Assessment to support the planning of sustainable data centers with high availability

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Agenda

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Introduction

– Data centers are growing

– Fact (Considering U.S.)

- Data centers consume about 2 % of the whole power generated .

– Concern about

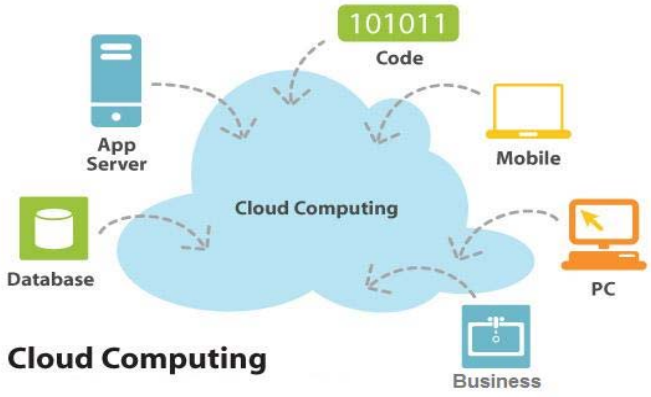
- Energy Consumption,
- Environmental Sustainability.

– Sustainable data centers

- Least amount of materials,
- Least energy consumption.

– Availability

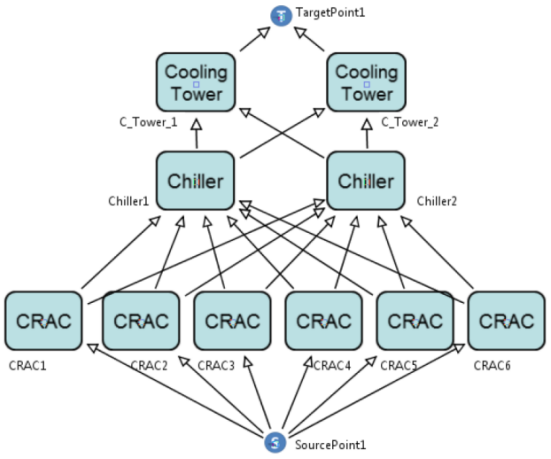
– Fault-Tolerance

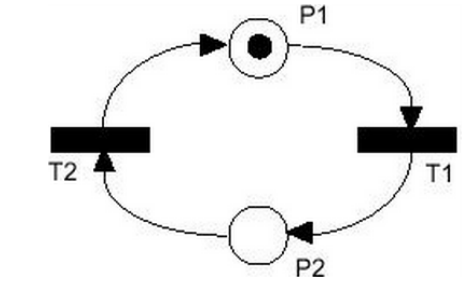


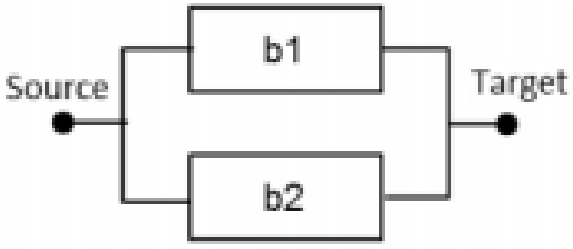
Objective

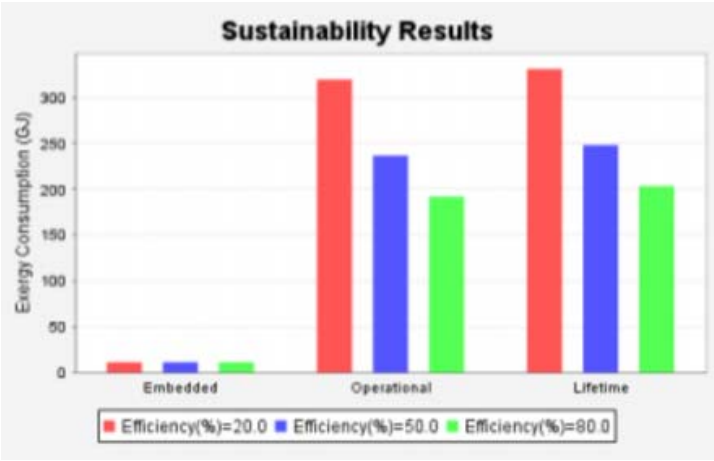
- **To provide:**
  - a set of **models** for the integrated **quantification** of **sustainability** impact, **cost** and **dependability** of data center power and cooling infrastructures.

