problems by building a large infrastructure needed for the experimental research on various aspects of distributed computing, networking, IoT and 5/6G networks. It will provide the resources needed to continuously design, experiment, operate and automate the full lifecycle management of digital infrastructures, data, applications, and services.

Based on the two preceding projects within SLICES-RI, SLICES-DS (Design Study) and SLICES-SC (Starting Community), the SLICES-PP (Preparatory Phase) project will validate the requirements to engage into the implementation phase of the RI lifecycle. It will set the policies and decision processes for the governance of SLICES-RI: i.e., the legal and financial frameworks, the business model, the required human resource capacities and training programme. It will also settle the final technical architecture design for implementation. It will engage member states and stakeholders to secure commitment and funding needed for the platform to operate. It will position SLICES as an impactful instrument to support European advanced research, industrial competitiveness and societal impact in the digital era.

MLSysOps

Participants: Valeria Loscri.

Title: Machine Learning for Autonomic System Operation in the Heterogeneous Cloud-Edge Continuum

Duration: From January 1, 2023 to December 31, 2025

Inria contact: Valeria Loscri

Coordinator: Spyros Lalis, Thessalis University

Summary: To address the ever-increasing deluge of data collected and processed by computing systems, there is a trend towards processing data as close as possible to their source (edge computing). It has been predicted that by 2025 around 80% of enterprise data will be generated and processed outside the traditional cloud. In fact, edge computing is becoming even more attractive with the advent of energy-efficient micro-servers and powerful embedded devices with significant storage and processing capabilities. Another driver towards a cloud-edge computing continuum is 5G, both as a client of continuum resources and as a communication service enabler. The advent of cloud-edge computing aggravates the challenging task of managing heterogeneous and distributed resources, this time at an extreme scale, making human-in-the-loop management completely unrealistic. To achieve dynamic and flexible system and application management with minimal

user involvement, the concept of autonomic computing systems was proposed a long time ago as "computing systems that can manage themselves given highlevel objectives from administrators". However, the scale, heterogeneity, high dynamicity, and intrinsic local properties/variability of the continuum yields rule-based approaches – traditionally used in autonomic systems – insufficient. AI-driven management is a promising alternative, but the quest to extend this to the full continuum faces several challenges.

Scalability: Existing AI approaches typically focus on a single problem, a single system, or a small collection of similar nodes (at best). The scale of the continuum is a challenge for AI-driven management, as it requires complex models and the collection, transfer, and processing of a significant amount of telemetry data.

Heterogeneity: Continuum nodes are widely heterogeneous in terms of type, resources, and capabilities. They are associated with different optimization problems, different software deployment mechanisms, and are often managed by different frameworks. Moreover, IaaS offerings are usually not interoperable out-of-the-box, resulting, apart from the management complexity to provider-silos and vendor lock-in.

Dynamics: The cloud-edge continuum is by nature nonstationary. On the one hand, high-frequency short-adaptation is necessary to handle changes in the behavior of co-located workloads, availability of compute and storage resources, node mobility, and the unpredictable physical layer in wireless communication. On the other hand, the topology and type of available resources evolves, particularly at the edge, as is also the case for the applications competing for the resources of the infrastructure and the respective QoS/QoE requirements.

Trust & security: As several parts/nodes of the system reside outside well-protected datacenters, cross-cutting concerns such as security and trust become more crucial than ever. On the one hand, it is important not only to prevent but also to detect security incidents early on, so that appropriate countermeasures are taken as soon as possible. On the other hand, physically exposed nodes that belong to different parties cannot be trusted by default: they may operate non-properly, and may provide erroneous, or even misleading information.

Transparency: Last but not least, one of the roadblocks towards the widespread adoption of AI is the lack of transparency in the decisions taken by ML models. This is crucial for system management tasks, particularly in the level of infrastructure commercially supporting many applications and users. In such settings, transparency and explainability are often more important than sheer efficiency and performance.

