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Hadronization in small and large ultrarelativistic hadronic systems in the framework of the open quantum systems

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Description

The context: The interpretation of the ultra-relativistic heavy ion collision (URHIC) data collected at the CERN and RHIC Collider is the center of interest of the high energy theory group at Subatech. It is believed that in such collisions, a new state of matter is achieved, the so-called quark-gluon plasma (QGP), where quarks and gluons usually confined in protons and neutrons are deconfined and free to propagate over large distances for a short lapse of time before cooling down and being converted in usual hadronic matter. We have developed in the recent years the event generator EPOS4 (https://klaus.pages.in2p3.fr/epos4/) to study the soft physics as well as the joined EPOS-HQ to study heavy quarks which traverse the plasma of quark and gluons, formed in these reactions. The goal of this approach is to develop a program which reproduces simultaneously the heavy as well as the light quark physics to reduce the uncertainties inherent in this approaches because the underlying theory of strong interactions, the Quantum-Chromo-Dynamics (QCD) can only solved in special cases.

One of the most intriguing mechanisms associated with this area of physics is the process of (re)hadronization itself: how quarks emanating from the QGP will be dynamically converted into hadrons and which properties from the QGP will be imprinted on these hadrons. This question is crucial to be able to interpret the wealth of data measured by RHIC and LHC experiments. During the last years, we (among some researchers) have started to investigate the feasibility to deal with the hadronization of heavy quarks (c and b quarks) with their antiquark partner – into a so-called quarkonia – by adopting the viewpoint and concepts of the so-called "open quantum system" (see f.i. ref. [1-3]), which appears to be the correct dynamical framework for such situation. In particular, we were able to treat the somehow simpler case of bottomonia production at the large hadron collider (LHC) where only one beauty-antibeauty pair is considered, with promising perspectives. More recently, we have investigated the question of open-quantum system resorting to Linblad-like equations acting on the operator-density, simplified by resorting to semi-classical approximations [4]. This approach could be quite relevant in order to deal with the production of charmonia in AA collisions, a process which appears to be dominated by the recombination of exogenous pairs happening when the QGP cools down where semiclassical approximations may me relevant. In the future, we also plan to

apply these methods to the recombination of one heavy quark with one light quark which more complicated due to relativistic effects.

The thesis project: During the PhD thesis, we plan to pursue the investigation of quarkonia production in URHIC resorting to the concepts and methods of open quantum systems. In particular, we will focus our investigations on the topic of the dynamical Q-Qbar confinement that is restored during the cooling down of the QGP, that will be treated in the open-quantum system approach; expectedly, the method will be extended to address the question of the hadronization of heavy quarks into open flavor mesons (and hadrons) in order to aim at a universal description,... Apart from theoretical developments, some part of the PhD is expected to be devoted to phenomenological studies on the URHIC studied experimentally at RHIC and LHC colliders, in the framework of the EPOS4 framework. This will encompass some extension to the case of collisions performed with large and small nuclei, as the resulting QGP properties depend on the system size. This project offers the possibility to perform significant progresses in this highly debated topic of probing one of the most intriguing state of matter ever discovered by Mankind. It will help the candidate to develop skills both in the field of theoretical nuclear and particle physics, as well as in statistical physics, while being balanced between theoretical developments and numerical investigations depending on the candidate's skills. It can thus be considered as a real springboard for the candidate's future career.

The candidate: We expect from the candidate a solid background in theoretical physics, especially of the different aspects of QCD as well as basic knowledge in numerical physics. Candidates with good knowledge of open quantum systems are encouraged to apply as well, even if they have a less extended background in QCD. In addition to disciplinary knowledge, the expected skills are: ability to carry out long and complex tasks by implementing control processes, spirit of initiative, imagination, curiosity,...

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Magnon beamforming at the nanoscale

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Description

Academic environment:
IMT Atlantique, internationally recognized for the quality of its research, is a leading general engineering school under the aegis of the Ministry of Industry and Digital Technology, ranked in the three main international rankings (THE, SHANGHAI, QS). Located on three campuses, Brest, Nantes and Rennes, IMT Atlantique aims to combine digital technology and energy to transform society and industry through training, research and innovation. It aims to be the leading French higher education and research institution in this field on an international scale. With 290 researchers and permanent lecturers, 1000 publications and 18 M€ of contracts, it supervises 2300 students each year and its training courses are based on cutting-edge research carried out within 6 joint research units: GEPEA, IRISA, LATIM, LABSTICC, LS2N and SUBATECH.
The proposed thesis is part of the research activities of the Magnonic team within the Microwave department. The scientific activities of this department are related to the propagation of electromagnetic waves, and concern mainly the modelling, design, construction and characterization of high-frequency signal processing devices, as well as original propagation media for their applications in various communications systems

Scientific Context:
The emerging field of magnonics focuses on the transport and processing of information by elementary magnetic excitations called spin waves (or their quanta magnons) [1]. A Travelling spin wave carries angular momentum without a net motion of charges; therefore, it appears as a potential building block for low-power data processing and computing [2]. Furthermore, magnons display unique properties of anisotropy, non-linearity, and non-reciprocity that are finely tunable in a broad range of the microwave spectrum. The peculiar wave nature of magnon constitutes of formidable ground for novel wave computing methods, such as spin wave logic, holographic memory, and neuromorphic computing, all of which are essentially interference based methods.

Expected contributions of the Thesis:
Along this global effort to explore the interferometric potential of magnons, we offer at IMT Atlantique in Brest (https://www.imt-atlantique.fr/en/research-innovation/phd) a PhD position starting in the fall 2024 to study the shaping and the manipulation of spin wave beams at the nanoscale. Recent advances inspired from the concepts of optics

demonstrated the focusing or diffracting of spin wave beams in continuous film with properly designed microwave antennas [3,4]. In parallel, unidirectional transmission of micron-size spin waves beam was achieved very recently using the chiral coupling between the uniform resonance of NiFe nanowires and exchange spin waves in a thin YIG film [5]. In this project, we aim at combining both ideas, and explore configurations of magnetic nanostructures coupled to a continuous thin film that can create interference pattern readily adjustable.

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Mesuring online communities'efficiency and viability

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Description

The aim of this thesis project is to understand the sustainability factors of online collaborative communities (epistemic communities, communities of practice, crisis management communities, etc.). By establishing reproducible methods for assessing usage, this project will contribute to the challenges of digital transformation of organizations through multidisciplinary research in management and data science.
Extending the Institutional Analysis and Development Framework (Hess & Ostrom 2007) by theoretical and conceptual perspectives on virtual teams (Morrison-Smith & Ruiz, 2020) and team viability and safety (Cao et al. 2021), this project will:

- develop a conceptual framework consisting of variables to describe virtual collaboration in knowledge production, based on a review of the literature; This framework will detail 1) the different input-process-output elements to look at in the evaluation of an online community, and 2) the relations between the inputs, the process, the output and the viability;
- collect data on a project to evaluate how these variables, or a sub-set of these variables, can be measured in an online community;
- test machine learning models that can explain one variable, for instance the viability in the case of Wikipedia.