Energy Flow Model, SPN and RBD → availability, downtime, cost sustainability impact, etc



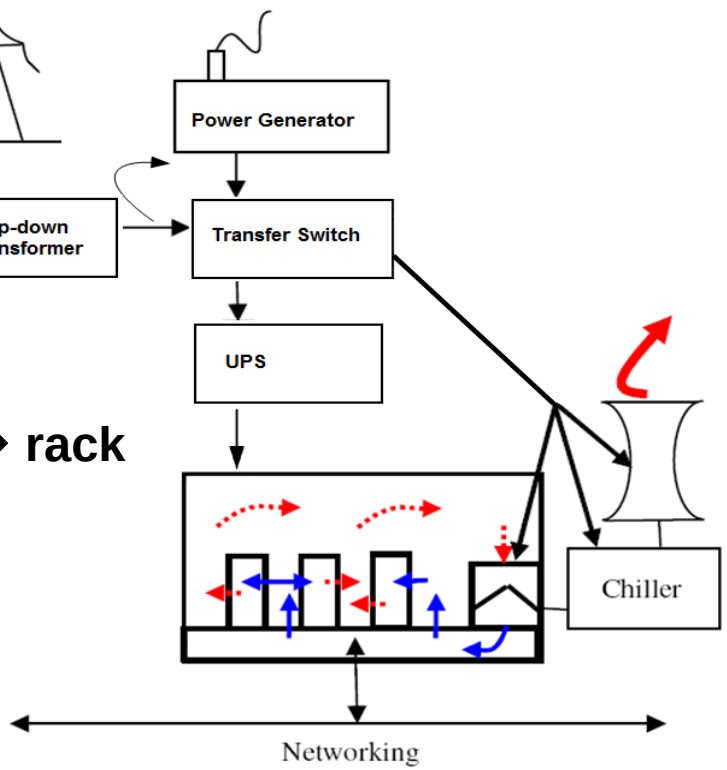






Data Center Infrastructure

- IT infrastructure:
  - Servers,
  - Networking equipment,
  - Storage devices.
- **Power infrastructure:**
  - **SDT → transfer switches → UPS → PDUs → rack**
- **Cooling infrastructure:**
  - **Extracts heat → prevents overheating**
  - **CRAC, Cooling Tower, Chiller**



Metrics

- Dependability
  - Availability
  - Reliability
  - Reliability Importance (RI)
  - Reliability and Cost Importance (RCI)
- Sustainability Impact
  - Exergy Consumption
  - CO2 Emissions
- Cost
  - Acquisition cost
  - Operational cost

