Wireless channel prediction for ultra reliable communications

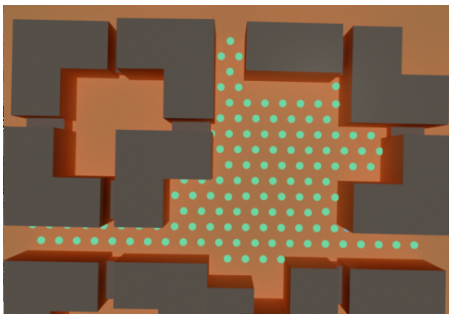
The wireless communication channel is subject to effects such as fast and slow fading. To combat these effects, transmissions are coded to enable detection and possibly correction of errors. If a non-correctable error is detected, the receiver can ask for a re-transmission. While this approach works well for many systems, it is not sufficient for applications with very strict requirements on reliability and latency.

URLLC (Ultra Reliable Low Latency Communication) is one of the pillars of the 5G network. Use cases include remote diagnosis and surgery, virtual and augmented reality, and remote-controlled vehicles and drones. Common for these applications is the need for high reliability and low latency. By conventional methods, high reliability and low latency can be achieved by over-provisioning network resources such as power, time, and frequency. This approach, however, has two big issues: 1. By over-provisioning resources, the quality of the service delivered to other users degrades. 2. Without knowing some statistics of the channel to the URLLC user, it is difficult to determine an acceptable number of resources to dedicate.

By measuring the channel between multiple UWB tags in real-time, information about the statistics of the channel can be computed and possibly used to predict future states of the channel, allowing the system to be proactive rather than reactive. Measurements can be combined with ray tracing software (such as Sionna [1]) to enhance the accuracy of the channel predictions and do localization. Network simulations can be conducted using ns-3 [2].

For the project multiple Qorvo DWM30001CDK development kits are available.

Relation to semester theme:
- Sensing through multiple devices and centralized computation
- Communication of the sensing units via a network towards one or more processing units that infer the state of the sensed system
- Modeling and assessment of the behavior of the system for different assumptions on the underlying information exchange (reliability, periodicity, delay, sparsity, noise levels, transmission errors, etc.)



Top: outdoor scenario satellite picture
Bottom: Raytraced model

References:
[1] 'Sionna: An Open-Source Library for Next-Generation Physical Layer Research' (https://arxiv.org/abs/2203.11854)
[2]: 'Toward Digital Network Twins: Integrating Sionna RT in ns-3 for 6G Multi-RAT Networks Simulations' (https://arxiv.org/pdf/2501.00372)
[3]: 'Geometry-informed Channel Statistics Prediction Based upon Uncalibrated Digital Twins' (https://arxiv.org/pdf/2411.13360)
[4]: 'Learning Radio Environments by Differentiable Ray Tracing' (https://arxiv.org/pdf/2311.18558)

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