Open Thesis / Project

Data-Driven Optimization of Low-Power Wireless Protocols using Large Language Models

Thesis Type

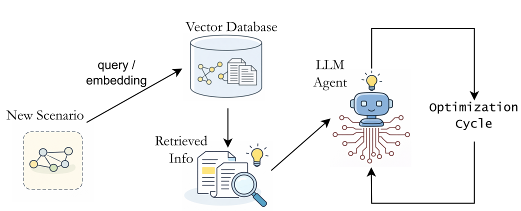
Master Project / Master Thesis

Motivation

Parametrizing low-power wireless (LPW) protocols is inherently complex. Protocol performance is affected by environmental conditions and hardware characteristics: therefore, to assess and compare the suitability of different parameter sets, one requires real-world testing (e.g., testbed experiments). At the same time, blindly testing all possible parameter configurations on a testbed (or performing an exploration giving sufficient statistical significance given the noisiness introduced by wireless experiments and real-world dynamics) is largely undesirable. We hence need solutions that allow one to identify the best parameter set for a given LPW protocol while *minimizing the number of necessary real-world trials*.

In this context, we have recently designed different optimization frameworks capable of intelligently navigating a LPW protocol's parameter space and identify the best parameter set with a limited number of real-world trials (e.g., APEX), also with the help of Large Language Models (LLMs). In our current solution, however, the identified best parameter set is specific to the characteristic of the environment in which the real-world trials are executed. As LPW protocol performance drastically varies across different environments, one would currently need to repeat the entire optimization process (which starts by randomly exploring parameter combinations before converging towards optimality) to identify the most suitable parameter set for a new environment.

We aim to improve this process by investigating, for example, the transferability of knowledge collected in prior real-world trials to new environments.



Goals and Tasks

The idea is to extract information about the characteristics of the environment in which real-world trials were previously executed (such as the network topology, which is shaped by device placement and connectivity, as well as the traffic patterns and load), and provide it as an additional input to the optimization framework. By leveraging this existing knowledge, the framework could begin the search of suitable parameter sets with promising configurations instead of random exploration. This could speed up convergence and improve the overall efficiency of the optimization process. The goal of this project/thesis is hence to investigate methods for reusing available data sources, including traces, protocol artifacts, and prior results, to support LLM-informed parameter optimization of LPW protocols, with the goal of accelerating convergence by leveraging relevant prior knowledge.

Within this context, students can explore several directions and perform different tasks, such as:

- Evaluate similarity methods (e.g., node degree, network depth), and implement warm-start strategies that reuse the best parameter sets from similar testbed layouts;
- Build a knowledge base of protocol artifacts and past results, and implement a vector database with a retrieval pipeline to support retrieval augmented generation (RAG) for the LLM;
- Compare optimization performance with and without historical data reuse, and derive practical guidelines on when warm starts and RAG provide clear benefits.

Target Group

- Students of ICE/Telematics;
- Students of Computer Science;
- Students of Digital and Electrical Engineering.

Required Prior Knowledge

- Basic knowledge of ML and networked systems;
- Solid programming skills in Python.

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