Exploiting Channel Reciprocity in Massive MIMO

PhD Thesis Proposal for Labex UCN@Sophia

Applicants

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Scientific Themes Addressed

- Distributed and ubiquitous computing: “To invent novel and accessible models, methods and techniques for the creation of reliable and efficient UCN applications”.
- Infrastructures: Heterogeneity and Efficiency “To design novel wired/wireless infrastructures, offering high performance and autonomous operation”.

Context

Multi-user multiple-input multiple-output (MU-MIMO) systems offer big advantages over conventional point-to-point MIMO: they work with single antenna user terminals and they do not require a rich scattering environment. However, MU-MIMO requires sophisticated feedback and precoding mechanisms that are not very robust (against channel and hardware imperfections) and scalable.

Massive MIMO takes MU-MIMO to the next level by scaling up the number of antennas at the base station by an order of magnitude, providing additional degrees of freedom in the channel. These additional degrees of freedom can be used to design more simple and scalable signal processing algorithms and help focusing energy into small regions of space and thus reducing interference [1,2].

Despite the huge theoretical gains of massive MIMO, the practical feasibility still remains to be proven. Therefore recently a lot of effort has been spent on building testbeds for massive MIMO. The Argos testbed [3] for example was developed at Rice university in cooperation with Alcatel-Lucent, and shows the basic feasibility of the massive MIMO concept using 64 coherently

operating antennas. This testbed however does not provide bi-directional real-time communication.

Together with its partner IABG, Eurecom is currently developing a massive MIMO platform based on its established OpenAirInterface platform. The platform will feature a 64 elements antenna array from IABG and a rack of 16 ExpressMIMO2 cards, each able to control 4 radio frequency (RF) chains. The goal of the platform is to validate the feasibility of massive MIMO for real-time communication using the OpenAirInterface LTE software modem.

Challenges

Exploiting channel reciprocity. Massive MIMO relies to a great extent on the exploitation of channel reciprocity to gain channel state information at the transmitter (CSIT). However, while the physical radio channel is reciprocal, the radio frequency circuits are not and must be calibrated. Such calibration procedures exist [4,5], but they have never been tested in real-life massive MIMO scenarios.

Channel characterization and modeling. Large antenna arrays built with cheap hardware have different characteristics than conventional antennas used in current cellular systems. The impact of mutual coupling and hardware imperfections needs to be studied based on measurements and new models need to be designed.

Channel estimation and pilot de-contamination. Channel estimation, due to the very high number of parameters to estimate, is definitely a challenge, both in terms of estimation performance and of complexity (computational, but also number of pilots). Current proposed systems mainly rely on linear estimation, which leads to the problem of pilot contamination. Pilot contamination is the phenomenon by which a base station, relying on a pilot sequence to estimate the channel of a given user in it's cell, overhears a neighbor's cell user, using the same pilot. This leads to a corrupted channel estimation and in turn, while beamforming in the downlink, the base station beamforms its data to the neighbor's cell user, generating interference.

Scalability and distributed signal processing. Massive MIMO system should be designed in a scalable way, i.e., the complexity of the signal processing should not increase significantly when adding more antennas to the system. The idea is to use distributed signal processing algorithms, processing the antenna signals locally before combining or transmission. The most simple example is the matched filter precoder, which only requires local channel knowledge at each antenna.

Expected results

The goal of this PhD thesis is to advance the state of the art in massive MIMO systems with a strong focus on practical feasibility of such systems. The successful applicant is expected to make use of the OpenAirInterface platform as much as possible, for example by conducting and analyzing measurements and by prototyping and evaluating some of the algorithms developed during the thesis.

More precisely the following tasks should be carried out:

- Plan and carry out a measurement campaign with Eurecom's massive MIMO testbed ; analyze the measurements and derive models.
- Investigate the feasibility of channel reciprocity, i.e., quantify the channel estimation error due to the hardware imperfections.
- Research blind and semi-blind channel estimation algorithms to deal with the pilot contamination.
- Analyze the impact of channel estimation errors on different massive MIMO algorithms.
- Analyze the gains that can be achieved with massive MIMO taking all the practical impairments analyzed into account.
- Study the impact of massive MIMO on a system level, especially in the context of heterogeneous networks.

References

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