CALL 2-2023-1 PhD Fellowship in Advanced Artificial Intelligence/Machine Learning Techniques for Massive MIMO in 6G Communication Systems

Who are we looking for?

The Information and Signal Processing for Intelligent Communications (ISPIC) of the CTTC is looking for candidates to pursue a PhD degree in telecommunications. The contract will be funded by the Spanish Government (MICINN, Ministry of Science and Innovation) under its prestigious program 'Contratos predoctorales para la Formación de Doctores/as 2022'. Specifically, a PhD fellowship has been awarded to carry out research in the context of the 6G-AINA (Artificial Intelligence-Native Air interface for 6G, ref. PID2021-128373OB-I00) project. Highly motivated candidates are sought for this position.

T**his PhD thesis** will revolve around the **application of advanced AI/ML techniques to the design of large-dimensional antenna systems for 6G networks**. In this area, conventional AI/ML architectures such as Deep or Convolutional Neural Networks have been explored in recent years. However, they suffer from several drawbacks. On the one hand, the time-varying nature of the communications channel and network conditions impose frequent re-training those AI/ML systems which is time- and resource-consuming. On the other, conventional architectures generally ignore the topology of the network (i.e., how users, terminals and base stations are deployed). As a result, they often yield poor performance in large scale networks (i.e., poor scalability) and unseen network settings (i.e., poor generalization). The exploitation of advanced tools such as **Deep Reinforcement Learning** (DRL) schemes, **Transfer Learning** (TL) techniques, or ***Graph* Neural Networks** (GNNs) can be instrumental in overcoming such limitations. Hence, we will investigate how to leverage those tools to tackle **challenging problems in the design of the 6G physical layer** such as precoder design, user grouping, or beam selection in massive MIMO scenarios. Further details of the research project see annex (at the end).

What do we offer?

The duration of the contract is 4 years, starting in Q2-Q3/2023. As per the MICINN call conditions, the salary for the research fellow will be according with EPIF regulation. The contract includes the tuition fees of the PhD program, as well as a travel grant to carry out a research stay abroad. For details, please, see the official webpage of the call link Predocs fellowships

In addition, the CTTC offers **great benefits to employees**:

- Paid time off: vacation (33 working days per year), holidays, sick and parental leave and more
- Up to 3 days of telework per week. Other requests may be studied to accommodate special needs.
- Flexible working hours for work-life balance
- Tax-free optional benefits: restaurant ticket, nursery ticket, transport pass, private health insurance for employees and family.

Qualifications and Experience

We are looking for highly motivated candidates, with a strong desire to learn and interest in performing cutting edge research in a truly international R&D center with a very high involvement in international (e.g., Horizon Europe) projects.

Required qualification and skills:

- Master's degree in telecommunications, electronic/electrical engineering or in related fields (or soon to be completed).
- Strong mathematical/analytical skills and problem-solving capabilities.
- Solid academic record.
- Fluency in English (both written and oral).

Valuable skills (yet not required):

- Strong Python, Matlab or Octave programming skills.
- Knowledge in machine/deep learning techniques.
- Experience in working with Tensorflow, Keras and Machine Learning libraries (e.g. SciKit Learn).
- Experience in using GPU technology

Even if you do not meet all the requirements, we encourage you to apply. The candidates' past performance but also future potential will be considered as selection criteria.

How to apply?

Interested candidates can submit their applications **here.**

Application deadline: 26th January 2023, 14.00 h

VERY IMPORTANT: In the beginning of the process, the applicant is required to identify the project to which the PhD fellowship is associated to. The code and title of the 6G-AINA project are as follows:

- PID2021-128373OB-I00
- DISEÑO DE INTERFAZ RADIO 6G BASADOS EN INTELIGENCIA ARTIFICIAL

Please, **make sure you select this code and project**. Only one application per candidate is allowed.

Despite that applications can be directly submitted at the above link, candidates are more than welcome to contact the 6G-AINA project coordinator for further information and support:

Dr. Carles Antón-Haro

Director of EU Programmes and Industry Contracts, Research Director

e-mail: carles.anton@cttc.es

Who are we?

- The Center Tecnològic de Telecomunicaciones de Catalunya (CTTC) is a non-profit **public sector** research institution dedicated to fundamental and applied research activities, focused mainly on technologies related to the physical, data link and network layers of communication systems and Geomatics.

