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Bachelor's Thesis

Analysis and Quantification of Error Sources in Ultra-Wideband Localization Systems

Abstract

Ultra-Wideband (UWB), as specified in IEEE 802.15.4a/z, is a widely used wireless technology enabling centimeter-level accurate indoor localization. Within the avarange project [1, 2], UWB has also been applied to outdoor localization in order to reconstruct the trajectories of sensor nodes and investigate the internal dynamics of snow avalanches. However, such outdoor experiments are often costly and not always feasible. Therefore, simulations represent an efficient and scalable alternative for evaluating new UWB-based localization protocols and mechanisms. To ensure dependable and realistic simulation results, it is essential to accurately model the underlying error sources. These include, but are not limited to, mobility effects, geometric conditions, bandwidth limitations, and clock imperfections. In particular, node velocity becomes a critical factor in highly dynamic environments such as avalanches. Consequently, identifying and quantifying dominant error sources for different scenarios and UWB configurations is essential.

Goal of Thesis

The objective of this bachelor's thesis consists of the following parts:

- Extensive literature review to compile and classify all UWB error sources
- Perform experiments and simulations to investigate each error source
- Create a comprehensive error model, combining own results with the literature to systematically decompose and quantify the overall error
- Discuss dominant error sources for different scenarios, configurations and hardware
- Implement the errors into the OMNeT++ simulator

The thesis will provide detailled insights into the UWB technology, error modeling, and wireless localization.

Requirements

The following skills are beneficial and will be used within this thesis:

- Basic understanding of wireless communication and localization
- Strong literature research skills
- Solid analytical and mathematical background (e.g., CRLB)
- Experience with simulation tools (e.g., Python, MATLAB, C++)
- Interest in hardware-based validation and data acquisition

Literature

Starting points might be found in datasheets of real hardware e.g. DW1000 (https://www.qorvo.com/products/p/DW1000#documents)

Context for the avarange project can be found in:

[1] J. Kuß et al., "Distributed UWB-based Ranging for Particle Tracking in Avalanches," WONS 2024.

[2] T. Bibi et al., "Deep Bidirectional LSTM-Based Sensor Fusion for 3D Localization in Dynamic Environments," MASS 2025.

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