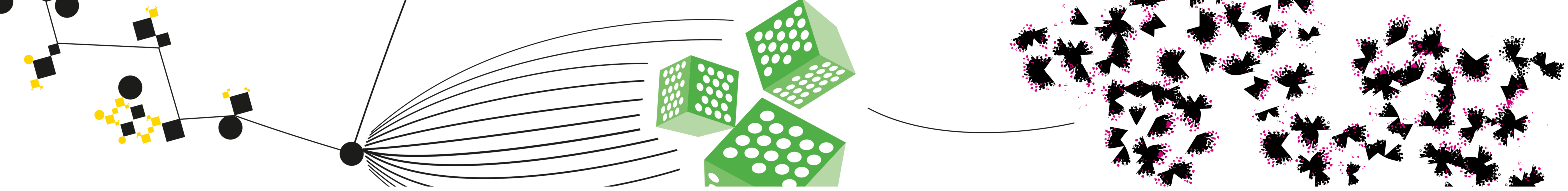

Power and Performance Analysis in Data Centres

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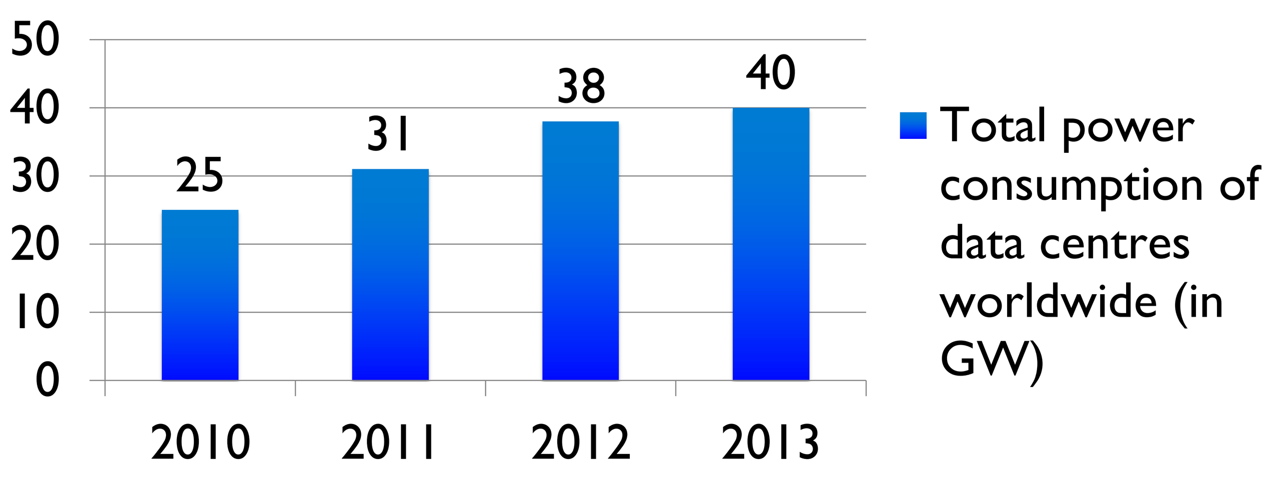
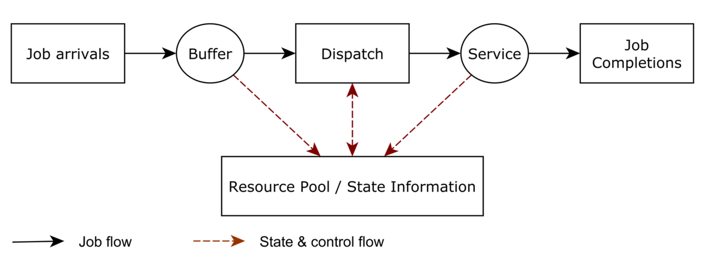
How to obtain better insight in power consumption and performance already in design phase of a data centre?

