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Predicting Energy Consumption by Extending the Palladio Component Model

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Agenda

- Motivation
- Power Consumption Model
  - Calculation
  - Meta-Model Extension
  - Power Consumption Model Generation
- Evaluation
  - SPECjEnterprise 2010
  - Runtastic for Android
- Conclusion

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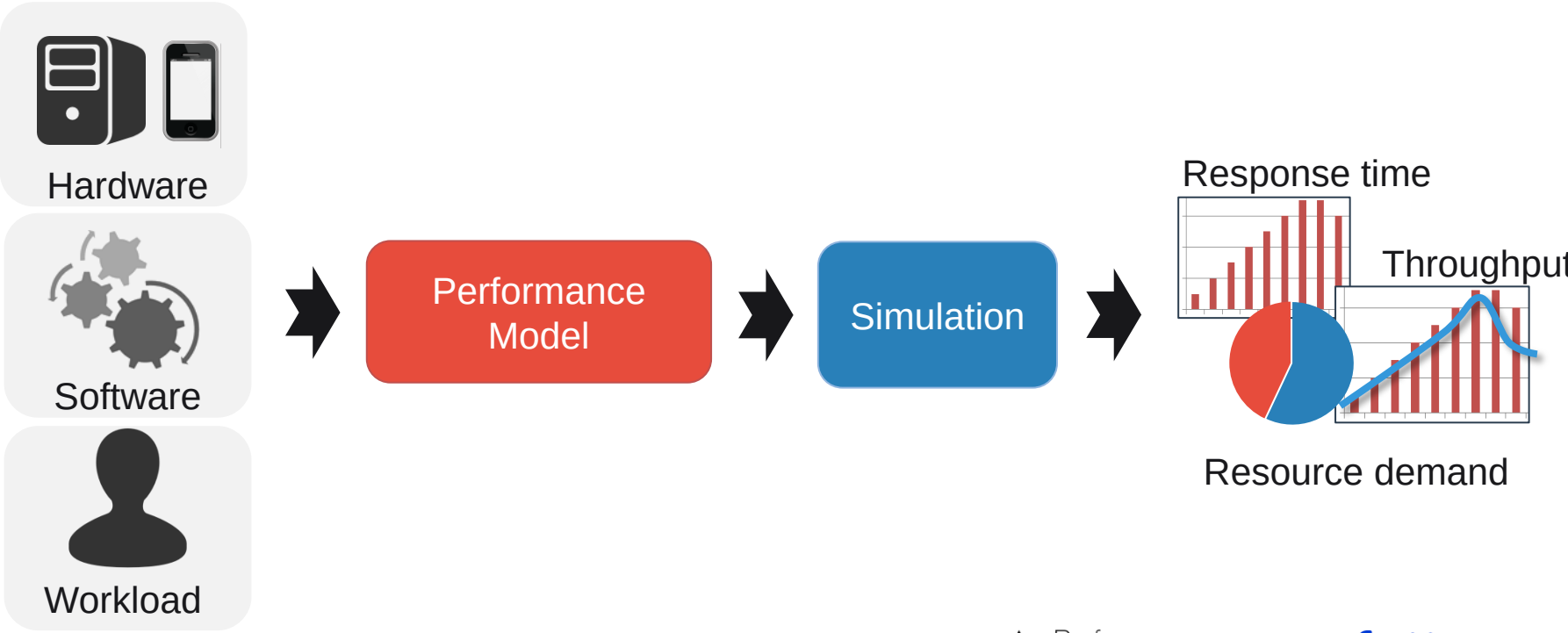
Motivation

- Energy Consumption of Information and Communication Technology is growing (Stobbe et al. 2009, Willnecker et al. 2014)
- Optimization on hardware and operating system level cannot compensate rising demand (Gottschalk et al. 2012)
- Investigating the energy efficiency on application level becomes a growing software engineering challenge (Brunnert et al. 2014)
- Main challenges and goals:
  - Reduce operation costs in data centers
  - Increase battery life time of portable devices
  - Ease carbon footprint

Motivation

- Performance metrics and energy consumption rely on the same underlying parameters of resource demand and hardware capabilities
- Performance simulation and prediction techniques can be used to predict the energy consumption of applications



