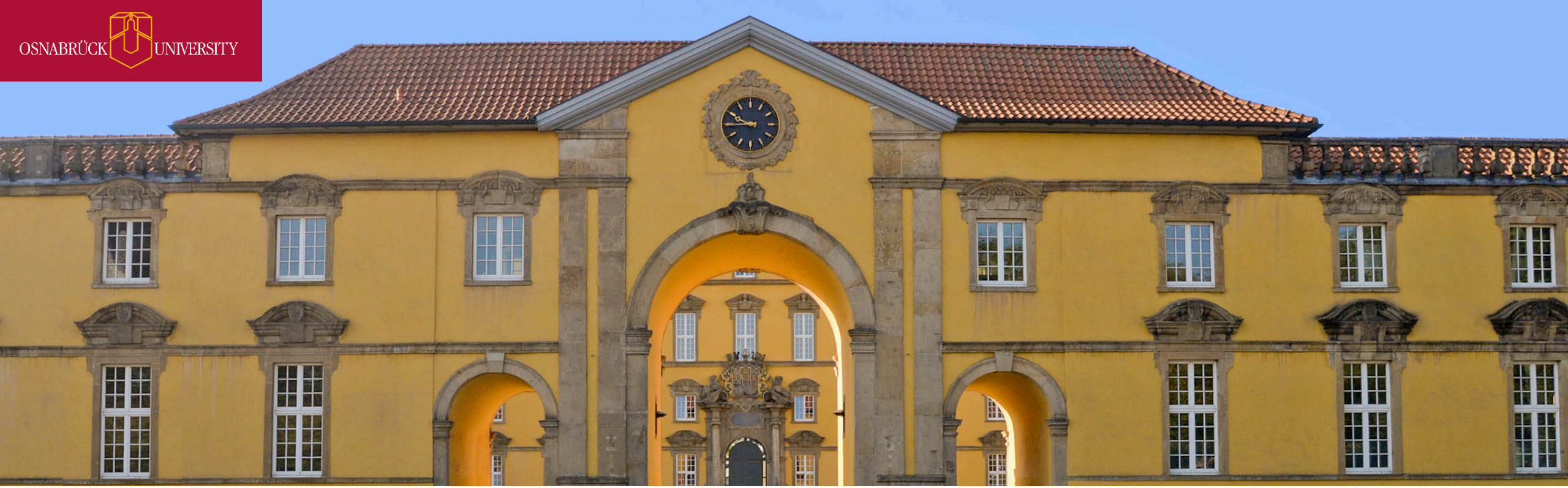
OSNABRÜCK UNIVERSITY

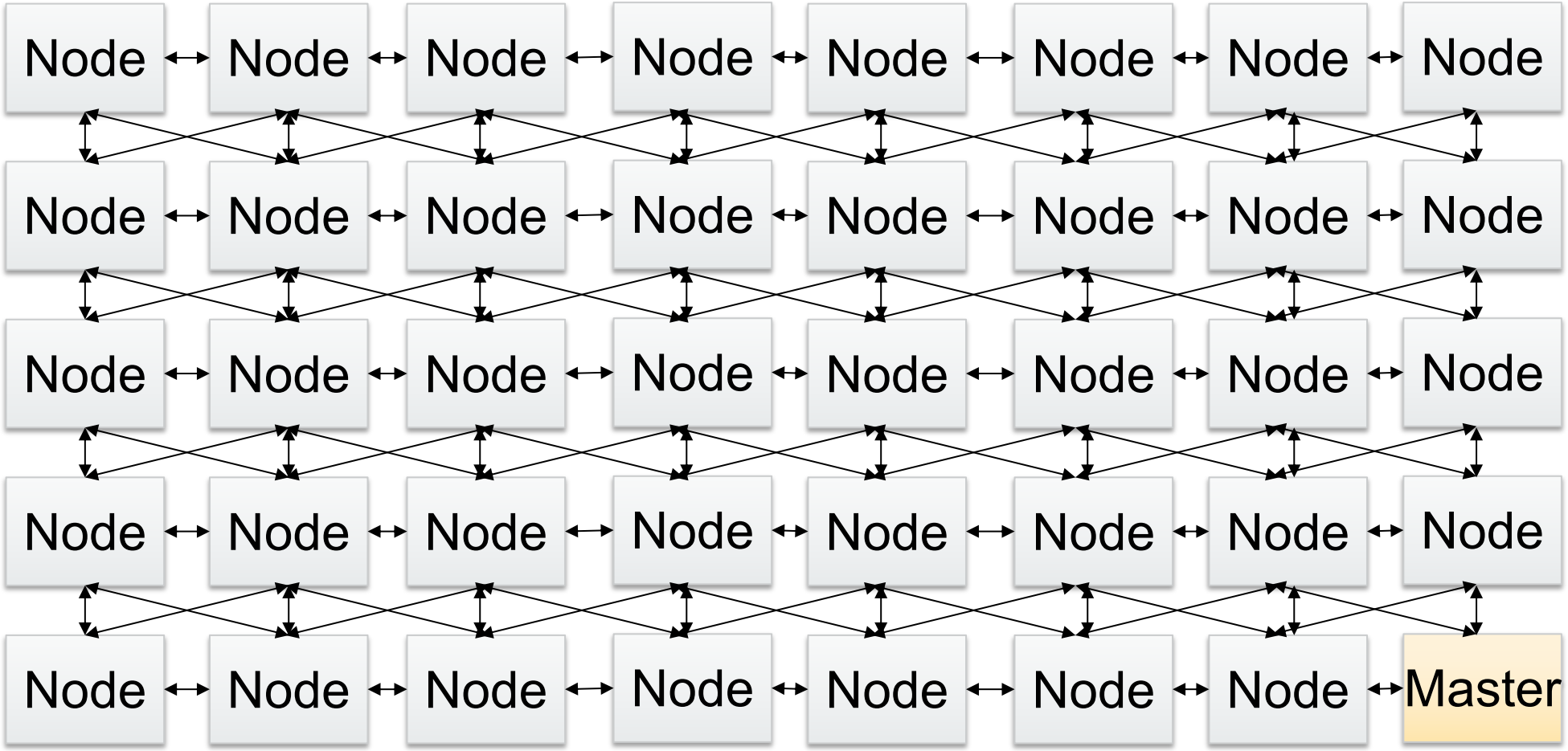


Managing Resources in the Data Center with the MxKernel

Bamberg, Sep 28, 2023

Michael Müller (michael.mueller@uos.de)

Today's Data Center



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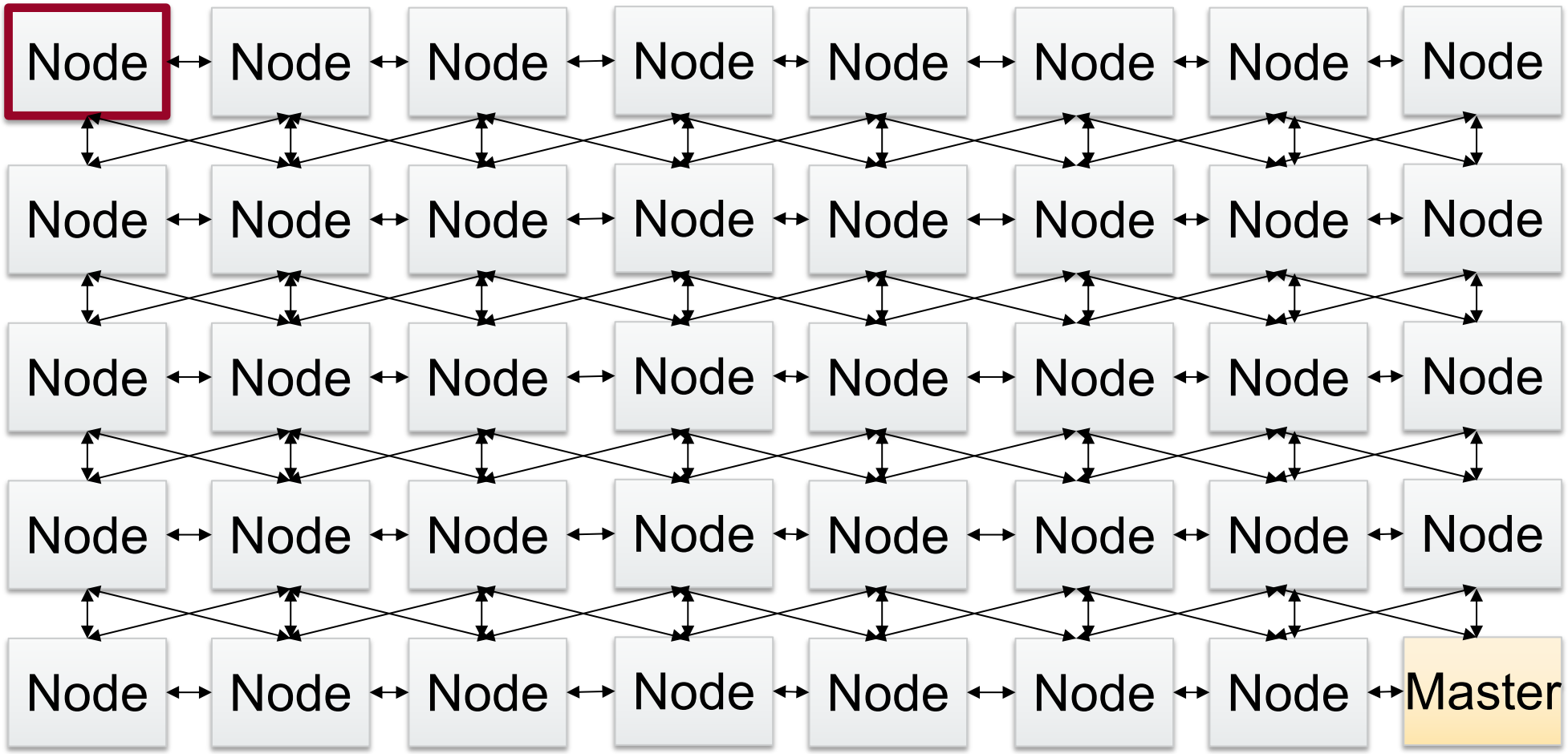
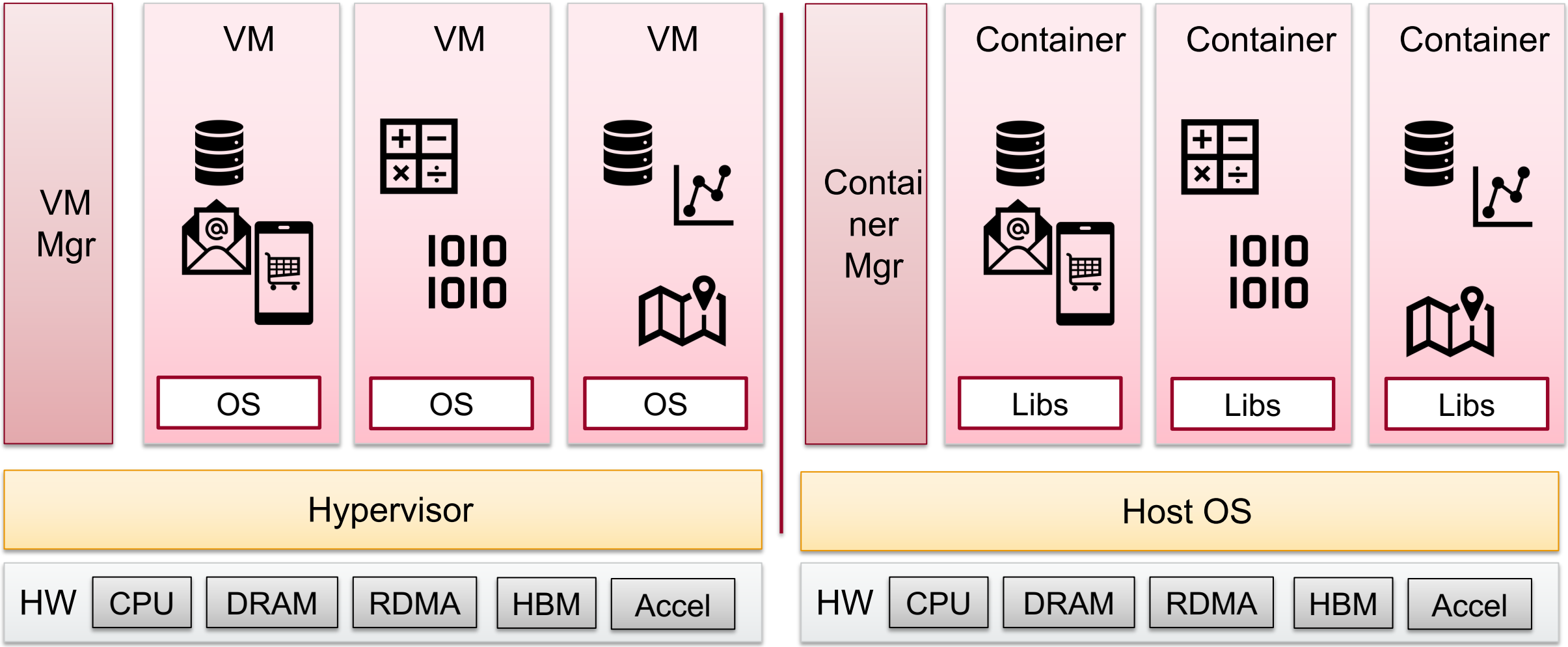