The MLSysOps project will address these challenges to enable autonomic, efficient and adaptive end-to-end system management on the heterogeneous and dynamic edge-cloud continuum. To this end, MLSysOps will (i) disassociate the management from the control of continuum resources, (ii) introduce an AI-driven control and management framework which interfaces with off-the-shelf management mechanisms, and (iii) employ a hierarchical, distributed, explainable and evolving AI architecture for autonomic system operation.

8.2.2 H2020 projects

CyberSANE

Participants: Valeria Loscri, Nathalie Mitton, Edward Staddon.

CyberSANE project

Title: Cyber Security Incident Handling, Warning and Response System for the European Critical Infrastructures

Duration: From September 1, 2019 to August 31, 2022

Inria contact: Nathalie Mitton

Summary: In the digital era, Critical Infrastructures (CIs) are operating under the premise of robust and reliable ICT components, complex ICT infrastructures and emerging technologies and are transforming into Critical Information Infrastructures (CIIs) that can offer a high degree of flexibility, scalability, and efficiency in the communication and coordination of advanced services and processes. The increased usage of information technology in modern CIIs means that they are becoming more vulnerable to the activities of hackers and other perpetrators of cyber-related crime (cyber criminals). Several recent studies have shown that the landscape of cyber threats is changing continuously and the nature of attacks of this sort are evolving, involving a great degree of persistence and (technical) sophistication.

In addition to this, barriers to entry for would-be cyber criminals are falling rapidly, and nowadays, the attackers have a range of (technical) capabilities and substantial resources at their disposal, since malware and malware-as-a service become more easily and cheaply available through various means and sources (such as Dark Web, Deep Web). Thus, a variety of advanced techniques and tools (e.g. social engineering techniques and zero-day exploits programs) are available and can be used by the cyber criminals to initiate advanced targeted attacks. These threats employ multiple technologies and malware, deployed in multiple stages, to bypass traditional security mechanisms in order to penetrate an organization's defenses. The attack vectors vary significantly including Application-Layer, Social Engineering Unauthorized Access, Malicious Code, and Reconnaissance and Networking-based service attacks that target applications, host and client operating systems, and even networking equipment. In this vein, the attackers use these techniques to get valuable data assets, such as financial transaction information, user credentials, insider information etc.

8.2.3 Other european programs/initiatives

Druid-Net

Participants: Adriana Arteaga Arce, Kevin Jiokeng, Nathalie Mitton, Nina Santi.

Title: eDge computing ResoUrce allocatIon for Dynamic NETworks

Duration: May 2020 - September 2023

Inria contact: Nathalie Mitton

Summary: Following the NFV/SDN paradigm, DRUID-NET separates the flow of information into control and data plane. At the lowest layer, the IoT-enabled applications are deployed, and the generated workload (data flow) can be offloaded for further processing at the above EC layer, which provides essential virtualized services. The DRUID-NET framework collects information (control flow) about the status of the computing and network infrastructure at the EC level in order to create workload-resource profiles, update the performance model for every application, and realize the feedback control mechanism for the resource allocation and simultaneously implements a resource-aware control strategy for the CPS to be controlled (control flow). This holistic approach allows the application's dynamical modelling taking into account various contextual information. Furthermore, the controller co-design treats the resource allocation algorithms as application components in the virtualized services.

NEWFOCUS

Participants: Valeria Loscri, Meysam Mayahi.