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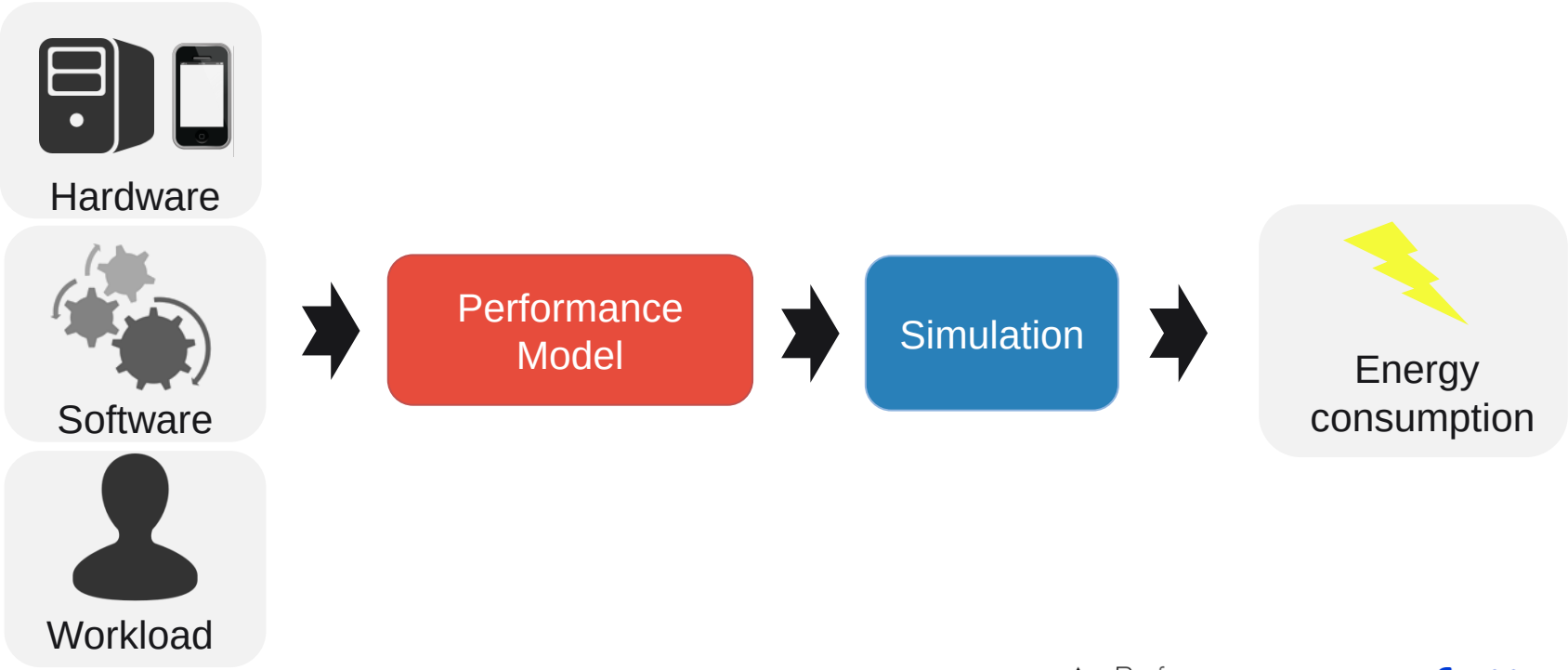

