FZI Research Center for
Information Technology

Co-Simulation of Hardware and Software in Palladio

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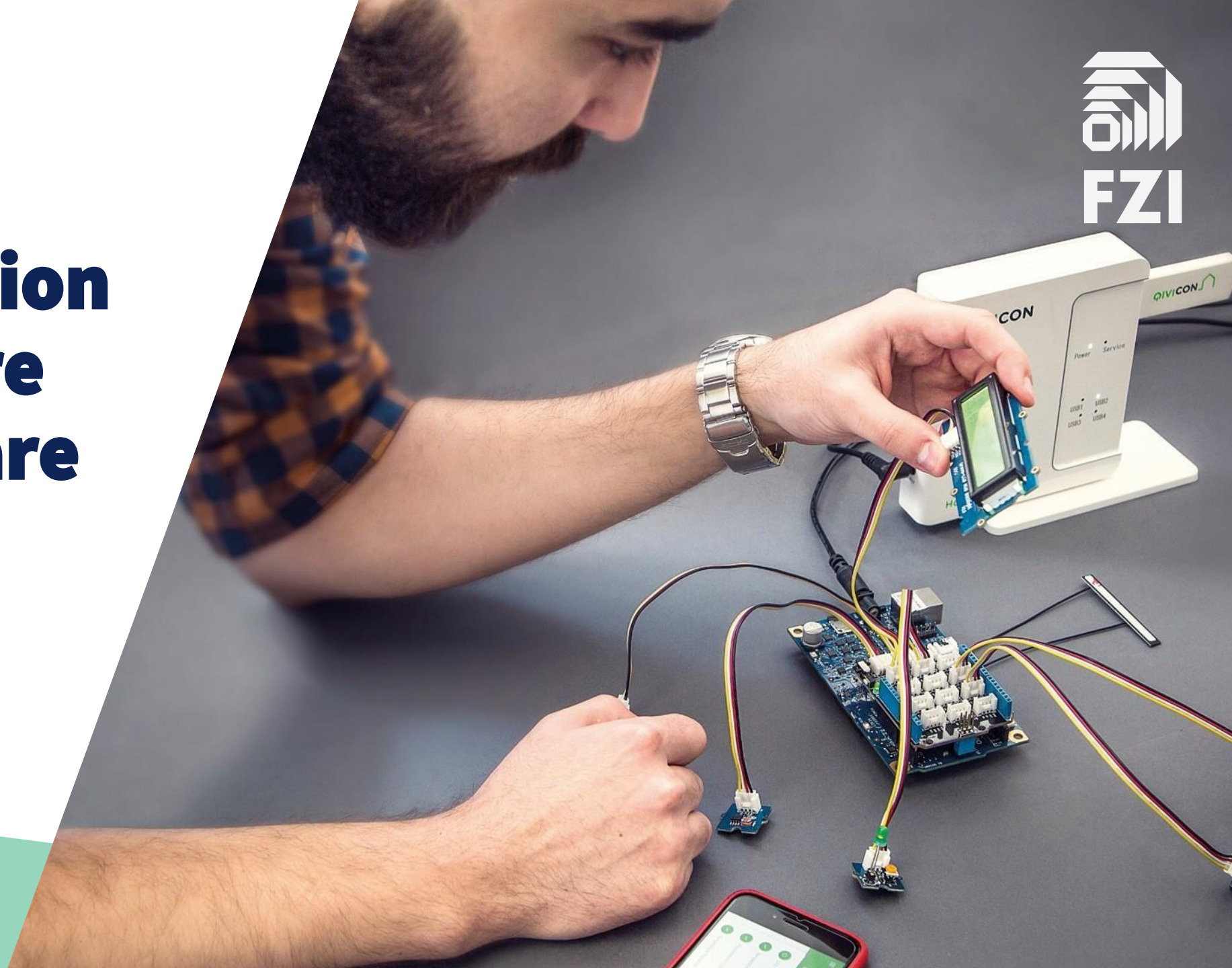
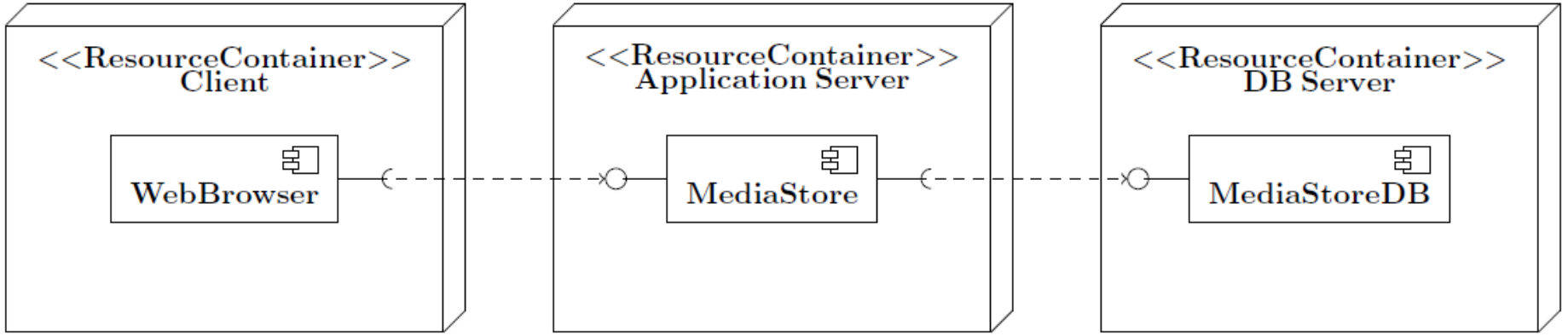
Ralf Reussner (KIT)



