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Predicting Scaling Efficiency of Distributed Stream Processing Systems via Task Level Performance Simulation

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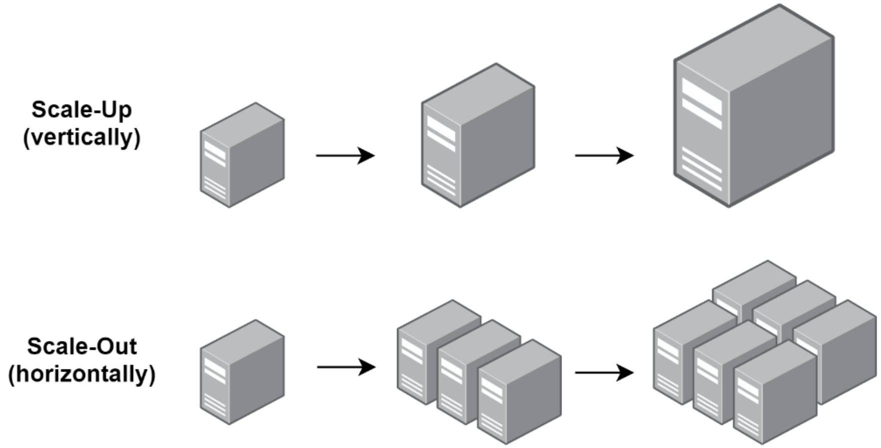
Motivation

- Distributed stream processing systems are the backbone of many Big Data implementations and can reach a considerable size in terms of cores / workers
- **CPU efficiency** becomes **increasingly important** from both, an environmental as well as a cost perspective
- Most streaming systems allow for **flexibility regarding their scaling direction**
- Most DevOps do not know what scaling actually means in terms of CPU efficiency?



Example – Azure Hosting

Which Architecture would you **choose as a manager**?

- 2x Instance “A4 v2” (4 cores, 8GB RAM, 0.286$/h)

417.56 $ per month

Scale-Out

- 1x Instance “A8 v2” (8 cores, 16GB RAM, 0.600 $/h)

438.00 $ per month

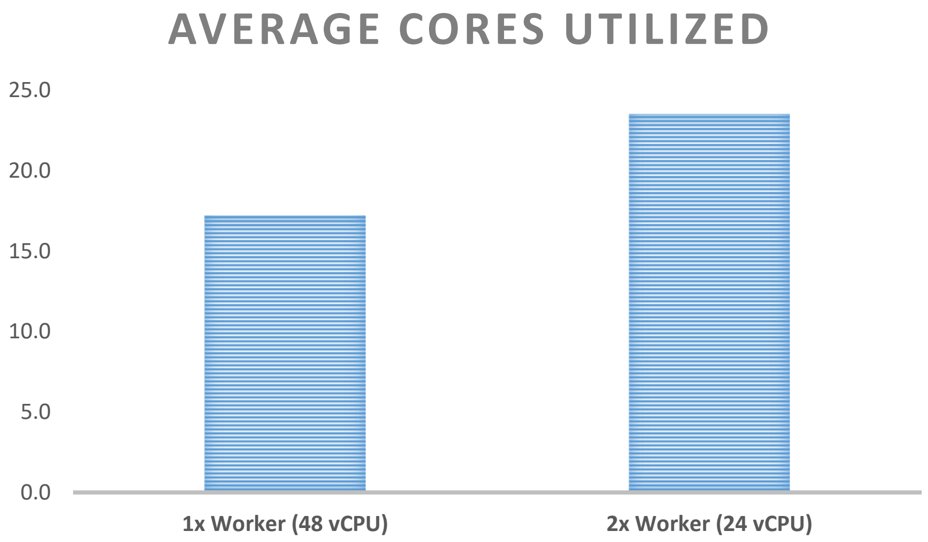
Scale-Up

➢ **Scale-Out architecture 4.66% cheaper**

Example – CPU Efficiency

Which Architecture would you **choose as a manager**?

- Example: Yahoo Streaming Benchmark with Apache Flink
- Workload: 600k events/s



➢ **Scale-Up architecture 26.79% more efficient**

Paper Topic

Question: How efficient are 3, 4, 5 ... N workers?