Today's Data Center Software Stack



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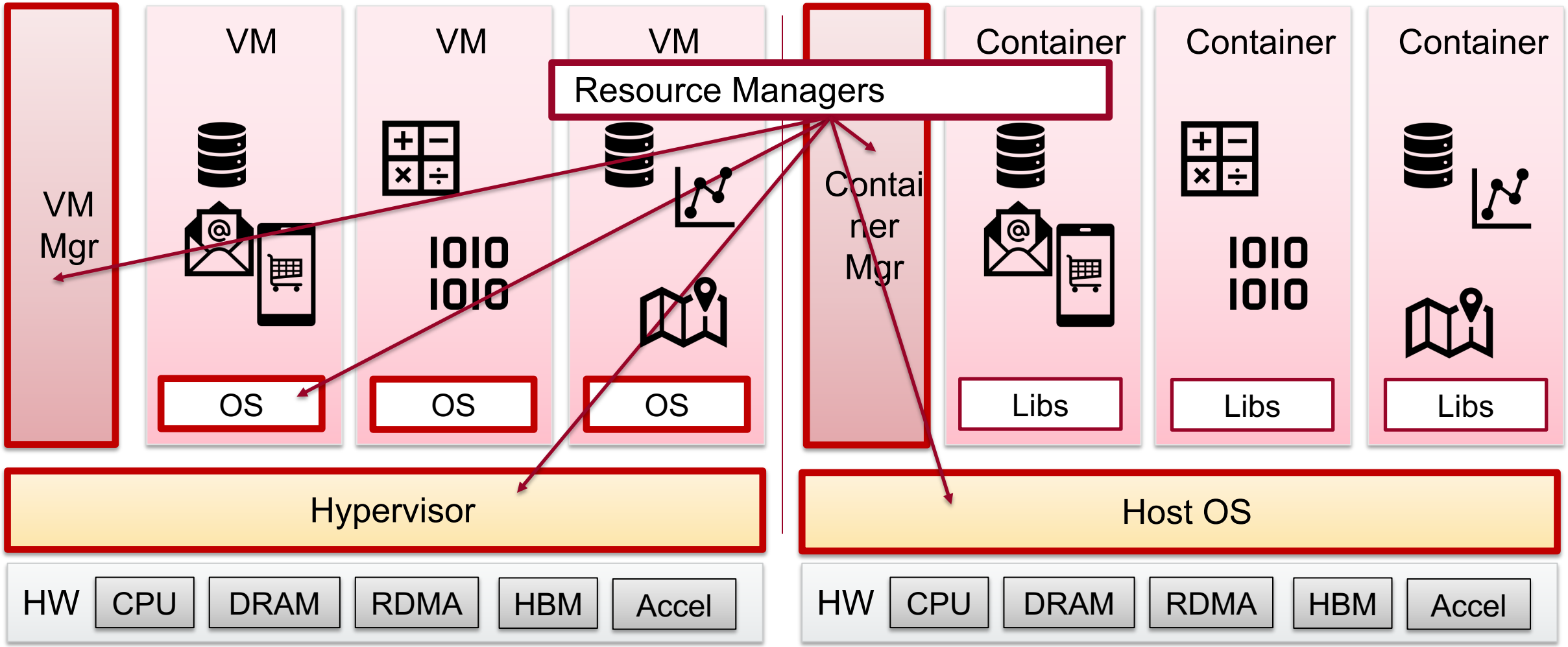

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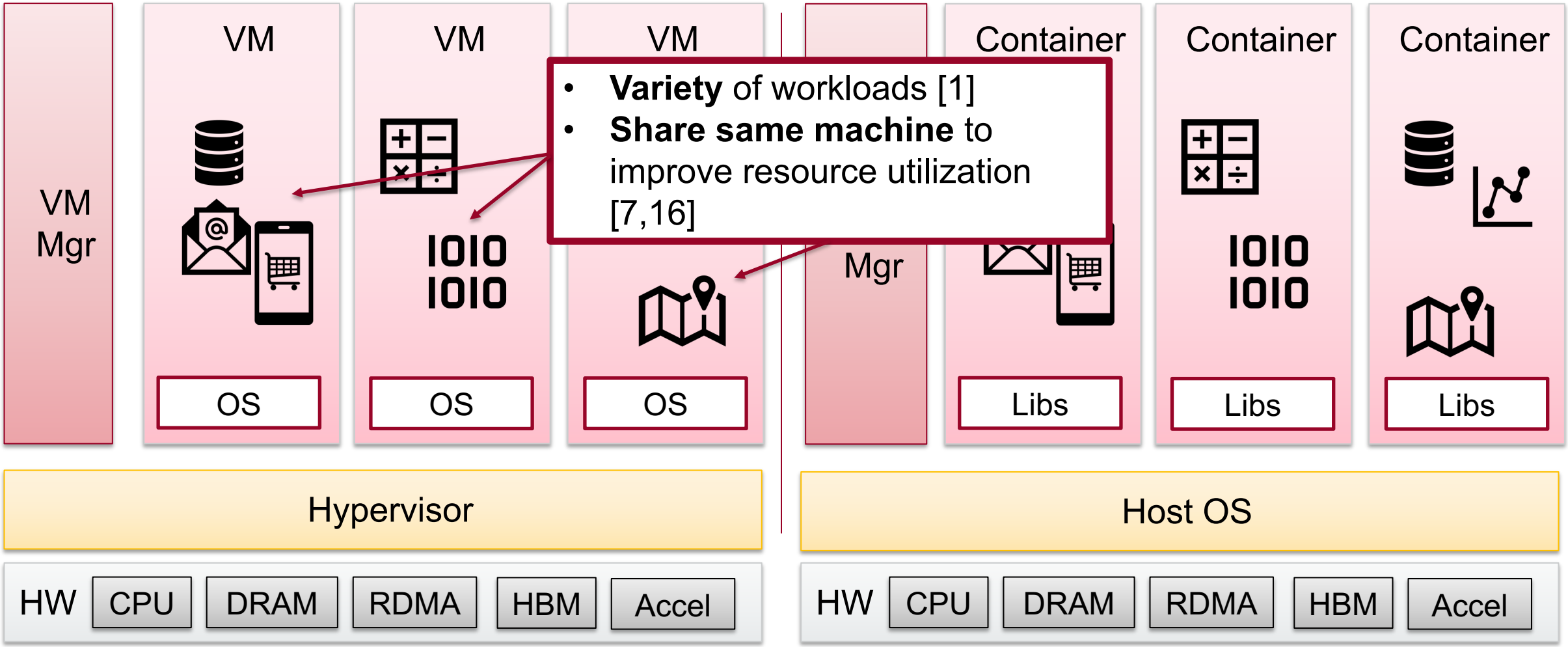
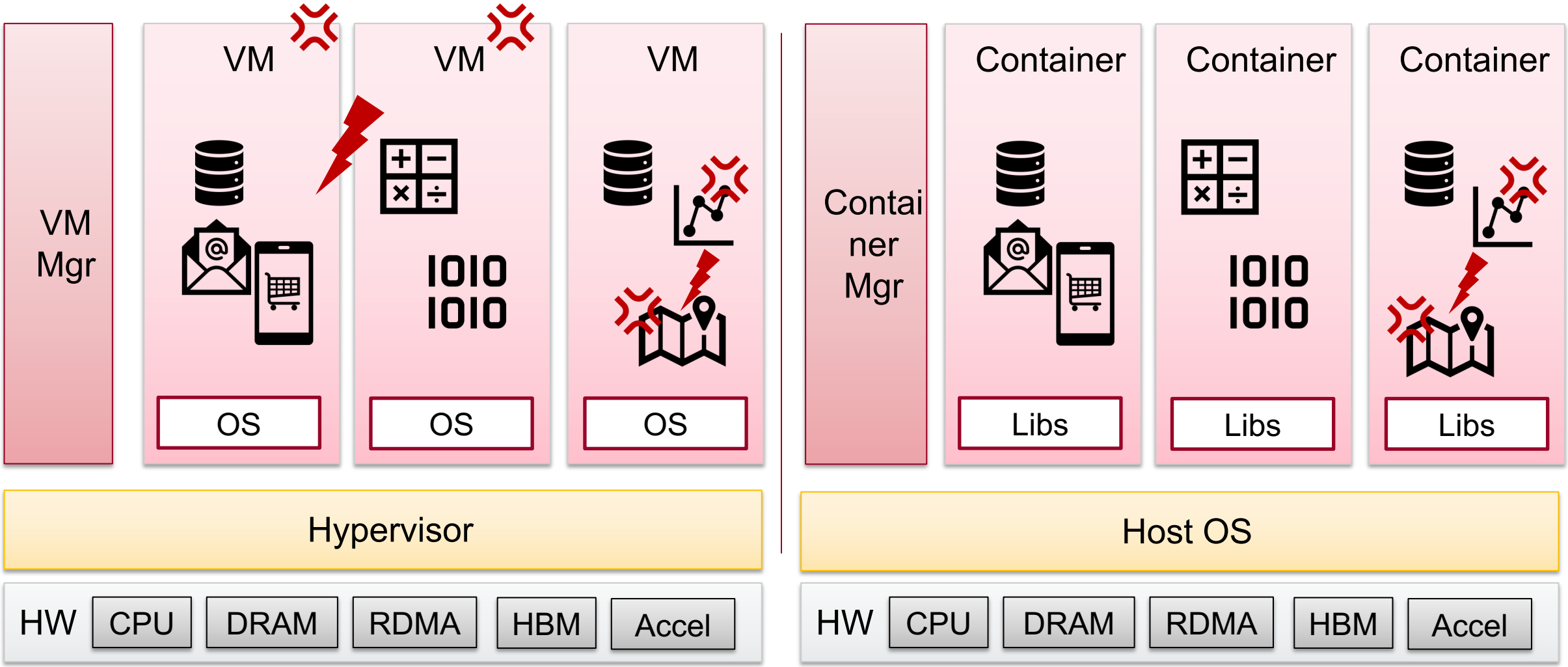
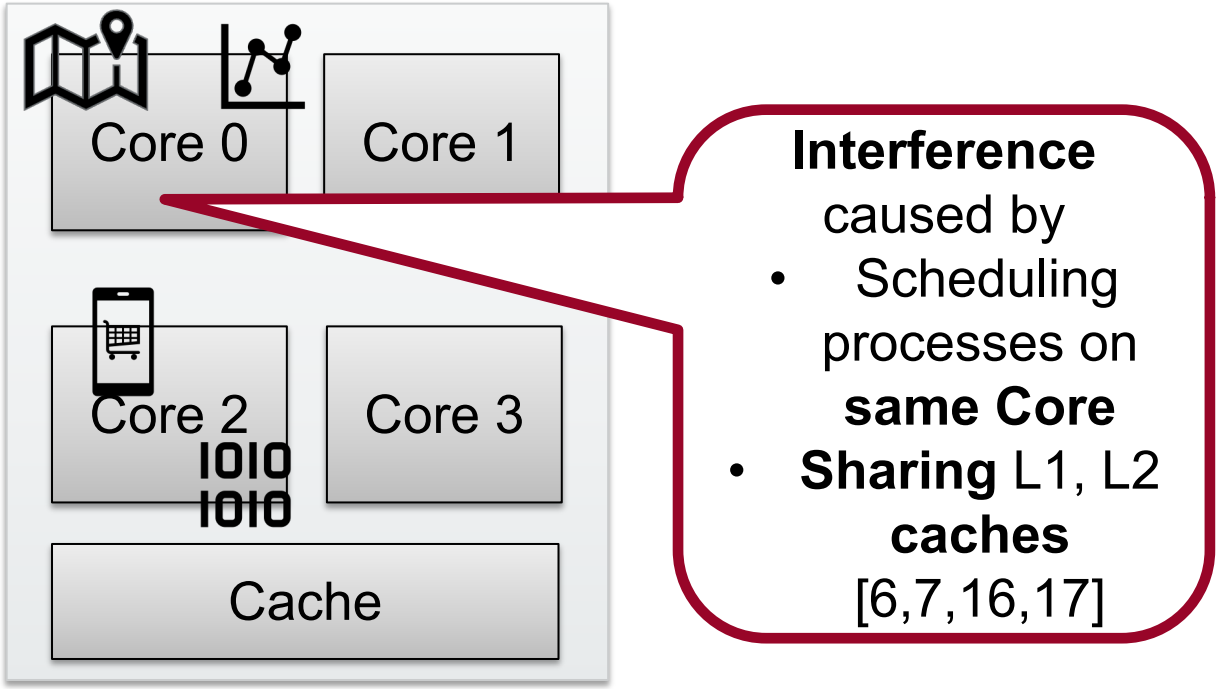