Title: European network on future generation optical wireless communication technologies

Duration: September 2020 - September 2024

Inria contact: Valeria Loscri

Summary: The COST Action NEWFOCUS will propose truly radical solutions with the potential to impact the design of future wireless networks. Particularly, NEWFOCUS aims to establish optical wireless communications (OWC) as an efficient technology that can satisfy the demanding requirements of backhaul and access network levels in beyond 5G networks. This also includes the use of hybrid links that associate OWC with radiofrequency or wired/fiber-based technologies. Towards this vision, NEWFOCUS will carry out a comprehensive research programme under two major pillars. The first pillar is on the development of OWC-based solutions capable of delivering ubiquitous, ultra-high-speed, low-power consumption, highly secure, and low-cost wireless access in diverse application scenarios. The developed solutions will in particular support Internet-of-Things (IoT) for smart environments with applications in vertical sectors. The second pillar concerns the development of flexible and efficient backhaul/fronthaul OWC links with low latency and compatible with access traffic growth.

8.3 National initiatives

GoodFloow

Participants: Damien Wohwe Sambo, Nathalie Mitton.

Title: ADEME GoodFloow Project

Duration: October 2021 - September 2023

Coordinator: GoodFloow

Inria contact: Nathalie Mitton

Summary: The goal of this project, funded by ADEME, is to design a very energy efficient node to manage reusable packaging in a more sustainable way by combining enhanced IA techniques, wake up radio and multi MAC layers.

DEPOSIA

Participants: Valeria Loscri, Nassima Merabtine.

Title: ANR

Duration: October 2021 - September 2024

Coordinator: Virginie Deniau

Inria contact: Valeria Loscri

Summary: DEPOSIA focuses on the detection and geolocation of various radio frequency signal sources in order to thwart attacks on connected systems and infrastructures. The sources considered are elements which by their characteristics or their position, present an illicit character and which threaten the people security or the infrastructures. For outdoor cases, we consider drones flying over forbidden areas, telecommunication jammers, spoofing signal transmitters or wireless connected sensors used to introduce false data in monitoring platforms. For indoor cases, we also consider jamming or spoofing sources that can cause denial of service within networks or infrastructures, or fake access points that aim to carry out man-in-the-middle attacks to intercept information. In this proposal, the indoor and outdoor use cases are considered separately in order to design monitoring infrastructures adapted to each case. For the outdoor case, we consider a surveillance architecture

that could join the already existing cellular or WLAN communication infrastructures. In particular, with 5G technology and the higher employed frequencies, cellular networks are evolving towards finer meshes and have interfaces with the core network at each of their nodes. Thus, these interface points, equipped with receivers dedicated to monitoring, could enable the routing of monitoring data to centralized platforms, feeding an Artificial Intelligence for analysis, anomaly detection and source geolocation. For the indoor case, we consider a distributed monitoring architecture deployed within a building, based on SDR sensors and a data centralization and synchronization network. In these two cases, we envisage an Artificial Intelligence working on data evolving in three dimensions : time, space and direction, all for data of different natures, namely those from the physical layer and the data link layer. Whether for indoor or outdoor configurations, the algorithms that will constitute the Artificial Intelligence will be based on learning approaches that will correspond to Machine Learning and Deep Learning algorithms. These algorithms will deal with the problems of detecting attacks and locating illicit sources. These algorithms will have to take into account: the evolutionary aspect brought by the non-fixed character in time of the attacks and the non-fixed location aspect of the localization of the source of the attack. A first Artificial Intelligence will be dedicated to data analysis and anomaly detection, i.e., highlighting the suspicious nature of the data, and a second Artificial Intelligence will be dedicated to extracting the location information of the attack source. Due to the multi-layered nature of the data, model aggregation algorithms will be deployed in order to homogenize the decision process.

8.3.1 Exploratory Action

Ethicam

Participants: Valeria Loscri, Carola Rizza.

Title: Emerging TecHnologies for new CommunicAtions paradigMs

Duration: October 2019 - October 2022

Inria contact: Valeria Loscri

Summary: The evolution of IoT towards the Internet of Everything (IoE) paradigm represents an important and emerging research direction, capable to connect and interconnect massive number of heterogeneous nodes, both inanimate and living entities, encompassing molecules, nanosensors, vehicles and people. This new paradigm demands new engineering communication solutions to overcome miniaturization and spectrum scarcity. Novel pervasive communication paradigms will be conceived by the means of a cutting edge multidisciplinary research approach integrating (quasi) particles (e.g. phonons) and specific features of the (meta)material (e.g. chirality) in the design of the communication mechanisms. In particular, by the means of the meta-materials, it would be possible to control the propagation environment. More specifically, through this paradigm it will be possible to manipulate not only the desired signals, but also the interfering signals.