Performing and comparing N measurments is not efficient

Idea: Performance Simulation of different cluster sizes (with PCM)

Assumption: We have a fixed number of cores and want to simulate how many workers we should distribute them to (e.g. 2x C6 or 1x C12)

PCM Design Requirement: Accurate approach that is quick&simple to implement

- No automation is in place that allows an easy PCM generation!
- One manually created PCM model that allows to predict different cluster sizes, without changing the model
  - No changes in the ResourceEnvironment, Allocation or System Model
  - Cluster size is specified as an input parameter of the Usage model
- Despite the quick&simple approach, the results should provide sufficient accuracy

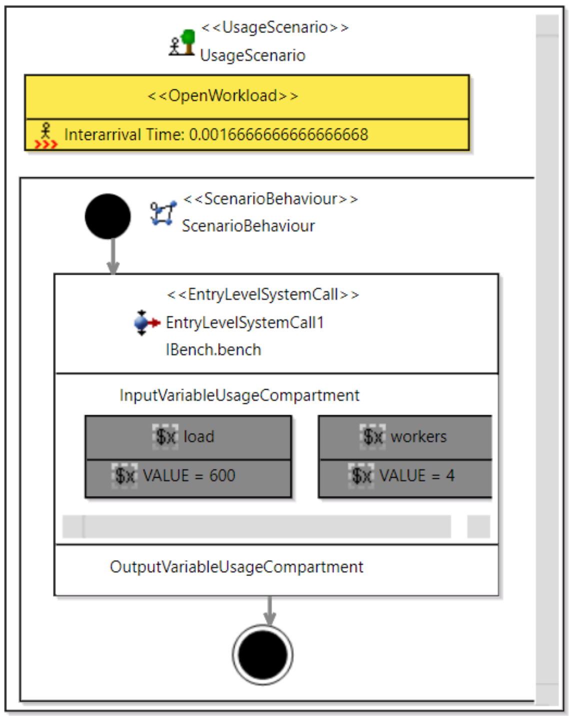
PCM Design Requirement

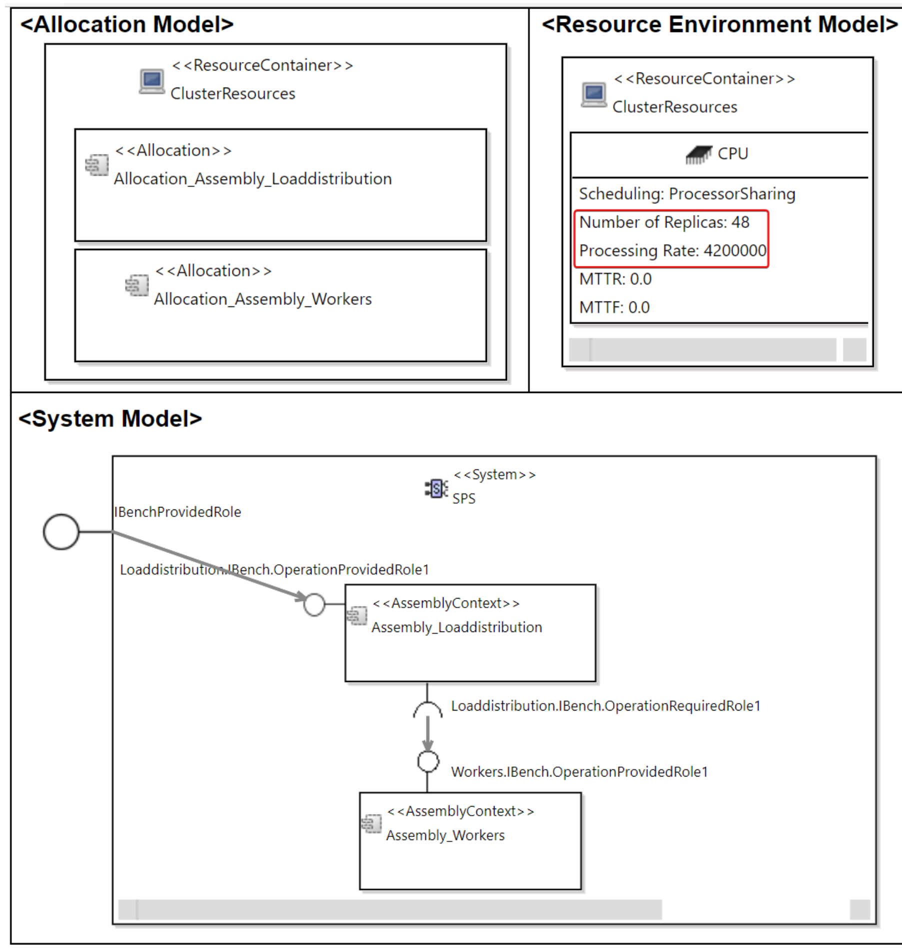
quick&simple

12x IBM Power9 CPU cores (4.2 GHz)
Simultaneous Multithreading 4 (SMT4)) 48 vCPU

Simulation Example:

