# PhD position (M/F) – Thesis offer (M/F) in Wireless Communications

(Reference: SC_DS_PhD_ADEL_082016)

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**Description**

This PhD thesis will start in the context of the EU FP7 project ADEL, "Advanced Dynamic Spectrum 5G mobile networks Employing Licensed shared access" [http://www.fp7-adel.eu/](http://www.fp7-adel.eu/).

Today's important and urgent challenges associated with tomorrow's mobile broadband systems are largely related to the requirements for spectrum efficiency increase, energy efficiency improvement and deployment/operation cost reduction of such systems. With the advent of mobile internet and the associated data-starving mobile internet devices such as smartphones, tablets and notebooks, the wireless capacity demand has been rising exponentially in the past few years and is expected to continue its abrupt increase in the years to come according to several market studies. Therefore several wireless system design criteria have to be fulfilled more efficiently than in currently deployed 3G and 4G mobile broadband systems. These include fairness among users over the whole network coverage area as well as support for a multitude of Quality of Service (QoS) and user experience requirements originating from different services. It is commonly accepted that satisfying the requirements on spectral efficiency, energy efficiency and network deployment/operation cost reduction can only be fulfilled by the synergy of multiple enabling factors and technological advancements, most notably:

- **F1.** Increased spectrally efficient transmission schemes based on Multiple-Input Multiple-Output (MIMO) / cooperative communication techniques (e.g., LTE-A is expected to offer 4x higher capacity compared to currently deployed 3G mobile broadband systems);
- **F2.** Auctioning of new spectrum bands for mobile broadband networks;
- **F3.** More efficient and flexible spectrum sharing techniques enabled by Cognitive Radio (CR) and the Licensed Shared Access (LSA) (or Authorised Shared Access (ASA)) concept;
- **F4.** Traffic offloading to small cells and Wireless Local Area Networks (WLANs), e.g. Wi-Fi.

CR is traditionally thought of as a technology that enables non-licensed secondary users (SUs) to make use of idle spectrum without causing harmful interference to licensed primary users (PUs). As such, it was regarded with suspicion by mobile broadband operators that were reluctant to allow the use of their expensively acquired spectrum by any SU who claims that will respect the regulatory CR policies. From the SUs' viewpoint, traditional CR was also problematic as it could only guarantee a QoS level similar (at best) to unlicensed access. In early 2011, Nokia and Qualcomm formally introduced the concept of ASA, also known as Licensed Shared Access (LSA), as a means of bridging the gap between traditional CR-based shared access technologies and their potential commercial adoption and deployment. According to the EU Radio Spectrum Policy Group [RSPG11], LSA is: “An individual licensed regime of a limited number of licensees in a frequency band, already allocated to one or more incumbent users, for which the additional users are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in the rights of use of spectrum granted to the licensees, thereby allowing all the licensees to provide a certain level of QoS”.

Since then an in-depth dialogue among industry, national administrations, ETSI, CEPT and EC has started, which lately focused on common LSA definitions, architecture and essential technology targets to be addressed.

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EURECOM specifically encourages women to apply with a view towards increasing the proportion of female researchers.

The ADEL FP7 STREP project

In ADEL the following key challenges within the LSA wireless access paradigm are addressed: i) the dynamic and optimised allocation of the spectral and power resources at a short time scale (on the order of seconds to even milliseconds); ii) the guarantee of Quality of Service to the users of all participating spectrum-sharing networks; and iii) the minimisation of the overall energy expenditure of LSA networks. As key technology enablers towards these goals, we pursue the utilisation of: i) decentralised spectrum sharing techniques that allow both faster decision making and less control overhead; ii) advanced collaborative sensing between the cooperating wireless networks and individual nodes for better network coordination; iii) advanced frequency agile transceiver techniques; and iv) self-optimisation techniques at the LSA networks to further minimise the EMF radiation and the interference caused to the incumbent network parts.

Research Topics of this PhD thesis

The Multi-User (MU) Multi-Antenna transmitter/receiver (MIMO) downlink or MIMO Broadcast Channel (BC) formulation is relevant for cell center users. Whereas multiple receive antennas do not allow to increase the total number of streams (or degrees of freedom (DoF)) in the BC, they allow the sharing of zero-forcing (ZF) between transmitter (Tx) and receivers (Rx) so that a secondary (licensee) base station (SBS) can serve its secondary users (SU) while ZF beamforming (BF) to primary (incumbent) users (PU). For cell edge users, a multi-cell scenario or Interference Channel formulation is more appropriate. In a cognitive MIMO Interference Channel (IC) we may have K MIMO secondary base station (SBS) – secondary user (SU) pairs and an additional set of L Primary Users (PUs).