Exergy

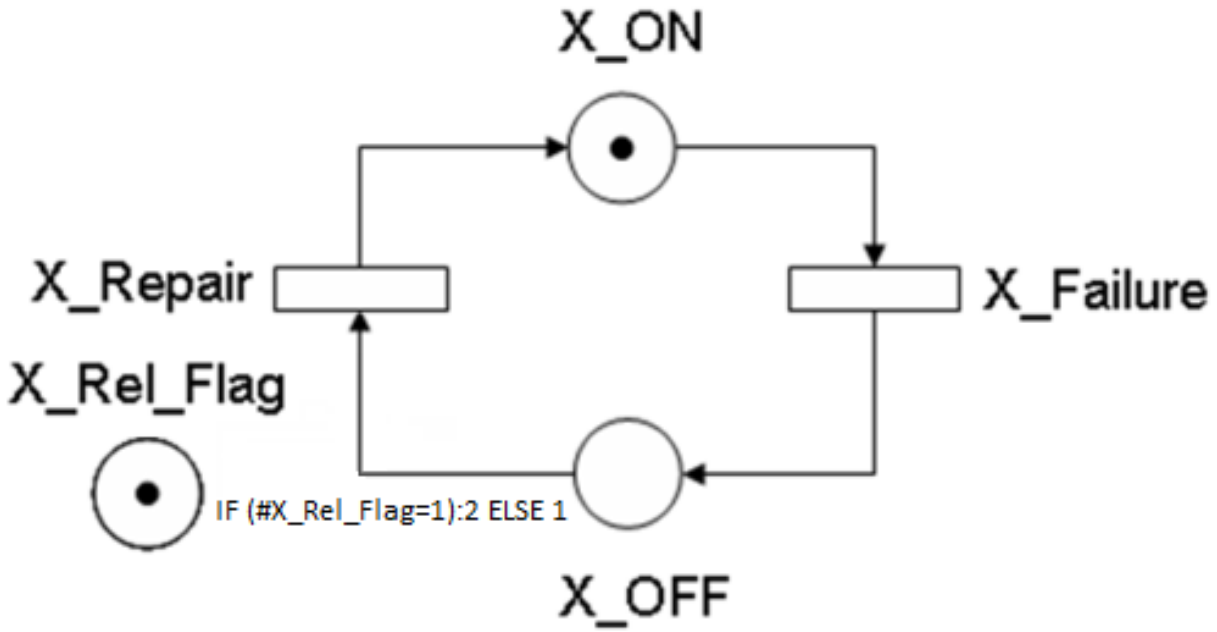
- **Energy** can **never** be **destroyed** (FLT).
- **Exergy** can be **destroyed** (SLT).
- The **exergy** destruction or **consumption** (**irreversibility**) must be appropriately **minimized** to obtain sustainable development.

- Exergy (available energy)
  - Represents the maximal theoretical portion of the energy that could be converted into work;
  - A system which consumes the least amount of exergy is often the most sustainable;
  - **Exergy** is **useful** when **measuring** the **efficiency** of an energy conversion process

Stochastic Petri Net (SPN)

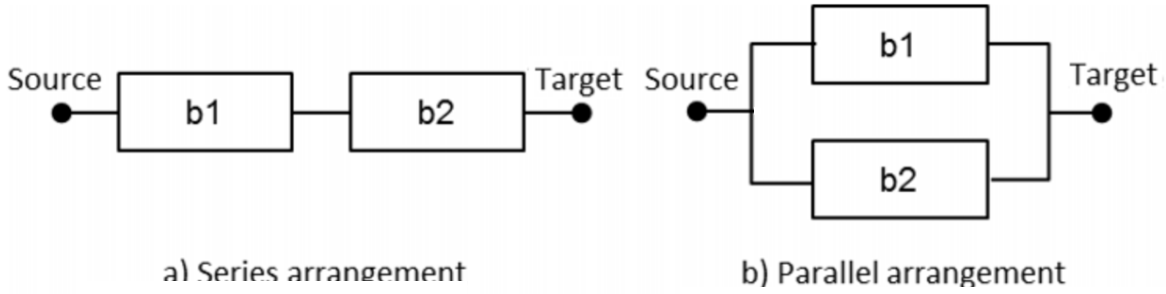
- Simple Component

$$A\_R = P\{\#X\_ON > 0\}$$



Reliability Block Diagrams (RBD)

- A **Reliability Block Diagram** (RBD) is a non-state space model that enables analysis of **reliability** and **availability** of complex systems using block diagrams.
- In a block diagram model, components are combined into blocks in series, parallel, or *k-out-of-n*.
- The structure of RBD establishes the logical interaction among components



$$P_s = \prod_{i=1}^{n} P_i \qquad P_p = 1 - \prod_{i=1}^{n} (1 - P_i)$$

where P_i is the reliability - $R_i(t)$ (instantaneous availability $(A_i(t))$ or steady state availability (A_i)) of block b_i.