- Workload = 600k events/s
- Workers = 4 (each 12vCPU)

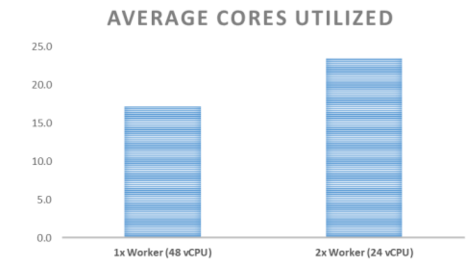




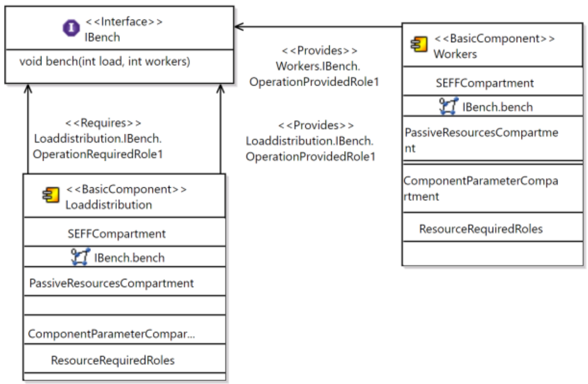
Dynamic Resource Demands

quick&simple

- We know that the Resource Demands change in dependence of the number of workers

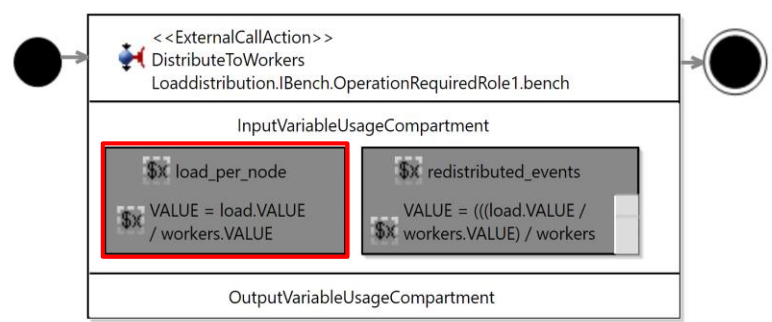


- Usually we would need to model each cluster configuration as a separate combination **Allocation+ResourceEnv+System Model**



➢ Instead we model the Resource Demand in dependence of the received events (the more events a node receives the more efficient it works)

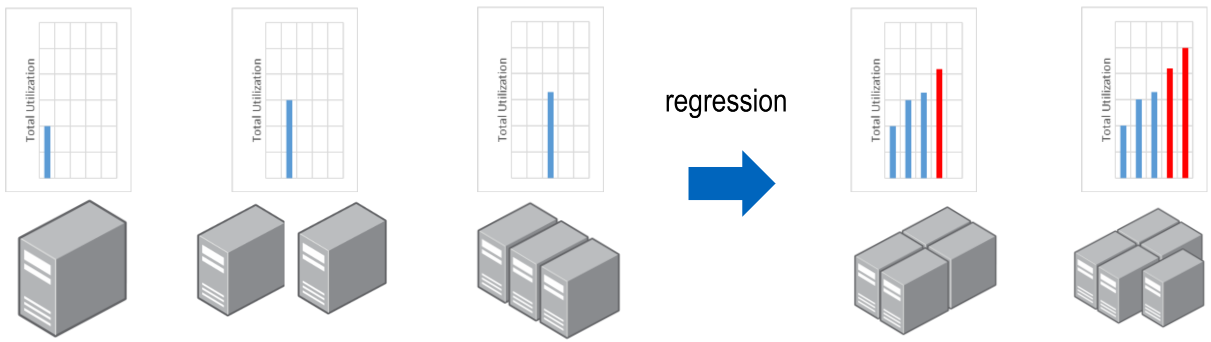
9.1259 * load_per_node.
VALUE + 326.7 <CP ...