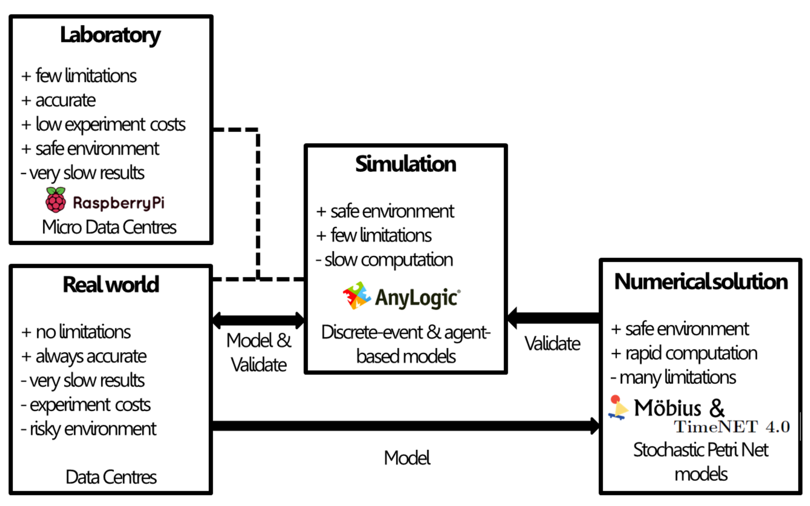
Design high-level models for both **power consumption** and **performance** for give data centre configuration and job streams. Analyse these models to obtain insight in the **power-performance trade-off**, which is caused by **power management**.



Approach

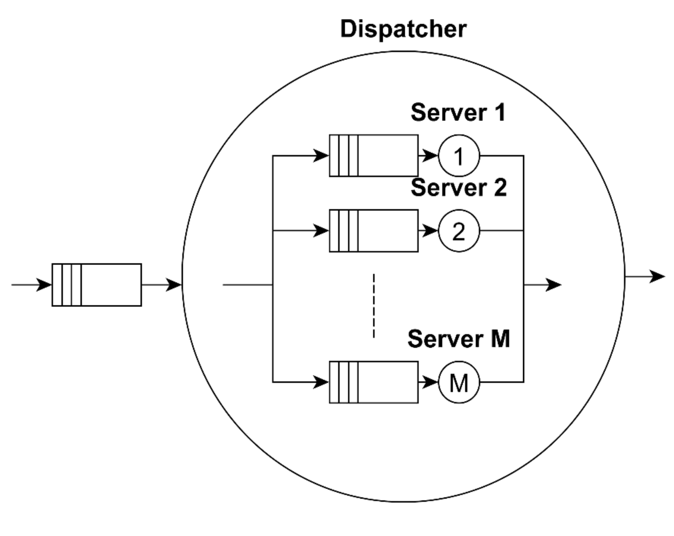
Accurate high-level models for simulation and numerical solution are obtained from "real world" data centres via a modelling and validation cycle. Additionally, a cheap laboratory setup proofs the concept. The basic model below distinguishes the most relevant parts to be modelled.





