MS Thesis Topic: AI-based Signal Design for Localization and Sensing in Beyond 5G/6G Systems

August 2022

1 Main Goal

The goal of this thesis study is to design new signals for high-accuracy localization and sensing in Beyond 5G and 6G systems. The thesis work will be carried out within the **Communication Systems Group**, which is a part of Chalmers E2, **Communications, Antennas, and Optical Networks Division**.

2 Background

For 5G radio positioning, dedicated signals are broadcast by base stations in time, frequency and space. In Beyond 5G systems, such signals will likely be specific for each user or for groups of users, in order to maximize localization accuracy. There have been a number of recent studies on the spatial design of positioning signals. Such designs have been shown to work well, but suffer from a number of drawbacks: (i) they come with additional computational complexity, (ii) they require several processing steps to be compatible with typical array constraints, thus losing optimality, and (iii) they are very challenging to design in case of hardware impairments.

In this thesis, you will design spatial signals for Beyond 5G positioning using artificial intelligence (AI)-based data-driven approaches. We foresee the following stages:

1. AI-based signal design with a standard model-based receiver, ignoring hardware impairments
2. AI-based signal design with an AI-based receiver, ignoring hardware impairments
3. AI-based signal design with an AI-based receiver, accounting for hardware impairments

The approach will rely on auto-encoder (AE) networks, which have been shown to be powerful in optimization of communication links. The AE comprises a transmitter and a receiver, implemented as deep neural networks (NNs). You will need to design: (a) *The transmitter NN at the base station*, its layers, and activation functions. The inputs will include the spatial distribution of the relevant parameters (user position, user clock bias, environment positions), while the output should include a sequence of beamformers, satisfying the array hardware constraints; (b) *The receiver NN at the user*, its layers, and activation functions. The inputs will include the received signal, while the output should include the spatial distribution of the relevant parameters (user position, user clock bias, environment positions), in order to be fed back to the transmitter for the next optimization stage. (c) *A suitable loss function.* Possibilities include the squared Euclidean distance between the estimated states and the ground-truth, as well as the negative log-likelihood.

3 Scope

- Literature study on signal design and radio localization and sensing, focusing specifically on Beyond 5G and 6G.

- Benchmark implementation of the transmitter and receiver. Performance evaluation with and without hardware impairments.
- Transmitter learning
- Joint transmitter and receiver learning
- Depending on the outcome of the work, write a conference or journal paper.

4 Profile

- Master's degree students in MPCOM, MPSYS, MPCAS, etc.
- Solid math background is needed.
- Knowledge in statistical signal processing or array signal processing is a benefit.
- Programming skills in Python/MATLAB are required.

5 Duration

- For 2 students: 1 semester, 30 ECTS points
- For 1 student: 2 semesters, 60 ECTS points (outstanding academic track record needed)

6 Application

- Attach your resume, transcript, and cover letter (stating your interests and thoughts within the given area).
- Send your application by email to furkan@chalmers.se

7 Questions

In case of questions, please contact

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