➢ Therefore, we need a virtual load balancer that divides the total load through the number of workers accurate

Task-Level Performance Modelling

- The probably simplest approach would be to measure the total CPU utilization for a few cluster configurations and to perform a regression analysis

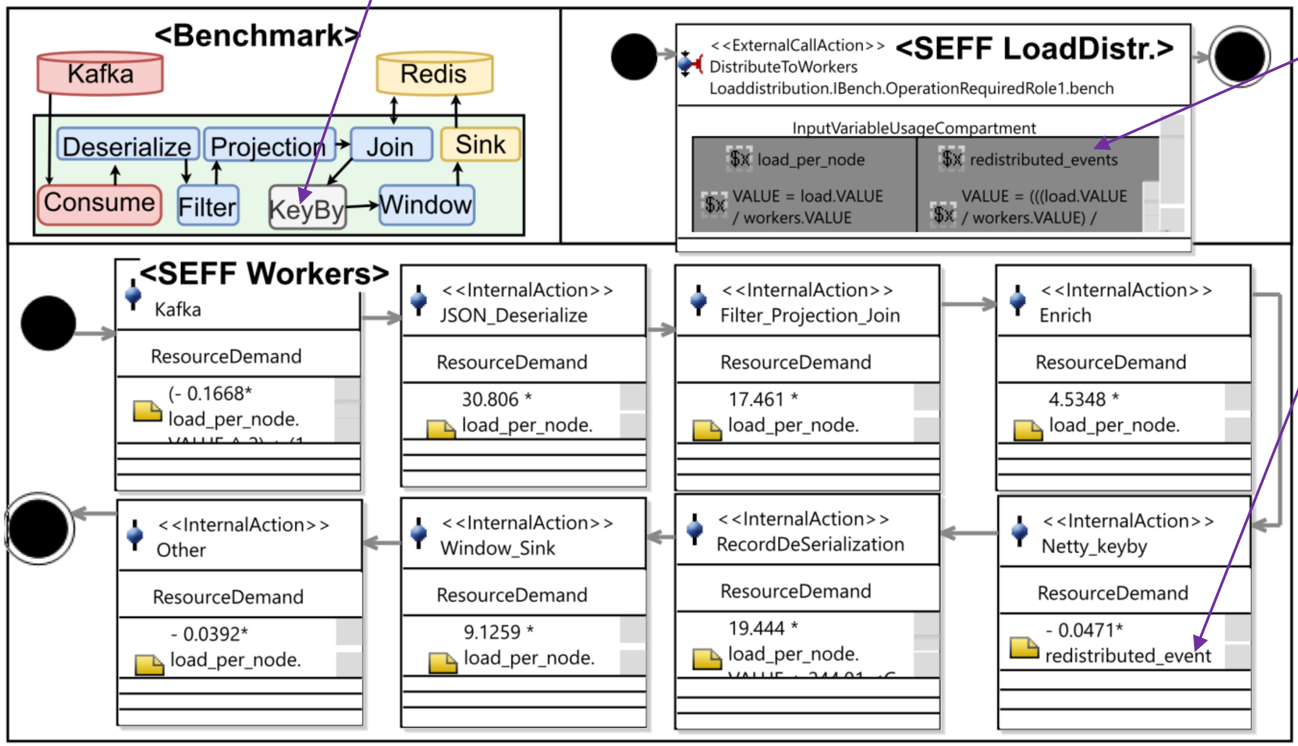


- However, looking only at the total utilization is not accurate enough (abstraction level too high)
  – Each streaming task has its own efficiency curve that can either grow linear, logarithmic, polynomial or exponential to the workload.
  – The PCM Resource Effect Specification will model each task as an internal action with its own ResourceDemand

Task-level Performance Modelling

how many events do we send AND receive during re-distribution?