The first field of analysis we are considering is the well-known epistemic community, Wikipedia. We will choose a wide range of projects (e.g. ...), more or less sustainable, of different sizes, so as to detect regularities related to sustainability. Then we'll analyze other types of online collectives (crisis management communities, innovation communities) and seek to assess the generalizability of the models, and where appropriate, common and differentiating properties.

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Analysing Civic Tech project to design replicable process models allowing them to scale-up

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Description

Civic technology refers to the diverse ways people are using - mostly digital - technology (exchange platforms, data aggregation platforms, but also physical sensors) to provide more accurate and complete information about a problem, coordinate to address it, and ultimately improve its democratic governance. Common to all these projects is that they address a societal need identified by the citizens, or together with the citizens. Examples are: identifying air pollution (i.e. sensor.community), transparency (i.e. open water quality data in TrinkWasser), or developing participatory governance (e.g. participatory budgeting using the decidim.org open-source infrastructure, like in Brest).

Civic tech projects are often driven by volunteers, in that they develop the technologies, participate in the data collection, or in the debates on how to solve social issues by designing policy proposals. For these projects to be truly democratic, they must rely on platforms easy to access for everybody, regardless of their computer skills, both in terms of their usage and of people's capacity to request design evolutions. Most of the time, the solutions are created together with or bespoke for the community making them specific both technically and in terms of functionalities developed. However, to have a tangible impact, successful approaches at the local level must scale up by sharing the tools (technologies and action plans). Some nonprofits have started such a plan, such as “code for all”, but several challenges have to be addressed to do so.

1) The projects have to be able to inboard the different stakeholders, from those who have the technical skills to contribute to the technologies developed to those who need help to use these technologies or to feedback on their needs,

2) The projects have to develop the socio-technical organisation that allows them to govern tens to hundreds of participants, from different local places, having different needs.

This research aims to help projects scale up by developing models of their organisation and processes, informed by the literature in software engineering and digital commons institutional studies.

IMT Atlantique
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A multi-source energy harvesting platform for smart sensors. Application to an air quality monitoring network.

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Description

This thesis aims to develop a platform able to aggregate energy from different sources such as Radio Frequencies (RF) waves, thermoelectricity and piezoelectricity. The aim is to maximise energy harvesting so that it can be stored in electrostatic devices. The stored energy will then be used to operate on-board sensors that will transmit their data. The context envisaged is the set-up of a network of sensors to measure environmental parameters. The platform has a number of objectives, including being able to handle different input power levels, optimising storage, and ensuring a good match in terms of instantaneous power between the platform and the chosen sensors.

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Secure and Robust IoT Communications

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Description

The IoT sector keeps on developing with applications in critical fields such as health, energy... Effort to produce low-cost low-power devices are considerable in order to fit in the IoT business model. However, in the aforementioned application fields, security is as important as cost and power. The issue can be tackled in different ways. The most natural one is the encryption of data. A complementary alternative applies at the signal-level before its transmission. This PhD aims at investigating signal processing techniques to prevent the IoT communication to be detected by an eavesdropper even when located in the neighborhood of either the source or the destination: in these cases, the assumption that the legitimate user and the eavesdropper experience a different channel no longer holds.

One of the key performance indicators in the IoT ecosystem is the energy consumption of the transmitter, especially for standalone battery-operated devices. It is thus necessary to come up with constant envelope signals in order to efficiently amplify the transmitted signal. Other physical properties of the equipment will be ignored in a first time. They could be exploited in a second phase to further enhance the security.

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Design of an ASIC for a DC/DC converter dedicated to radio frequency energy harvesting

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Description

Radio frequency energy harvesting is a technique for powering sensors to make them autonomous. The usual architecture consists of a rectenna associated with a DC to DC converter enabling the DC voltage delivered by the rectenna to be matched to the sensor supply voltage.
The aim of this thesis is to design an analogue integrated circuit in CMOS technology that performs this DC/DC conversion. The incident power and voltage levels obtained are often very low (a few uW and a few hundred mV). It is therefore necessary to design specialised start-up circuits to raise the input voltage to an output voltage of around 1.5 V, in line with the needs of the sensor. The power efficiency of the converter must also be maximised. The candidate must be familiar with analogue integrated circuit design and will use Cadence software.

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Enhancing Radomes functionalities and active antennas performances for millimeterwave reconfigurable multibeam solutions using additive manufacturing & flex technologies

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Description

Exploiting mmWave frequencies for future 5G networks appears as a fundamental ambition, bringing scientific challenges and issues regarding both new design concepts for antennas architectures and technologies toward agile and low power consumption solutions critical for the development of future mmWave communication networks

The main challenges in the millimeter band lie in the design of energy-efficient systems inducing co-designed RF circuits and antennas. The objectives are to create reconfigurable antenna solutions with beamforming and multi-users MIMO capabilities, and to design advanced digital processing techniques to manage these systems.

A high-gain and wideband antennas remain mandatory at mmWave frequencies to exploit efficiently the huge available spectrum. Array solutions including thousands of elements guarantee the required power budget specifications in terms of realized gain and EIRP (Effective Isotopically Radiated Power), as well as sectorization possibilities through individual amplitude/phase controls.

Nevertheless, specific investigations have to be done regarding spatial feeding techniques to achieve extremely energy efficient solutions, while preserving flexibility on multibeam radiation patterns possibilities. In particular, individual amplitude-phase planar array excitation modules have to be ideally suppressed to reduce feeding module losses.

Emerging concepts are addressed by this thesis, considering new combinations of low-profile transmit-array or flat-lens architectures with alternative beamforming approaches exploiting either holographic techniques or artificial beamforming through surface impedance modulations. Indeed, a spatial surface impedance modulation controlled through holographic techniques or metamaterial structuration can be exploited to transform a reference excitation mode to guided surface mode and then to a desired radiation pattern through an appropriate controlled nearfield illumination. A near-field illumination of the planar array can be ensured through 3D multi-materials-based radome-likely functionalities using additive manufacturing, eventually combined with flexible technologies to report tuning components for holographic mode control.

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Design of advanced beam-forming techniques for simultaneous scanning & communication operating modes antennas for 5G/6G OpenRAN

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Description

The improvement of 5G communication networks performances brings strong constraints on the implementation of MIMO systems in the RU (Radio Unit), with enhanced capabilities in terms of multi-beam operating modes that can be dynamically changed depending on expected data rates and environmental impact. The ability to scan and to optimize communication links, with the ambition of reducing power consumption and ensuring interoperability and multimodal connections are addressed by this thesis.
As part of this proposal, we are working on the development of “Plug-in” solutions for radio access interface components at the OpenRAN (Open Radio Access Network) layer, focusing on antenna systems to provide new features.
Based on the analysis of the limitations of “off-the-shelf” solutions, the first part of the thesis aims to identify concepts of antenna networks currently used for 5G/6G Radio Units, including in particular reconfigurability radiation properties.
We will investigate new approaches, with proofs of concept allowing us to offer new radio sensing and multiple beamforming functionalities. We will contribute to the design and optimization of multi-beam antennas for spatial diversity and multi-band capabilities.
Finally, We propose to investigate radio sensing techniques to better manage this radio link according to user needs and quality of service, with a better consideration of the use of radio, electromagnetic and energy resources.