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Power Consumption Model

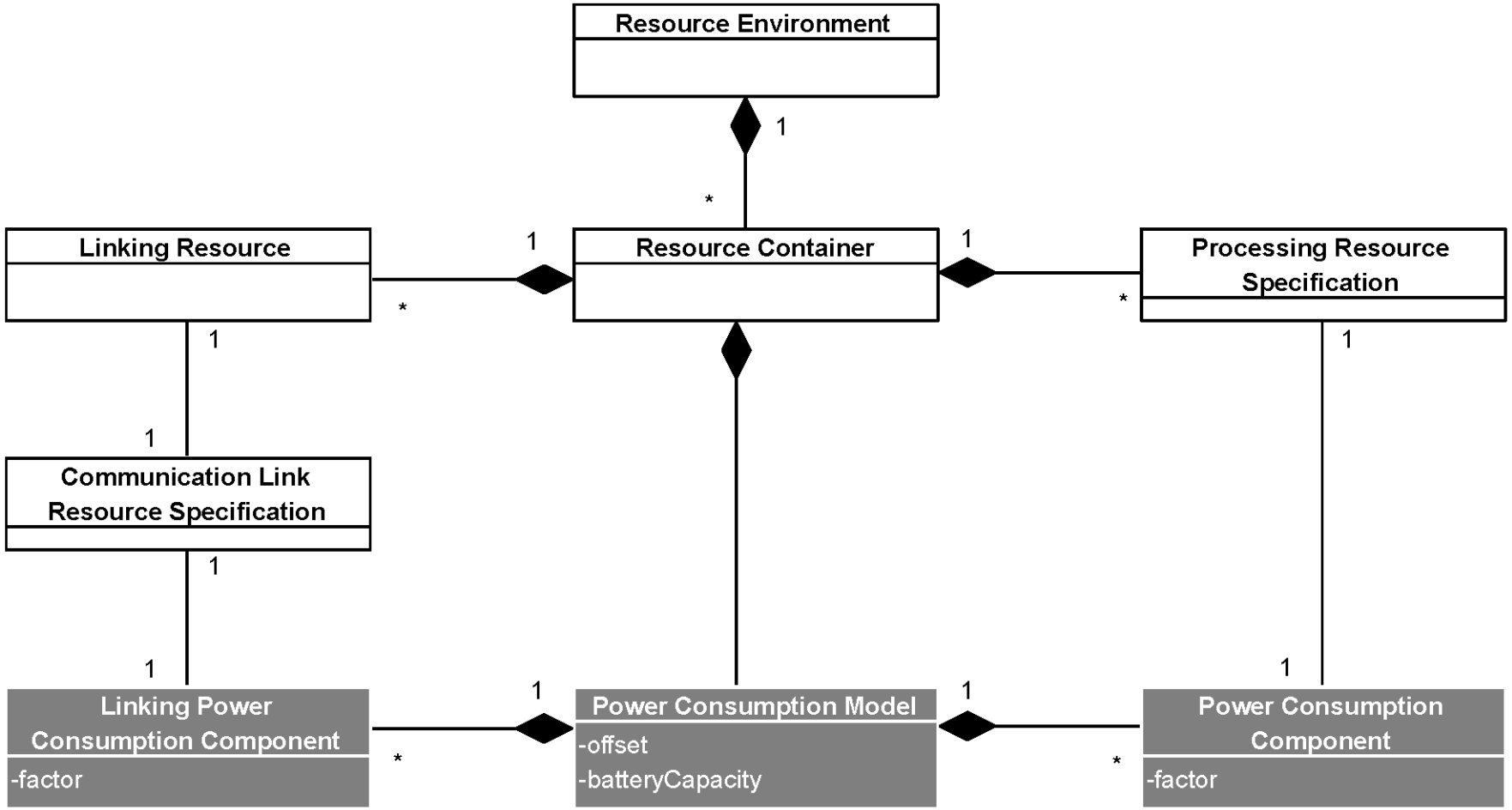
Calculation

$$P_{pred} = P_{idle,0} + \sum_{1 \leq i \leq n} P_{idle,i} * u_i$$

- This function is calculated for each resource container or linking resource based on the utilization of the components in this resource container.
- $\boldsymbol{P_{pred}}$ is the Predicted Power Consumption of a resource container
- $\boldsymbol{P_{idle,0}}$ is the Power Consumption function of the resource container in idle state
- $\boldsymbol{P_{idle,i}}$ is the Power Consumption factor function of a component in this resource container
- $\boldsymbol{u_i}$ is the utilization factor of the component (e.g, CPU utilization, GPS on/off state, throughput)