Modelling & validation cycle

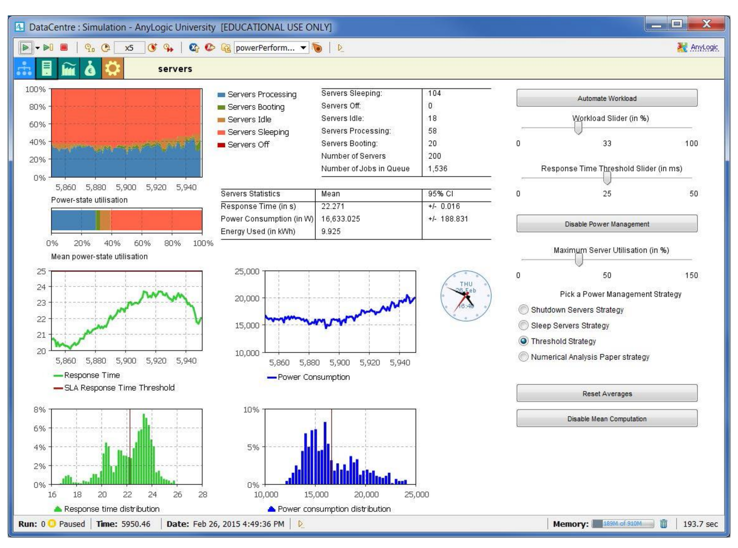
Simulation framework



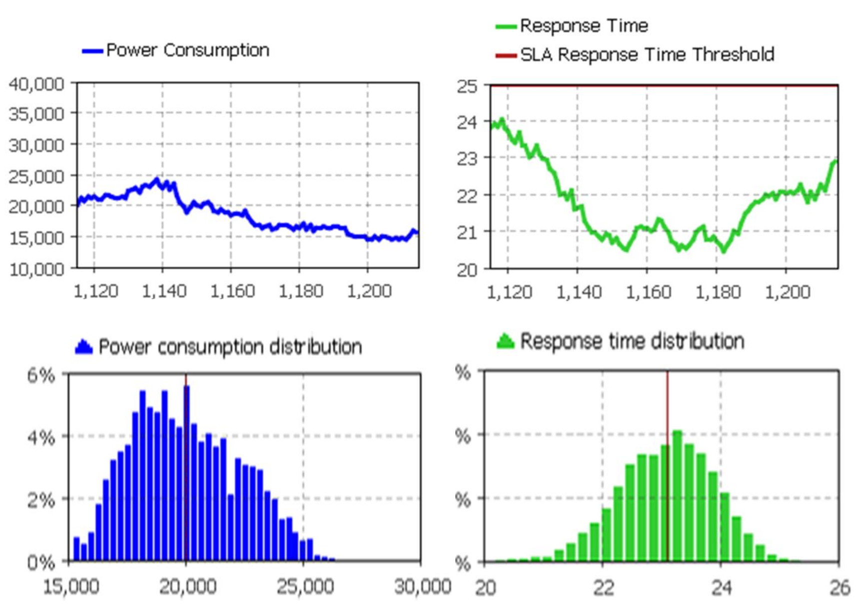
Queueing model

The simulation framework, implemented in AnyLogic, consist of cooperating **discrete-event** and **agent-based** models for data centres, allowing:

- Various configurations
- Different workload
- Heterogeneous servers
- Different power management strategies



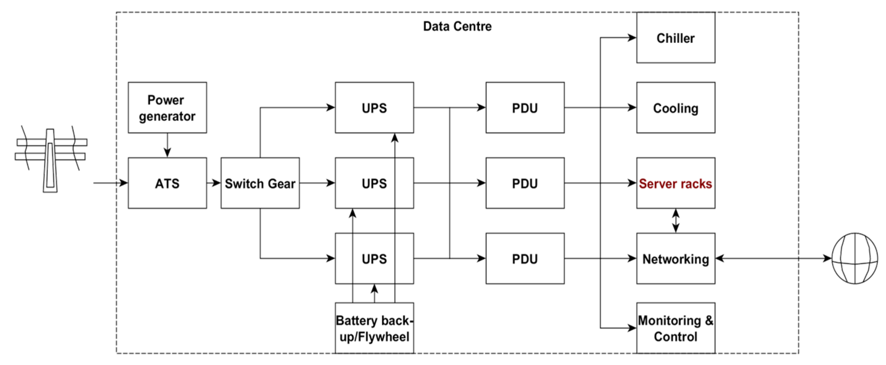
Tool with dashboard



Results

Averages are computed in a few seconds.

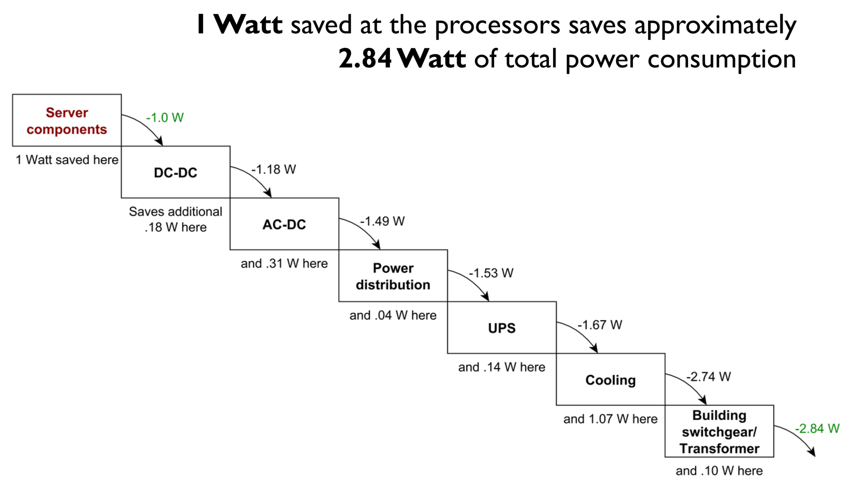
Data Centres



Typical power consuming components

How to reduce energy consumption in a data centre?