- **Variety** of workloads [1]
- **Share same machine** to improve resource utilization [7,16]

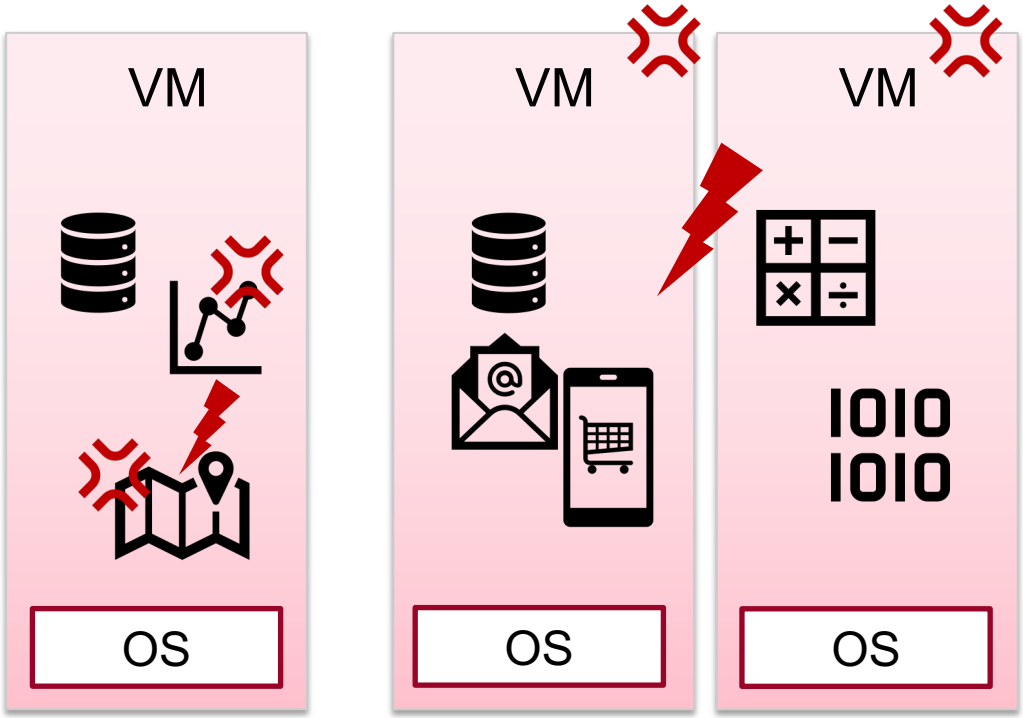
Challenges in Resource Management



Challenges in Resource Management: Interferences



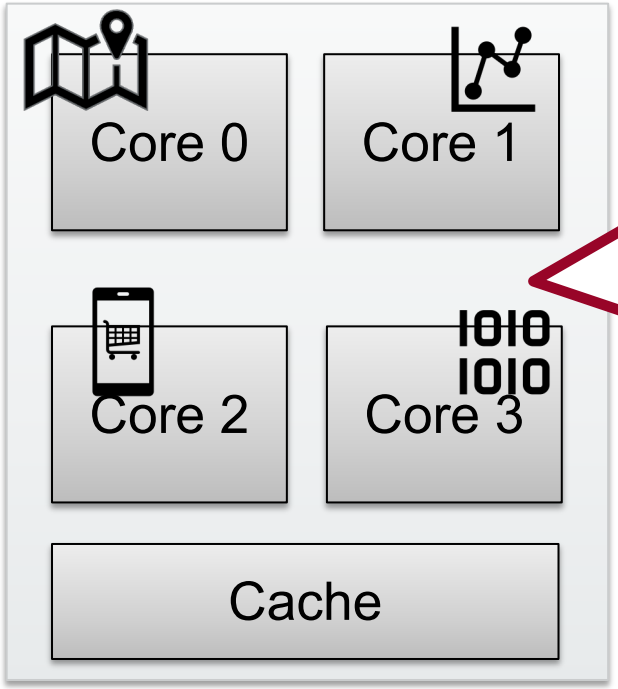
Interference caused by
- Scheduling processes on **same Core**
- **Sharing** L1, L2 **caches** [6,7,16,17]



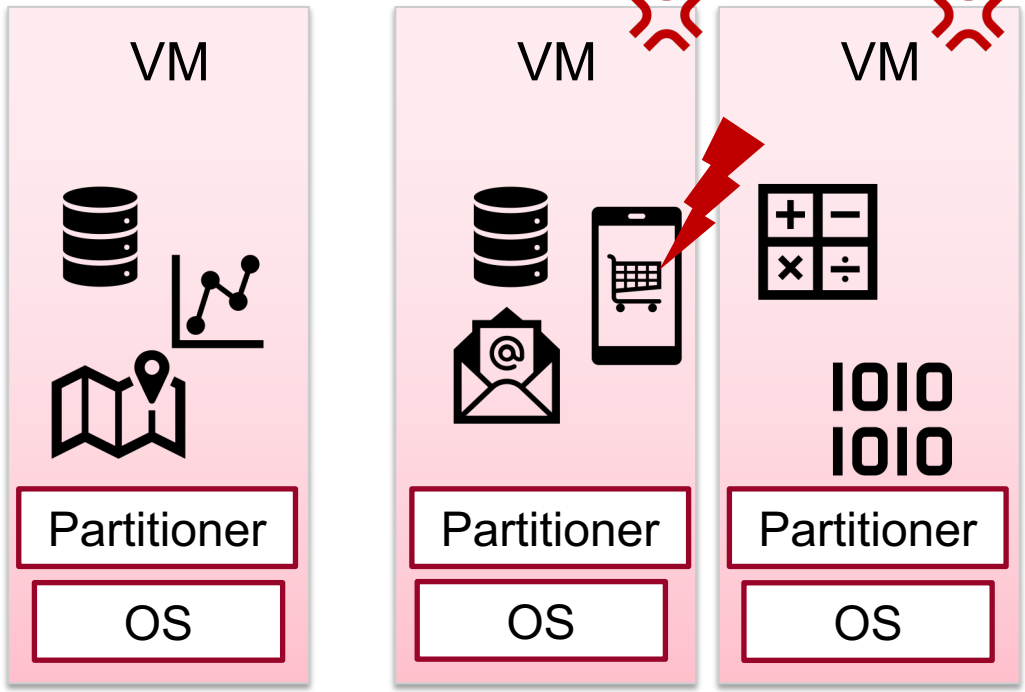
Consequences:
- **High** tail latencies
- **Degraded** throughput

⇒ SLA **penalties** for operator

Challenges in Resource Management: Interferences

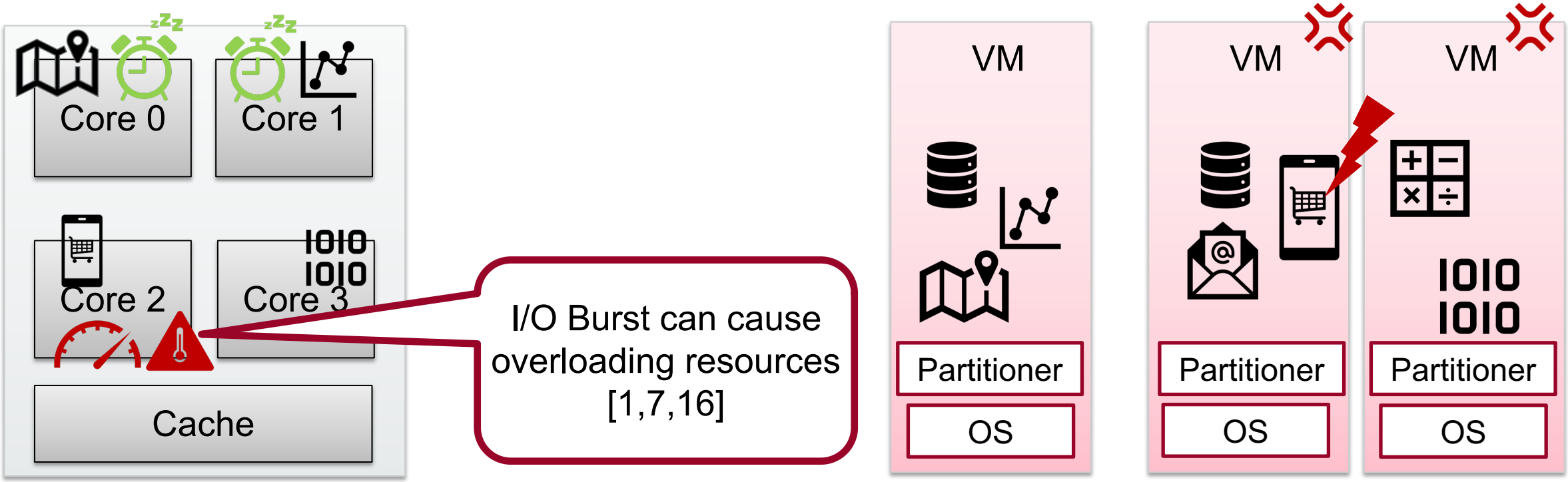


Common **Solution: Resource Partitioning** [7,15,17]



Pitfall: To **rigid** partitioning may cause **overloading** VMs/containers **and** under-utilization of resources **simultaneously** [6,7,11,17]