Each worker **sends** `(load_per_node/workers)*(workers-1)` events to other workers
and **receives** `(load_per_node/worker)*(worker´-1)` from the other workers

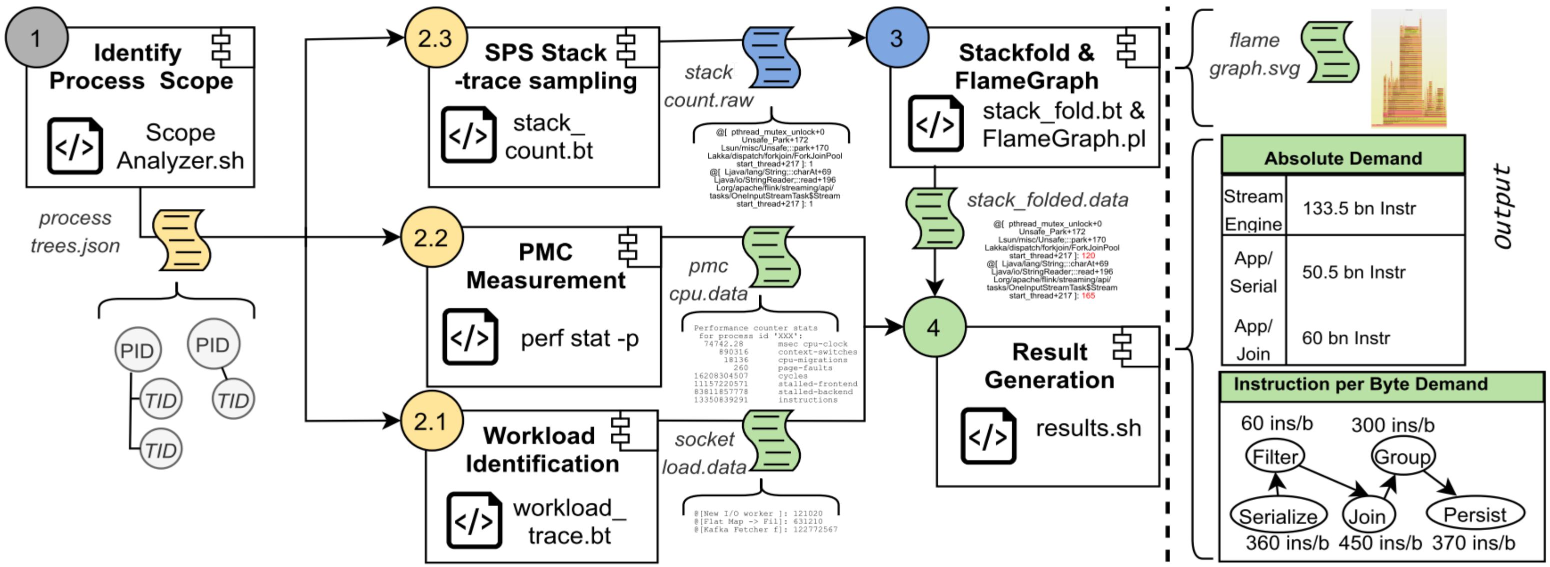


- How to get the parametrization in dependence of the workers / load?

Task-level Measurment

accurate

Our toolchain proposed in (Rank, et al. 2020) profiles applications with BPF and combines the results with PMU measurments[1]