8.3.2 DEFI Inria

ROAD-AI, common DEFI Inria et Cerema

Participants: Nathalie Mitton.

Title: Routes et ouvrages d'art Diversiformes, Augmentés et intégrés

Duration: July 2021 - June 2024

Inria contact: Nathalie Mitton

Summary: Integrated management of infrastructure assets is an approach which aims at reconciling long-term issues with short-term constraints and operational logic. The main objective is to enjoy more sustainable, safer and more resilient transport infrastructure through effective, efficient and responsible management. To achieve this, CEREMA and Inria are joining forces in this Inria Challenge (DEFI) which main goals are to overcome scientific and technical barriers that lead to the asset management of tomorrow for the benefit of road operators: (i) build a "digital twin" of the road and its environment at the scale of a complete network; (ii) define "laws" of pavement behavior; (iii) instrument system-wide bridges and tunnels and use the data in real time; (iv) define methods for strategic planning of investments and maintenance.

8.4 Regional initiatives

CORTESE

Participants: Valeria Loscri.

Title: Intelligent Coexistence in Wireless Networks of Technologies communications for safety

Duration:

Coordinator: Valeria Loscri

Summary: This project led by the Inria Lille - Nord Europe center and in partnership with Gustave Eiffel University (UGE), LAMIH (Université Polytechnique Hauts de France (UPHF)) aims at the coexistence of different technologies of wireless communication, in the vehicular context. The objective is to advance in the search for methods based on a sustainable Artificial Intelligence (AI) that can automate the selection of the most relevant to improve performance in terms of latency (i.e., of the order of 1 ms), reliability (i.e., of the order of 99.99% of data delivered) in order to reduce the energy envelope of the communication system and guarantee increased robustness against cyber attacks. Given the high dynamics of the environment, learning approaches developed must be able to respond in real time. Particular attention will be given to aspects of durability and security of wireless communication networks. This project is part of the field of Intelligence Embedded artificial and in the new emerging sector of cyber security for critical systems such as the vehicular context. With a clear experimental footprint, this project will advance the search for Hauts-de-France region in 5G technology in a key sector such as Intelligent Transport. The cost of the project including the valuation of statutory persons amounts to €246,500 excluding tax and the regional subsidy requested is €197,000, or 80% of the total cost of the project.

9 Dissemination

General chair, scientific chair

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri was organizer of SIoT Workshop (in conjunction with WiMob'22), Poster and Demo chair for ICNP'22
  Valeria Loscri co-organized a Special Issue issue on Revolutionary Paradigms for Smart Connected Vehicles in the 6G Era in Vehicular Communications Journal

- Nathalie Mitton was demo chair of MeditCom 2022, keynote chair for CIoT 2022 and workshop chair of ISCC 2022.

Chair of conference program committees

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri was Short Papers and Demo Session chair of WiMob 2022,
- Nathalie Mitton was co-TPC chair of the 2022 Net4Us@Sigcom workshop and track co-chair of VTC 2022.

Member of the conference program committees

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri has been a TPC member of IEEE CNS 2022, Infocom 2022, Percom 2022, Globecom 2022, ICC 2022, VTC 2022, SmartComp 2022, ICDCN 2022, IoTDI 2022
- Nathalie Mitton has been a TPC member of Infocom 2022, DCOSS 2022 CORES 2022, Percom 2022, Globecom 2022, ICC 2022, VTC 2022 and WCNC 2022.

