Towards Modeling and Analysis of Power Consumption of Self-Adaptive Software Systems in Palladio
Symposium on Software Performance 2014
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Motivation

Performance
Reliability

…
Motivation

Performance
Reliability

MediaStore
Web GUI
Media Store
Encoder

Motivation

Becker et al. [BBM13,BLB13]
Motivation

Performance
Reliability
Energy Efficiency

Becker et al. [BBM13,BLB13]
Motivation

Total Cost of Ownership of Data Centers
Source: [GHMP08]

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servers</td>
<td>45%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>25%</td>
</tr>
<tr>
<td>Power</td>
<td>15%</td>
</tr>
<tr>
<td>Network</td>
<td>15%</td>
</tr>
</tbody>
</table>

Performance
Reliability
Energy Efficiency

Becker et al. [BBM13, BLB13]
Towards? – Results and Roadmap

- Extending PCM with power consumption characteristics
- Power consumption analysis
- Validation for static software systems
- Support for power-conscious self-adaptations
Related Work

Architecture-level energy consumption analysis

- Seo et al. [SEMM08]
- Meedenyia [MBAG10]
- Brunnert et al. [BWK14]

Mobile software systems

- Willnecker et al. [WBK14]

Energy-conscious self-adaptive software systems

- Götz et al. [GWCA12,GWR13]
- Calheiros et al. [CRB+11]
Foundations – Power and Energy Consumption

**Power Consumption**
- Rate at which system consumes energy

**Energy Consumption**
- Power consumption over time

![Graph illustrating power consumption over time](image)
Foundations – Power Models

- **Purpose:** Estimate power consumption based on system metrics, e.g. CPU utilization
- Regression-based correlation of system metrics and power consumption
Foundations – Peak Power

- Maximum power consumption in an interval: \( \max_{t \in [a,b]} P(t) \)
Foundations – Why Peak Power matters

- Power distribution infrastructure needs to be capable of handling peak load
- Higher supported peak power draw → Higher infrastructure cost: $10 to $20 per available Watt of peak power [FWB07]
- Stronger overprovisioning → Higher risk of blackout/HW failure

Degree of overprovisioning depends on

- Usage profile
- Workload mix
- Accepted risk
Foundations – Why Peak Power matters

Energy cost depend upon

- Energy consumption
- Peak power consumption [ZWW12]
Analyzing Power Consumption with Palladio

- Extend Palladio by definition of power consumption characteristics
- **Purpose:** Power consumption analysis
Power Consumption Model – Infrastructure

- Power distribution hierarchy
- Consumption characteristics per resource

```
infrastructure
  power distribution hierarchy
<<annotates>>

binding
  consumption characteristics
<<determines>>

specification
  power model
<<determines>>

pcm::resourceenvironment
```

Power Consumption Model – Binding

- Consumption properties of *resource types*
- Examples:
  - Power consumption of Xeon E5-4650 under full/idle load
  - Conversion loss of power distribution unit under full/idle load
Power Consumption Model – Specification

- Power models of resources and distribution infrastructure
- Examples:
  - Linear CPU-based
  - Complex regression model for CPU and HDD
Power Consumption Analyzer (PCA)

- Calculate power consumption per entity

![Diagram showing power consumption analysis]

- Analyze Power Consumption over Time

- Power vs Utilization (Linear vs Non-Linear)

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Power Consumption Analyzer (PCA)

- Calculate power consumption per entity
- Dedicated calculator implementation per regression model

\[ P_{Total} = P_{CPU} + P_{HDD} \]
PCA – Use Cases

Post-simulation analysis

- Analyze power consumption of a software system
- **Challenges:**
  - Separate consumption analysis and simulation logic
  - Aggregation of results over distribution hierarchy and time
  - Enable reconfigurability and extensibility of analysis

Intra-simulation analysis

- Evaluate the impact of power-conscious self-adaptation tactics on multiple quality characteristics
- **Challenge:** Integrate consumption analysis with self-adaptation process
Integrating the PCA with Palladio

- **Use case 1 – Post-simulation analysis**

![Diagram](image)

Legend:
- QuAL
- Extension

[Le14] Quality Analysis Lab (QuAL)

Software Architecture Simulator → Probe Framework → Recorder Framework (EDP2) → Utilization Filter → Power Consumption View

- Evaluation Context
- Post-Simulation Context

Power Consumption Analyzer (PCA)

LinearPowerModel Calculator

<<uses>>

<<parameterizes>>
Integrating the PCA with Palladio

- Use case 2 – Intra-simulation analysis
Palladio Workbench Integration

1) Select infrastructure element

2) Select experiment run in EDP2

3) Start analysis
Palladio Workbench Integration

Power Consumption over Time

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Extending PCM with power consumption characteristics

Power consumption analysis

Validation for static software systems

Support for power-conscious self-adaptations

Thank you!

Questions?

Ideas?

Suggestions?
Energy Consumption of Data Centers

Source: [K11]
Total Cost of Ownership of Data Centers

- Servers: 45%
- Infrastructure: 25%
- Power: 15%
- Network: 15%

Source: [GHMP08]
Foundations – Self-Adaptive Systems

- Self-adaptive systems modify their structure and functionality based on changes in the environment
- MAPE-K loop [KC03]
Foundations – Self-Adaptive Software Systems

- Becker et al. [BBM13,BLB13]: Design and analysis of self-adaptive software systems

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Towards Modeling and Analysis of Power Consumption of Self-Adaptive Software Systems in Palladio
References (1)


References (2)


References (3)


References (4)

- **[Le14]** Quality Analysis Lab (QuAL): Software Design Description and Developer Guide Version 0.2. Universität Paderborn, Faculty of Electrical Engineering - Computer Science - Mathematics, 2014


References (5)

Image sources

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- Nichole, Gears Clipart, retrieved from:  