➢ This way we get the consumed CPU cycles for each streaming task

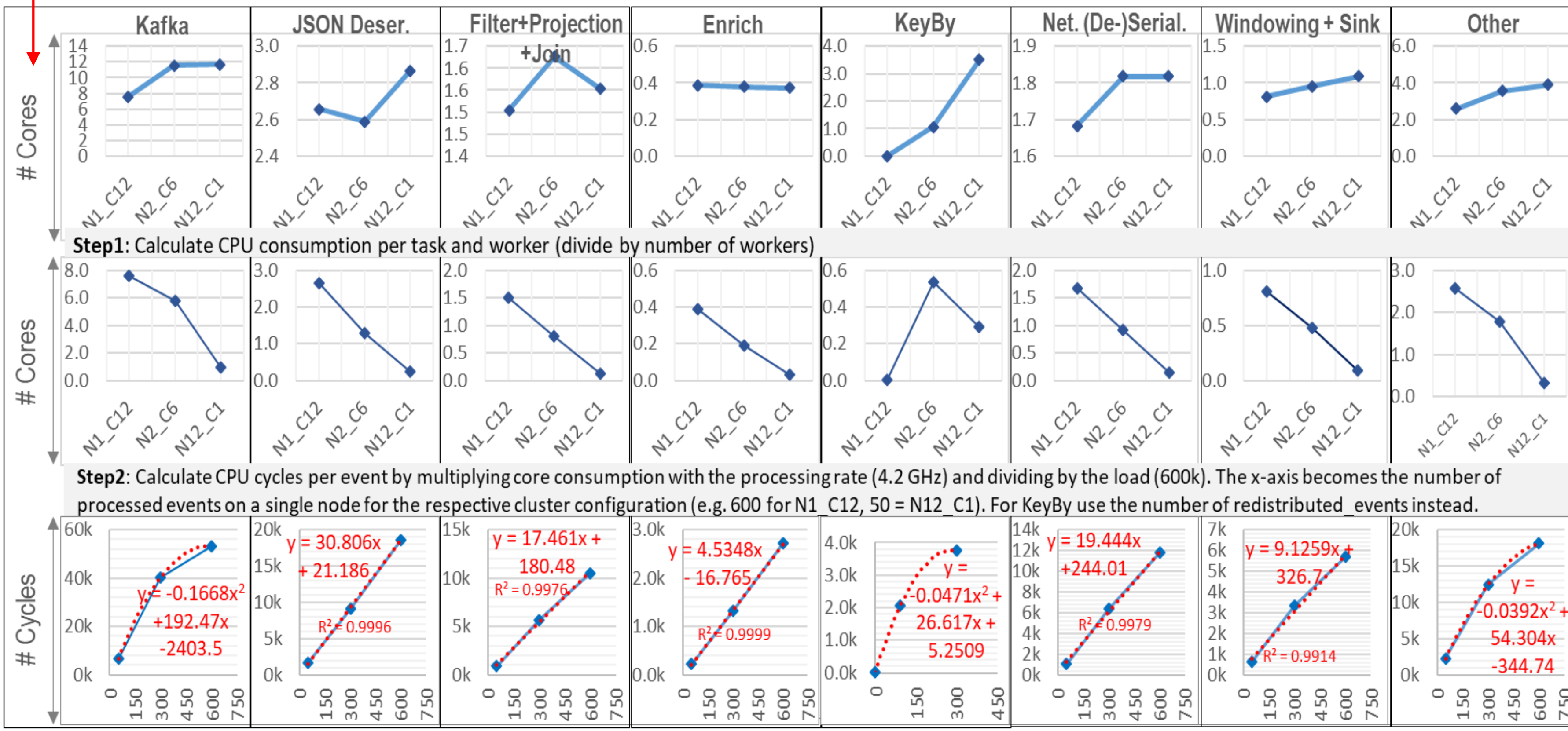
[1] Rank, J., et al. (2020). "A Dynamic Resource Demand Analysis Approach for Stream Processing Systems." Softwaretechnik-Trends **40(3): 40-42.**

accurate

Task-level Parametrization Approach

- Our approach requires to measure three cluster configurations
  - lowest (1 worker), highest (12 workers) and one in between (we chose)
  - N=workers, C=phys_cores_per_worker -> N1_C12, N2_C6 and N12_C1

vCPU



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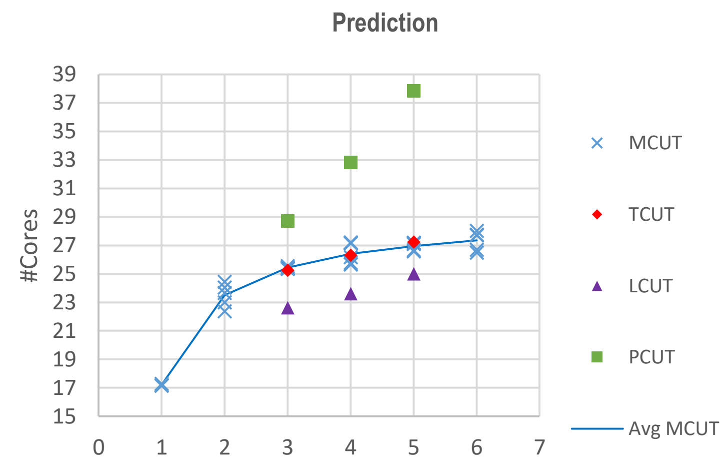
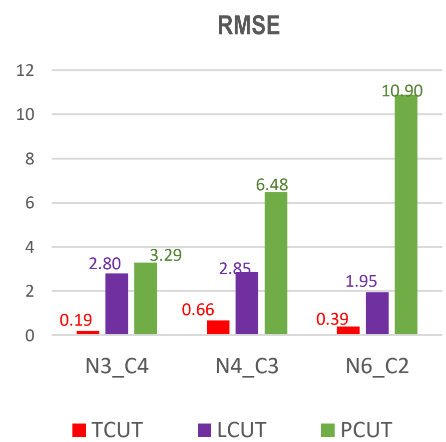
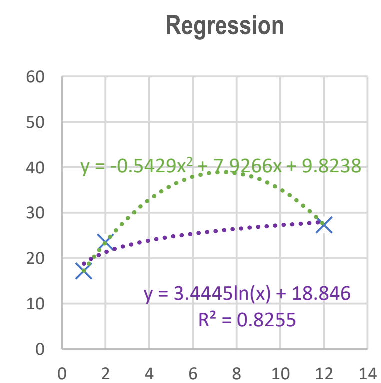
Experiment