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From design to use: realism of healthcare simulators to improve immersion training and learning experience in medical technologies

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Description

High-fidelity health simulators for training purposes replace the patient with a sophisticated manikin, enabling medical and nursing staff to train safely. The research focuses on the issue of the realism of healthcare simulators to improve students' immersion training. An initial qualitative study was carried out with trainees to understand their perception of the realism of simulators, as well as the reasons for embracing simulation practice. Our results show that, beyond the physical resemblance of the manikin, what enables students to engage with the simulation is the fact that the situation is possible and plausible. To ensure that the simulation is as realistic as possible, the manikin obviously must be closely associated with its context, i.e., to other equipment, material, operating environment and scenarios.

The aim of the PhD will be to extend this study and include manikin manufacturers, to understand how realism is considered in the design and improvement process of simulators, in accordance with the needs of students and trainees. Simulation on manikins is undergoing numerous technological developments (high-fidelity – and augmented reality manikins, hybrid patient simulators, etc.), which leads to questioning the impact of technology on the performance of simulation-based training. A central question is the extent to which technology can suggest the feeling of a patient's presence during simulation. Ultimately, the aim is to adapt simulation technology as closely as possible to its uses: defining concrete needs in terms of simulation realism raises the question of functionality, resemblance and, more generally, of all the interactions with the manikin.

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Power supplying integrated circuits using low energy RF sources.

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Description

Sensors are becoming more and more ubiquitous in our daily life whether for monitoring our environment or our health. Sensors are typically powered using a limited source of power, i.e. a battery, which effectively limit the effective life of the sensor. To extend the sensor's life, it is usually better to put some intelligence into the sensors so that instead of transmitting raw data it rather transmits information, thus significantly reducing the amont of bit to transmit via the RF link, hence the terms smart sensor. Doing so, also has the benefit of significantly reduce the smart sensors power consumption that one can envisage getting rid of the battery and power the smart sensor using energy harvested from the environment.

A known solution is to use NFC to power integrated circuits, however, the energy transfert is usually llow. Another solution consists in harvested RF sources such as mobile phone or wifi, but again energy levels are low and existing technical solutions are not suited for integration.

This Ph.D aims at exploring on-chip methods to power integrated circuits using low energy RF signals.

The research work will done in the general context of smart autonomous sensors, and a fully functional prototype able to power an M0 cortex core is expected at the end of the Ph.D work.

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AI-augmented Techniques for Consistency and Validity in Continuous Digital Twin Engineering

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Description

The PhD thesis will be realized in the context of the MATISSE European collaborative project funded by Horizon Europe and the KDT (now Chips) Joint Undertaking. The objective of MATISSE is to provide a global approach and supporting framework for the model-based engineering of Digital Twins (DTs). Nowadays, DTs and their practical usages are very hot topics both in the industry and in research communities. In MATISSE, the produced model-based DTs will be used for the early verification and validation of the corresponding industrial systems.

The candidate will work on the core model-based framework supporting the MATISSE approach. Engineering a DT involves dealing with different kinds of Digital Models or DMs (e.g., software models, physical models, mathematical and/or AI models) and Digital Shadows or DSs (providing the data from the actual system). These heterogeneous DMs and DSs can be combined within model views so that the DT engineers can get a better global understanding of the DT being engineered, as well as of the underlying system. Thus, how to ensure traceability and synchronization when the views, DMs and DSs frequently evolve over time?

We currently envision the combination of a model view solution (EMF Views) with different model transformation-related techniques, complemented by the use of AI (notably Large-Language Models or LLMs as state-of-the-art generative AI techniques). The candidate will conduct research in this direction, design and develop corresponding software prototypes, and experiment with the proposed solutions in the context of industrial use cases provided by MATISSE. We target the publication of the obtained results in international scientific journals and conferences on Software & Systems Engineering and Modeling.

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Towards a Comprehensive Evaluation Framework for Dynamic Community Detection Algorithms

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Description

Keywords: Graph mining, clustering, Complex Networks, algorithm, temporal networks, dynamic, community detection, benchmark

The study of community structure in networks that change over time is an important area of research because many real-world networks, such as social networks, communication networks, and biological networks, are dynamic and evolve over time. Understanding how communities change and evolve in these networks can provide insights into the underlying mechanisms that drive their behavior.

Various algorithms have been developed to tackle the challenge of detecting evolving communities in dynamic networks. Comparing these methods is complex because, similar to static networks, there is no universally accepted definition of what constitutes a community. Community detection algorithms may prioritize optimizing certain metrics, making it challenging to determine what they can detect within a given context. Furthermore, establishing a benchmark framework for evaluating dynamic community detection algorithms is a significant challenge While benchmark like LFR adaptation to temporal networks, RDyn, and Mosaic have been proposed for synthetic temporal networks, these approaches come with their limitations. Choices such as modeling in the form of snapshots, the use of decay metrics, and a preference for non-overlapping and continuous communities inherently exclude certain algorithms that may not align well with these criteria. Finally, to date, there is currently no established model for community evolution, though efforts have been made to extend the stochastic block model to dynamic networks. Limited research has focused on metrics describing temporal communities, and there is a lack of studies categorizing the typology of temporal community structures. While some works have endeavored to characterize how communities interact over time [9, 10], unlike research in static communities [4, 7, 8], exploring the classification of temporal community structures' typology is a research gap yet to be addressed.

This PhD thesis will contribute to the broader consideration of defining the concept of dynamic communities. We plan an exhaustive empirical analysis of the communities revealed by existing algorithms on a large variety of datasets. The first step is to propose

new algorithms for dynamic community detection, e.g. hybrid approaches to emphasize different criteria. The second challenge is to build a typology of the different forms of structures that can be retrieved at a meso scale and evolving over time by algorithms. Due to the diversity of techniques and the variety of definitions of what a community is, it would be necessary to define quantitative and qualitative metrics that characterize dynamic partitions and the nature of communities retrieved by algorithms.
Finally, the aim is to contribute to the development of a benchmarking framework. This framework will facilitate algorithm comparison by generating synthetic datasets with ground truth data and adjustable parameters that reflects community dynamics diversity. The work will build on the Dyn-Bench benchmark project within the DECIDE team.