- **Power management** aims to switch servers into a lower power state to reduce power consumption, while performance is kept intact.
- **Per server monitoring and control** of temperature, humidity, etc. to increase cooling efficiency.
- and many more …



The cascade effect

Thermal-aware extension

An extension of the framework integrates a thermodynamical model to refine energy usage of cooling. This model indicates **server temperatures** based on three state variables:

1. Server temperature T_{out}
2. Supply temperature T_{sup}
3. Server power consumption P

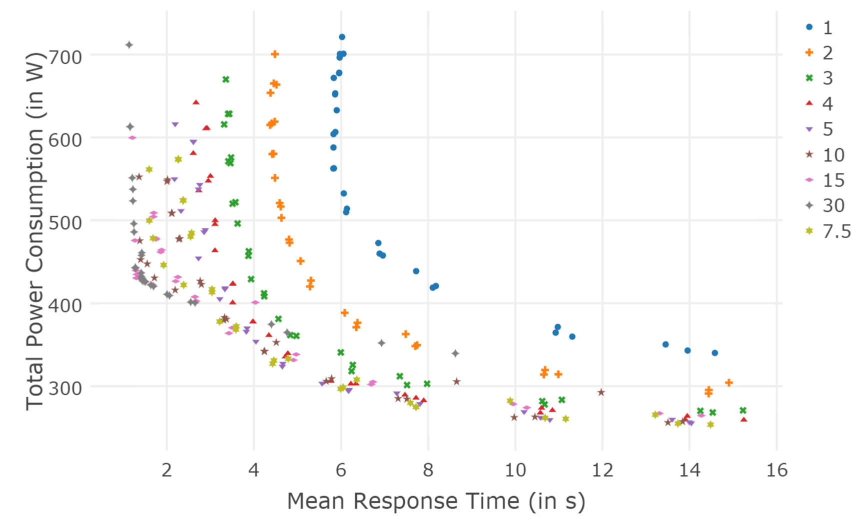
$$
\begin{aligned}
\frac{d}{dt}T_{out}(t) &= \underbrace{\begin{bmatrix} \frac{\rho}{m_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{\rho}{m_N} \end{bmatrix}}_{\hat{K}} \underbrace{\begin{bmatrix} \gamma_{11}-1 & \cdots & \gamma_{Ni} \\ \vdots & \ddots & \vdots \\ \gamma_{iN} & \cdots & \gamma_{NN}-1 \end{bmatrix}}_{\Gamma'-I_N} \underbrace{\begin{bmatrix} f_1(t) & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & f_N(t) \end{bmatrix}}_{F(t)} T_{out}(t) \\
&+ \underbrace{\begin{bmatrix} \frac{\rho}{m_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{\rho}{m_N} \end{bmatrix}}_{\hat{K}} \underbrace{\begin{bmatrix} 1-\gamma_{11} & \cdots & -\gamma_{Ni} \\ \vdots & \ddots & \vdots \\ -\gamma_{iN} & \cdots & 1-\gamma_{NN} \end{bmatrix}}_{I_N-\Gamma'} \underbrace{\begin{bmatrix} f_1(t) & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & f_N(t) \end{bmatrix}}_{F(t)} T_{sup} \\
&+ \underbrace{\begin{bmatrix} \frac{1}{m_1 c_p} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{1}{m_N c_p} \end{bmatrix}}_{\tilde{K}} P(t) \\
&= \hat{K}(\Gamma' - I_N)F(t)T_{out}(t) + \hat{K}(I_N - \Gamma')F(t)T_{sup} + \tilde{K}P(t)
\end{aligned}
$$

Thermodynamical model

Power management & job scheduling extension

An extension of the framework allows to express job scheduling and power management behaviour via policies. These policies allow to check various variables:

1. Queue size threshold Q
2. Idle time-out switch TO
3. Temperature Temp
4. Power state PS
5. Response time threshold R



Power-performance trade-off of many designs for different TO and Q

Conclusions

Simulation models of data centres lead to insight into important power and performance indicators. Moreover, model refinement leads to even more accurate insight in these indicators.

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