Challenges in Resource Management: Allocation



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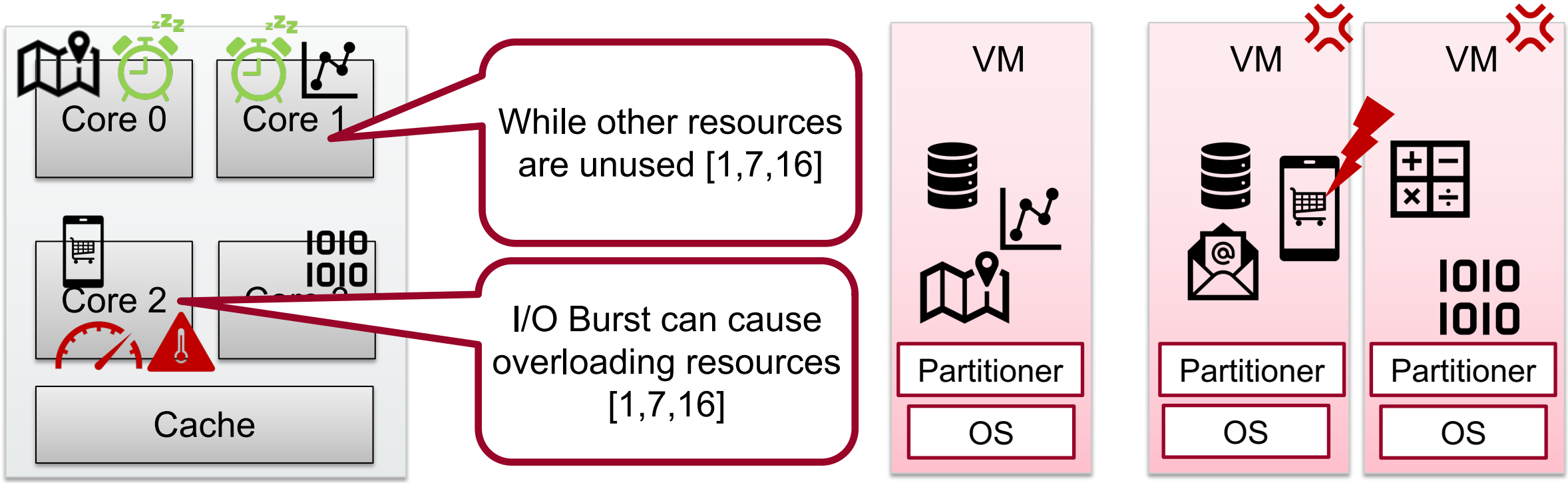

Solution: **Dynamic** Resource Partitioning **or Allocation** [4,6,7,17]

But, determining resource **allocation** for VMs and application partitions is **difficult** without **application knowledge** [6,11] **and** decisions must be made **fast** [6,11]

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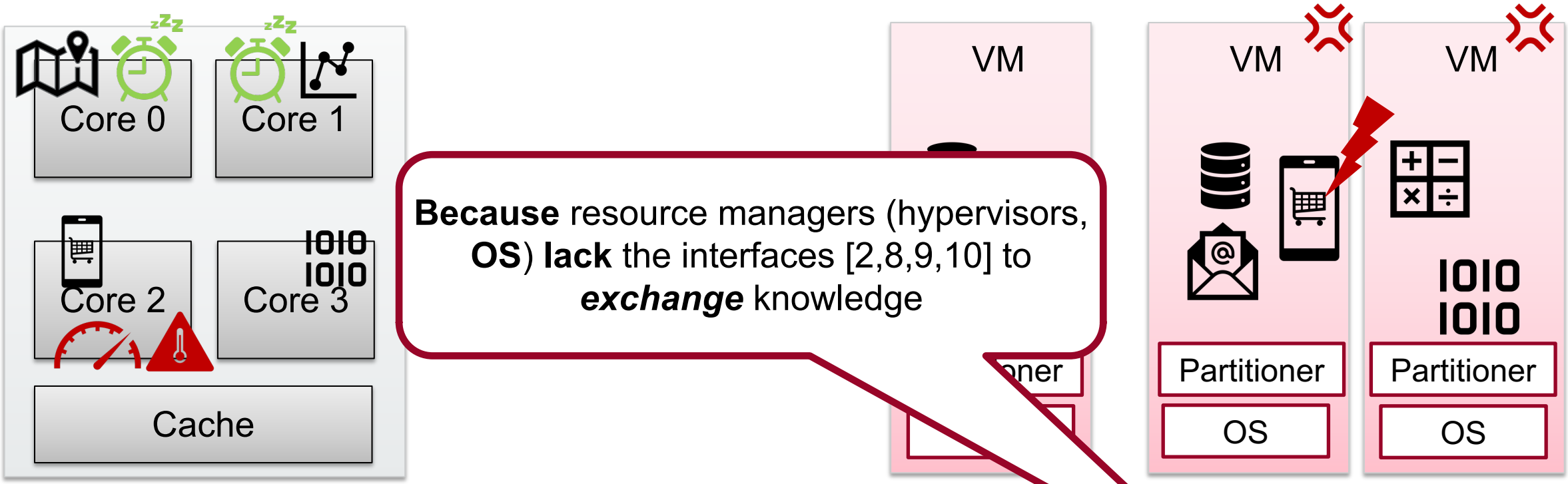

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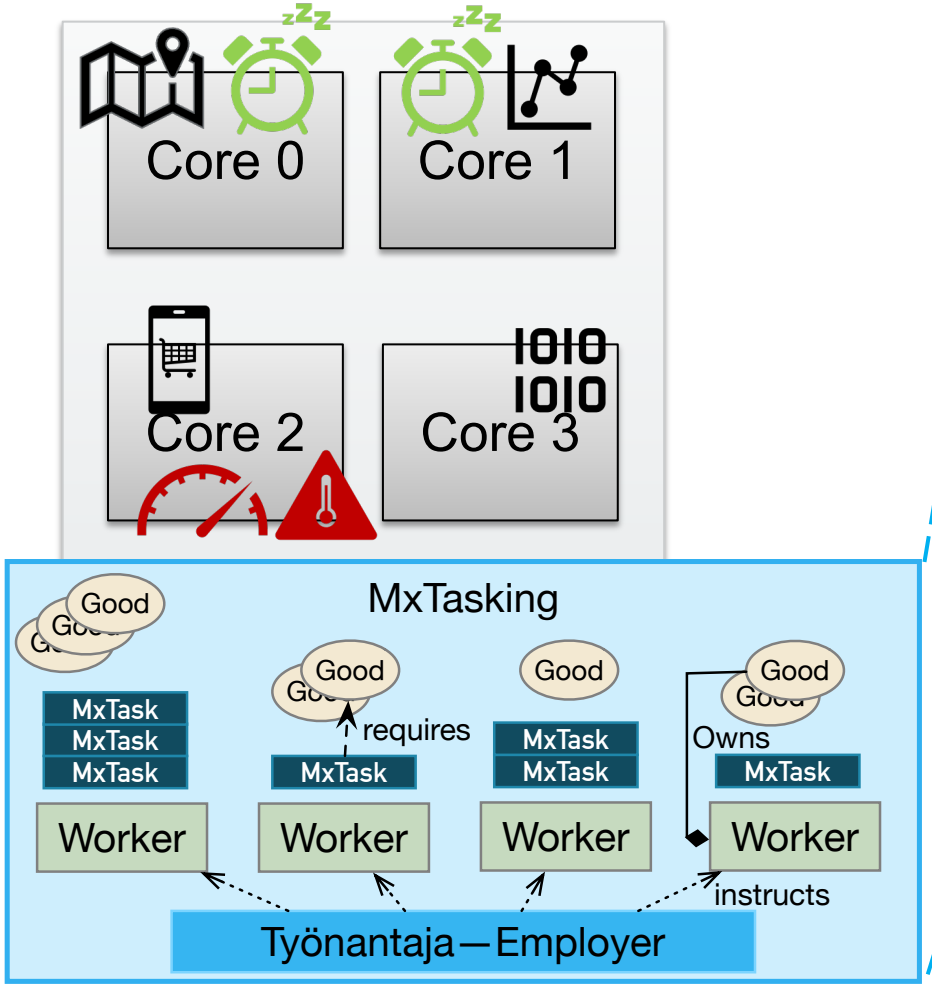
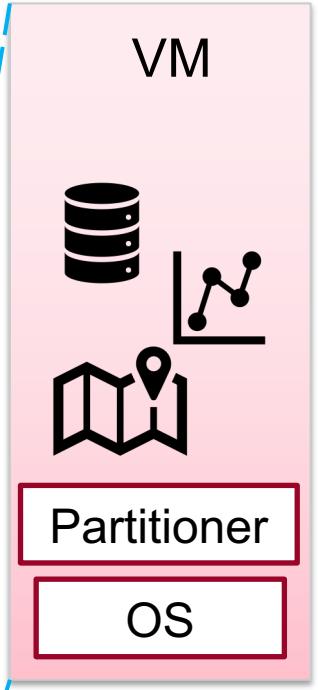
MxKernel Concepts





MxTasks

- Provide **annotations** to **predict future** resource demands
- Are **non-preemptable, light-weight closed units** of work
- Provide **task-parallel** programming
- **Benefits** for **automatic prefetching** and **synchronization** already shown*

*) Mühlig, J. and Teubner, J. 2021. MxTasks: How to Make Efficient Synchronization and Prefetching Easy. *Proceedings of the 2021 International Conference on Management of Data* (New York, NY, USA, Jun. 2021), 1331–1344.

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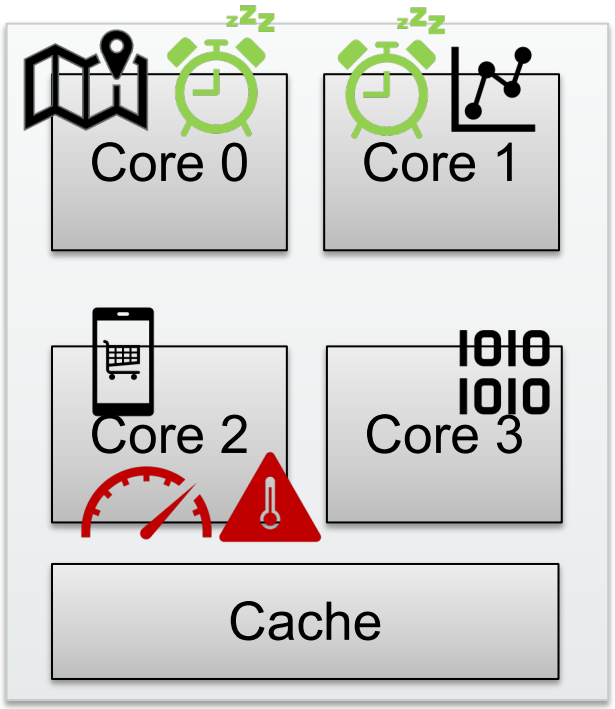

Cells

- Represent **processes** of a workload
- **Minimize interference** between **online** and **offline services** among workloads
- **Fast** reaction to **load changes**
- **By**
  - ***Elastic*** resource domains
  - Featuring **task-based** runtime environment
  - **Managed** by **the zookeeper (Hoitaja)**

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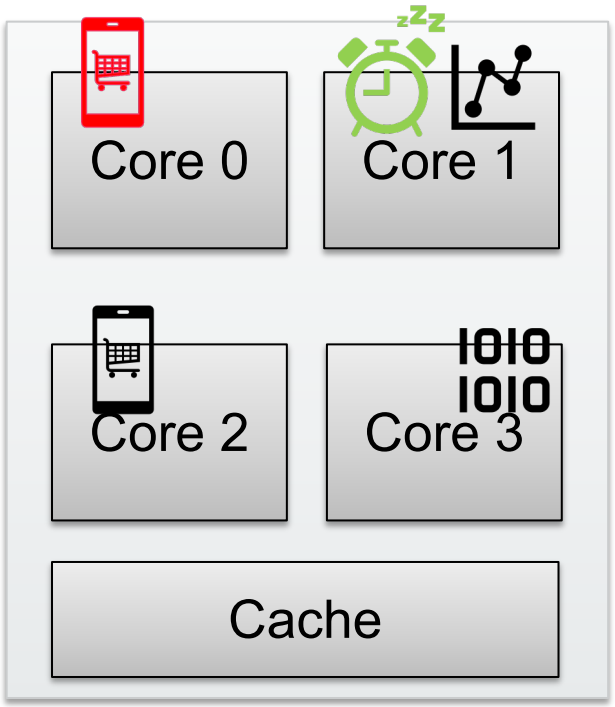