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Study and Design of RF Sensors Based on Coupled Resonator Topologies

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Description

The use of Radiofrequency (RF) sensors allows for real-time, continuous and non-invasive data extraction, which is an asset for many applications, particularly those operating in constrained or complex environments. In this context, one of the main challenges related to the development of RF sensors relies in the achievable sensitivities of these devices. Indeed, non-invasiveness, while being an undeniable asset for many applications and an essential characteristic of electromagnetic sensors, implies a weaker/more difficult interaction with the media to be characterized, especially in the case of complex environments (such as the presence of an enclosure or a container, for example). Thus, to compensate for this lower interaction between the transducer and the media to be characterized, it is necessary to increase the sensor's sensitivity to the measurands to be detected while ensuring significant selectivity to avoid contaminating measurements with errors related to the surrounding environment. The objective of this PhD is to develop new high-sensitivity microwave sensor topologies based on coupled resonator structures.

IMT Atlantique
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Information Theory for Machine Learning over Compressed Data

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Description

In the emerging field of "goal-oriented communications" [1], the aim of the receiver is no longer to reconstruct data, but instead to perform a specific learning task (classification, decision-making, semantic analysis, etc.) on the received data. To significantly improve transmission efficiency, it is essential to address this task and its specific performance criteria when designing the communication system. Such an approach is even more critical today as the amount of data available online is huge: every minute, 500 hours of video are uploaded to YouTube, and 240,000 images are sent on Facebook. Therefore, it is essential to resort to advanced learning methods to process the data, sort it, or recommend it to users.

In this PhD, we will aim to consider the common case of a storage server containing a large amount of compressed multimedia data (images, video, etc.), issued, for example, from a social network. The goal of the PhD will be to design compression systems dedicated to learning tasks to be applied on the coded data. We will focus particularly on unsupervised learning tasks, i.e., those for which no labels are available for learning. These labels can indeed be difficult to obtain in such a context. The PhD work will first consist of a theoretical analysis by using information theory tools to predict the performance which can be achieved by a coding scheme dedicated to learning. In a second part, the objective will be to design efficient coding schemes dedicated to learning, by resorting to tools from both source/channel coding and Machine Learning.

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Channel code design for GEO satellite free-space optical communications

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Description

Urged by the demand for the high capacity requirements stipulated by the deployment of expansive telecommunications services, such as HD-TV and broadband Internet, the necessity for Geostationary Orbit (GEO) very high throughput satellites (VHTS) has become of high interest. Traditional RF technologies, challenged by regulatory constraints, saturation of usable RF spectral bands, and technical limitations, are rapidly reaching their saturation points. Consequently, Free Space Optical Communication (FSOC) has emerged as a promising high-speed satellite data transmission technology. However, the implementation of FSO-based satellite communication is not without its difficulties. These systems are particularly susceptible to atmospheric conditions, causing considerable signal degradation and loss. Moreover, additional impairments such as signal distortions, low received powers, ambitious targeted data rates, and constrained onboard resources, further increase the challenges of the FSO communication deployment.

In the proposed thesis, the main focus will be set on the development of several key areas within the optical physical layer functions. The first step will be to model an optical transmission channel operating in free space, designed to be representative of an uplink and a downlink of a GEO feeder link. Then, the next step of the work will involve the design and validation of forward error-correcting codes suitable for the stringent performance and hardware constraints of very-high-throughput coherent optical GEO feeder links. Having designed the codes and decoders, the next step will be to investigate how to best combine them with high-order constellations. Here, the goal is to design modulation and coding schemes with close to capacity performance over a wide range of receive optical power values. In contrast to RF satellite communications, coherent optical communications are impaired by strong phase noise that can only be partially compensated. Another challenge is to preserve low decoding complexity for the overall coded modulation scheme without compromising the performance. A particular attention will be paid to probabilistic shaping (PS). PS is a powerful DSP technique that has proved particularly useful in improving the performance of fiber-optic communications, especially in terms of capacity-approaching performance and rate adaptation. On the other hand it requires a distribution matcher which increases the complexity and latency of the system. Geometric shaping is another approach to near-

capacity performance. This was the solution adopted for DVB-S2. We would like to assess and compare these two approaches within the GEO feeder context. In a final step, we plan on investigating how FEC can help mitigating the detrimental fadings induced by atmospheric turbulence. The first and most natural approach is through the combination of interleaving and code rate adaptation. But other error control coding strategies may be considered, for example the use of ARQ or erasure coding at the link layer level. This calls for a comparison of these different strategies, in terms of performance, complexity (especially the memory), uplink utilization, latency, and link efficiency.

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Energy Harvesting and Storage by an LTCC device

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Description

In the context of electronics miniaturization, various solutions exist for integrating, powering and protecting integrated circuits (ICs). LTCC (Low Temperature Cofired Ceramics) technology has been one of these solutions since its invention some forty years ago. The advantages of LTCC over other types of packaging platforms are its high temperature resistance (500°C), miniaturization capability, 2.5D integration, good conductivity of the metals used for metallized vias and tracks, its coefficient of thermal expansion (CTE) close to that of ICs, the possibility of creating cavities and channels on the outside or inside, and its inherent hermeticity, to mention just a few. A LTCC design and manufacturing platform has been part of the Lab-STCC Microwave Department since 2009.

In this thesis, we plan to develop energy harvesting and storage components and integrate them into a single device to improve the energy autonomy of on-board equipment. Our aim is to provide an answer to the questions raised about size, weight, energy consumption and performance, and we even hope to improve the thermal management of the devices. In the future, our system could be integrated with sensors, taking advantage of the integration capability offered by LTCC technology.

The PhD student will propose and study different possible solutions to maximize energy recovery and to store the energy until use.

Proposed work program
1) Bibliographical study in which the different types of harvesters and storage devices will be detailed and compared
2) Development of LTCC tape and ink (from powder)
3) Development, production and characterization of one or more energy harvesters (different types can be considered)
4) Development, production and characterization of one or more energy storage devices
5) Proof of concept module

The final aim of the project will be to produce, in a single module:
- one or more energy harvester
- one or more storage device (MIM capacitor, multi-MIM or solid state battery)

- a device to use the harvested energy.

Moreover, it is essential to build a complete subsystem comprising a voltage converter and regulation to take the fluctuating power from the various collectors and convert it into a stable supply voltage.

The successful candidate should have a Master's of science degree with background in material science, physical chemistry and/or nano/microtechnology. Ideally, the candidate has knowledge in ceramic materials and their creation from powder to ceramic device and some basic knowledge in electronics.

The candidate must also enjoy practical laboratory work and be able to carry out precision manual work.

Oral and written expression skills in English are required.

IMT Atlantique
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Data-Driven Simulation and Optimization of Green Supply Chain using Petri Nets

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Description

Green supply chain are an emerging approach in supply chain management to reduce environmental impact of the process concerning the flow of goods and material. It is considered as a discrete-event system. One possible tool to model discrete- event systems is Petri nets. A Colored Petri Net (CPN) model of the said green supply chain model is developed, the reason to use a CPN rather than ordinary Petri nets is because it allows the attachment of data (or color).