The objective is to find the set of beamforming (BF) vectors that maximize the Weighted Sum Rate (WSR) of the cognitive network, under Tx power constraints for the secondary BS, and interference level constraints at the primary Rxs. Unfortunately, this problem is non-convex. The existing centralized solutions are iterative algorithms based on alternating optimization of subsets of variables. They allow to converge to a local optimum. Deterministic Annealing (DA) could be added to find the global optimum. Alternative problem formulations such as SINR balancing will also be considered and in fact more customized objective functions for spectrum sharing settings will be researched.

Channel State Information at the Transmitter (CSIT), which is crucial in multi-user systems, is always imperfect in practice, especially for the SBS-PU link. Partial CSIT formulations can typically be categorized as either bounded error / worst case (relevant for quantization error in digital feedback) or Gaussian error (relevant for analog feedback, prediction error, second-order statistics information etc.). The Gaussian CSIT formulation with mean and covariance information was first introduced for SDMA (a Direction of Arrival (DoA) based historical precedent of MU MIMO), in which the full channel covariance was typically replaced by the transmit side channel correlation matrix, and worked out in more detail for single user (SU) MIMO. The use of covariance CSIT has recently reappeared in the context of Massive MIMO, where a not so rich propagation environment leads to subspaces (slow CSIT) for the channel vectors so that the fast CSIT can be reduced to the smaller dimension of the subspace. Such CSIT (feedback) reduction is especially crucial for Massive MIMO. In the partial CSIT case, the objective function typically becomes the ergodic sum rate. But outage of various players can be considered also.

The previous CSIT discussion also leads to another aspect. A centralized design requires global CSIT (from all Tx). A more practical alternative would be distributed designs with only local CSIT and exchange of limited key quantities (e.g. Rxs and rate). The convergence dynamics of distributed approaches are a current hot research topic, as also the best tradeoffs between exchange overhead and performance.

ADEL emphasizes the need for relevant R&D that will be applicable to real systems. The applicability of the developed algorithms and protocols in real-world conditions will be evaluated through simulation results and testbed experimentation. In particular, the EURECOM OpenAirInterface testbed will be expanded to demonstrate some of the beamforming techniques developed in a multi-user licensee-incumbent scenario, exploiting TDD channel reciprocity. This will be facilitated by the help of another running project that
deals with reciprocity calibration and its extension to Massive MIMO antenna arrays.

**Requirements**

We are looking for a highly motivated person with a master degree in electrical engineering with a strong background in applied mathematics and signal processing as well as excellent programming skills (Matlab). Previous experience in the area of statistical signal processing, possibly applied to wireless radio communications will also constitute a significant advantage. English language and general communication skills also constitute a plus.

**Application**

The application must include:

- CV,
- 2-3 letters of reference (especially by the Master’s thesis/project/internship supervisor),
- Master’s degree grades and any evidence of good academic performance (e.g. rank),
- a one page statement of research interests and motivations.

Applications should be submitted by e-mail to secretariat@eurecom.fr and dirk.slock@eurecom.fr with the reference: SC_DS_PhD_ADEL_082016

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EURECOM is a French graduate school and a research center in communication systems based in the international science park of Sophia Antipolis, which brings together renowned universities such as Télécom ParisTech, Aalto University (Helsinki), Politecnico di Torino, Technische Universität München (TUM), Norwegian University of Science and Technology (NTNU), Chalmers University (Sweden) and Czech Technical University in Prague (CTU). The Principality of Monaco is a new institutional member. The Institut Mines-Télécom is EURECOM's founding member.

EURECOM benefits from a strong interaction with the industry through its specific administrative structure: Economic Interest Group (kind of consortium), which brings together international companies such as: Orange, ST Microelectronics, BMW Group Research & Technology, Symantec, Monaco Telecom, SAP, IABG.

EURECOM deploys its expertise around three major fields: Digital Security, Data Science and Communication Systems. EURECOM is particularly active in research in its areas of excellence while also training a large number of doctoral candidates. Its contractual research is recognized across Europe and contributes largely to its budget.

Thanks to its strong ties set up with the industry, EURECOM was awarded the “Institut Carnot” label jointly with the Institut Telecom right from 2006. The Carnot Label was designed to develop and professionalize cooperative research. It encourages the realization of research projects in public research centers that work together with socioeconomic actors, especially companies.