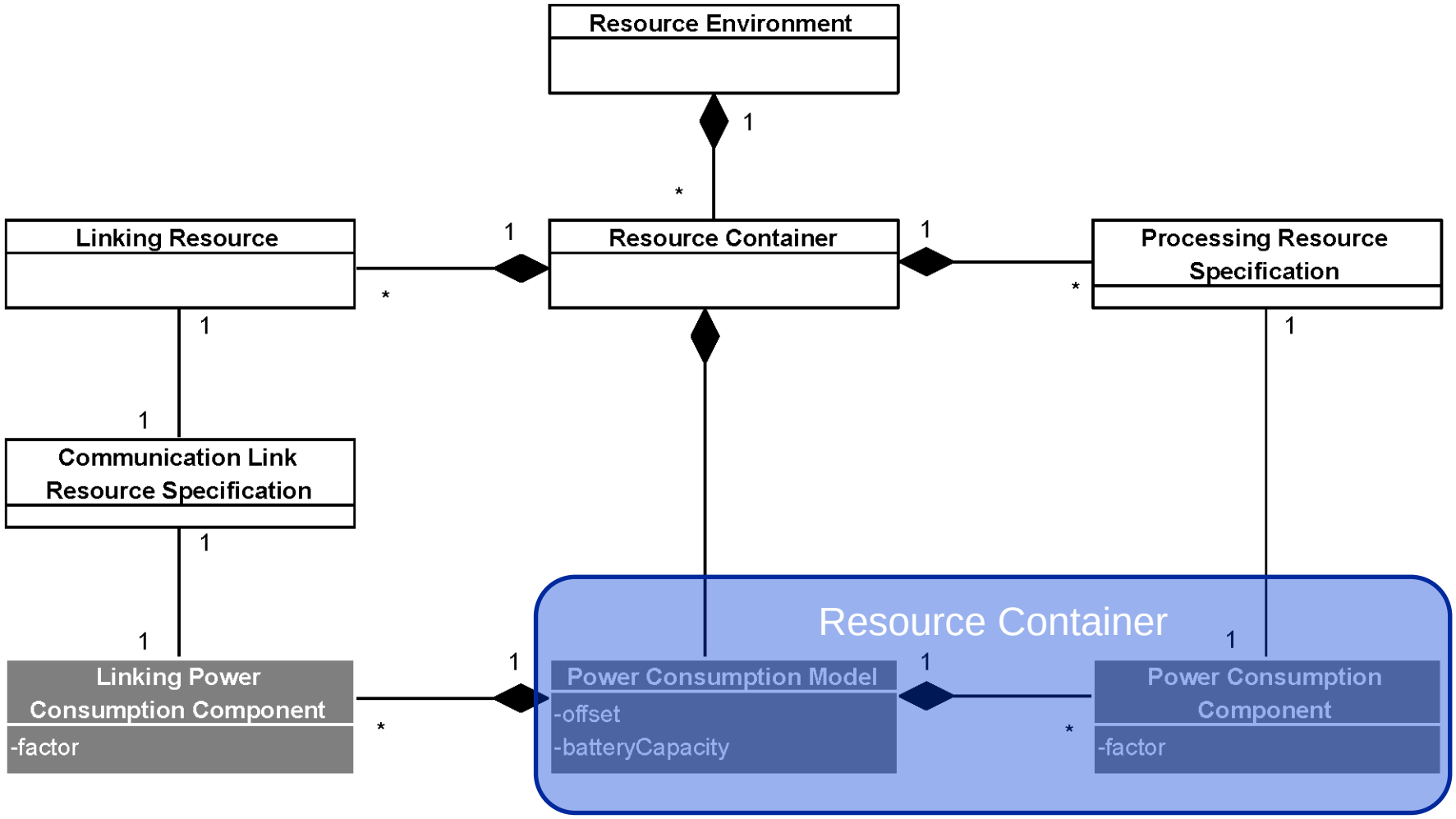
Power Consumption Model

Meta-Model Extension



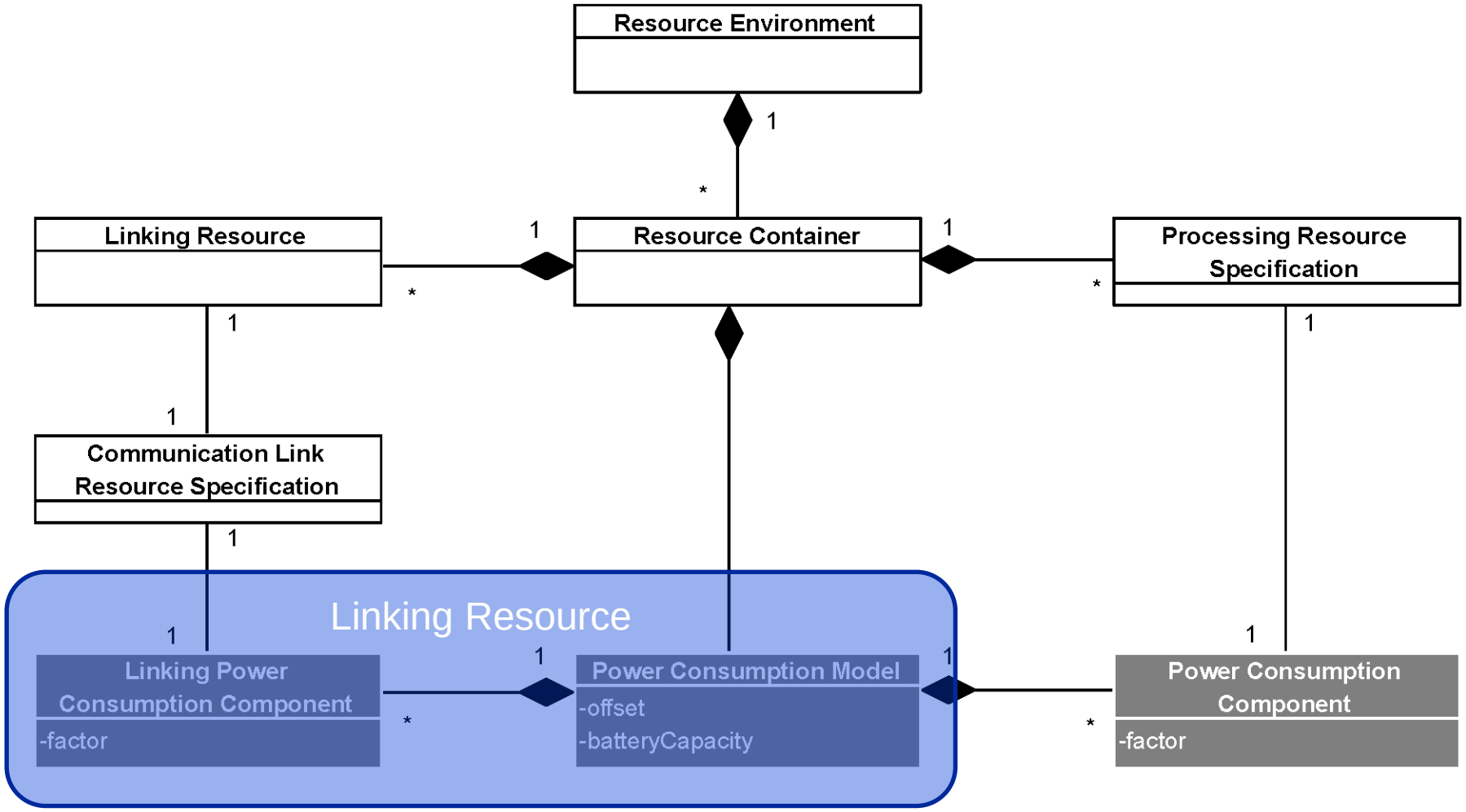
Power Consumption Model