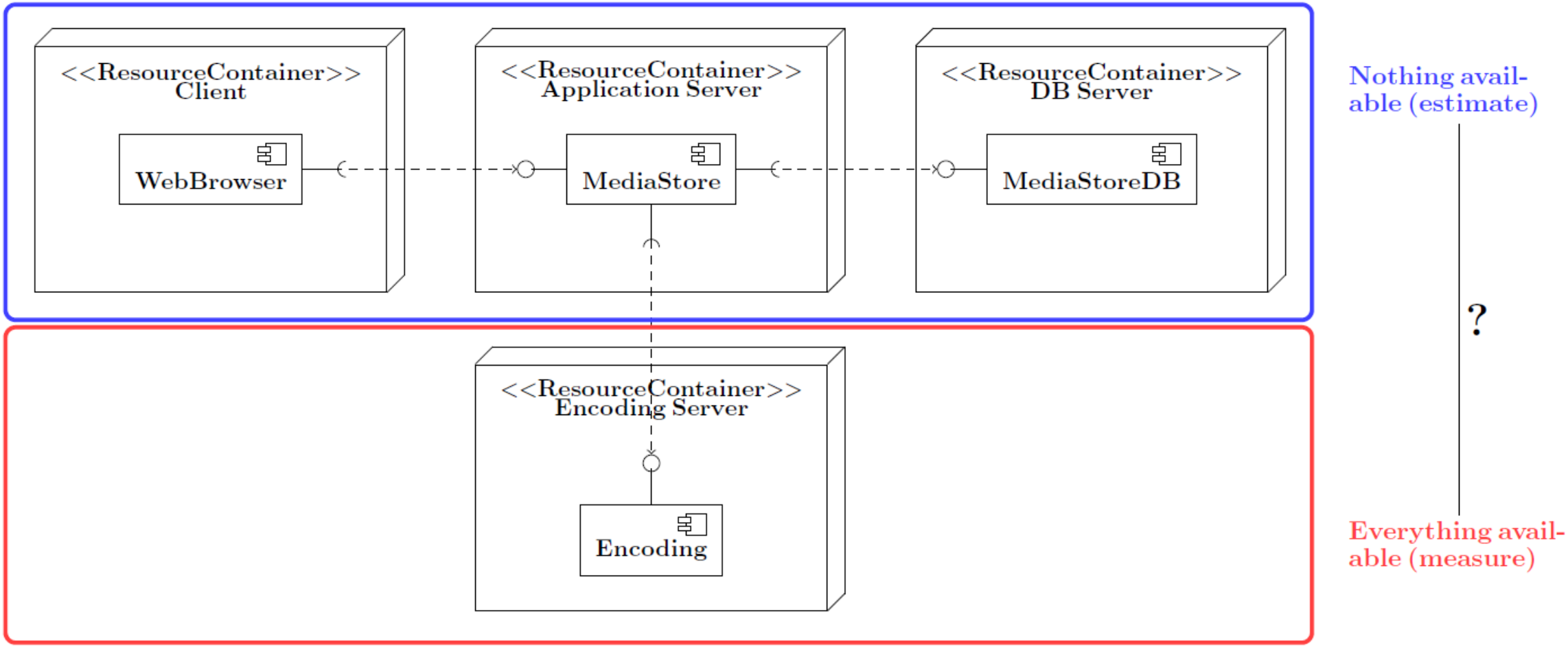
Motivation: How to parameterize a PCM?

Starting point: modeling system and estimating resource demands



Motivation: How to parameterize a PCM?

COTS: accurate measurements instead of estimations



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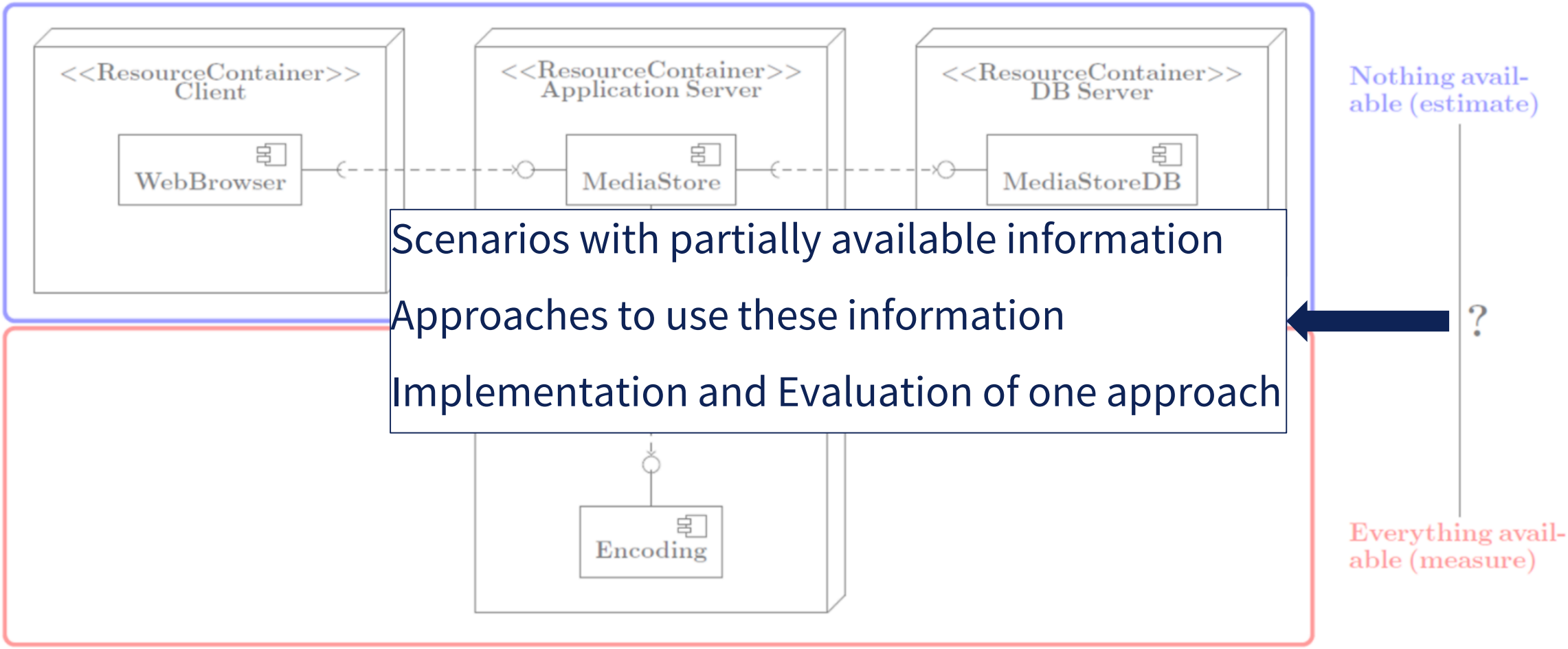