Green Supply Chains are considered at the intersection of 3 main domains: Control, for the Simulation Point of view, Operations Research for the Optimization aspects, and Environmental for the Green part.

The objective of the Thesis is to propose a new model of Petri Nets for simulation and optimization of Green Supply Chains. The proposed new model could be a colored Petri Nets or High-Level Petri Nets. It will take into account, for the optimization aspects, the tools and methods from Operations Research. This new model will beneft also from the new tools from Artificial Intelligence (A.I.) that will be used to gather and analyze the data in an optimized way. A software will be developed to support this new model of Petri Nets for Green Supply Chains. The software will be either developed from scratch or it can be and extension of an existing (free) software.

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Control of Hospital Logistics Systems using Dioid Theory

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Description

The logistics flows associated with hospital centers are undergoing partial automation nowadays. This trend of applying proven solutions from the industry has allowed hospital staff to free up time while simultaneously ensuring the availability of materials and information necessary for care operations. From the perspective of healthcare system reliability, this logistic automation also ensures a certain traceability of specific medications and materials.

Thus, successive experiments in hospital settings involving automated logistics, whether for linen, cleaning and sterilization of specific equipment, or the transfer of medical records between services contribute to the coexistence of heterogeneous logistic systems. However, these systems use shared resources such as corridors and elevators. Furthermore, despite the fact that these logistic systems share critical segments, it is noteworthy that they are generally acquired from specialized suppliers, and their successive integration into the hospital center's environment occurs without necessarily reconsidering pre-existing logistic systems, imposing additional operational constraints that need to be tackled.

In summary, hospital logistic systems, both internal [8, 3, 7] and external [2], generally include shared sections allowing the crossing of flows or a choice between different routes, but these aspects must be regulated either a priori or, at the latest, upon the arrival of a carrier, to avoid the risk of collision, for instance. A relevant research direction for supervising these conflict zones would be to use the framework of switching dioids [1].

The identified study subjects include:

• the robustness of trajectories for members of different fleets. The duration of a mission for vehicles and robots related to logistics may be altered due to stops for public safety or circumvention of obstacles. Thus, in the case of urgent missions with deadlines to meet, it is essential to find a route ensuring the deadline is effectively met or, at the very least, to quantify the expected delay;

• the rules for assigning different missions to fleet elements based on criteria established by managers of hospital systems;

• the possibility of breaking down the fleet management problem and using modular local control or iterative constraint integration. Dealing with supervisory control theory [6], the modular local partitionning has already been tackled [5], as well as the iterative integration [4]. But these contributions appear to be missing in the particular case of dioid

rameworks and promising tracks, such as the one presented by [1], whose application cases exhibit character- istics similar to those of shared sections.

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Energy-Efficient Slice Placement in 5G

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Description

Context

In 5G networks, the concepts of slicing and network function virtualization offer network operators
the ability to automate the creation and management of network services dynamically. To do
this, they need efficient placement algorithms capable of considering various constraints (quality
of service, cost, energy consumption, etc.) [4] and a potentially complex network architecture
composed of virtual infrastructures and data centers from different network providers [3].
However, in 5G networks, network services must be deployed not only in large data centers
but also at the edge. Particularly, placing virtual network functions (VNFs) involved in slices or
network services at an appropriate location to reduce energy and communication costs becomes
challenging in edge systems [5] due to the scarcity of their resources. The energy cost of the
system must be well assessed to consider the different facets involved: consumption from both the
user side and the infrastructure, and the cost of migration for VNF replacement or scaling [1].

Approach and Thesis Work

In this thesis, we propose to study the optimization of the overall network energy consumption
based on a realistic energy model depending on the load of each node. Placement optimization
involves considering network management parameters and a thorough analysis of function chains

to achieve the desired objective. In [3], we have already proposed a mathematical model and
resolution algorithms for the problem of placing virtual network function chains to accommodate
as many requests as possible. In this thesis, we aim to address the placement of more complex
slices and network services, as well as to improve placement by considering both maximizing
the number of accepted requests and minimizing network energy consumption [2]. Therefore, we
need to integrate an accurate energy model as mentioned above and derive optimal solutions,
approximations, or heuristics estimating the theoretical limits we can achieve for optimal network
management.

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High fidelity bio-electromagnetic solvers next generation EEG devices

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Description

The EIC Pathfinder project CEREBRO (an electric Contrast medium for computationally intensive Electroencephalographies for high REsolution BRain imaging withOut skull trepanation) will target the development of a new modality imaging the brain's anatomy and electrophysiologic activity which are critical to numerous applications including electromagnetic dosimetry, neurostimulation, brain computer interfaces, and the diagnosis of diseases such as cancer, epilepsy, and Parkinson's.

The traditionally, imaging of the brain activity is performed using an electroencephalograph (EEG), but because of the shielding effects of the skull, the spatial resolution of the readings is limited. One frequent solution to overcome this problem is to implant electrodes directly under the skull (ECoG) or on the cortex. The resulting imaging is of higher quality, but is only local.

CEREBRO will see the conception and design of a new imaging modality based on an electromagnetic contrast medium that will allow for the shielding effect of the skull to be circumvented, thus allowing for a high spatial resolution imaging of the whole brain activity, while preserving the high temporal resolution of modalities directly imaging the electrophysiologic activity.

The information that will be made available to the medical community has never been extracted before, and should allow for significant breakthroughs in the field of neuroscience and patient care.

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Automatic metamorphic analysis to characterize trustworthy artificial intelligence

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Description

Beyond multiple envisioned opportunities for current artificial intelligence (AI) applications, we are starting to understand the numerous associated potential risks, e.g. lack of transparency, socially built bias, private life violation, wrong decisions, misinformation, threat for groups of users and society, among others. An approach to mitigate those risks, like trustworthy AI, relies on ethical principles applied through the AI conception, development, and production cycle, to verify accountability and reliability. However, numerous of these principles are neglected by designers and developers. Moreover, since AI is built with non-deterministic components and related information is either insufficient or unavailable, AI trustworthiness cannot be evaluated by means of precise normalized tests, requiring exhaustive human action to verify the system responses. Not knowing the correct output for a given input, it is possible nonetheless by means of particular tests to analyze an AI model in conformity with metamorphic relationships, to make emerge and characterize hidden design features. To investigate AI evaluation and confirm if a system could be trusted, the PhD objective is to conceive automatic metamorphic tests and the corresponding benchmarking, capable of defining and evaluating the trustworthiness ranked level of AI models. Metamorphic tests verify AI model results, by analyzing multiple iterations of the input-output relationships, which should hold true after transformations are applied. These transformations are based on domain knowledge or properties inherent to the problem being solved. In our case, such verification approach intends therefore to reveal failure-causing and non-failure-causing test cases, without requiring ground truth. The goal is to ensure that the AI system behaves robustly, consistently, and correctly without potential unintended or negative effects, under different conditions. The main expected contribution of the PhD is to assess the value of automatic metamorphic analysis according to emerging issues of responsible AI dimensions that ensure trustworthiness.