Meta-Model Extension



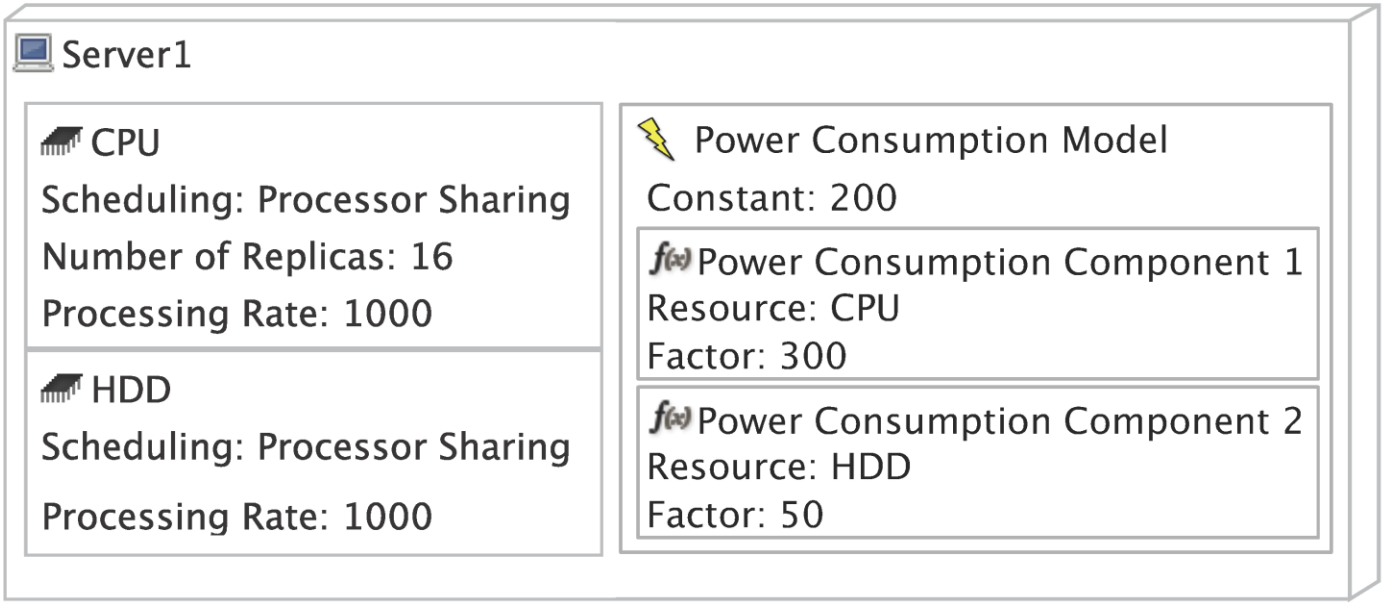
Power Consumption Model

Meta-Model Extension



Power Consumption Model