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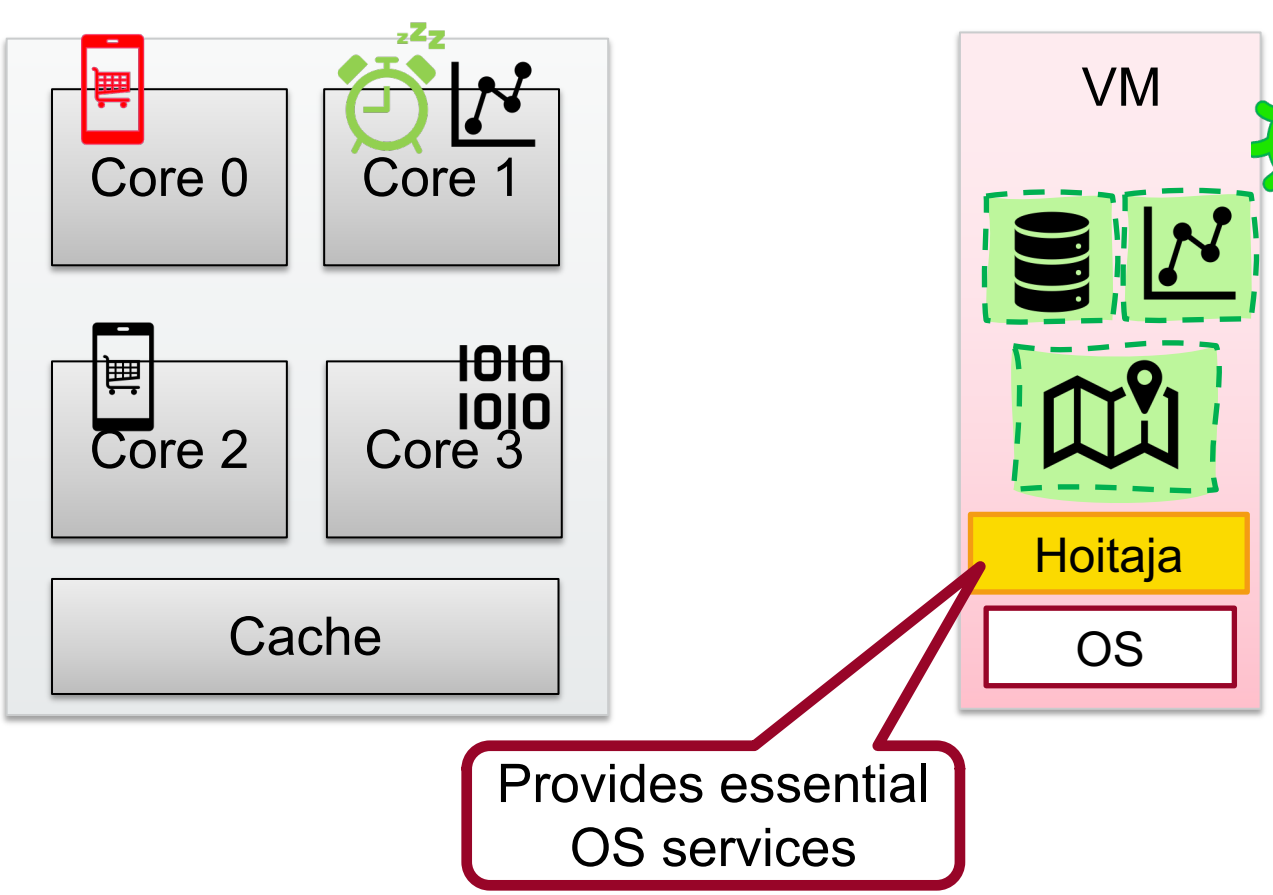

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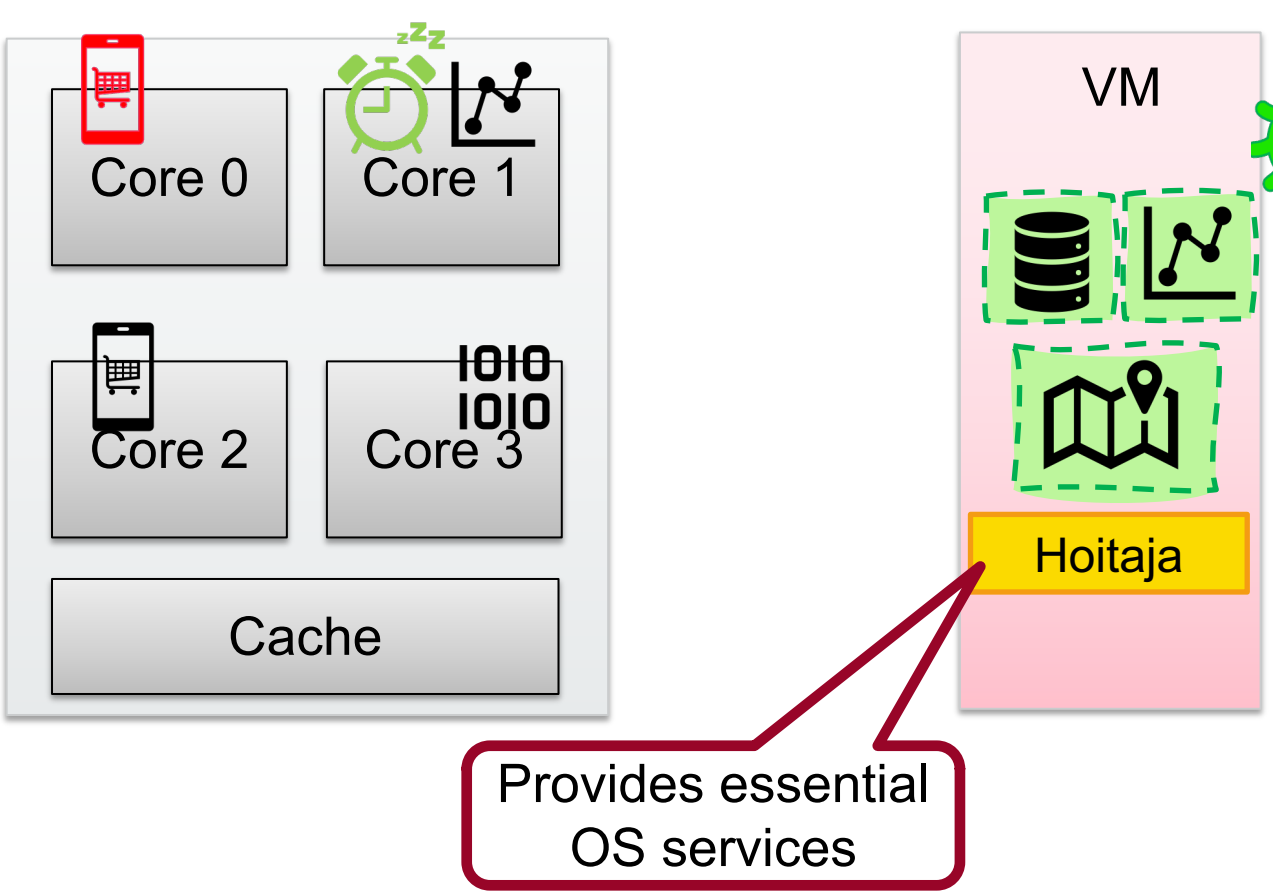

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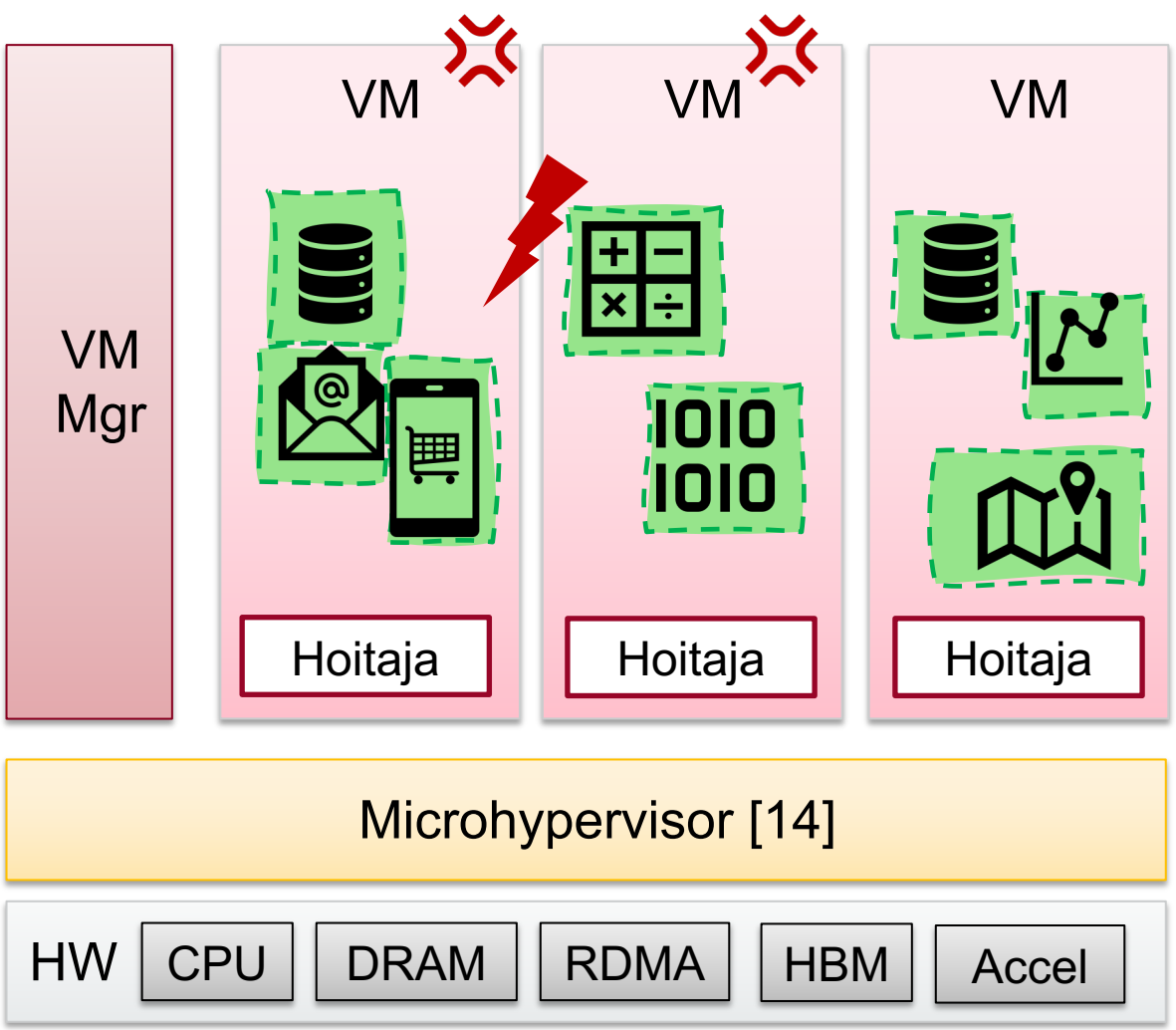
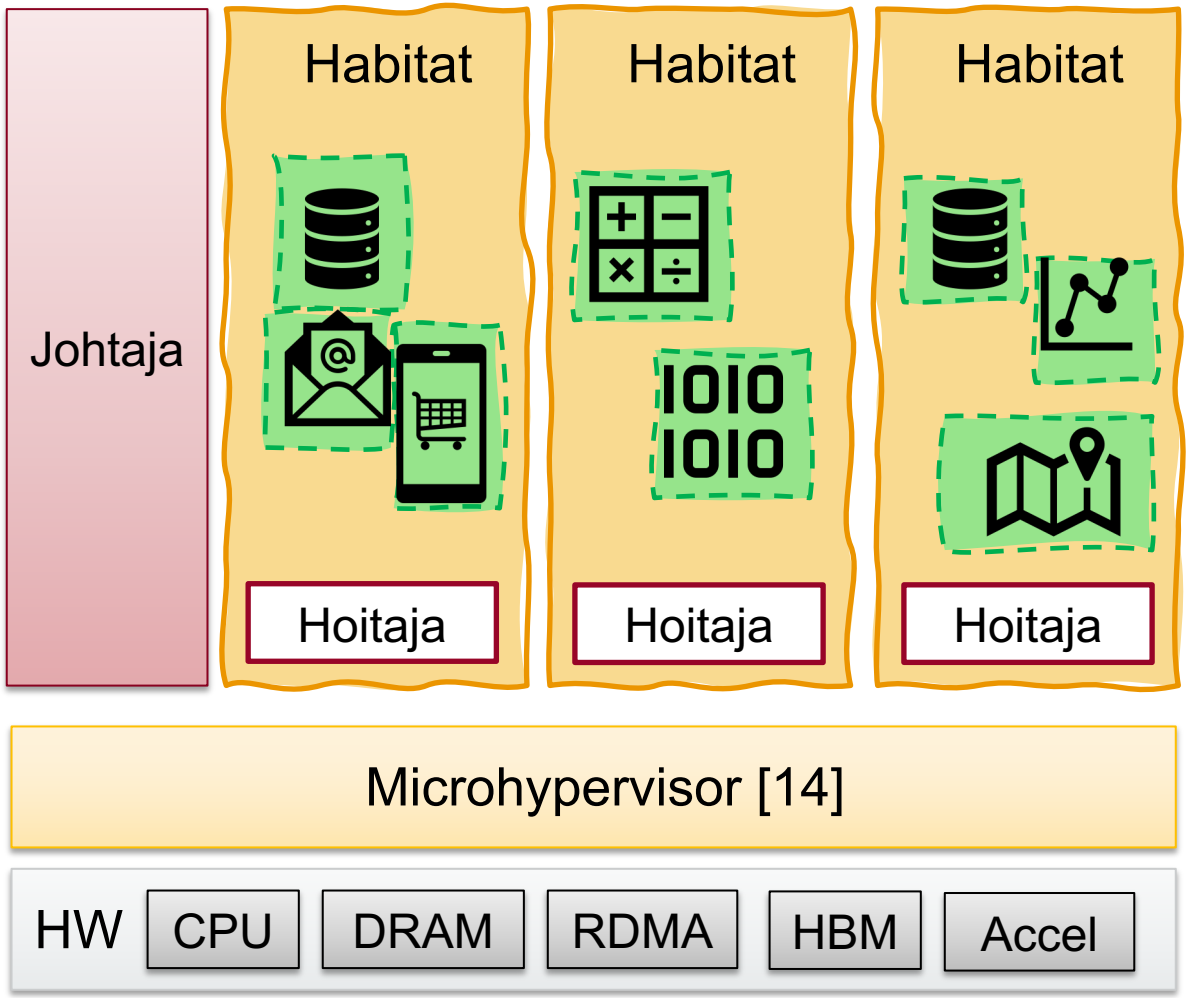