9.1 Journal

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri is Associate Editor of IEEE Transactions on Information Forensics and Security (since 2022), IEEE Communications Survey and Tutorials (COMST, since 2020), Elsevier ComCom (since 2021), Frontiers in Communications and Networks, ITU-FET Journal, IEEE Transactions on Nanobioscience journal since 2017, of Elsevier Computer Networks journal since 2016, of Robotics Software Design and Engineering of the International Journal of Advanced Robotic Systems since 2016, of Elsevier Journal of Networks and Computer Applications (JNCA) journal since 2016, of Wiley Transactions Emerging Telecommunications Technologies since 2019.
- Nathalie Mitton is an editorial board member of Adhoc Networks since 2012, of IET-WSS since 2013, of Wireless Communications and Mobile Computing since 2016, of Journal of Interconnection Networks since 2021.

9.2 Invited talks

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri was invited to deliver a talk on "Smart Attack and Countermeasures in Wireless Networks" at University of Padova, SPRITZ Team;
  Valeria Loscri was invited to deliver a talk on "Intelligent Connected Vehicles in 6G Networks" at University of Michigan;
  Valeria Loscri delivered a MasterClass "Attaques Intelligents dans les Réseaux sans fil" at International Forum on Cybersecurity (FIC) in the context of Inria Academy
- Nathalie Mitton was invited keynote at winter school of ACM SIGOPS 2022 and panelist member of NoF 2022.

9.3 Scientific expertise

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri has been appointed as member of the fellowship panel experts for Postdoc and PhD Fundamental Research of Research Foundation (FWO)
- Valeria Loscri has been appointed as scientific expert to evaluate projects submitted to ANR, CEFIPRA
- Valeria Loscri has been appointed as reviewer of transverse initiative project for Labex DigiCosme
- Valeria Loscri has been appointed as reviewer for doctoral funding projects for Labex DigiCosme
- Nathalie Mitton has been appointed as scientific expert to evaluate projects submitted to ANR, FWO-Research-Project (Germany), South Africa's National Research Foundation (NRF), NSERC (Canada) and NSC (Poland).
- Nathalie Mitton is a member of the advisory board of the H2020 NGI pointer, PLATOON and Smart Lagoon projects.
- Natjalie Mitton is an external expert of scientific board for Inrae and ESISAR.
- Nathalie Mitton has been appointed as a member of the expert committee in charge of the evaluation of France 2030 projects by BPI and Banque des territoires.

9.4 Research administration

Participants: Valeria Loscri, Nathalie Mitton.

- Valeria Loscri is co-chair of a Social Networks Technical Committee - Special Interest Group (SIG)
- Valeria Loscri and Nathalie Mitton are in the GIS CybCOMM, Scientific Interest Group in the Cyber Security for wireless networks.

9.5 Teaching - Supervision - Juries

Participants: Emilie Bout, Valeria Loscri, Nathalie Mitton, Nina Santi, Damien Wohwe Sambo.

9.5.1 Teaching

- **E-learning**
  - Mooc, Nathalie Mitton, "Internet of Things with Microcontrollers: a hands-on course", 5-week mooc by the FIT IoT LAB team, FUN, Inria, in February 2021
  - Remote course, Nathalie Mitton, Internet of things, 5-week + virtual face to face week in May 2021
- Master: Valeria Loscri, Objets Communicants, 24h (Mineure Habitat Intelligent), Ecole des Mines de Douai, France
- Master: Nathalie Mitton, Wireless networks, 16h eqTD (Master TC), Université Lille 1, France