— Scenarios and Approaches

01

- Hardware
- Software

Hardware

Not (yet) available

- Hardware not available to conduct measurements
- Hardware specification already available

Demand Evaluation

- Use hardware simulation to evaluate demands
- Co-Simulation to embed hardware simulation based resource demand evaluation in Palladio

Hardware resource usage

- Hardware simulation as resource usage evaluation in Palladio
- Co-Simulation of hardware simulation and remaining Palladio (usage and software)

Partially proprietary

- Hardware cannot be modelled in Palladio due to its structure
- Hardware cannot be modelled in Palladio at all

Modelling capabilities

- Improve modelling capabilities (beyond CPU, HDD and network)
- Encoding or encryption hardware

Hardware-in-the-loop

- Co-simulation of Palladio and the proprietary part
- Synchronization and data exchange

Software

Not completely available

- Parts of the software are not available yet
- Measurement of the complete system not possible

Enhance prototype

- Prototype to simulate system
- Enhance with available software components
- Couples prototype and code

With adaptive algorithms

- Algorithm adapts to system state
- Disable tracing, decrease sampling rate, reducing calculation accuracy, dynamic load balancing

Extend demand evaluation

- System state parameters accessible to demand evaluation
- Modelling of dependencies to those parameters in resource demands

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Enhance prototype

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- Modelling of dependencies to those parameters in resource demands

Hardware simulation based resource demand evaluation

- ✓ Wide applicability
- ✓ Low usage overhead
- ✓ Model compatibility
- ✓ Feasible for master's theses

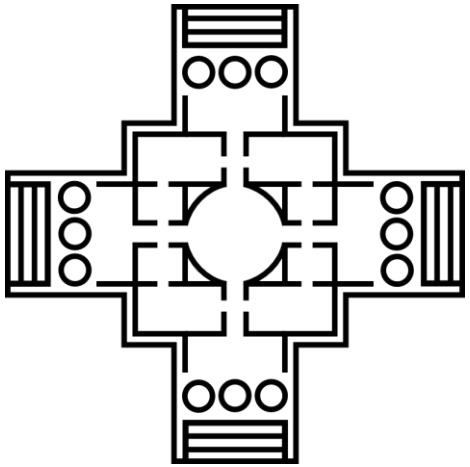
— Hardware simulation based resource demand estimation

02

- Tools and inputs
- Prototype
- Evaluation

Tools and inputs

Palladio	gem5
– Modelling and analysis of component based software systems – Performance and other quality attributes	– Hardware simulation for compiled software on ISA-level – Different ISAs and hardware configurations – Hardware statistics of the execution
– Components and system – Resource environment and deployment – Usage profile	– Compiled executable – Hardware description (processor, cache, memory) – Parameters