Habitats

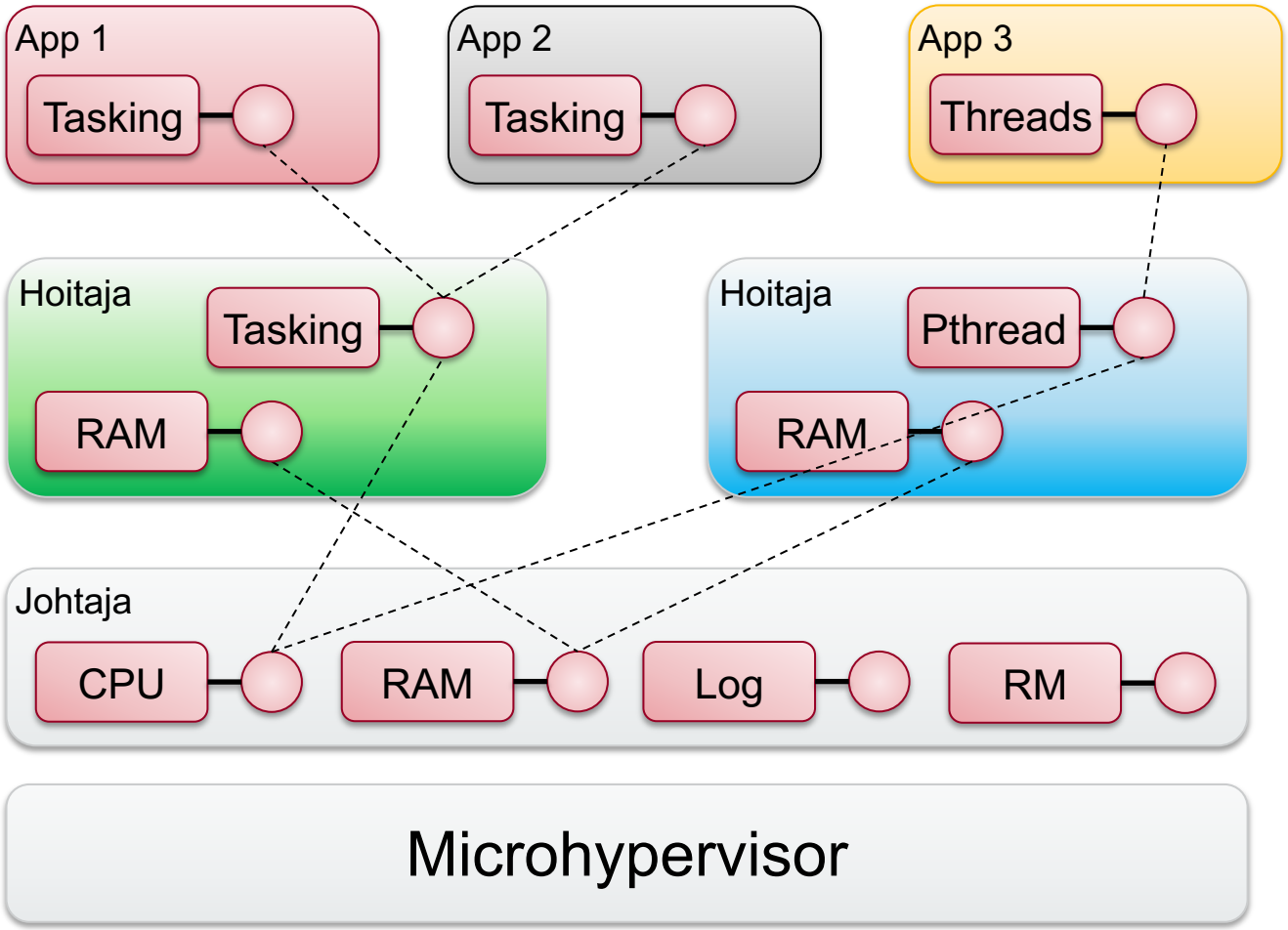
MxKernel Concepts



Habitats

- **Address**
  - **Fairness and Interferences** between workloads
- **By** providing
  - An **elastic** resource **container**
  - A **local** tailorable **resource manager, the zookeeper**
- **Managed** by **global** resource manager **(Johtaja, the director)**

MxKernel Architecture



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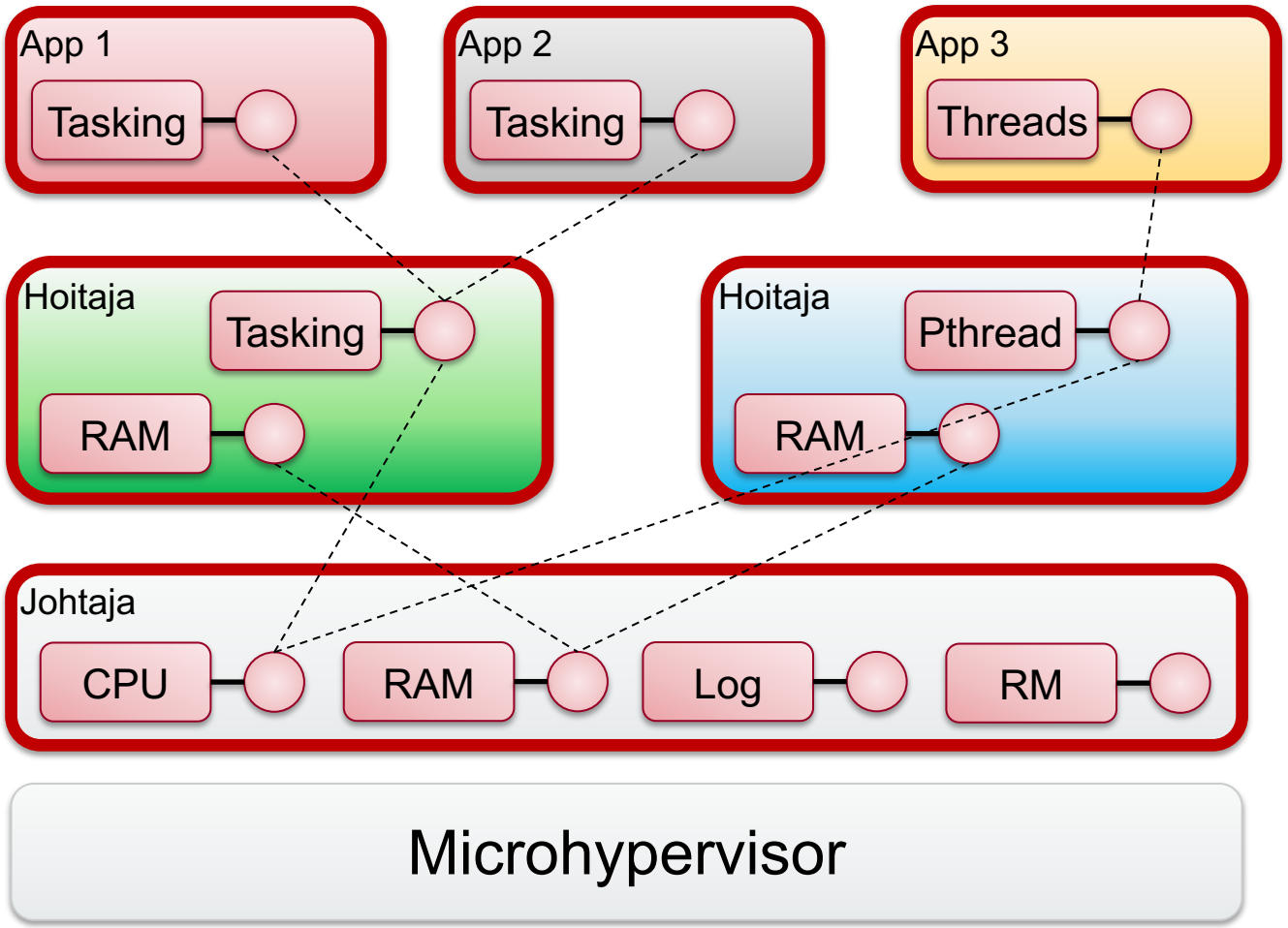
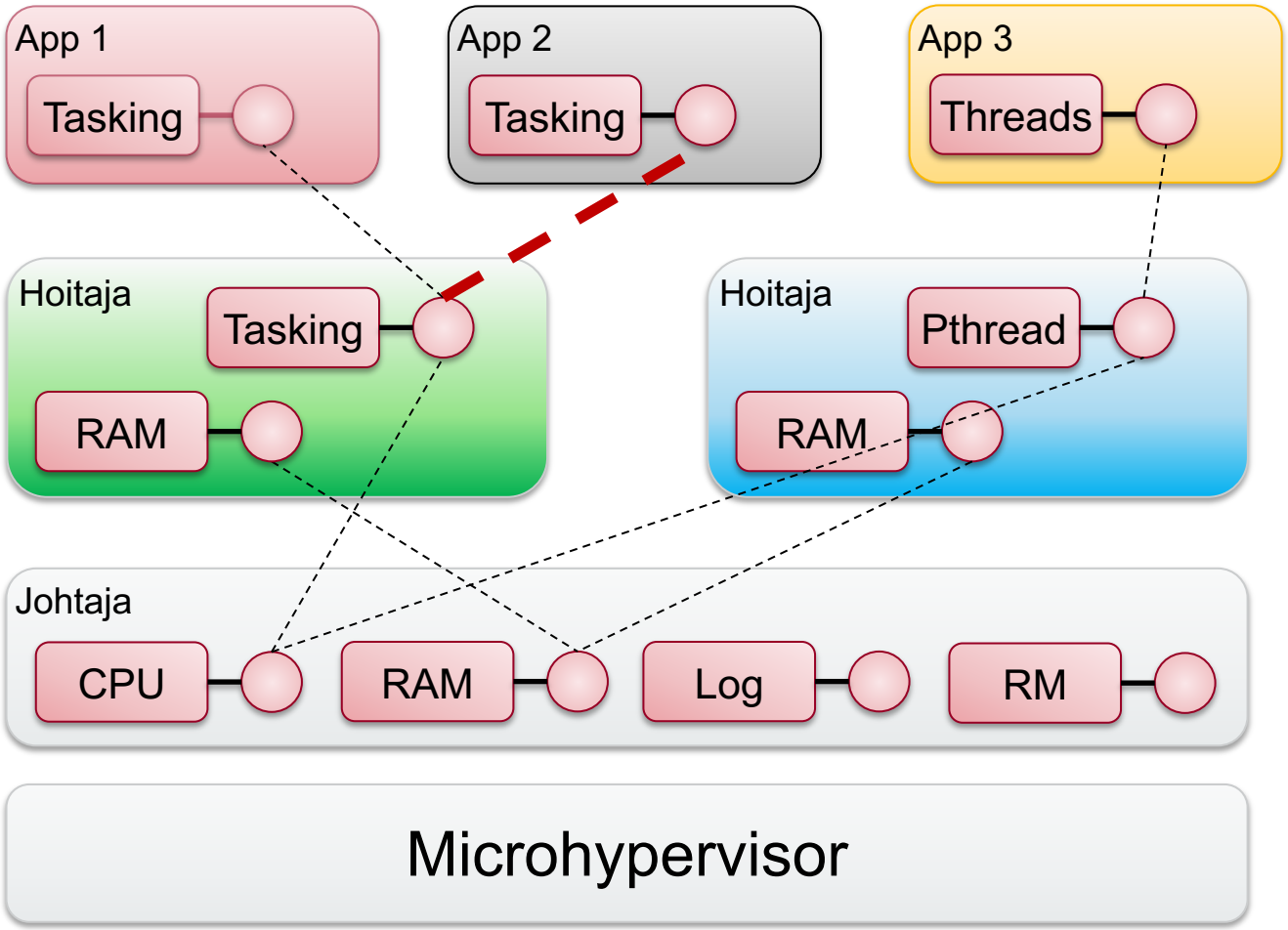