- Master: Damien, Wohwe Sambo, Wireless sensor networks, 16h eqTD (Master IdO), Université Lille 1, France
- Master: Nathalie Mitton, Smart objects, 10h CM + 12h TP, Ecole centrale de Lille, France
- Master: Nathalie Mitton, Industrial Internet of Things, 10h CM Ecole centrale de Lille, France
- Master: Damien, Wohwe Sambo, Industrial to Internet of Things, 12h TP Ecole centrale de Lille, France
- Master: Nathalie Mitton, Introduction to Internet of Things, 4h CM Ecole centrale de Lille, France
- Master: Damien, Wohwe Sambo, Introduction to Internet of Things, 8h TP Ecole centrale de Lille, France
- Master: Damien, Wohwe Sambo, Wireless sensor networks, 12h eqTD (Master ROC), IMT, France
- L3 INFO: Edward Staddon, Introduction aux Réseaux, 19.5 HTD, Université de Lille, France.
- L3 INFO: Emilie Bout, Introduction aux Réseaux, 19.5 HTD, Université de Lille, France.
- L3 INFO: Nina Santi, Programmation fonctionnelle, 42 HTD, Université de Lille, France.

9.5.2 Supervision

- PhD defended
  - Edward Staddon, Threat detection, identification and quarantine in wireless IoT based Critical Infrastructures, Université Lille 1, 2019-2022, Nathalie Mitton & Valeria Loscri
  - Carola Rizza, Nouveaux paradigmes de communication basés sur les technologies émergentes, Université Lille 1, 2019-2022, Valeria Loscri
  - Emilie Bout, Denial-of-sleep over IoT networks, Université Lille 1, 2019-2022, Valeria Loscri & Antoine Gallais
  - Meysam Mayahi, Communication Protocols based on alternative paradigm for wireless mobile devices, Université Lille 1, 2019-2022, Valeria Loscri
- PhD in progress:
  - Hazem Chaabi, Intelligent PhD Position F/M Intelligent IoT devices management and functionalities virtualization on the edge, Université Lille 1, 2022-2025, Nathalie Mitton
  - Ildi Alla, Monitoring for detection and localisation of cyber attacks in wireless networks, Université Lille 1, 2022-2025,Valeria Loscri
  - Jana Koteich, Context aware opportunistic forwarding strategy, Université Lille 1, 2021-2024, Nathalie Mitton
  - Nina Santi, adaptive and dynamic edge gateways IoT-oriented deployments, Université Lille 1, Université Lille 1, 2020-2022, Nathalie Mitton

9.5.3 Juries

PhD and HDR committees:

- Valeria Loscri is/was member of the following PhD thesis committees:
  - Andy Amoordon, University of Gustave Eiffel,
  - Luis Emmanuel PLASCENCIA CRUZ, University Paris Saclay, reviewer
- Nathalie Mitton is/was member of the following PhD thesis committees:
  - Y. Cui, Ecole Centrale de Lille, chair

  - Jean Philippe Abegg, Unistra, chair
  - Maysaa Khalil, UTT
  - Eyassu Diratie, Univ. Paris Saclay, reviewer
  - Nouman Bashir, Paris XIII
  - Sicheng Dai, ENS Lyon, reviewer
  - Ali Mamadou Mamadou, UCA, chair
  - Elhadja Chaalal, Univ. Bourgogne
  - Kevin Jioken, Université de Toulouse ENSEITH, reviewer
  - Mohamed Anis Fekih, INSA Lyon, reviewer
  - Dereje Molla, UGE, reviewer

- Nathalie Mitton is/was member of the following HDR thesis committees:
  - S. Hemour (reviewer) Univ. Bordeaux,
  - J. Montavont (reviewer) Univ. Strasbourg,
  - F. Bouabdallah (reviewer) Univ. Paris Est,
  - K. Singh (chair) Univ. St Etienne.

Research selection committees :

- Valeria Loscri is/was member of the following selection committees:
  - Inria Junior Research (CR) Admission Committee
- Nathalie Mitton was member of the following selection committees:
  - Inria researcher: chair of the junior researcher committee (CR) for Inria Bordeaux and member of Senior researcher committee (DR2)
  - Professor: Universités de Toulouse, Grenoble Alpes et de Lorraine.
  - Assistant professor: Université de Lille, CNAM, Sorbonne Université, IMT Lille Nord Europe

9.5.4 Internal or external Inria responsibilities

- Nathalie Mitton
  - is Deputy Scientific delegate for Lille Inria center
  - is member of the QVT (Quality of life at work) committee
  - is a member of the Bureau des Comités de Projets of Lille Inria center.
  - is an elected member of the evaluation committee of Inria.
- Valeria Loscri
  - is Scientific International Relation Responsible for Inria Lille.