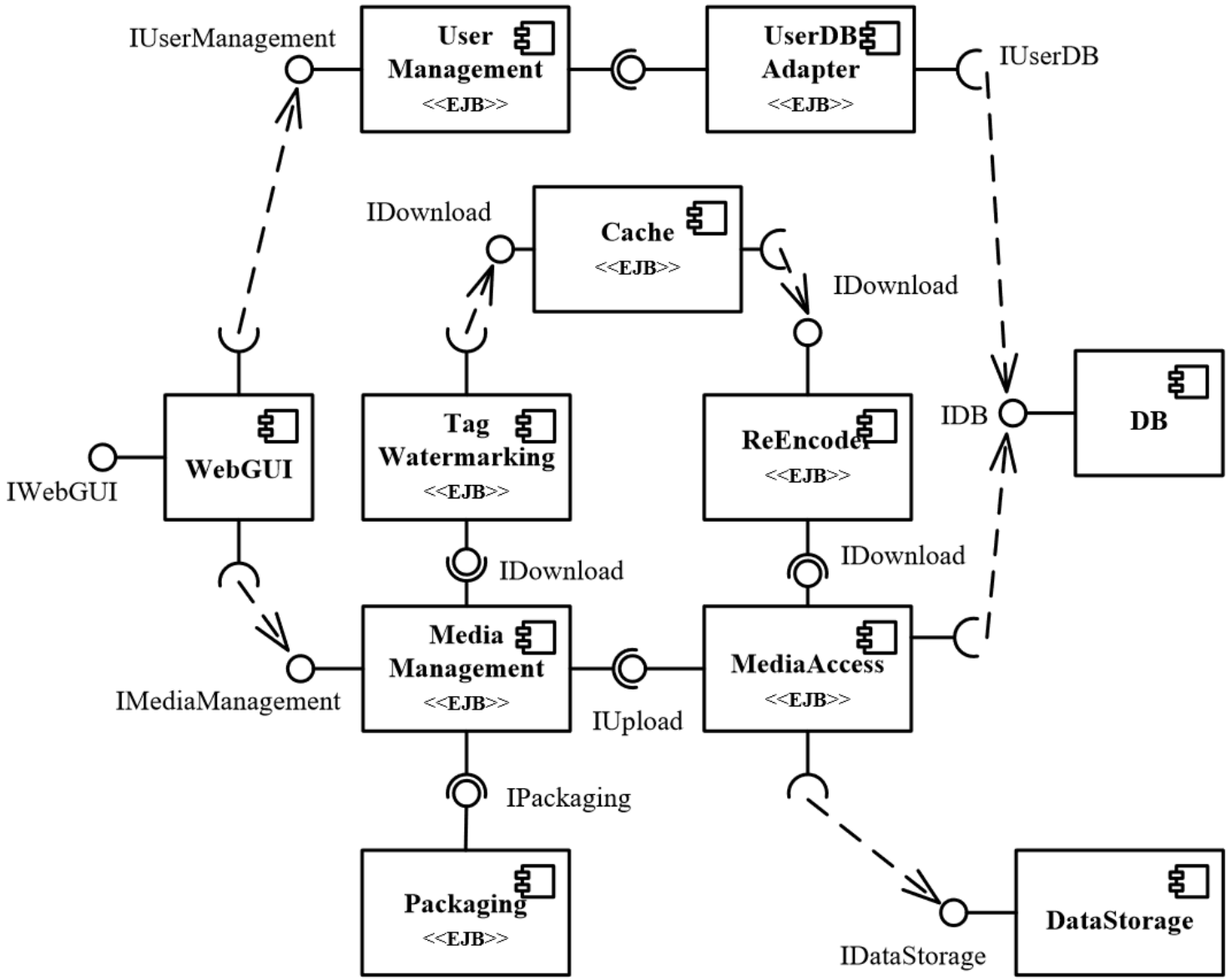


Tools and inputs

Palladio

- Modelling and analysis of component based software systems
- Performance and other quality attributes

- Components and system
- Resource environment and deployment
- Usage profile



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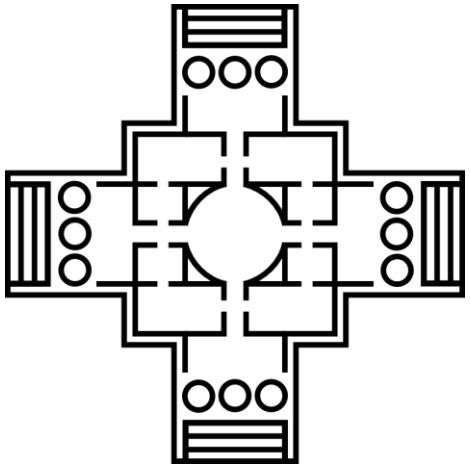

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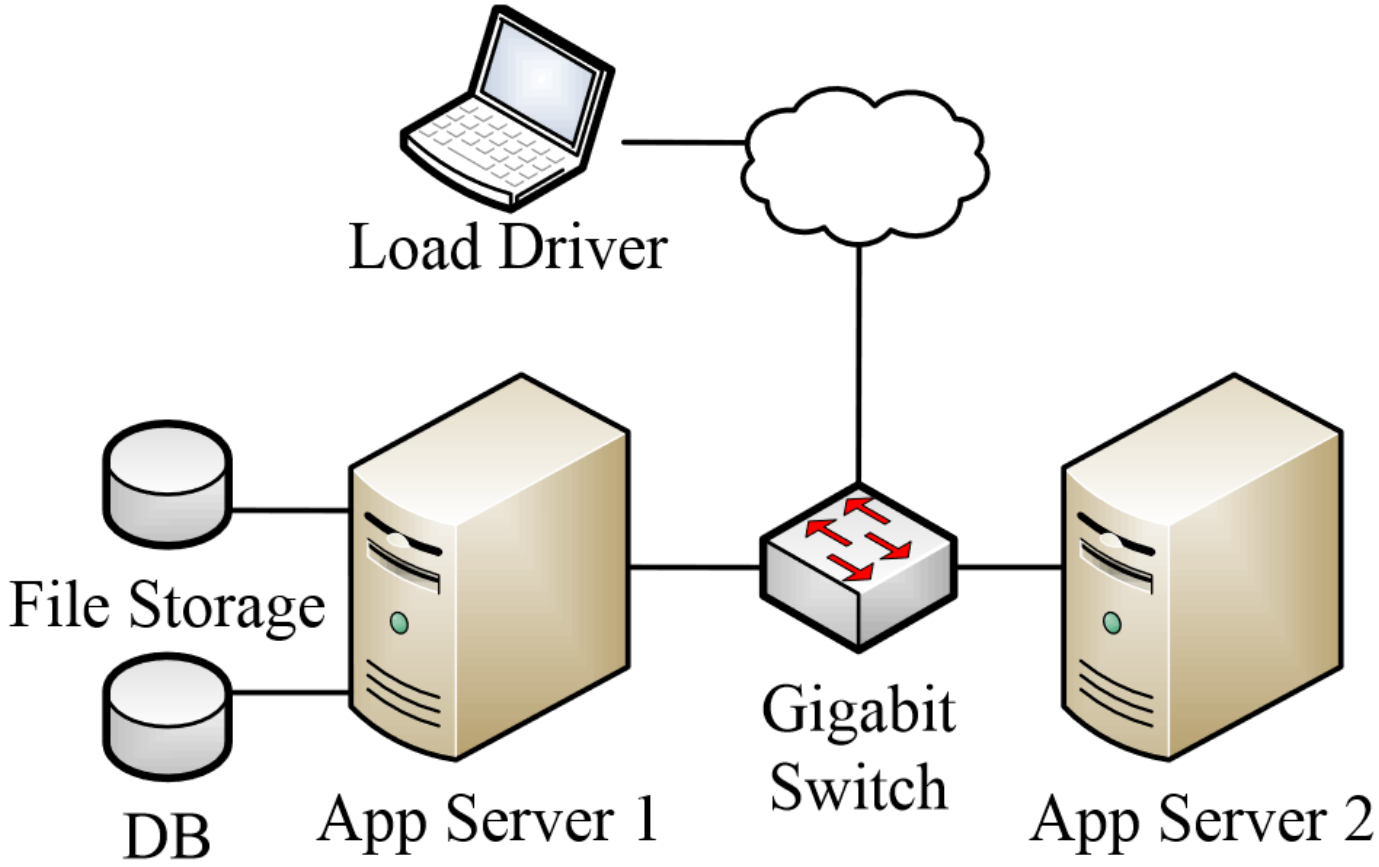