Power Consumption Model of a server



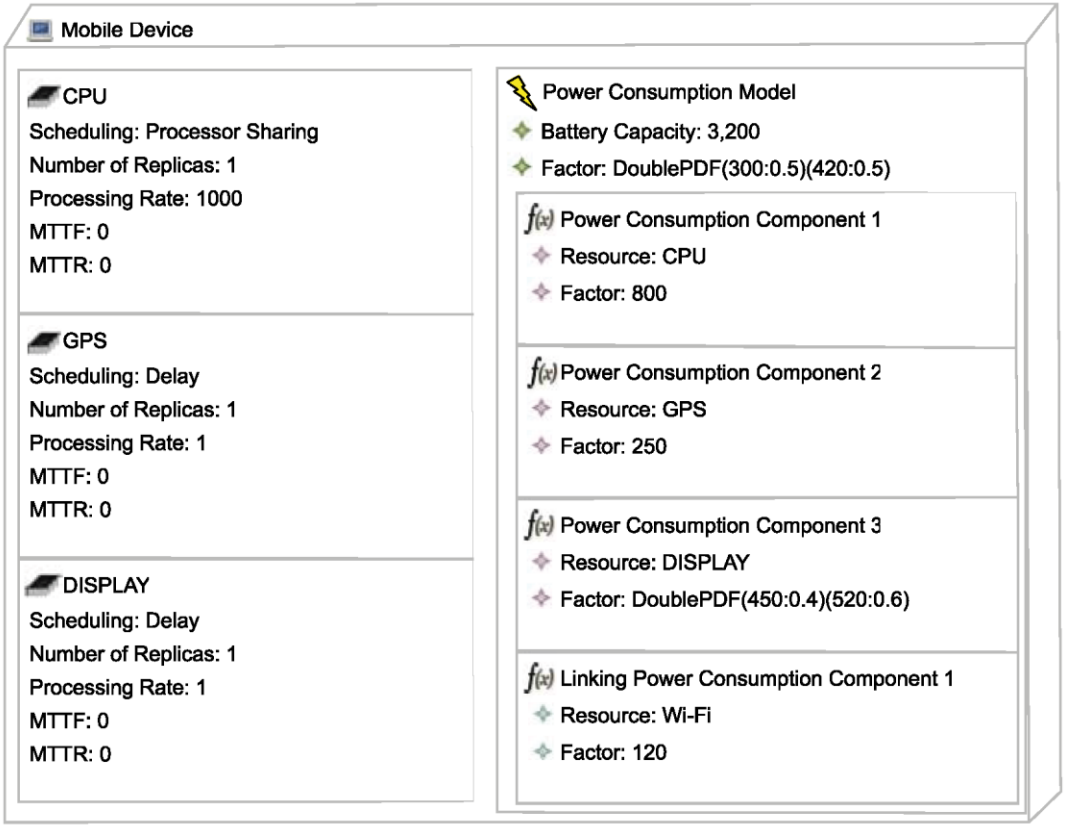
Server in PCM with Power Consumption Model (Brunnert et al. 2014b)