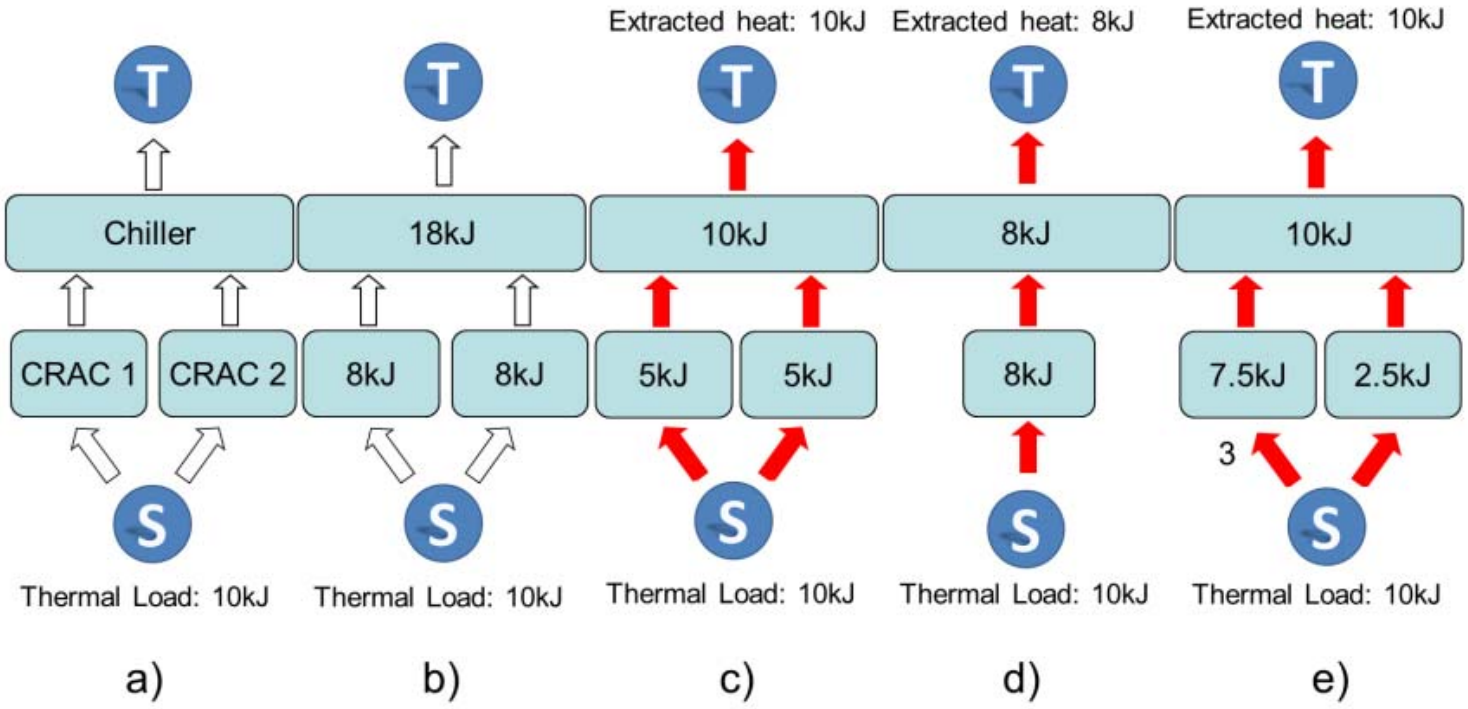
Optimization

- Greedy Randomized Adaptive Search Procedure (**GRASP**) is **adopted to optimize:**
  - dependability,
  - sustainability and
  - cost issues.

- Those values are **estimated** through the **EFM** and **dependability models**.

