Master Thesis
Design and Evaluation of 5G mmWave Beam Management in Ultra-Dense Cellular Scenarios

Motivation and Problem Statement

The recent move of 5G towards the millimeter-wave (mmWave) spectrum (> 24 GHz) is a reaction to the exponential growth of wireless mobile data consumption and the need for significantly higher data rates for emerging applications such as VR and 8K video [1]. A similar move has also already occurred with Wi-Fi amendments IEEE 802.11ad/aj/ay, and there is already speculation whether 6G could even use THz frequencies. This drastic change of carrier frequency comes with new challenges due to the rather hostile propagation characteristics at the mmWave domain [2]. To overcome these, large planar antenna arrays and novel beamforming transceiver architectures are facilitated [3]. As a result, mmWave communication becomes directional such that base station (BS) and user equipment (UE) side pencil beams have to be aligned precisely by means of beam management (a.k.a. beamsteering) to establish the mmWave link. Afterwards, the beams have to be realigned continuously to enable robust communication at Gbps data rates in mobile environments as shown in Fig. 1 [4].

So far, research has focused on beamsteering algorithms for initial access in scenarios where there is just one mmWave BS, cf. Figs. 2-3. In this context, it was found that there is a trade-off between delay (and energy consumption) for initial access, achieved link quality (signal strength/SNR/data rate) at time of the network access grant, and the coverage region in which UEs can access the network using a specific beamsteering algorithm [5]. However, due to the hostile propagation characteristics, mmWave BSs will be deployed very densely within hotspot regions (e.g. city centers, business districts, near tourist attractions) such that the cellular network can serve as many customers with high data rate demands as possible in these areas. This further means that the user may have the choice to select between several cells to connect to the network, hence beamsteering should consider such scenarios. Therefore, we want to find out how a network operator has to coordinate beam management of nearby mmWave BSs such that the user can access the network with low delay and high data rate at once. We want you to find the sweet spot for this problem based on ray-tracing data for a sample scenario.

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Goals of this Master Thesis

This master thesis brings together several interesting topics such as the ever-evolving mobile communication standards and - in particular - mmWave propagation and beam management. Expect to dive deeply into state-of-the-art mmWave beamsteering literature to become an expert on your topic. Afterwards you will implement several beamsteering flavors and evaluate the achievable performance based on ray-tracing simulation data.

Potential topics your master thesis will address:
- Research applicable beamsteering algorithms and mmWave channel characteristics. Most importantly, design your own algorithms based on the acquired skills.
- *Ray-tracing data-based evaluation:* Implement several different beamsteering algorithms and evaluate the achievable performance. Address the trade-off between the different schemes.

Requirements

- Interest in mmWave communication and the 5G standard
- Participation in MFN lecture (Grade: excellent/good); other CNI lectures are a plus
- Excellent English skills; highly desirable: Willingness to write thesis in English
- Basic MATLAB/Python and LaTeX/TikZ skills

References