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Waveform innovation for 6G: addressing synchronization, efficiency and integration challenges with filtered multi-carrier modulations

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Description

A. Context and motivations of the research topic

The applications and services envisioned for the 6G wireless communication systems are foreseen to provide ubiquitous connectivity and seamless service delivery in all circumstances. The important expected number of devices and the coexistence of human-centric and machine-type applications will lead to a large diversity of communication scenarios with stringent requirements on the system design. These requirements do not only concern increasing data throughput and achieving extremely reliable connections, with an availability of 99.999% [1-2]. The latency also becomes a crucial constraint for emerging applications such as tactile Internet or factory automation with an aim of 0.01ms end-to-end latency [1-2]. Furthermore, efficiency in terms of resources utilization, such as energy and radio spectrum, is becoming more and more critical.

Addressing these challenges requires investigation on new techniques from the application layer to the physical layer. For the latter, the current Orthogonal Frequency-Division Multiplexing (OFDM) waveform used in 5G suffers from a list of drawbacks that question its ability to support all these demanding constraints. In fact, OFDM was an attractive solution in 4G/5G due to its high robustness against multipath channel thanks to its Cyclic Prefix (CP), its orthogonality in both the time and frequency plane, its straightforward implementation with a Fast Fourier Transform (FFT), and the simple per-subcarrier equalizer.

However, the high Out-Of-Band Power Leakage (OOBPL) of OFDM compromises the coexistence of multiple services in the same carrier as foreseen in 5G. In addition, it requires strict synchronization with the base-station in time and frequency for each user, which adds important signaling overhead. Consequently, the latency and the energy consumption are highly impacted. In fact, with the emergence of efficient resource allocation techniques for grant-free multiple-access, the support by the physical layer of relaxed synchronization becomes of paramount importance. The waveform plays the central role in this regard.

Filtered multi-carrier waveforms, such as FBMC/OQAM, provide viable alternatives to OFDM. They exhibit better spectrum shape, resilience to imperfect synchronization (e.g. in dense networks with machine type asynchronous communications) robustness to high

mobility (e.g. in vehicular communications) and enable the coexistence of multiple diverse services.
In recent years, our research team has developed and patented several innovative contributions at the transmitter and receiver sides related to FBMC [3-11]. The conducted work has triggered several new ideas to address a few remaining challenges that we aim to investigate in this PhD topic.

B. Research objectives and work plan

In the context described above, our research team has recently proposed a novel transmission technique, namely Modulation Code Overlapping (MCO), based on intentionally overlapping the subcarriers of adjacent users to improve spectral efficiency of multicarrier systems. MCO was originally designed for SISO transmissions. However, since spectral efficiency (SE) is a crucial element of cellular communication networks, added to the continuous growth in mobile data traffic in wireless networks, there is a regain of interest in further enhancing SE for massive MIMO (mMIMO) systems. In mMIMO, user channels tend to be asymptotically orthogonal if the number of antennas at the receiver side is much larger than the number of users. However, the increase in number of users cannot remain unbounded indefinitely in the subband for improving the SE. Indeed, there is a compromise between system performance and SE since this increase will lead to a degradation in system performance dur to multiuser interference. To address this challenge, the MCO technique can be employed to potentially enhance the SE while maintaining optimal performance. The key idea is to overlap the subcarriers of adjacent subbands, with each subband accommodating different users. Essentially, the concept is to carefully manage the allocation of subcarriers and users across multiple subbands, leveraging the advantages of mMIMO while considering the limitations imposed by channel orthogonality and system performance. By exploring the potential of the MCO scheme in the context of mMIMO, we aim to strike a balance between achieving high SE and ensuring satisfactory overall system performance.
The second main objective of this thesis work concerns the investigation of algorithm simplification and complexity reduction techniques for the recently proposed contributions in our research team on waveform design at transmitter and receiver side. Efficient and optimized application-aware hardware/software architectures should be proposed and integrated into a demonstration platform as a proof-of-concept. For the demonstration platform, several options could be considered such as extending our available FPGA-based platform for wireless communications or adopting existing similar platforms from our academic and industrial partners.

C. Research group

Since the invention of turbo codes in IMT Atlantique by Prof. Claude Berrou (recipient of the Hamming Medal in 2003 and the Marconi Prize in 2005), the know-how of the MEE department has been extended and recognized in a wide range of cutting-edge communication techniques including diverse channel codes, modulation schemes, interleaving, MIMO systems, and generalized iterative processing targeting high-throughput, flexible-, energy- and cost-efficient air interface. A main strength

corresponds to the real algorithm/architecture interaction approach enabled by the recognized available skills at our department in both related fields.
The research group, proposing this PhD offer, has established a complete development framework with all required expertise, tools, and platforms for (a) algorithm definition, simplification and optimization, (b) architecture exploration, (c) hardware implementation, and (d) on-board validation and demonstration. Available design experiences can be classified in two main classes: proposal of highly optimized architectures for a specific application and exploring new architectural models and design methodologies to meet the emerging flexibility challenge. In this context, the ultimate target is to unify flexibility-oriented and optimization-oriented approaches in the design of flexible terminals for next generation communications systems. Different application requirements and key-performance indicators (KPI) in terms of throughput, latency, cost, energy consumption, error rate performance, and flexibility degree are considered in our research implementation activities.

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Supply chain resilience design and management in a BANI world

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Description

Various unforeseen events can severely affect supply chains, both in the long term (e.g., pandemics, global conflicts) and short term (e.g., acts of God like major earthquakes or floods, fires affecting facilities, or transportation disruptions at geopolitical chokepoints). The effects of unforeseen events may be critical, such as uncertainty or unavailability of supply, abrupt changes to costs and fulfillment conditions, disruption of production capacity, swift fluctuations in demand leading to mismatches between production capacity and demand. The effects of disruptive events are notably complex and can propagate throughout the supply chain. These disruptions occur more frequently, and today's world seems to be in constant chaos. As a result, business managers describe the current world (post-COVID-19 pandemic) as BANI (Brittle, Anxious, Non-linear, and Incomprehensible) in contrast to the VUCA (Volatile, Uncertain, Complex, and Ambiguous) world of the 80s.

In a VUCA environment (Bennett and Lemoine 2014), uncertainty are known and can be characterized and thus controlled. For instance, one may compute the demand distribution based on historical data. In this context, supply chain companies hedge against such uncertainties by applying mitigation actions (e.g., Graves and Willems 2000), such as safety stock, safety lead time, safety capacities, while minimizing the expected cost given the estimated probability distribution of the unknown parameters. These empirical probability distributions are also commonly used to design and manage the supply chain (Snyder 2006, Thevenin et al. 2021). In a BANI environment, events are rare, and very few historical data points exist. Nevertheless, the solution for supply chain stability and viability in a BANI world remains to build robust, stable, and resilient supply chains.

