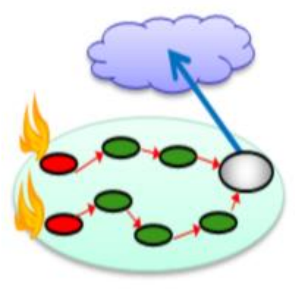
Pareto Analysis and Multi-Objective Optimization in Wireless Networks

Michael Tetemke Mehari[#1], Eli De Poorter[#2], Ivo Couckuyt[#3], Dirk Deschrijver[#4], Günter Vermeeren[#5]
David Plets[#6], Wout Joseph[#7], Luc Martens[#8], Tom Dhaene[#9], Ingrid Moerman[#10]
[#]Ghent University – iMinds, INTEC – Internet Based Communication Networks and Services (IBCN)
iGent Tower, Technologiepark Zwijnaarde 15, 9052 Ghent, Belgium
{ michael.mehari, eli.depoorter, ivo.couckuyt, dirk.deschrijver, gunter.vermeeren, david.plets, wout.joseph, luc.martens, tom.dhaene, ingrid.moerman } @intec.ugent.be

I. Problem Statement



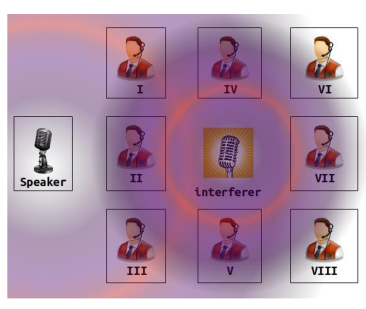
Wireless Sensor Networks

Cognitive MAClet selection and injection

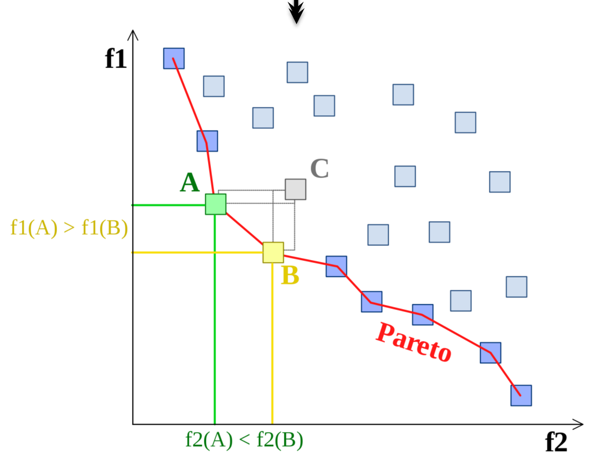
Design parameters
- Inter Frame Spaces
- TxPower
- Bitrate
- Codec parameters
- UDP/TCP parameters
- …

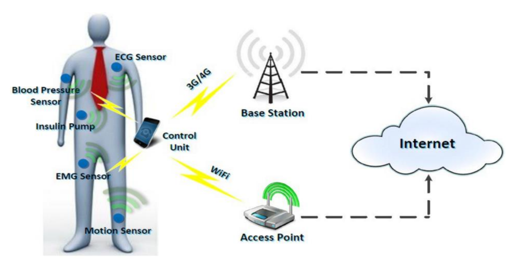
Wireless Networks

Conflicting Performance Objectives
- throughput vs power consumption
- audio quality vs exposure
- intrusion detection vs memory usage
- power consumption vs SNR quality
- …