Energy Flow Model

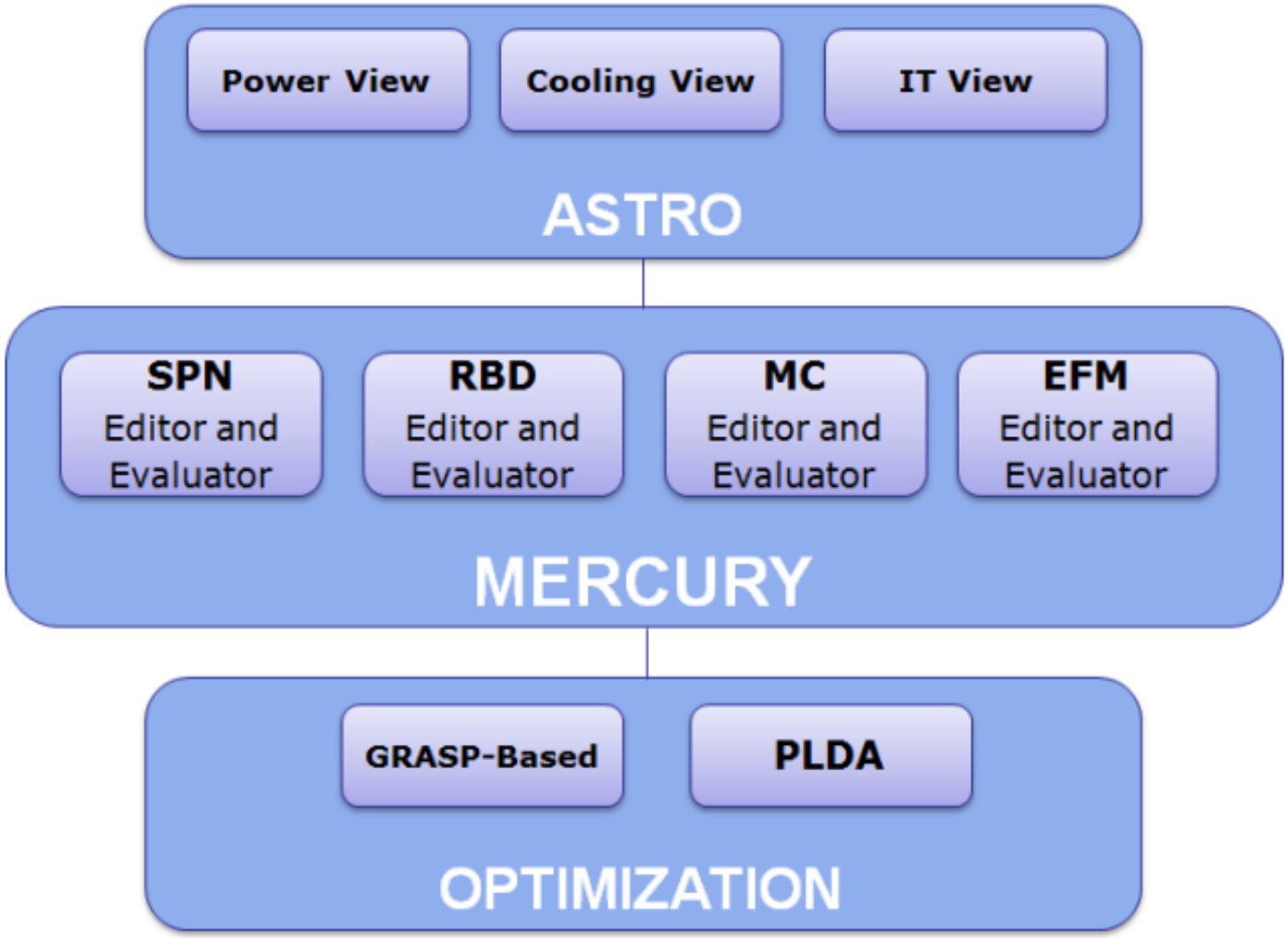
- The **system** under evaluation can be **correctly arranged**, **but** they **may not** be able to **meet system demand** for electrical energy or thermal load.