- Composed of components*

*) Based on the architecture of the Genode OS Framework (www.genode.org)

MxKernel Architecture



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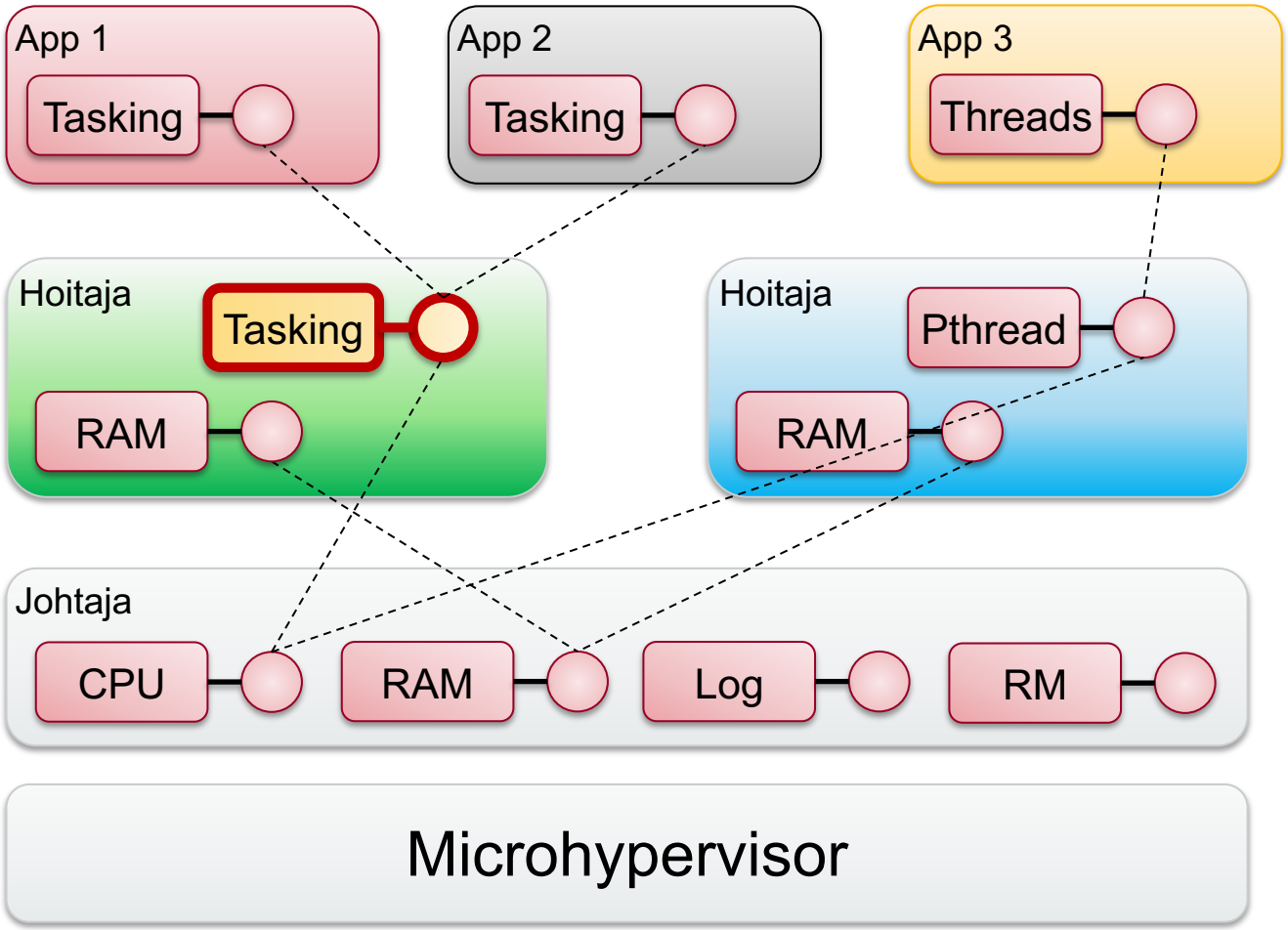

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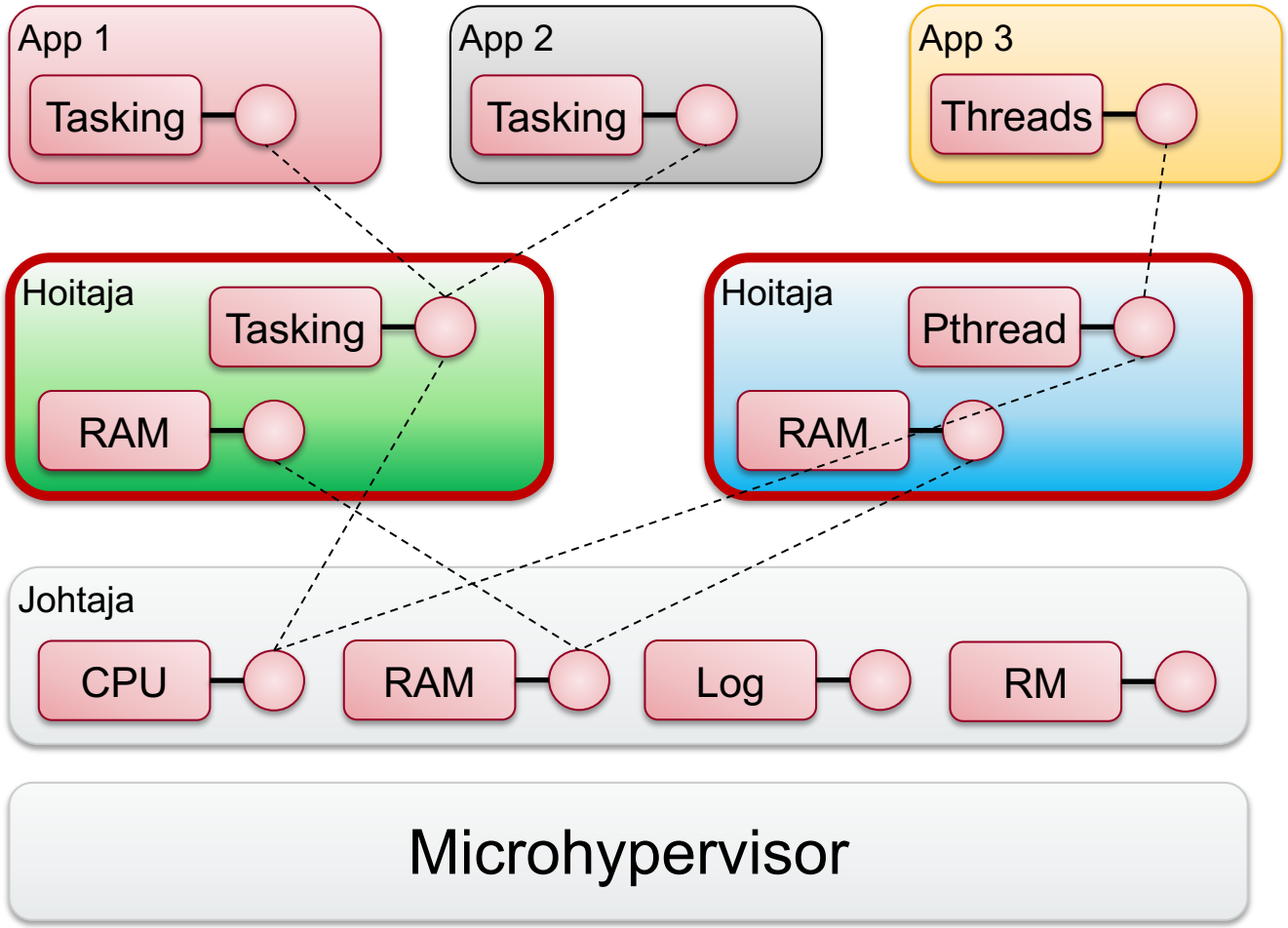