Wireless Conferencing System



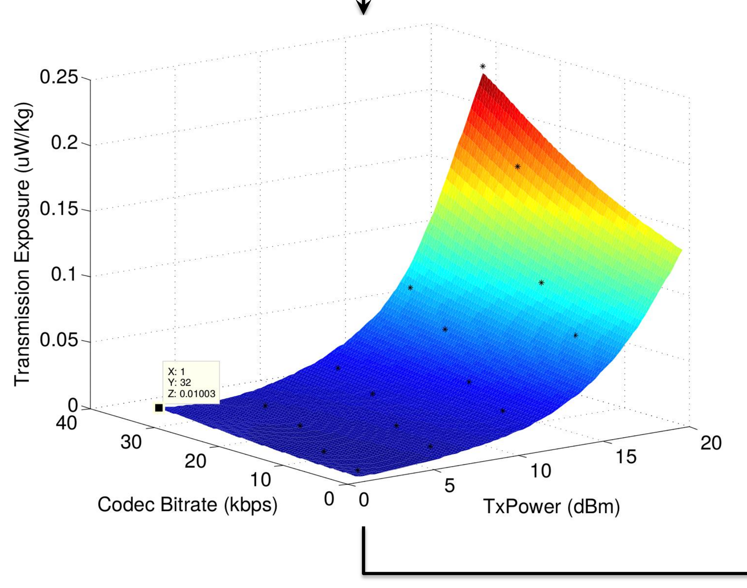


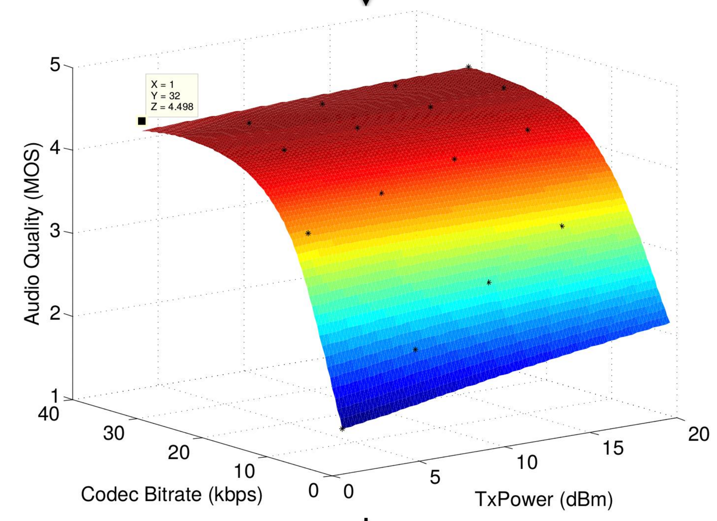
Body Area Network

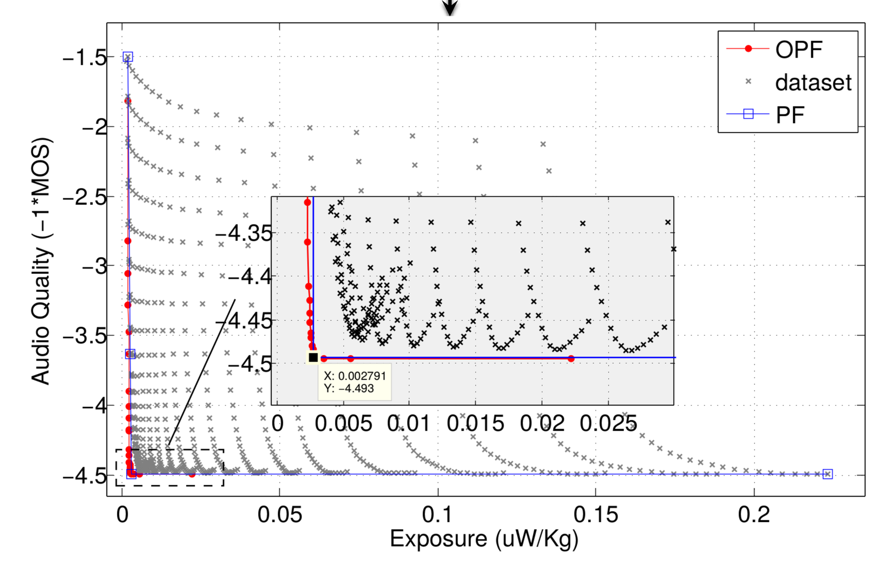
- Wireless systems are characterized by many variables, each of which influence multiple performance metrics such as reliability, throughput, latency, ….
- To find optimal settings, a large design space is explored, typically in the order of 1000+ combinations of parameter settings. As a result, finding optimal settings is very time-consuming

II. Solution

TxPower (dBm)	1	6	11	16	2	7	12	17	4	9	14	19	5	10	15	20	1	
BitRate (kbps)	1	3	5	7	9	11	13	15	18	20	22	24	26	28	30	32	32	
Exposure (nW/Kg)	1.803	6.019	19.296	63.718	2.58	8.477	27.711	89.564	4.624	15.337	50.466	160.72	6.427	21.695	68.564	223.55	**10.03**	**2.791**
MOS	1.5	2.234	2.826	3.285	3.637	3.902	4.095	4.232	4.362	4.412	4.443	4.462	4.473	4.481	4.487	4.494	**4.498**	**4.493**