10 Scientific production

10.1 Publications of the year

International journals

[1] E. Bout, V. Loscrì and A. Gallais. 'Evolution of IoT Security: the era of smart attacks'. In: *IEEE Internet of Things Magazine* (16th Mar. 2022). DOI: 10.1109/iotm.001.2100183. URL: https://hal.archives-ouvertes.fr/hal-03610715.

[2] E. Bout, V. Loscrì and A. Gallais. 'HARPAGON: An energy management framework for attacks in IoT networks'. In: *IEEE Internet of Things Journal* (2nd May 2022). DOI: 10.1109/jiot.2022.3172849. URL: https://hal.science/hal-03658197.

[3] F. Fabra, A. M. Vegni, V. Loscrì, C. T. Calafate, J. Cano and P. Manzoni. 'Collision-free Cooperative UAV Protocols for Sustainable Aerial Services'. In: *IET Smart Cities* (Apr. 2022). URL: https://hal.archives-ouvertes.fr/hal-03616495.

[4] A. Hameed, J. Violos, A. Leivadeas, N. Santi, R. Grünblatt and N. Mitton. 'Towards QoS Prediction based on Temporal Transformers for IoT Applications'. In: *IEEE Transactions on Network and Service Management* (2022). URL: https://hal.archives-ouvertes.fr/hal-03828639.

[5] G. Lia, M. Amadeo, G. Ruggeri, C. Campolo, A. Molinaro and V. Loscrì. 'In-Network Placement of Delay-constrained Computing Tasks in a Softwarized Intelligent Edge'. In: *Computer Networks* (Oct. 2022). URL: https://hal.archives-ouvertes.fr/hal-03827207.

[6] V. Loscrì and E. Bout. 'Cybersecurity of the Low Power Wide Area Networks (LPWAN)'. In: *Encyclopedia of Cryptography, Security and Privacy* (Nov. 2022). URL: https://hal.archives-ouvertes.fr/hal-03877629.

[7] D. Mishra, A. M. Vegni, V. Loscrì and E. Natalizio. 'Drone Networking in 6G Era - A Technology Overview'. In: *IEEE Communications Standards Magazine* (2022). URL: https://hal.inria.fr/hal-03450952.

International peer-reviewed conferences

[8] J. Koteich, C. Salim and N. Mitton. 'Spatio-Temporal Data Reduction Technique in WVSN for Smart Agriculture'. In: STWiMob 2022 - The 15th International Workshop on Selected Topics in Wireless and Mobile computing. Thessaloniki, Greece, 10th Oct. 2022. URL: https://hal.archives-ouvertes.fr/hal-03781866.

[9] V. Loscrì, A. Costanzo, R. Ushirobira and D. Efimov. 'OSCI-LIGHT: Oscillators based Synchronization for Visible Light Communication Systems'. In: *INTERNATIONAL CONFERENCE ON EMBEDDED WIRELESS SYSTEMS AND NETWORKS (EWSN)*. International conference on embedded wireless systems and networks (EWSN). Linz, Austria, Oct. 2022. URL: https://hal.science/hal-03765737.

[10] C. Rizza and V. Loscrì. 'Study on the Interference of a Communication System based on a Metasurface in mmWave'. In: *IEEE Global Communications Conference (GLOBECOM)*. IEEE Global Communications Conference (GLOBECOM). Rio de Janeiro, Brazil, Dec. 2022. URL: https://hal.science/hal-03765723.

