technische universität dortmund

ComNets Dortmund

Thesis (Bachelor's or Master's Thesis)

ML-Based Radio Propagation Model for Wi-Fi in Industrial Indoor Scenarios

Interested in machine learning, Wi-Fi, and modern 5G/6G networks?
Then become part of cutting-edge research at the ComNets Chair!

Why this thesis is exciting

- Participation in current research topics in the field of radio channel modeling for industrial scenarios
- Insights into modern Wi-Fi and 5G/6G networks as well as AI-based network planning
- Contribution to the further development of our award-winning IndoorDRaGon concept
- Application of modern machine learning methods and deep learning frameworks such as PyTorch
- Possibility of a scientific publication based on the research results
  Intensive supervision and close collaboration with the ComNets research team

Motivation

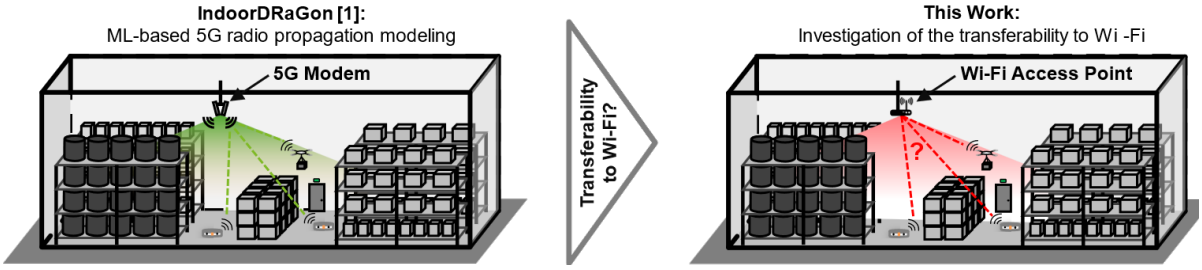

Fig. 1: With the introduction of Wi-Fi 6 and Wi-Fi 7, Wi-Fi is becoming increasingly important for industrial applications. Reliable operation requires careful network planning based on accurate and efficient radio propagation modeling. The aim of this thesis is to investigate to what extent the ML-based IndoorDRaGon radio propagation model for 5G can be transferred to Wi-Fi.

In the context of Industry 4.0, wireless communication systems are becoming increasingly important. Connected machines, mobile robots, and intelligent sensor systems place high demands on reliable and efficient wireless communication in industrial environments. Wi-Fi in particular has become a key component of industrial connectivity. Reasons include its widespread availability, comparatively low costs, and easy integration into existing infrastructures. Recent advancements such as Wi-Fi 6 and Wi-Fi 7 additionally enable higher data rates, improved efficiency, and larger network capacities, making Wi-Fi increasingly attractive for demanding industrial applications.

However, reliable deployment of Wi-Fi in industrial environments requires careful network planning. Precise and efficient radio propagation modeling plays a key role in this process. Classical analytical radio propagation models allow fast computation but often reach their limits in complex industrial indoor environments. At the same time, more precise deterministic methods such as ray tracing can model environments in much greater detail, but they involve high computational costs. Machine learning-based approaches offer the potential to address the trade-off between computational complexity and accuracy by enabling both efficient and accurate radio propagation prediction. This opens up new possibilities for flexible and efficient network planning, especially for future industrial Wi-Fi networks. At the ComNets

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Chair, the IndoorDRaGon method has already demonstrated that machine learning-based approaches have great potential for modeling 5G indoor radio propagation [1].

Against the backdrop of increasingly common multi-RAT (Radio Access Technology) networks in industrial applications, there is a growing need to integrate Wi-Fi into such planning approaches. The development of an ML-based Wi-Fi radio propagation model therefore represents a current and relevant research topic that will be investigated within this thesis.

Objectives of the thesis:
The scope of the thesis will be adapted depending on whether it is a Bachelor's or Master's thesis. Network planning aspects are intended primarily for a Master's thesis.

This thesis combines several exciting fields, including Wi-Fi technologies, machine learning, and radio propagation modeling. It provides insights into current research at the ComNets Chair and contributes to the development of efficient methods for multi-RAT network planning in industrial environments.

The thesis may focus on some of the following aspects, though not necessarily all of them:

- Familiarization with Wi-Fi technologies and industrial Wi-Fi networks (e.g., Wi-Fi 7)
  - Investigation of relevant Wi-Fi properties such as channel structure, bandwidth, co-channel interference, CSMA/CA, and typical KPIs (e.g., RSSI, SINR, data rate)
- Creation of synthetic training dataset
  - Familiarization with ray-tracing software for generating synthetic training data
  - Derivation of realistic industrial indoor scenarios and selection of suitable Wi-Fi frequencies
  - Generation of training datasets through simulations (Optional: conducting measurement campaigns to generate measurement-based data)
- Development of a „Wi-Fi-IndoorDRaGon" model. The goal is to transfer and adapt the existing IndoorDRaGon method for 5G to the Wi-Fi frequency range
  - Generation of features based on the 5G IndoorDRaGon approach [1]
  - Training a machine learning model (e.g., artificial neural network) for radio propagation prediction
  - Validation oft he developed model using different indoor scenarios and evaluation of prediction accuracy
- Development of a simple network planning framework based on the trained model
  - Investigation of the optimal number and positioning of access points in industrial indoor scenarios using clustering methods
  - Consideration of co-channel interference in network planning
- Potential and sensitivity analyses
  - Analysis of the robustness and generalization capability of the developed model
  - Comparison of Wi-Fi IndoorDRaGon vs. 5G IndoorDRaGon regarding relevant KPIs (e.g., data rate)
  - Analysis of different KPIs (e.g., coverage, SINR, data rate) for different network configurations
  - *… and according to your interests!*

Your profile

- Interest in wireless communication, especially Wi-Fi and radio propagation modeling
- Basic knowledge of machine learning
- Good knowledge of Python and LaTeX as well as strong presentation skills
- Successful participation in ComNets modules is an advantage

References

[1] M. Geis, H. Schippers, M. Danger, C. Krieger, S. Böcker, J. Freytag, I. Priyanta, M. Roidl, and C. Wietfeld, "IndoorDRaGon: Data-Driven 3D Radio Propagation Modeling for Highly Dynamic 6G Environments", in *European Wireless 2023*, Rome, Italy, October 2023. IEEE. [pdf]