- CTTC received the "HR Excellence in Research" award in 2015 from the European Commission and successfully passed into the Award Renewal phase in 2023. This is a recognition of the Institute's commitment to develop a Human Resources Strategy for Researchers (HRS4R), designed to bring the practices and procedures in line with the principles of the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers (Charter and Code). Our institution's comprehensive analysis and HRS4R action plan meet all the requirements of progress and quality of our HR policies. CTTC promotes itself as a provider of a stimulating and favourable work environment for researchers.
- The CTTC is located in the beautiful Mediterranean Technological Park of Castelldefels, a science park that houses the Polytechnic University of Catalonia, research institutions, innovative companies and startups. The PMT-UPC is located 10 minutes' walk from the beach and the city center of Castelldefels, also close to childcare centers, public schools and the best international schools. It can be reached by car, train (RENFE) and various bus lines.
- We have 2 buildings on campus, with state-of-the-art facilities, comfortable work spaces, meeting rooms, and multipurpose spaces, as well as social spaces.
- The institute has **a multicultural environment** with more than 130 members (scientific, technical and administrative staff) from all over the world.

CTTC offers and promotes a diverse and inclusive environment and welcomes applicants regardless of age, disability, gender, national origin, race, religion, or sexual orientation.

The CTTC seeks to increase the presence of women in those areas where they are underrepresented and therefore explicitly encourages them to stand as candidates.

It is also committed to increasing the number of people with disabilities in its workforce and therefore encourages their applications.

ANNEX

PhD Fellowship in 'Advanced Artificial Intelligence/Machine Learning Techniques for Massive MIMO in 6G Communication Systems'

PROJECT DESCRIPTION

As 5G deployments get underway, the focus of wireless research is increasingly shifting towards the **definition of 6G communication networks**. In this process, we are witnessing a progressive introduction of sophisticated technologies such as Terahertz communications, ultra-massive and holographic radio, scalable cell-free MIMO networking, intelligent reflecting surfaces, non-orthogonal multiple and massive random access, or highly specialized slicing and network virtualization. This provides fundamental performance advantages in terms of enhanced user experience and enables futuristic use cases such as holographic communications, tactile internet for remote operations, or connectivity for everything. However, their introduction also entails the use of complex management solutions to fulfill the stringent requirements (e.g., sub-ms latencies, Tb/s peak data rates, location accuracy at the cm level,) associated to those services. Such complexity can only be addressed by introducing increasing levels of network automation to facilitate efficient resource exploitation and reduced operating

expenses (OPEX). In fulfilling such automation goals, Artificial Intelligence/Machine Learning (AI/ML) is called to play a pivotal role. Specifically, out of the six potential technology transformations identified by Nokia one can find AI/ML-driven air interface design and optimization. This is the main research area that the 6G-AINA project will tackle, mostly from a physical and link layer perspective (e.g., coding, modulation, detection, equalization, pre-coding, among other techniques), which are less mature and, thus more novel than e.g„ networking as an application domain of AI/ML techniques.

Specifically, this PhD thesis will revolve around the application of advanced AI/ML tools to the design of large-dimensional antenna systems in 6G networks. In recent years, the shift towards higher operating frequencies in the mmWave or Terahertz bands has facilitated the implementation of transceivers with a large number of antennas (i.e., massive MIMO). Despite that conventional AI/ML techniques such a Deep or Convolutional Neural Networks allow for a complexity reduction in e.g., precoder design, the time-varying nature of the communications channel occurring for instance in vehicular networks may impose frequent re-training. This, clearly, compromises its efficiency. Deep Reinforcement Learning (DRL) schemes, instead, continuously gather feedback from the wireless environment and, as such, are more suitable for those dynamic scenarios. Transfer Learning (TL) techniques, by which a coarsely-trained model can be fine-tuned to the actual network or propagation conditions with bounded complexity, offer additional tools to cope with such dynamic behavior.

Another drawback in the applicability of conventional neural network architectures to wireless communication problems lies in the fact that such approaches generally ignore the topology of the network (i.e, how users, terminals and base stations are deployed). As a result, they often yield poor performance in large scale networks (i.e., poor scalability) and unseen network settings (i.e., poor generalization). To resolve these issues, Graph Neural Networks (GNNs) have been recently adopted, as they can effectively exploit the domain knowledge, i.e., the graph topology in wireless communications problems and, by doing so, achieve near-optimal performance in large-scale networks and/or large antenna settings.

The aforementioned techniques (DRL, TL and GNNs) will allow to tackle challenging problems in the design of the 6G physical layer such as precoder design, user grouping, or beam selection in massive MIMO scenarios. For distributed settings with e.g., multiple base-stations or terminals, Multi- Agent Reinforcement Learning approaches will be explored, as well. In addressing those problems, particular attention will be paid to assess (i) the inherent complexity vs. performance trade-offs of the proposed techniques; (ii) their robustness with respect to imperfect channel state information or mismatches between the assumed and actual channel or system models (e.g., linear or not); and (iii) their scalability in the number of antenna elements or user terminals.