[11] E. Staddon, V. Loscrì and N. Mitton. 'AODV-Miner: Consensus-Based Routing Using Node Reputation'. In: WiMob 2022 - The 18th International Conference on Wireless and Mobile Computing, Networking and Communications. Thessaloniki, Greece, 10th Oct. 2022. URL: https://hal.inria.fr/hal-03787034.

[12] R. Ushirobira, D. Efimov, A. Costanzo and V. Loscrì. 'Synchronization of oscillators by nonlinear measurements with application to VLC'. In: CDC 2022 - IEEE Conference on Decision and Control. Cancun, Mexico, 2022. URL: https://hal.inria.fr/hal-03903836.

Conferences without proceedings

[13] E. Bout, A. Brighente, M. Conti and V. Loscrì. 'FOLPETTI: A Novel Multi-Armed Bandit Smart Attack for Wireless Networks'. In: ARES 2022 - 17th International Conference on Availability, Reliability and Security. Vienna, Austria, 23rd Aug. 2022. URL: https://hal.archives-ouvertes.fr/hal-03696288.

[14] E. Bout and V. Loscrì. 'An adaptable module for designing jamming attacks in WiFi networks for ns-3'. In: MSWIM 2022. Montreal, Canada, 24th Oct. 2022. URL: https://hal.archives-ouvertes.fr/hal-03765858.

[15] E. Bout and V. Loscrì. 'Un nouveau module pour simuler des attaques de brouillage sur Ns-3'. In: CORES 2022 – 7ème Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Saint-Rémy-Lès-Chevreuse, France, 30th May 2022. URL: https://hal.archives-ouvertes.fr/hal-03661969.

[16] A. Costanzo and V. Loscrì. 'Adaptive Energy Saving Technique with Saturation Avoidance for Outdoor VLC'. In: VTC 2022 - IEEE 95th Vehicular Technology Conference. Helsinki, Finland, 19th June 2022. URL: https://hal.archives-ouvertes.fr/hal-03610904.

[17] M. Mayahi, A. Costanzo, V. Loscrì and A. Vegni. 'An Interference to Noise Ratio Handover mechanism for Mobile Visible Light Communication Networks'. In: CSNDSP 2022 - 13th International Symposium on Communication Systems, Networks and Digital Signal Processing. Porto, Portugal, 20th July 2022. URL: https://hal.archives-ouvertes.fr/hal-03689831.

[18] M. Mayahi, V. Loscrì and A. Costanzo. 'INVISIBLE: Enhanced Handover technique for Vehicular Visible Light Networks'. In: VTC 2022 - Spring IEEE 95th Vehicular Technology Conference. Helsinki, Finland, 19th June 2022. URL: https://hal.archives-ouvertes.fr/hal-03615732.

[19] E. Staddon, V. Loscrì and N. Mitton. 'AODV-Miner : Routage par Consensus Basé sur la Réputation'. In: CORES 2022 – 7ème Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performance et l'Expérimentation des Réseaux de Communication. Saint-Rémy-Lès-Chevreuse, France, 30th May 2022. URL: https://hal.archives-ouvertes.fr/hal-03659299.

Scientific books

[20] V. Bellon Maurel, L. Brossard, F. Garcia, N. Mitton and A. Termier. *Agriculture and Digital Technology: Getting the most out of digital technology to contribute to the transition to sustainable agriculture and food systems*. Jan. 2022, pp. 1–185. DOI: 10.17180/wmkb-ty56-en. URL: https://hal.inrae.fr/hal-03604970.

[21] V. Bellon Maurel, L. Brossard, F. Garcia, N. Mitton and A. Termier. *Agriculture et numérique: Tirer le meilleur du numérique pour contribuer à la transition vers des agricultures et des systèmes alimentaires durables*. INRIA, Jan. 2022, pp. 1–195. DOI: 10.17180/wmkb-ty56. URL: https://hal.inrae.fr/hal-02887646.