Manufacturing as a Service (MaaS) is a recent paradigm dedicated to helping manufacturers to improve the robustness and resilience of a supply chain. In a MaaS supply chain, a producer rents production resources (including data and software) from various factories to create its finished goods. In this context, each node of the supply chain can produce "on demand" a large variety of items without a long ramp-up time or a large down payment. MaaS is enabled by flexible manufacturing technologies, flexible contracts with suppliers, and the required information technologies in different supply chain nodes. In the context of MaaS, the specific supply chain (path from raw materials, production sites, distribution centers) for each order can be decided dynamically upon receiving the order. Therefore, a MaaS framework enhances resilience and robustness

since a manufacturer can still produce by selecting a different supply chain when one is not functioning properly.

The thesis aims to propose approaches to design and manage the resilience of supply chains in a BANI world, by leveraging the concept of MaaS. The objective of this thesis is to provide a decision support system that helps manufacturers to design robust, stable, and resilient MaaS supply chains and manage them under disturbances and disruptions. Various levers will be considered, including: (i) improving the efficiency of the supply chain design (such as efficient production, efficient logistics, efficient inventory), (ii) creating supply chain flexibility by redundancy (back-up facilities and links, capacity flexibility, inventory buffers), and (iii) monitoring the supply chain (Ivanov 2018).

For tractability reasons, the management of manufacturing decisions is generally decomposed according to the time horizon granularity, namely: long-term (strategic), mid-term (tactical) and short-term (operational). Generally, decisions are made independently per decision level. This decision process can lead to inconsistent or unfeasible decisions even under normal operating conditions. To enable a swift adaptation of supply chains subject to disruptions and minimize the impact of the disruption propagation, particular attention will be paid to ensure the consistency between strategic and tactical decisions, while levering the concept of MaaS and digital twin technologies. The research encompasses the following contributions:

- Perform a literature review on robust, stable, and resilient supply chain design,
- Propose key performance indicators to assess the robustness, stability, and resilience of a supply chain,
- Characterize the disruptions and associated mitigation policies and develop appropriate optimization approaches for an efficient SC design and management under disruptions,
- Design a simulation approach to track, trace, and evaluate the propagation of uncertainties, horizontally across the SC stakeholders, and vertically from strategic level to tactical one of the decision making process. The simulation includes the following capabilities: (i) assessment of the robustness, stability, and resilience of the supply chain to disruptions, (ii) the implications of strategic decisions on tactical and operational decision-making levels.
- Extend the capabilities of the decision support system to ensure the consistency from strategic level to operational level for swift adaptation purposes in case of disruption.
- Conduct case studies in collaboration with the industrial partners of the ACCURATE project to validate the proposed solution approaches and assess their relevance and applicability in real-life settings.

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Environment representation through multi-sensors systems: how to build automatically 3D sonar image mosaics from survey data.

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Description

This research deals with underwater environment assessment when operating on unknown areas. The main problem is to build a map (i.e. a mosaic) of the sea bottom from range-limited, multiple and overlapping observations (i.e. the collected images). These observations may come from one or several different sensors moving within the surveyed area.

From an operational viewpoint (e.g. mine warfare), estimation of the sensors actual coverage along the mission is crucial in order to detect accurately all seabed objects or mines. Comparing mosaics built from different surveys and checking differences allow such a global detection process.

Acquiring a scene or an environment is usually performed through several sensors, each sensor being dedicated to characterize a limited set of environment features. From one sensor to another, part of these sets may overlap. Thus, the reconstruction and global interpretation of the observed environment can only result from a fusion process merging adequately all these features acquired separately. In this study, we also assume that no global localization information exist along with the acquired data. This involves a very poor direct knowledge of the sensors positions during the acquisitions. The proposed research subject expands already existing works conducted at Telecom Bretagne about harbor monitoring and surveillance.

Indeed, underwater data collections (both image & bathymetric) often face these issues with all the presented hypotheses or constraints. Imaging sonars (sidescan or front-looking) produce images informing about the seabed sedimentology depending on textural aspects and local elevations through projected shadows. Furthermore, multibeam echosounders measure global seabottom topography. However, each sensor has a limited range. Thus, a whole survey consists of a series of acquisitions performed along specific trajectories followed by these sensors, in order to grant a complete coverage of the wide area to study. Along these pathes, sensors positions accuracy are not very reliable. For instance, imaging sonars are often mounted on underwater vehicles towed by a surface vessel using a long cable. Operational conditions (tow-fish / vessel sheers due to currents, ...) have a huge impact (almost non measured) on the tow-fish actual position.

In order to build a global representation of the surveyed area gathering all theses sources of information (both images and bathymetry), a registration process operating on these

heterogeneous data is required to relocate them within a unique relative spatial reference. It may become global when some pieces of data possess such global coordinates.

Thus the main goal of this Ph.D thesis is to design and implement an automatic fusion procedure in order to produce a synthetic and rich 3D representation of the surveyed seabed. The first step will consist in studying Simultaneous Localization And Mapping (SLAM) techniques to retrieve the actual sensors trajectories as they embed within an either local or global optimization procedure, kinematic and sensors acquisition models, extraction and pairing of the detected landmarks from data.

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Design of Near-Memory AI Accelerator

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Description

The last few years have seen the emergence of several specialized accelerators for embedded AI. Parallel architectures and specialized processing units have been integrated to meet the evolving computation needs of AI applications. However, there is still a huge gap in terms of energy efficiency, where at least one order of magnitude improvement is still required to enable battery-powered AI. Indeed, the time and energy cost of data movement between memory and processing units, encountered in conventional von Neumann architectures, is aggravated by the recent growth in AI applications.

The main objective of this PhD proposal is to investigate the design of a novel Memory-Centric Multicore Processor (MCMP) architecture for ultra-low power embedded AI accelerator. The target architecture should devise the best of memory-oriented techniques in order to drastically minimize the power consumption. Based on our team previous results on Memory-Based Computing (MBC) and Processing-In-Memory (PIM) design approaches, we will target the heterogeneous multicore architecture. MBC replaces logic by Non-Volatile power-gated memories (NVM) to leverage computation redundancy. PIM is a promising approach to reduce memory transfers and power consumption, particularly when using memristive memory arrays. PIM is very efficient for bulk-bitwise logic operations and for matrix multiplications, where the energy cost of moving data is orders of magnitude higher than the computation itself. Nevertheless, for some complex arithmetic tasks that require many successive basic PIM computation steps, passing the operands to a near-memory computing (NMC) unit can be more time and energy efficient. This unit is basically an embedded processor tightly coupled with PIM controllers. It will also be enhanced with a smart Network Interfaces (NI) to perform MBC.