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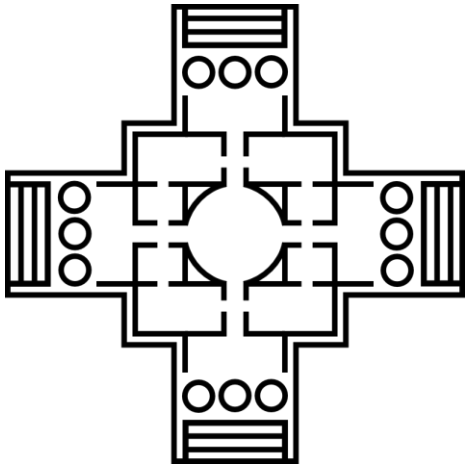

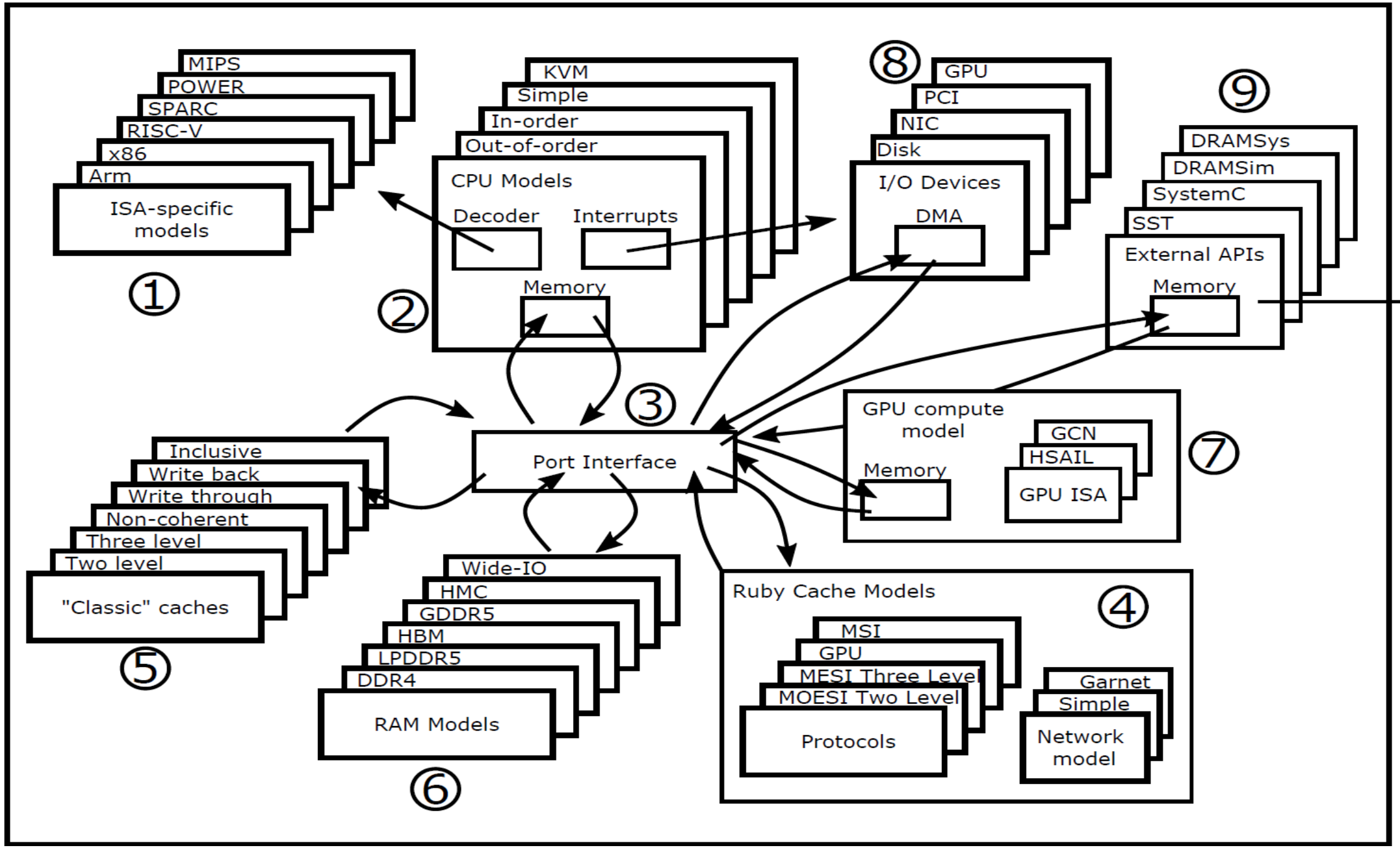
MIPS
POWER
SPARC
RISC-V
x86
Arm
ISA-specific models
①
KVM
Simple
In-order
Out-of-order
CPU Models
Decoder
Interrupts
Memory
②
⑧
GPU
PCI
NIC
Disk
I/O Devices
DMA
⑨
DRAMSys
DRAMSim
SystemC
SST
External APIs
Memory
③
Port Interface
GPU compute model
GCN
HSAIL
GPU ISA
Memory
⑦
Inclusive
Write back
Write through
Non-coherent
Three level
Two level
"Classic" caches
⑤
Wide-IO
HMC
GDDR5
HBM
LPDDR5
DDR4
RAM Models
⑥
Ruby Cache Models
④
MSI
GPU
MESI Three Level
MOESI Two Level
Protocols
Garnet
Simple
Network model

Tools and inputs

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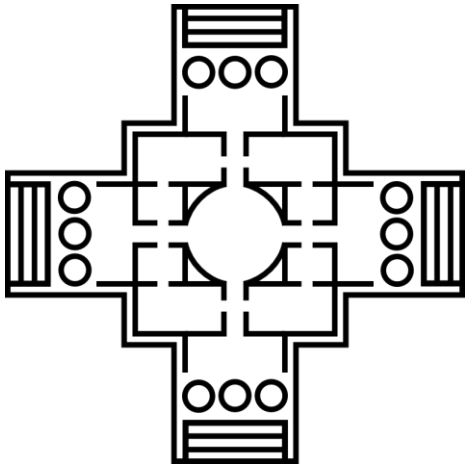