- "quick&simple"
  - ✓ PCM Model
  - ✓ Required model changes to simulate different cluster sizes
  - ✓ 3x Measurements for parametrization
  - ○ Profiling approach (fully automated)



- "accurate"
  - Does the task-level prediction perform better?
  - **Baseline**: More accurate than a simple regression approach (that only looks at the total CPU consumption) based on the same number of measurments
  - Predict N3, N4, N5





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Conclusion and Limitation

- Fast and easy PCM based prediction approach
- Achieves highly accurate results
- Can be applied to running systems (no instrumentation) required

- For the experiment we assumed a constant load (600k events/s). We did not test how accurate the prediction works for different load levels
- We only scaled our cluster from 1 to 12 worker nodes. We did not test how accurate the prediction works for even bigger cluster sizes

Thank you for your attention!

Questions?

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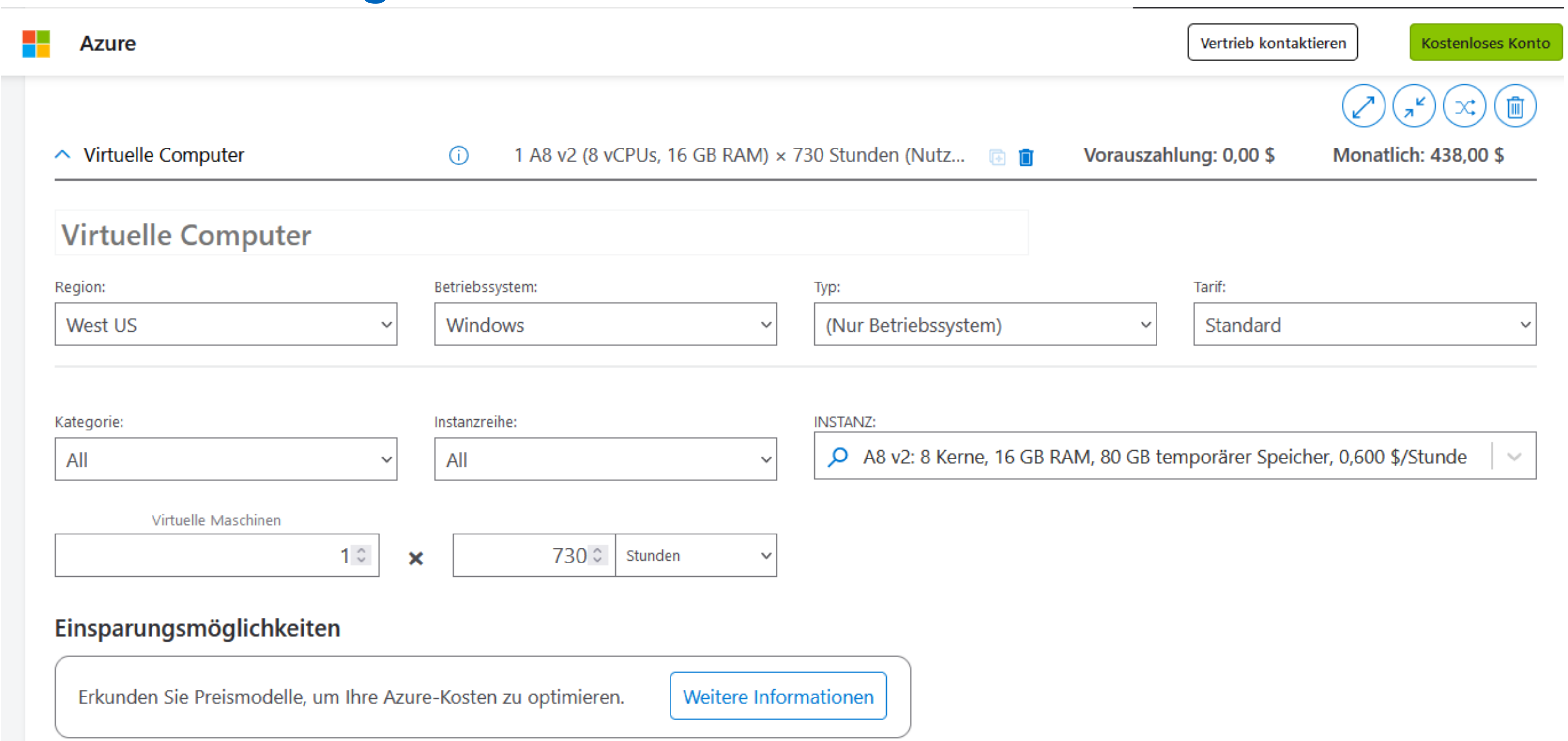
Azure Hosting