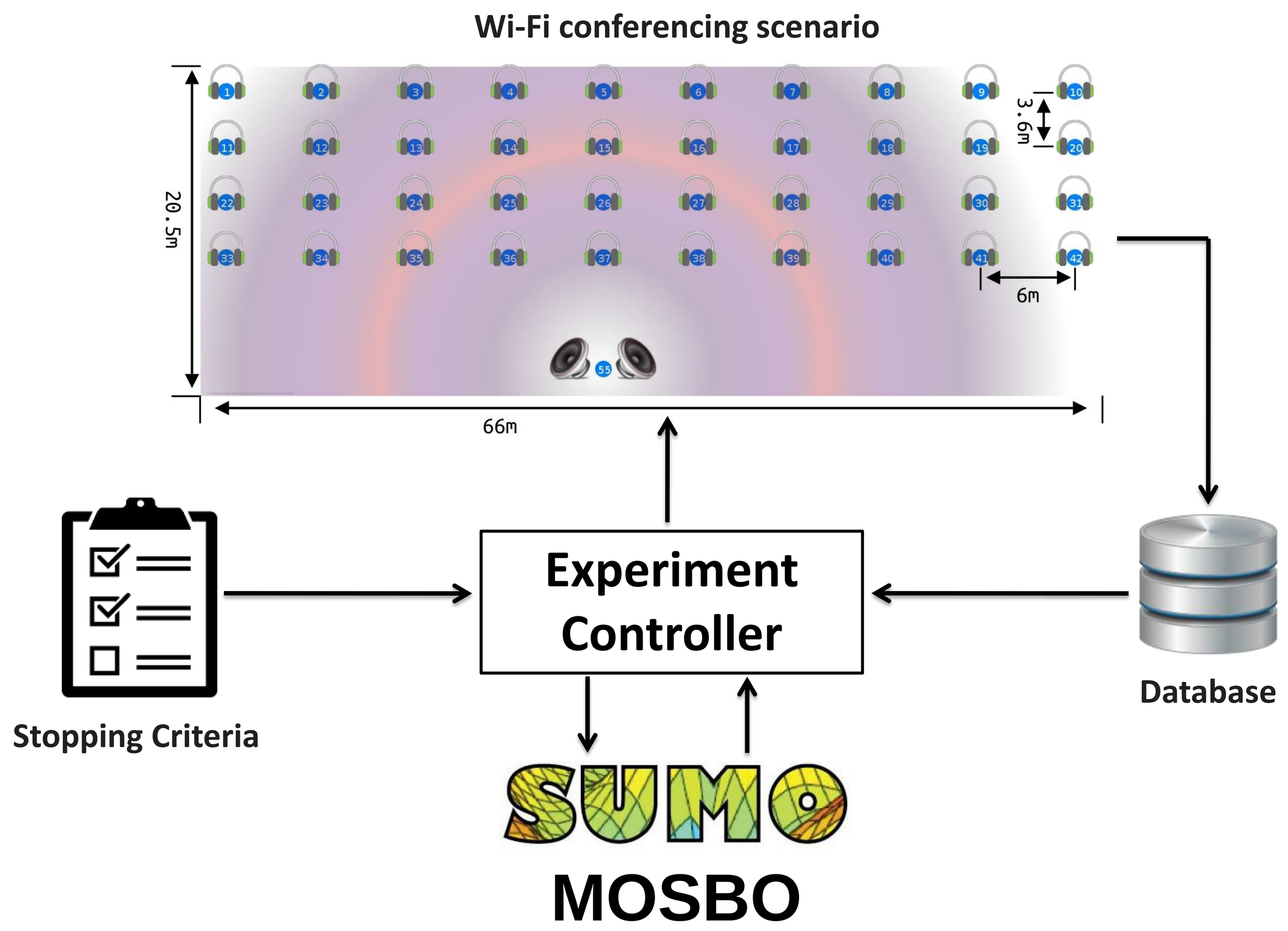






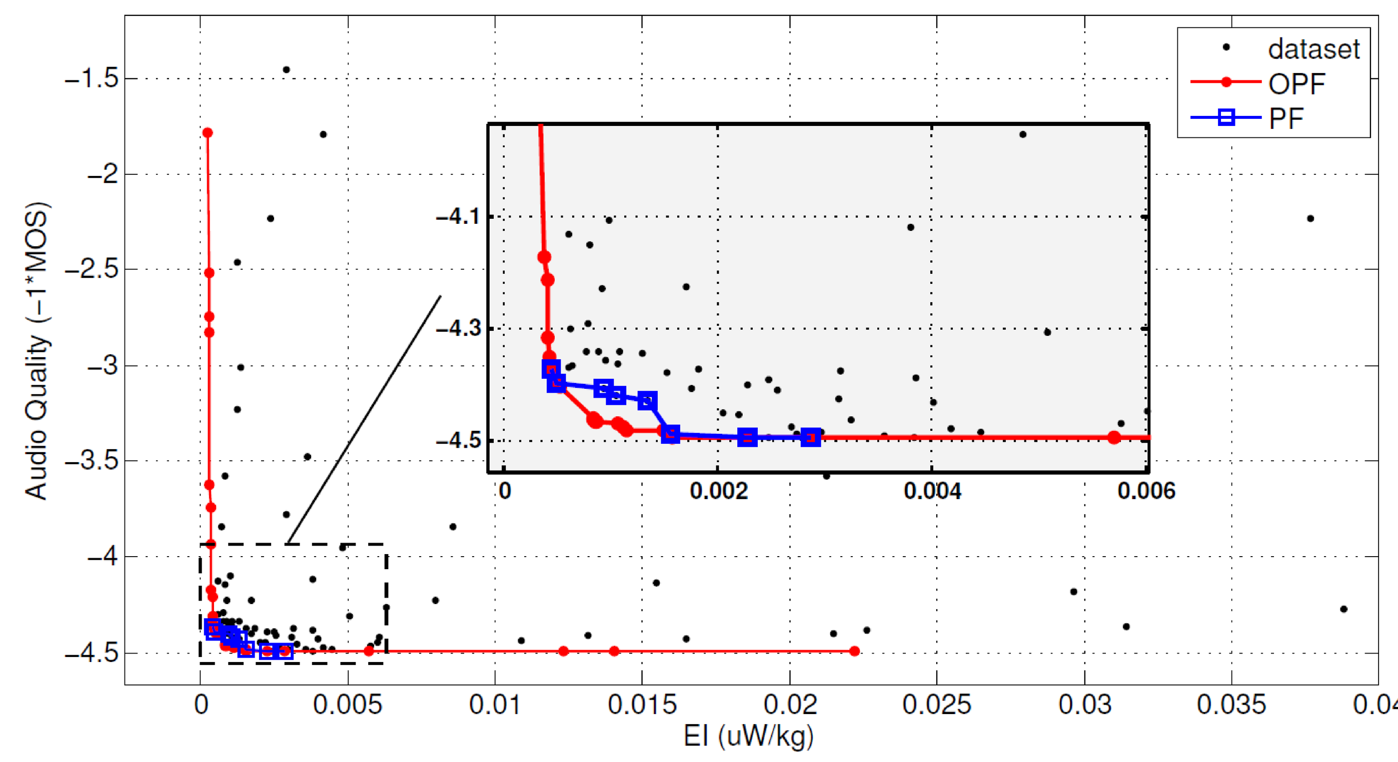
- Surrogate models are created based on a small number of experiments and these models are used to quickly identify optimal settings.
- During optimization, the Multi-Objective Surrogate Based Optimizer (**MOSBO**) predicts the performance from the surrogate model constructed (green cells in the table) and compare it to the real performance (blue cells in the table) retrieved through experimentation.

III. Experimental Validation



- An experimental validation of the MOSBO optimizer using the iMinds w-ilab.t wireless testbed.
- **1** speaker broadcasts audio to **40** Listeners out of which they calculate audio quality and transmission exposure and store it into the database.
- The speaker node configures **codec BitRate**, **codec FrameLength**, **Wi-Fi TxRate** and **Wi-Fi TxPower** which in total consists of **32 x 3 x 4 x 20 = 7680** parameter combinations.
- The experiment controller reads all objective performances from the database and hands it to the MOSBO optimizer for next sample calculation.
- The experiment is iterated until a stopping criteria is satisfied which is a combination of **Progress Indicators** (PI), **Evidence Gathering Processes** (EGP) and **Stopping Decisions** (SD).

IV. Result



- The MOSBO optimizer locates the Approximate Pareto Front (APF) after 82 runs (Speed Up Factor = **7680/82 = 93.65**) and covers **98.36%** of the dominated elements bounded within the Optimum Pareto Front (OPF)
- The knee point of the optimization problem corresponds to a MOS score of **4.480865** and exposure value of **1.153** nW/kg

V. Conclusions

- Optimizing Multi-Objective Wireless Systems in search of the optimum settings is computational expensive.
- Most of the time, it is impractical to retrieve the Optimum Pareto Front (**OPF**) of Wireless Systems.
- To tackle such problems, a Multi-Objective Surrogate Based Optimization (MOSBO) is presented.
- MOSBO works by building kriging models of design objectives and predicts the next parameters.
- To validate the approach, a Wi-Fi conferencing system is selected having 2 conflicting objectives (**Transmission Exposure and Audio Quality**) and 4 design parameters (**codec BitRate, codec FrameLength, Wi-Fi TxRate and Wi-Fi TxPower**).
- The MOSBO optimizer locates the Approximate Pareto Front (APF) after 82 runs (Speed Up Factor = **93.65)** and dominates **98.36%** of the elements bounded within the Optimum Pareto Front (OPF)