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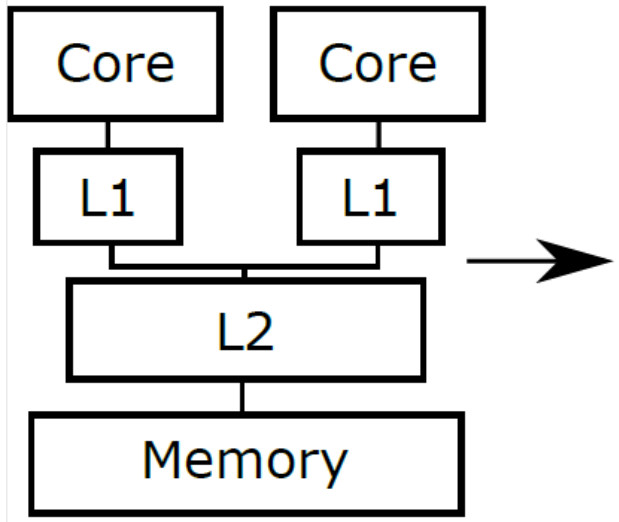



```
system = System()
system.cpu = OOO_CPU()
system.cpu.width = 8
system.l1 = Cache()
...
system.l1.mem_side = \
 system.l2.cpu_side
...
system.workload = \
 'hello.exe'
simulate()
```

```
> ./gem5 script.py
```

```
hello world!
```

```
l1.misses 2836
l1.hits   10374
cpu.ipc     1.3
```

- Components and system
- Resource environment and deployment
- Usage profile

- Compiled executable
- Hardware description (processor, cache, memory)
- Parameters

Prototype

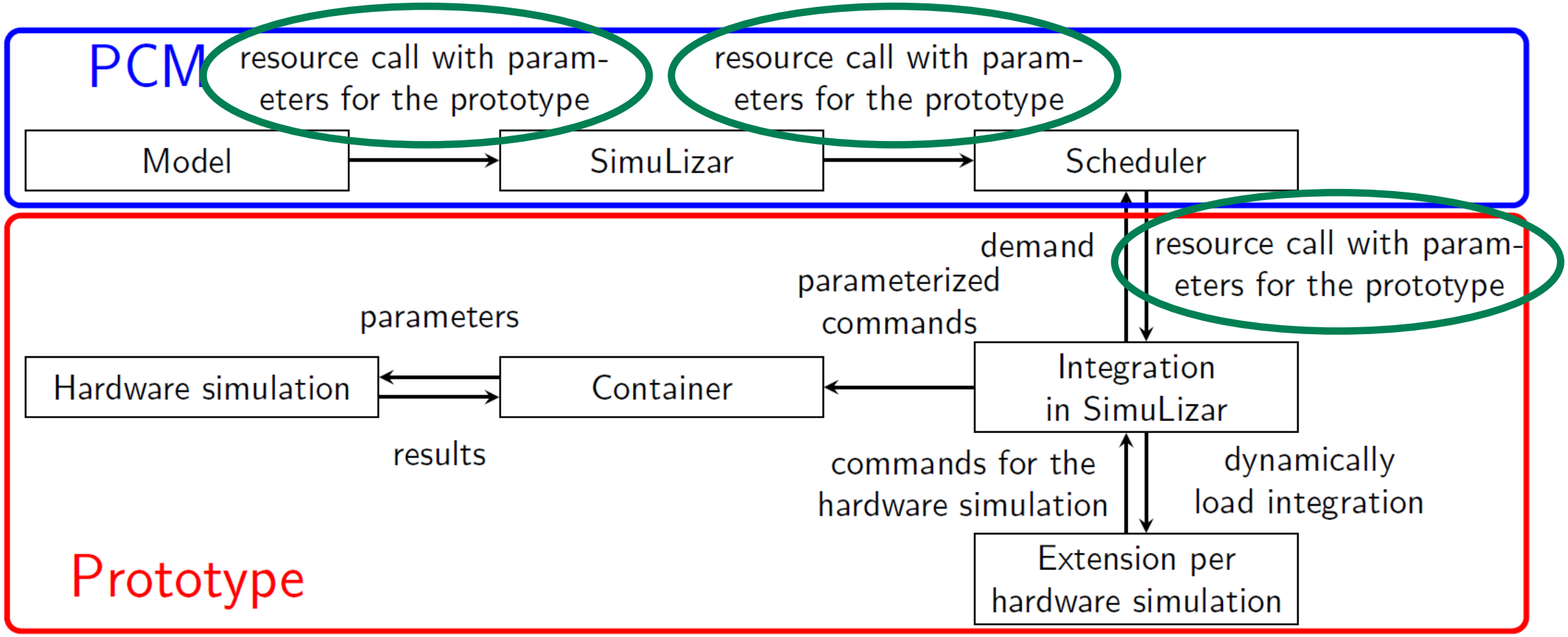
Idea

- Demand specification not as stochastic expression
- Demand evaluation with hardware simulation
- Caching for results

Requirements

- Extension point in Palladio
- Specification of additional parameters in Palladio models
- Communication and synchronization between Palladio and hardware simulation
- Caching requires deterministic hardware simulation

Prototype - Overview



Prototype - Parameters

Repository

- Path to executable
- Parameters for executable
- Method in the executable to calculate used cycles