- P_{pred} = **200** + **300** x u_{CPU} + **50** x u_{HDD}
- The energy consumption **E** of the system is the integral over P_{pred} over the simulation time **T**

$$E = \int_0^T P(t)\,\mathrm{d}t$$

Power Consumption Model

Power Consumption Model of a mobile device



Mobile Device in PCM with Power Consumption Model

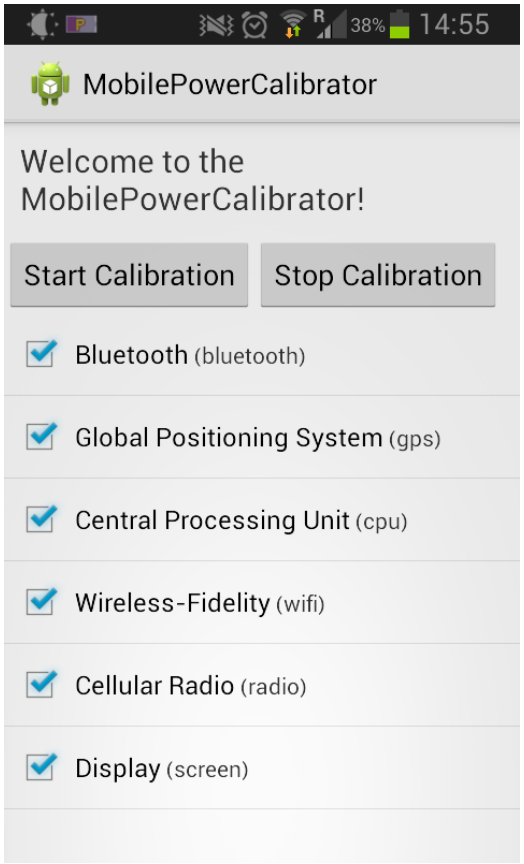
- **Battery capacity** specified to calculate discharging
- **Stochastic functions** for varying power consumptions
- Added two resource types: **GPS** and **DISPLAY**
- **Linking resource power consumption model** to calculate energy demand of network traffic based on throughput

Power Consumption Model

Power Consumption Model Generation

- Manually creation based on specifications and estimations
  - Resource Specifications from manufacturer
  - Android Vendor Profiles

- Calibration by stressing resources independently
  - Intelligent Plattform Management Interface
  - Android Calibration App



