Demo: Efficient Multi-Objective Optimization of Network Problems on Wireless Testbeds

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ABSTRACT

A large amount of research focuses on experimentally optimizing performance of wireless solutions. Finding the optimal performance settings typically requires investigating all possible combinations of design parameters, and as a result the number of required experiments increases exponentially for each considered design parameter. However, Efficient Global Optimization (EGO) algorithms overcome this limitation and arrive at the global optimum performance in a very short time compared to the exhaustive search technique.

In this demo, we apply the SUrrogate MOdeling (SUMO) toolbox, an efficient implementation of EGO algorithms, in order to improve the experimentation time of a realistic wireless conference solution. By tuning a speaker's transmit power and channel parameters, the SUMO toolbox searches for an improved listeners' audio quality having minimum transmission exposure. Moreover, the SUMO experiment is compared to an exhaustive search experiment and it is found that SUMO reached 99.51% of the global optimum performance while requiring 10 times less experiments.

Keywords

wireless experimentation, optimization, testbeds, SUMO

1. INTRODUCTION

Wireless network solutions often tune a number of configurable parameters in order to locate the *optimum settings*. For example, Wi-Fi networks have parameters that can be tweaked at the physical layer (e.g. transmit power, channel, modulation), MAC layer (e.g. inter frame spacing, contention window), network layer (e.g. routing protocol, mobility, topology) and application layer (e.g. throughput, server configurations). Optimizing all or a subset of these parameters is time consuming since the design space grows exponentially for every investigated design parameter. In order to mitigate the time overhead, Efficient Global Optimization (EGO) algorithms [4] can be used that are best fitted to wireless testbeds. SUrrogate MOdeling (SUMO) toolbox [3] is one example of such efficient algorithms. The optimization algorithm starts from a well-chosen initial experimental design, and a global (but only locally accurate) Kriging surrogate model of the objective function is computed. By picking additional points with the highest Expected Improvement (EI) value in the parameter space, the optimization process is directed towards an optimal configuration until a stopping criterion is met.

In literature, the SUMO toolbox is widely applied in electromagnetic and aerodynamic optimization problems [2] [6]. However, this paper for the first time integrates the SUMO toolbox into a wireless testbed to optimize wireless network problems. Specifically, the iMinds w-iLab.t wireless testbed [1] is used for this demonstration. In this demo, a wireless conference solution is optimized using the SUMO toolbox and compared to an exhaustive search approach. In both approaches, the speaker's transmit power and channel parameters are optimized in search of good listener's audio quality and reduced transmission exposure. Moreover, the demonstration is conducted remotely on the iMinds testbed requiring only one monitor and a fast internet connection.

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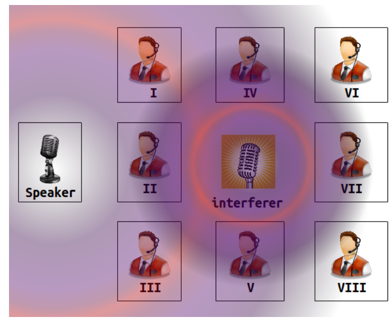

Figure 1: wireless conferencing scenario consisting of 8 listeners, 1 speaker, and 1 interferer.

2. DEMONSTRATION

2.1 Experiment scenario

Figure 1 shows the wireless conferencing scenario which comprises a wireless speaker broadcasting a speaker's voice over the air and 8 listeners, with a wireless microphone, receiving the audio stream in the presence of an interferer. The interfere transmits a 10Mbps continuous UDP stream on dual channels (i.e. 1 and 13) interfering the speaker's

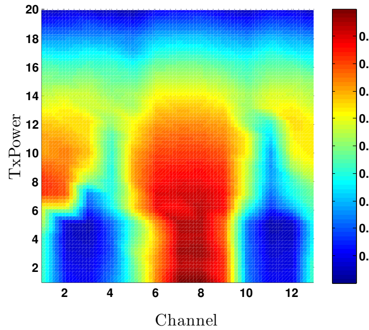

Figure 2: Exhaustive search model with background interference at channels 1 and 13

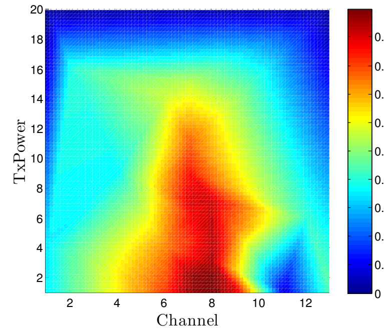

Figure 3: SUMO optimization model after 26 iterations. Background interference at channels 1 and 13

voice which lasts for 10 second and each listener calculates the average audio quality and transmission exposure during transmission. At last, the individual objectives are combined and the result is further optimized to locate the optimum settings. Since our goal is to validate the SUMO toolbox, we used equal weights to the normalized audio quality and transmission exposure objectives but for different problems, random weights can be applied as well.

2.2 Exhaustive search experiment

The exhaustive search experiment evaluates all possible parameter settings of the wireless conference scenario and will be used as a reference model by which the SUMO optimization experiment is compared against. Figure 2 shows the exhaustive search model after conducting 260 experiments at all parameter settings (i.e. 13 Channels × 20 Transmit Powers). The Colour bar indicates the combined objective normalized to a [0-1] or [blue-red] scale. Moreover, the highest combined objective (i.e. good audio quality + low transmission exposure) is located between channels 7 to 8 and transmit powers 1 dBm to 5 dBm. Indeed this area has less interference and low transmit power which could possibly be an optimum region and the place where we want the SUMO optimizer to converge in a short amount of time.

2.3 SUMO optimized experiment

The main goal of the SUMO optimizer is to reduce the number of experiments until optimum settings are located. SUMO has a number of configurable parameters which affect its efficiency. The major ones are initial sample size, initial sampling method and stopping criteria. As outlined in [5], the calculation behind setting these parameter values has a lengthy process and depends on the problem type considered. In this demonstration, 12 initial samples are selected using Latin Hypercube Sampling (LHS) method and Objective Function Improvement (OFI), using a standard deviation metric, as a stopping criterion. Figure 3 shows the SUMO optimized model of the wireless conference solution when the stopping criterion is met at the 26^{th} iteration.

Comparing Figure 2 and Figure 3, there is a difference in the model since the data points used for generating the model are not the same but the optimum settings are located around the same region which accounts for the optimization benefit of SUMO. The SUMO experiment, after 26^{th} iterations, achieved 99.51% performance and 10 times faster experiment duration compared to the exhaustive search experiment.

3. CONCLUSION

This paper demonstrated the use of the SUrrogate MOdeling (SUMO) optimizer for reducing experimentation time of wireless network solutions in a wireless testbed. We start by developing an exhaustive search model to compare to a SUMO optimized experiment. Next, we conducted the SUMO experiment having 12 initial points sampled using a Latin Hypercube Sampling (LHS) method. At last, the optimization iterated until the Objective Function Improvement (OFI) stopping criterion is satisfied. In our demonstration, the SUMO experiment runs 10 times faster compared to the exhaustive search experiment while achieving 99.51% of the global optimum performance.

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