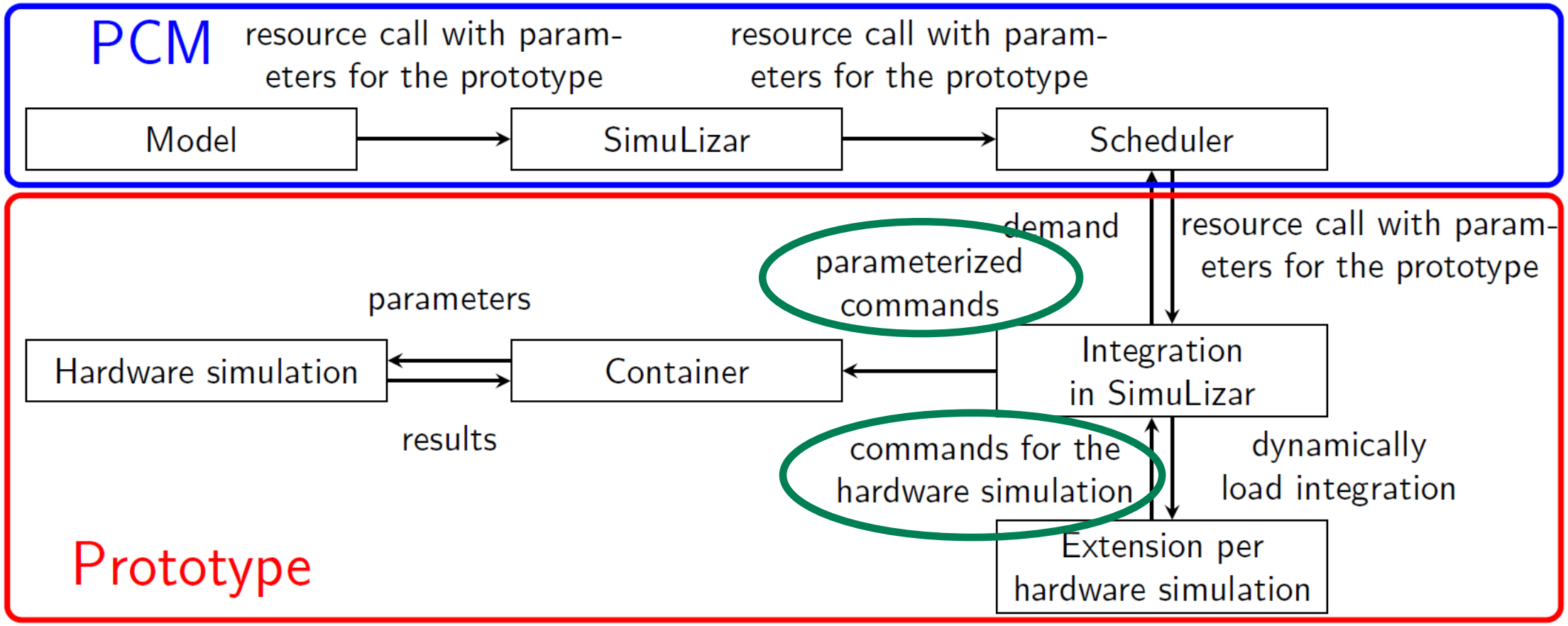
Parameter	Example value
executable	fibonacci.exe
parameter	30
method	main

Resource Environment

- Path to hardware description
- Identifier of the resource container in the PCM

Parameter	Example value
system	hardware.py
containerID	AppServerGem5

Prototype - Overview



Prototype - Communication

Commands

- Copy file
- Execute simulation
- Extract results and compute demand
- Specific for a hardware simulation and its wrapping

Extract results and compute demand

- Check first and last occurrence of method in function symbol trace
- Calculate resource demand in cycles

Execute simulation

- Pass the execution command through the wrapping to the hardware simulation
  - docker exec gem5
- Execute the simulation with the corresponding parameters
  - build/gem5/gem5.opt hardware.py fibonacci main 30

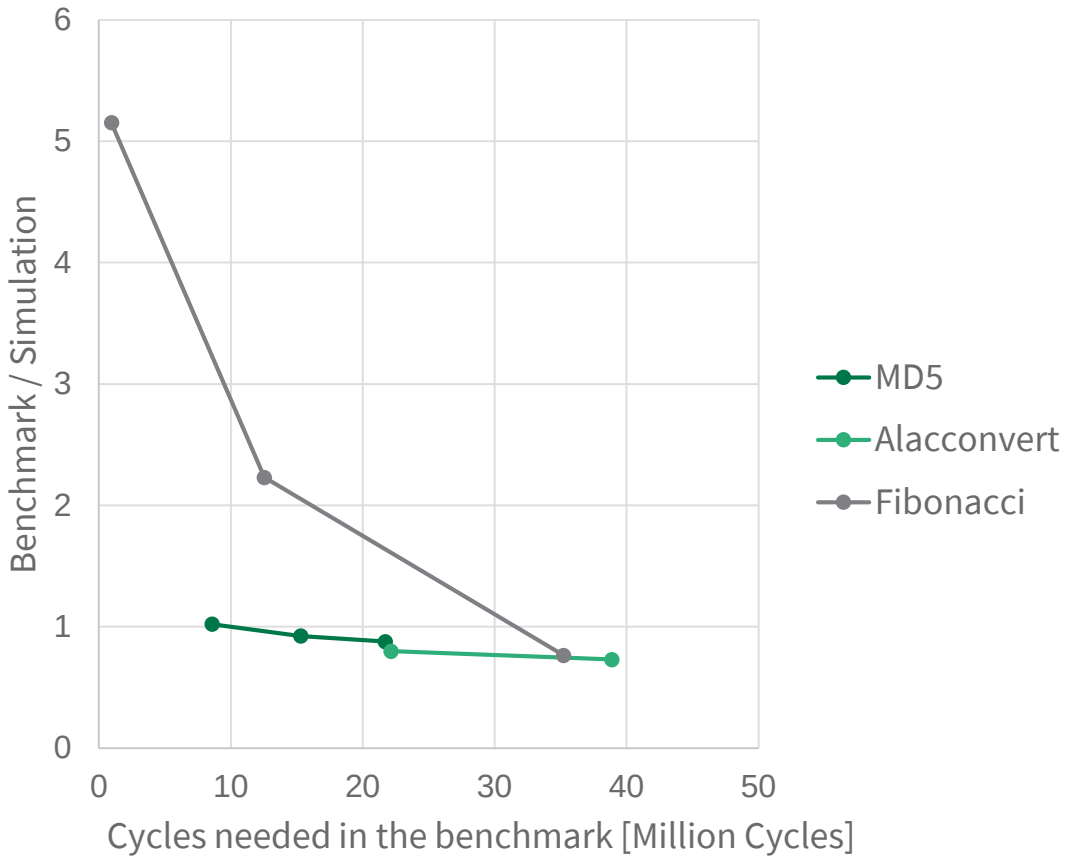
Parameter	Value
executable	fibonacci
parameter	30
method	main
system	hardware.py
containerID	AppServerGem5