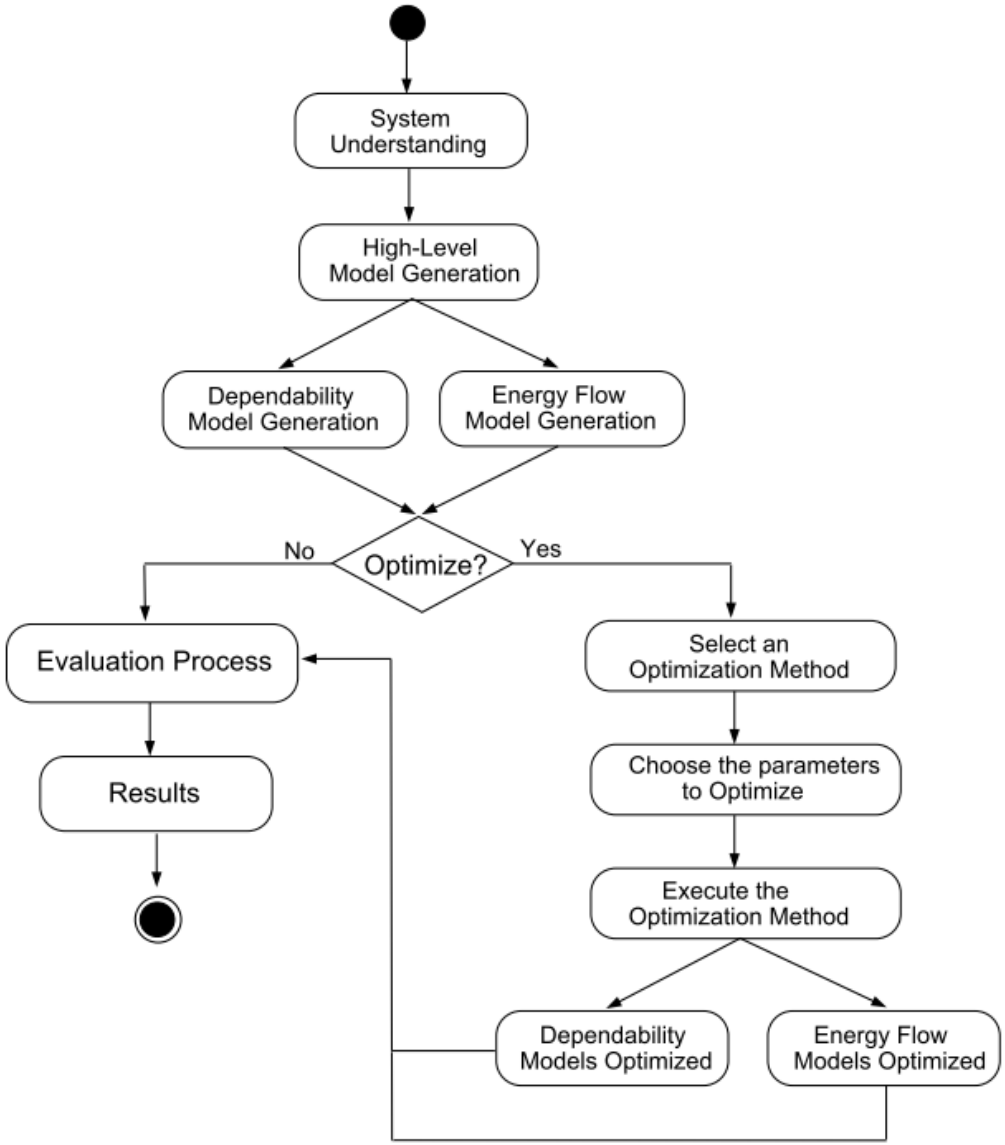
Energy Flow Model

- Algorithms:
  - Verifying the energy flow
  - Quantifying Operational Exergy Consumption
  - Quantifying acquisition and operational costs

