Master Thesis on Site-Specific SNR Distribution Estimation Using Gaussian Mixture Models

In order to perform optimal RAN configuration in campus networks and be able to respond to strict QoS requirements of URLLC applications in industrial manufacturing, we need to understand and model the exact channel behaviour in challenging factory environments. Factory halls are especially challenging environments for reliable wireless communication, because of their high dynamicity level, the existence of many moving machines and metal surfaces, which cause many reflections, high multi-path fading effects to the wireless signal.

Network digital twins (NDT) are a powerful tool for analysis and test of various communication scenarios for the upcoming 6G wireless communication systems. An NDT will enable a safe environment to try out different RAN configurations (such as different scheduling algorithms, radio resource management, transmit power adjustment, packet duplication, numerology and TDD pattern settings, and so on). The NDT has to tightly and synchronously work with several other digital twins, such as a digital representation of the environment as well as a digital twin of the application. Having an as-precise-as-possible factory-site channel description will enable the computation of a precise QoS-profile across the shop floor and influence the process of factory hall and network design. The nodes placement or repositioning, such as navigation and control of AGVs and AMRs (autonomous mobile robots) can be triggered by the decisions and observations done by the NDT.

In this thesis, the goal is to obtain a site-specific SNR distribution estimation [5]. For the research and development of channel estimation methods, a link-level simulation with a realistic radio channel model is a key prerequisite. By means of a link-level simulator (e.g. Sionna by NVIDIA [3, 4, 7, 10]), we plan to use ray-tracing for a particular given digital representation of the environment in order to compute spatially consistent channel impulse response (CIR), which statistical and stochastic models in network simulators cannot achieve [2, 4]. The student would have to first represent the laboratory environment as a scene file. Such file would represent a 3D model which contains the dielectric properties of the object within it. The 3D model will be the input of the Sionna ray-tracer. In the second step, Sionna will be used to obtain the CIR from which the power delay and phase delay profile can be obtained. Using GMM (Gaussian Mixture Models) we aim to use the CIR in order to obtain a Mixture of Gaussian (MoG) to approximate the SNR distribution and the envelope of a wireless channel propagating in the given factory environment [1, 8]. By forming a grid of the underlying environment, the ray-tracer is going to compute the CIR for all the possible Tx-Rx pairs in the grid. From the obtained SNR, a block error rate (BLER) will be obtained in the simulation, using a phy-abstraction model from Sionna or related work [9].

Finally, the result will be validated in a real test bed, using USRP (Universal Software Radio Peripheral) devices [11]. First, a validation of the correctness of the power delay profile (PDP) will be conducted, to verify the accuracy of the NDT to represent the industrial environment under study. By producing various numerical results for different scenario setups (moving vs. static objects, varying transmit power, location of the Tx-Rx pair, using RIS in the scenario, etc.) the obtained BLER and hence, SNR distribution will be validated and compared.

Requirements by the student:

- The student attends master programme in the domain of electrical engineering, informatics or a related study program, with background to wireless communication.
- Experience using Blender or similar software for the 3D model design, Sionna, and/or working with USRPs will be a considered as a plus.
- Strong analytical and mathematics skills, especially in the domain of optimization and machine learning methods (e.g. Gaussian mixture models, etc.).
- Self-initiative and independent work, especially when facing problems.
- Solid programming skills in python and C++.
- Excellent English skills, strong scientific writing skills.

To apply:

Please send your documents via e-mail to Neda Petreska (neda.petreska@siemens.com) and Luis Torres-Figueroa (luis.torres.figueroa@tum.de) with the following documents:

- CV
- Academic transcript
- Short motivation (up to 1 page)

Literature:

- [1] B. Selim, O. Alhussein, S. Muhaidat, G. K. Karagiannidis and J. Liang, "Modeling and Analysis of Wireless Channels via the Mixture of Gaussian Distribution," in *IEEE Transactions on Vehicular Technology*, vol. 65, no. 10, pp. 8309-8321, Oct. 2016
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- [9] S. Lagen, K. Wanuga, H. Elkotby, S. Goyal, N. Patriciello and L. Giupponi, "New Radio Physical Layer Abstraction for System-Level Simulations of 5G Networks," *ICC 2020 - 2020 IEEE International Conference on Communications (ICC)*, Dublin, Ireland, 2020, pp. 1-7
- [10] J. Hoydis *et al*., "Sionna RT: Differentiable Ray Tracing for Radio Propagation Modeling," *2023 IEEE Globecom Workshops (GC Wkshps)*, Kuala Lumpur, Malaysia, 2023, pp. 317-321
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