Evaluation

- Three main goals
  - Accuracy of gem5
  - Performance of gem5
  - Performance of the prototype

Executable	Input
MD5-Hash	1/2/3 MB input files
Alacconvert [Convert from wav (Pulse Code Modulation) to alac (Apple Lossless Audio Codec)]	1/2 seconds white noise
Fibonacci [recursive algorithm]	10/20/30/35

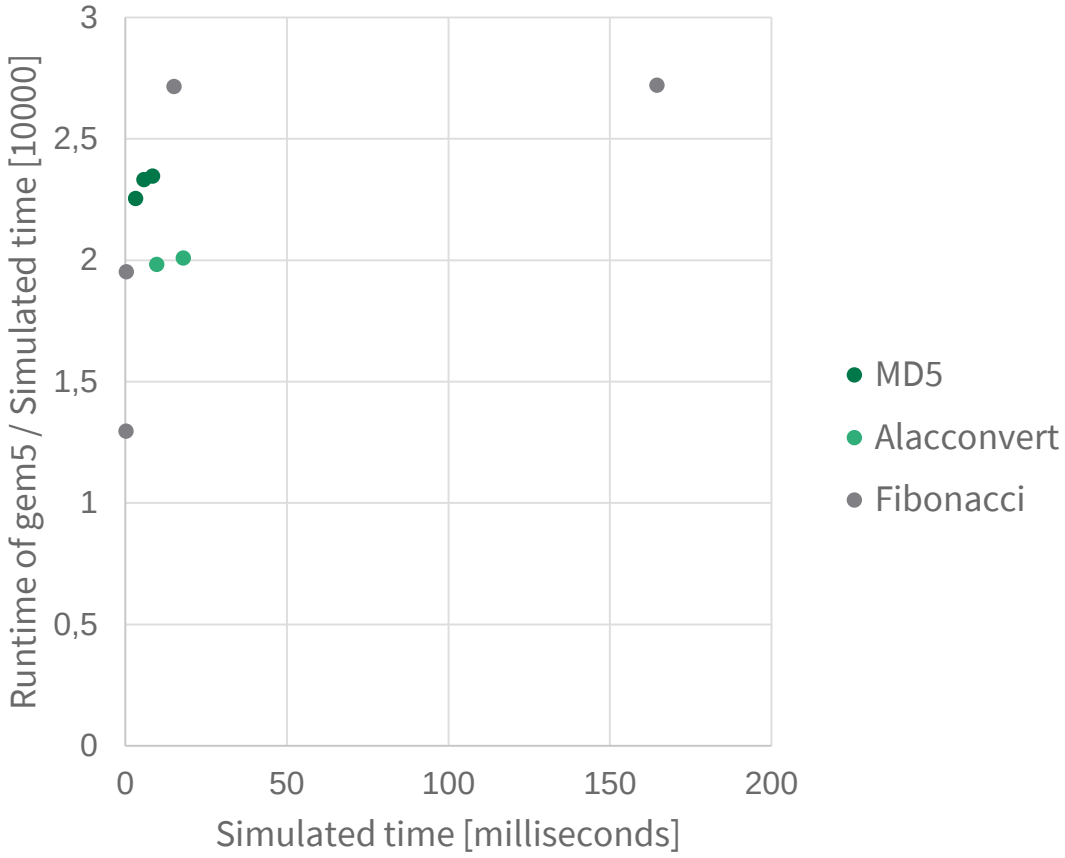
Evaluation - Accuracy of gem5



- Results
  - Ratio below 1 million cycles above 5
  - Ratio above 20 million cycles approximately 0.75
- Possible reasons
  - Startup overhead simulated not accurately due to syscall emulation
  - Parameterization based on ISA does not account for different processor types and families

Evaluation - Performance

of gem5



of the prototype

Hardware simulation			
MD5		Alacconvert	
PCM	Prototype	PCM	Prototype
3,18	454,58	3,32	557,51

Cache			
MD5		Alacconvert	
PCM	Prototype	PCM	Prototype
3,18	4,69	3,32	4,87

Conclusions

Scenarios and approaches

- Parameterization based on partially available information possible and helpful
- Future work: Explore the approach of using a hardware simulation as resource usage evaluation in Palladio

Prototype

- Accuracy vs runtime tradeoff
- Accuracy of gem5
  - Hardware specification not precise enough
  - Parameterization in gem5 code required
- Performance
  - Runtime of simulation high
  - Parameter space discrete and small
- Future work: better parameterization, other hardware simulations

Thank You

For Your Attention

Sources

Images

- Palladio logo (8-15): Palladio GitHub repository avatar, https://avatars.githubusercontent.com/u/19326271?s=200&v=4
- gem5 logo (8-15): https://en.wikipedia.org/wiki/File:Gem5_Logo,_Veritcal_Color_Version.png
- System and Resource Environment (7): Strittmatter, Misha, and Amine Kechaou. *The Media Store 3 Case Study System*. KIT, 2016.
- gem5 big picture and usage (7): Binkert, Nathan, et al. "The gem5 simulator." *ACM SIGARCH computer architecture news* 39.2 (2011): 1-7.