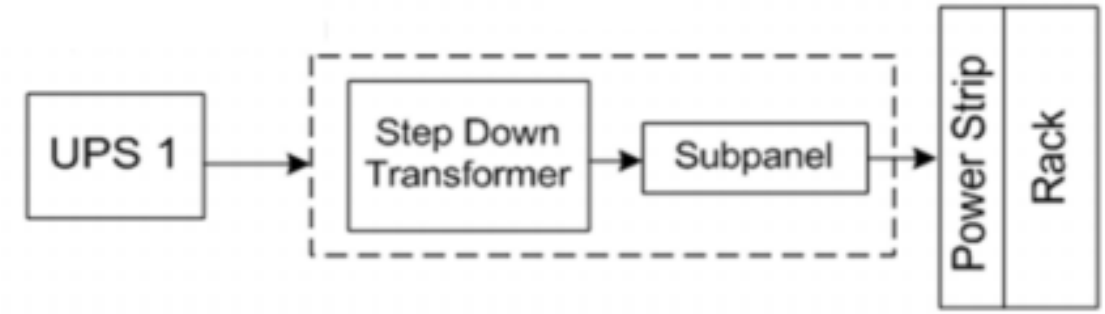
Evaluation Environment

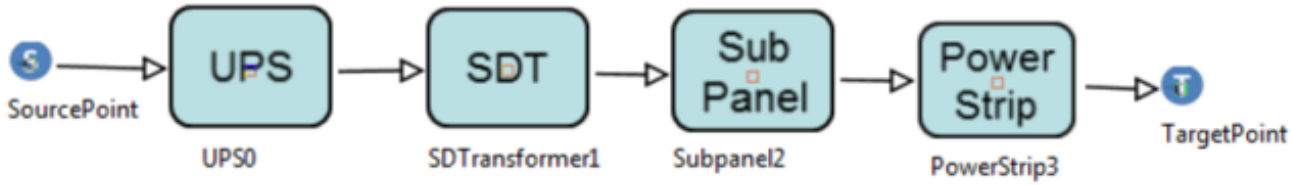


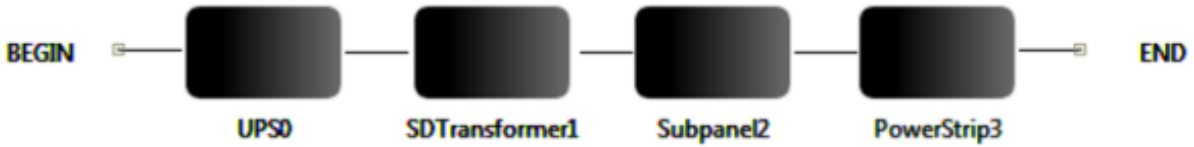
Methodology



Case Study







Results

ALL	$0.9998\ (3.73)$
$Opt.$	$0.9998\ (3.71)$

Final Remarks

- Data center **designers do not have** many **mechanisms** to support the **integrated** sustainability, cost and dependability **evaluation** of data center infrastructures.

- This work aims at **reducing** this **gap** by **proposing models** (supported by the developed environment ASTRO/Mercury)

- As a **future work**, we intend to **analyze other scenarios**.

Published Papers

- [1] M. Marwah, P. Maciel, A. Shah, R. Sharma, G. Callou. Quantifying the sustainability impact of data center availability. SIGMETRICS. Perform. Eval. Rev., 37:64–68, March 2010.

- [2]:G. Callou, P. Maciel, F. Magnani, J. Figueiredo. Estimating sustainability impact, total cost of ownership and dependability metrics on data center infrastructures. In Proceedings of the IEEE International Symposium on Sustainable Systems and Technology (ISSST), pages 1-6, Chicago, USA, 2011. **(IEEE Student Paper Competition – FIRST PLACE)**

- [3]: G. Callou, P. Maciel, F. Magnani, E. Tavares. Sustainability and dependability evaluation on data center architectures. In Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, pages 1-6, Anchorage, Alaska, USA, 2011.

- [4]: G. Callou, E. Sousa, P. Maciel, E. Tavares. A formal approach to the quantification of sustainability and dependability metrics on data center infrastructures. In Proceedings of the 2011 Symposium on Theory of Modeling and Simulation (TMS/DEVS), Boston, MA, USA, 2011. ACM.

- [5]: Callou, G.; Maciel, P.; Tutsch, D.; Araujo, J.; , "Models for dependability and sustainability analysis of data center cooling architectures, in Proceedings of *IEEE/IFIP 42nd International Conference on Dependable Systems and Networks Workshops (DSN-W)*, Boston, MA, USA, pp.1-6, 25-28 June 2012.

- [6] Gustavo Callou, Paulo Maciel, Dietmar Tutsch, Julian Araújo, João Ferreira, Rafael Souza: A Petri Net-Based Approach to the Quantification of Data Center Dependability, in: Petri Nets - Manufacturing and Computer Science, InTech, Open Access Publisher, August 2012.

Thanks!

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