Bachelor's Thesis

Engine for Speculative Computation of CSI in ns3sionna

Abstract

At TKN, we developed ns3sionna, an open-source framework that integrates GPU-accelerated, ray-tracing-based wireless channel modeling into the widely used ns-3 network simulator. Ns3sionna bridges the gap between physically accurate link-level channel simulation and packet-level network simulation by coupling ns-3 with the Sionna RT ray-tracing engine.

Unlike conventional ns-3 channel models, which rely on simplified statistical abstractions, ns3sionna computes environment-specific, spatially and temporally consistent channel state information (CSI) based on detailed 3D scenes and material properties. This enables realistic modeling of multipath propagation, reflection, diffraction, and shadowing in both indoor and outdoor environments. The framework further supports ray-tracing-based mobility, ensuring that node movement respects physical obstacles in complex scenes.

While ns3sionna significantly increases the realism of wireless simulations, the high computational cost of ray tracing currently limits simulations to small and medium-sized scenarios. Even with GPU acceleration, channel computation quickly becomes a bottleneck for large-scale or highly mobile networks.

Goals of the Thesis

The goal of this Bachelor's thesis is to substantially improve the scalability of ns3sionna, enabling simulations of large wireless networks with many nodes and high mobility. This will be achieved by designing and implementing an engine for speculative computation of channel state information (CSI).

The core idea is to anticipate future channel states based on predicted node communication/mobility and exploit key properties of wireless channels, such as channel reciprocity and coherence time, to pre-compute CSI efficiently. By organizing channel computations as point-to-multipoint (P2MP) ray-tracing tasks and executing them massively in parallel on GPUs, redundant and latency-critical computations during simulation runtime can be avoided.

Concretely, the thesis includes:

- Designing a scalable architecture for speculative CSI computation in ns3sionna
- Implementing predictive pre-caching and cache management strategies
- Efficient parallelization of ray-tracing workloads across GPUs
- Evaluating scalability, performance, and accuracy in realistic indoor and outdoor scenarios

The main implementation work will be done in Python, interfacing with ns-3's C++ core. Experiments will be conducted on the GPU-based high-performance computing (HPC) infrastructure of TU Berlin.

Requirements

It is beneficial to have a basic understanding of:

- Wireless communication and wireless networks
- Network simulation and ns-3
- Programming in C++ and/or Python

Prior experience with ray tracing, GPU computing, or high-performance computing (e.g., singularity/docker container) is helpful but not required. Missing background knowledge can be acquired during the thesis.

Literature

- ns3sionna framework: https://github.com/tkn-tub/ns3sionna
- Zubow, Roesler, and Dressler. Ns3Sionna: Realistic Wireless Network Simulation with Ray Tracing in ns-3", to appear ICNC 2026
- TU Berlin HPC Service: https://www.tu.berlin/campusmanagement/angebot/high-performance-computing-hpc

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