https://azure.microsoft.com/de-de/pricing/calculator/

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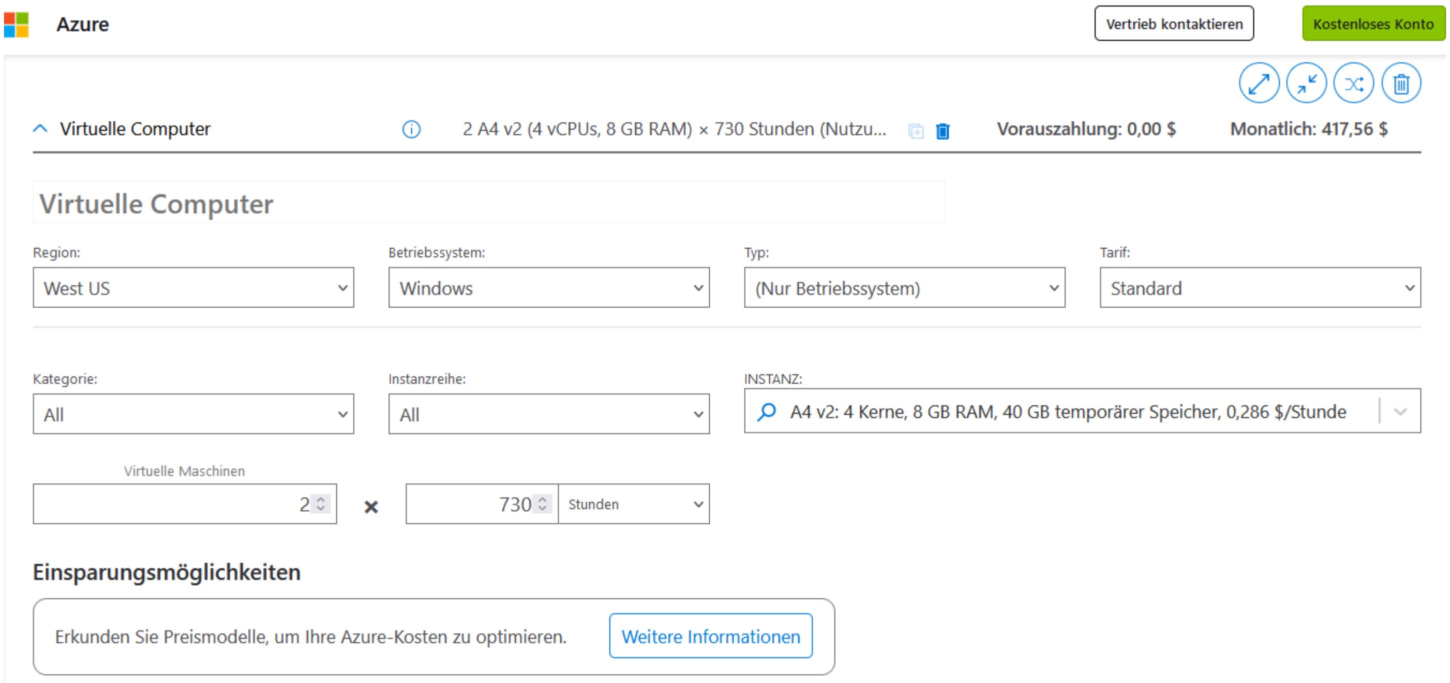
Azure Hosting



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