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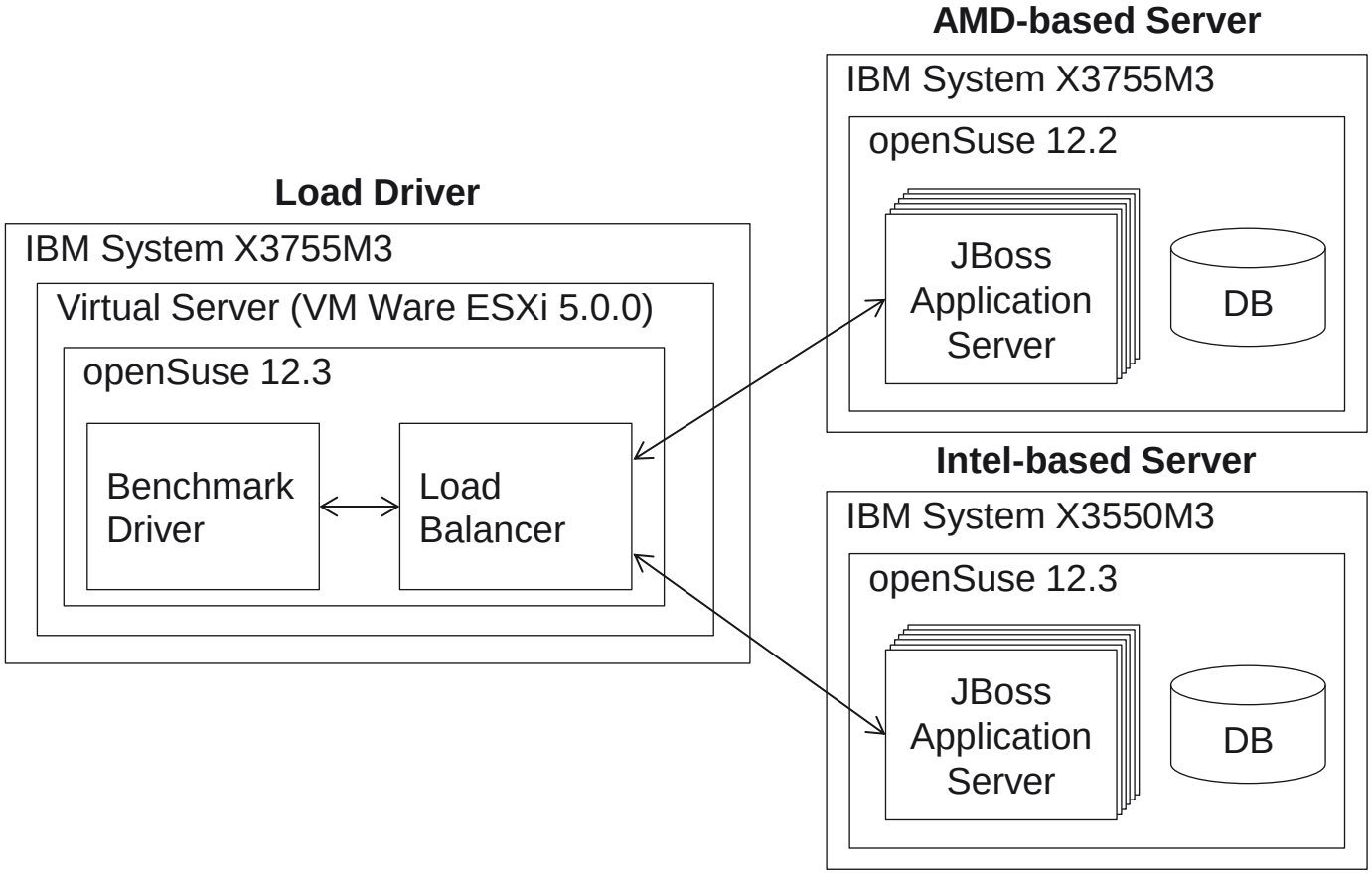
Evaluation

SPECjEnterprise 2010



System Under Test (Brunnert et al. 2014b)

Evaluation

SPECjEnterprise 2010

Measured and simulated results for the AMD-based server (Brunnert et al. 2014b)

Clients	MMPC[1]	SMPC[2]	PCPE[3]
1300	367.55 W	320.26 W	12.87 %
2300	403.87 W	352.22 W	12.79 %
3300	433.76 W	384.52 W	11.35 %
3500	436.47 W	390.95 W	10.43 %

Measured and simulated results for the Intel-based server (Brunnert et al. 2014b)

Clients	MMPC[1]	SMPC[2]	PCPE[3]
1300	197.05 W	175.94 W	10.71 %
2300	220.47 W	194.93 W	11.58 %
3300	241.67 W	213.91 W	11.49 %
4300	264.29 W	232.69 W	11.96 %

[1] Measured Mean Power Consumption
[2] Simulated Mean Power Consumption
[3] Power Consumption Prediction Error

Evaluation

Runtastic for Android

- Nexus 5
  running Android 4.4

- Galaxy Tab
  running Android 4.3

- Runtastic
  running on both devices
  30 mins run

Measured and simulated results for the mobile devices (Leimhofer 2014)

	Nexus 5	Galaxy Tab
MMPC[1]	0.883 W	1.251 W
SMPC[2]	0.732 W	1.084 W
PCPE[3]	17.12 %	13.35 %
BLPE[4]	0.67 %	1.01 %

[1] Measured Mean Power Consumption
[2] Simulated Mean Power Consumption
[3] Power Consumption Prediction Error
[4] Battery Level Prediction Error

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Conclusion

- Energy consumption can be predicted using the Palladio Component Model with an error of mostly below 13% for server systems and 17,2 % for mobile devices.

- Multi-Processor Environments for mobile hard to calibrate
- Extension for other device types (Windows, iOS, etc.)
- Additional resource types (e.g., accelerometer) are necessary for mobile device evaluations
- Power Consumption Model Repository for different devices from different vendors.
- Automatic Performance Model Generation for mobile devices.

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