This project will be carried out according to three main tasks:

1. The first task focuses on analyzing the most time-consuming functions of the embedded AI-application to be considered, and then devising the best mapping of their basic operations into the most appropriate computation scheme (PIM, NMC, or MBC).
2. The second task will focus on designing and implementing an application-specific processor (ASP) that directs the PIM controller and implements NMC operations.
3. The third task will propose an efficient NoC-based architecture that interconnects several instances of the devised ASP and make use of MBC to attain the optimal power efficiency. Performance, area and power consumption of the designed modules will be

characterized accurately. The model will execute the real basic functions considering accurate processing parameters and will provide accordingly accurate monitoring of the performance in terms of processing speed and energy budget. This task also includes the functional verification of the devised MCMP.

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Advanced ECC for Non-Volatile and DRAM Memories

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Description

Todays embedded systems including embedded AI require efficient memory components. Target applications such as autonomous driving have extremely challenging requirements with respect to bandwidth, latency and safety. In addition to high bandwidth and low access latencies, future DRAM and Flash memory architectures must provide extremely low error rates, availability and serviceability.

DRAM are volatile memories showing a low cost per stored bit with a bandwidth in the order of hundreds of GB/s. A periodic refresh mitigates the loss of stored information but penalizes bandwidth and latency, since accesses cannot be served during a refresh. Basic Error Correction Coding (ECC) is already used in today's DRAM devices to allow low refresh frequencies and guarantee a certain error rate. However, these are not sufficient to satisfy strict safety standards like the ISO26262 needed for autonomous driving.

Flash memories are Non-Volatile Memories (NVM) that enjoyed a continuous increase in capacity by 20% a year, leading to ubiquitous adoption. NVMs are liable to wear from write operations necessitating sophisticated wear leveling procedures and ECC to improve the endurance of NVMs. With recent NVM architectures like 3D-NAND-Flash storing multiple bits per memory cell, advanced ECC with soft decision decoding are needed. Non-binary codes can represent a viable alternative to currently considered Low-Density Parity-Check codes thanks to their ability to decode/correct multiple bits together, which matches modern memory cell architectures.

This project investigates advanced ECC for NVMs and DRAM including Non-Binary Turbo Codes first proposed in 2018 in the Region Bretagne. The goal is the joint design of code and decoding algorithm, explicitly considering the memory device architecture. Thus, we collaborate with the University of Würzburg who provides detailed knowledge on the memory device architectures.

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Model-Based Security Consistency Management for Complex Systems

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Description

Security is a critical concern in current software intensive systems in which vulnerabilities may have a severe impact and produce damages ranging from data privacy losses to even physical harm (e.g., cyber-physical systems). To alleviate this problem, security mechanisms (e.g., access-control, cryptography, etc.) have been integrated in many different components and artefacts so that it is possible to implement a security policy meeting the security requirements of a given system. Unfortunately, nowadays systems are very complex, encompass many different (evolving) components (e.g., code, libraries, models, databases, configurations), and interact with changing environments (e.g., they may be re-deployed). In this scenario, security is scattered between different components and artifacts, and consequently, the problem of security consistency arises (e.g., dependent components with available security mechanisms may fail to synchronize leading to potential security vulnerabilities). Contributing solutions to this problem is the high-level objective of this PhD proposal.

The concrete scientific and technical objectives of this proposal may be adapted to the expertise and skills of the successful candidate as long as they fall in the general objective of contributing to security consistency management. We list in the following some suitable contributions:

1. reverse engineering the security status of existing/deployed complex systems. This may include the means to: 1) represent and manage the security dependencies between components/artifacts; 2) express consistency requirements.

2. mechanisms to detect inconsistencies and semi-automatically repair them. As with the concrete scientific and technical objectives, the application domain for the works of this project is open and adaptable to the interests and knowledge of the successful candidate. Nevertheless, the P4S team is currently very active in the domain of digital twins, particular complex systems that may greatly benefit from security consistency.

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New trellis-based coding and decoding for post-5G applications

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Description

Future mobile networks will shape a fully connected, intelligent digital world, connecting people to vehicles, sensors, or resources stored in the cloud. Examples of envisioned use cases include augmented or virtual reality, holographic telepresence, e-health, and Industry 4.0. To make this vision a reality, 5G+ and 6G networks will have to be able to deliver higher data rates than 5G, with lower latency and better quality of service. These constraints apply in particular to the physical layer of these networks, where an essential building block for reliable radio transmission links is channel coding, also known as error correction coding. Coding solutions that satisfy each of these constraints separately are usually competing, requiring trade-offs. The goal of this PhD thesis is to reach a decisive step in the quest for better trade-offs than those of the state of the art. In order to do so, three paths can be explored:

1. Highly parallelizable decoding methods on graphs for long blocks: the approach followed in previous european collaborative projects allowed to better identify the links between the code structure and the degrees of parallelism be that can leveraged by the decoder. Thus, a new graph-based description of highly parallelizable code is currently under study and will be further developed by the candidate.

2. Simplified decoding methods approaching Maximum Likelihood (ML) for short blocks: mainly used for Internet of Things (IoT) applications where the target data rates are low, short block coding has to address the challenge of correction performance. In this case, iterative decoding seems to deliver sub-optimal performance due to a too high correlation between the information exchanged by the component decoders. Promising directions for quasi-ML decoders have been identified and will be investigated by the candidate.

3. Study of the contribution of artificial intelligence (AI) techniques to code design: the code design process can be described as a constrained optimization problem. The high number of constraints to be satisfied simultaneously and the non-complementarity, or even competition, of certain constraints requires the use of sub-optimal trade-off solutions. AI techniques represent an efficient tool for finding trade-offs adapted to the decoding structure, in order to reach correction performance very close to the theoretical

limit. In addition, implementation constraints can also be taken into account in the quest for very high throughput.

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Design of Fast NB-Decoder Architectures

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Description

Short packet transmission is the dominant type of communication in the internet of Things (IoT) ecosystem, where sensors, machines, and systems interact. The emerging applications of short-packet communication require ultra-reliable low-latency communications. Therefore, Non-Binary (NB) error-correcting codes are becoming more attractive than ever thanks to their error-correction capabilities over short-frames. In addition, data transmission over ultra-low Signal-to-Noise Ratio (SNR) can be achieved by coupling NB-codes with the Cyclic Code-Shift Keying (CCSK) modulation. However, the main drawback of NB-codes resides in the excessive complexity of their associated decoders when compared to their binary counterparts. Many recent research efforts were made in order to simplify and reduce the complexity of such decoders. When successful, this complexity reduction can pave the way for their adoption in future systems as attested by their recent introduction in the Chinese BeiDou Navigation Satellite System.
The main objective of this PhD proposal is to propose, starting from our team previous results, new simplified algorithms for NB-codes (NB-Polar, NB-LDPC and NB-Turbo codes), and then design the associated low complexity decoder architectures. The complexity analysis of the proposed decoder architectures will be conducted through their FPGA prototyping.
This project will be carried out according to the following four main tasks:

1. Study of the existing decoding algorithms
2. Algorithmic optimization and proposition of new simplified algorithms
3. Performance analysis
4. FPGA implementation of the proposed decoder architectures, and complexity analysis.