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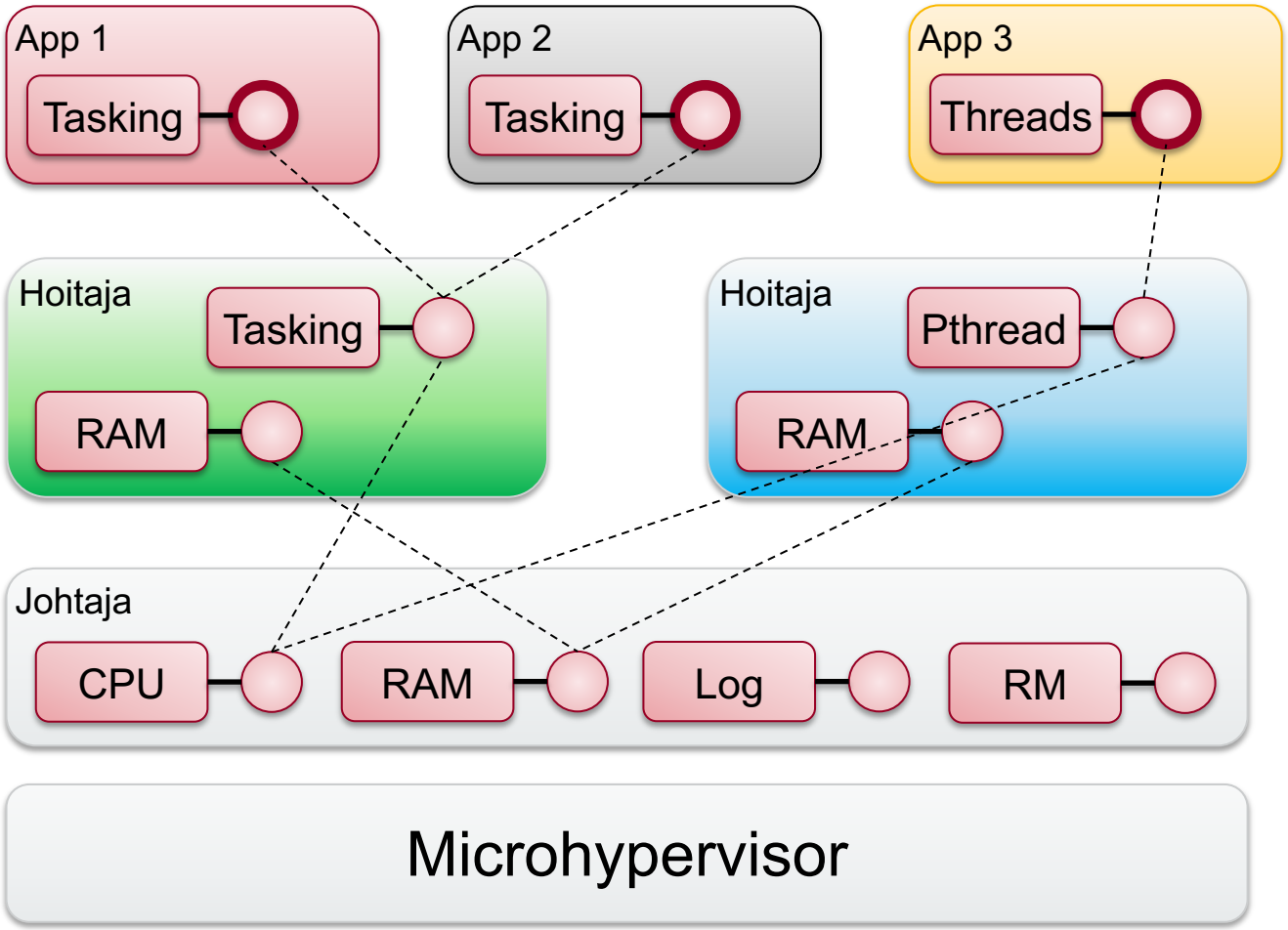

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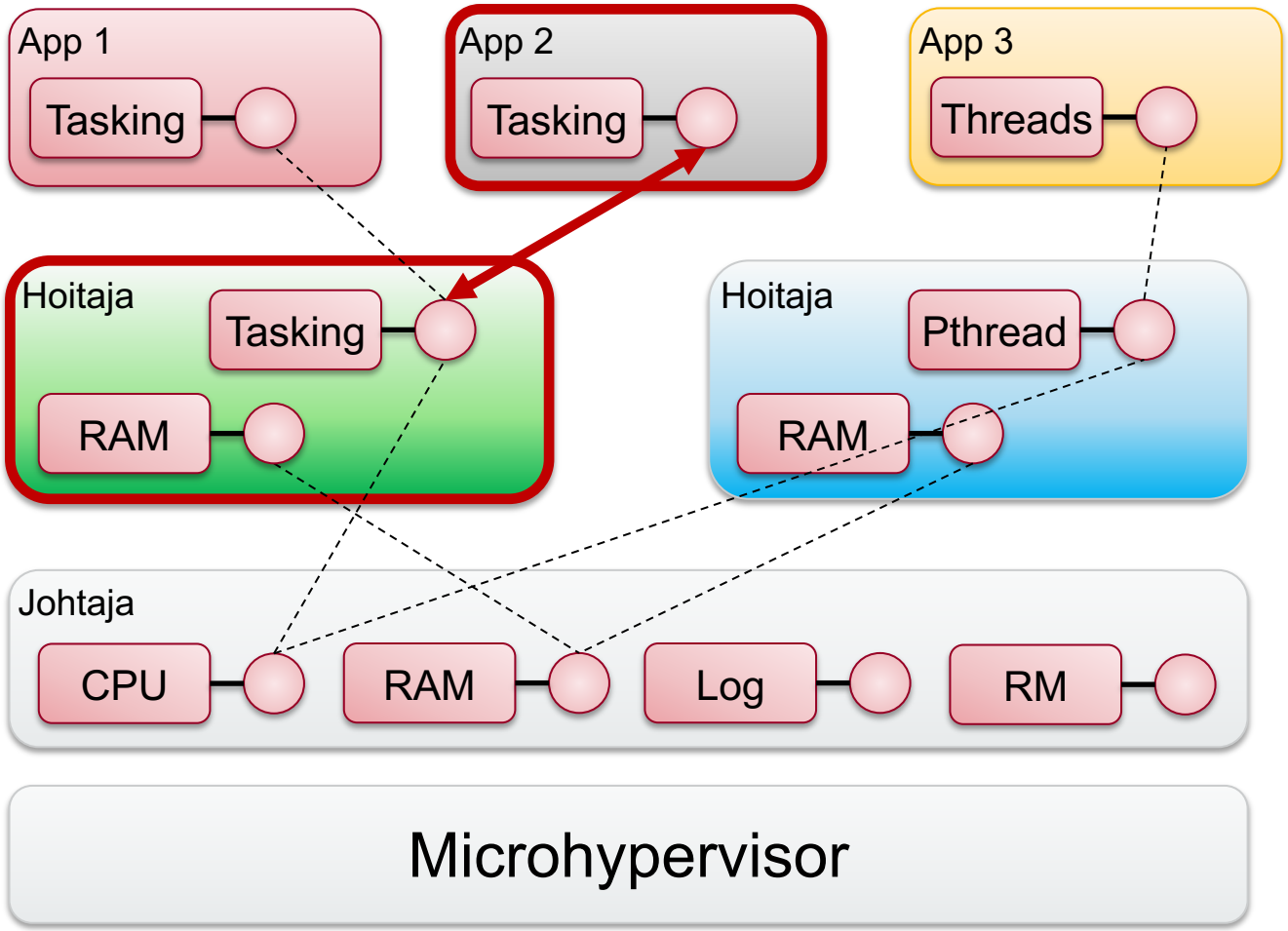

- Composed of components*
- Components interact via RPC
- And can offer (OS) services
- Parents control access to services and resources
- Using capabilities
- Children negotiate resource allocations with parents

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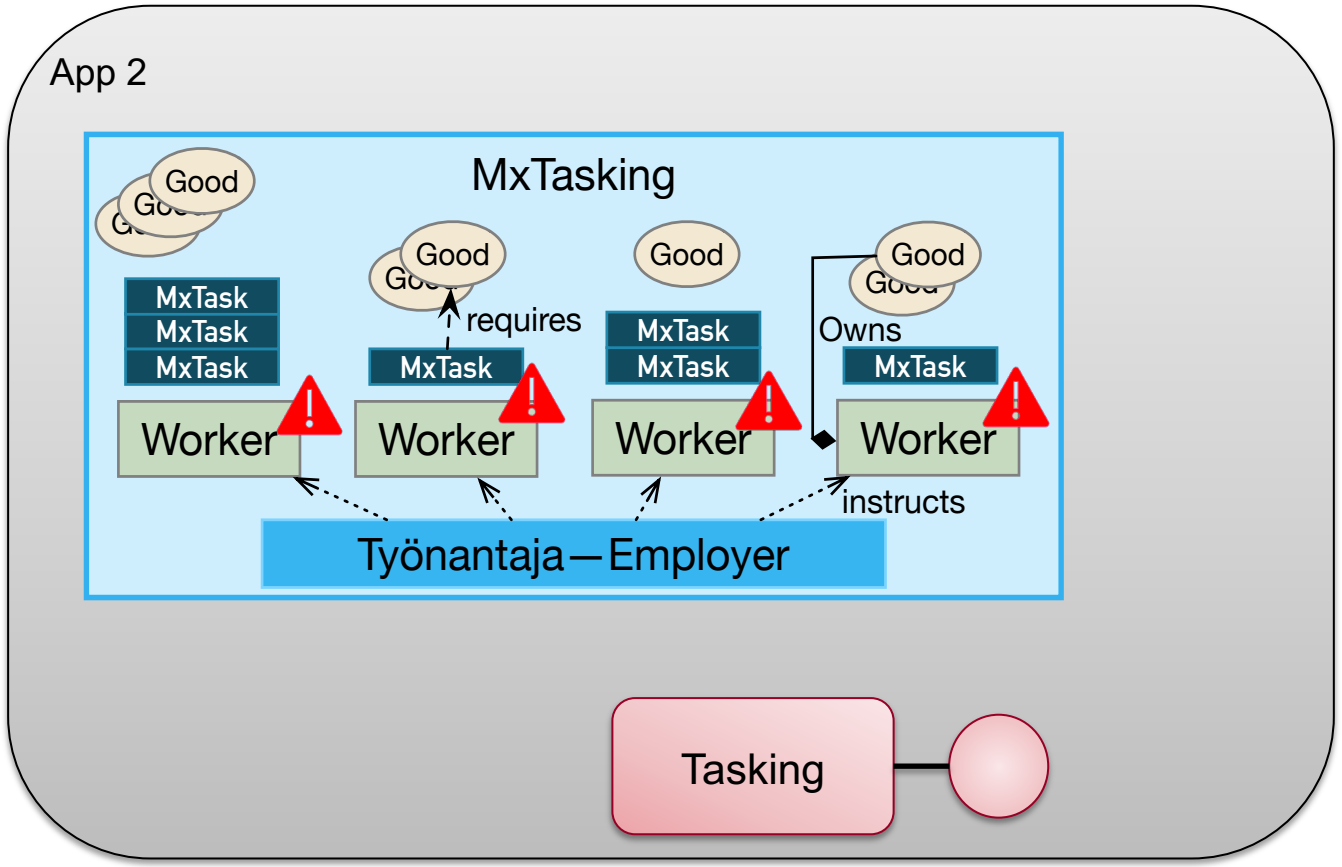
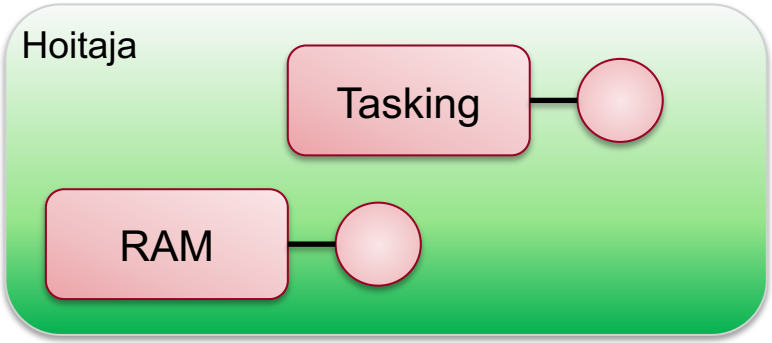
Resource Allocation Negotiation





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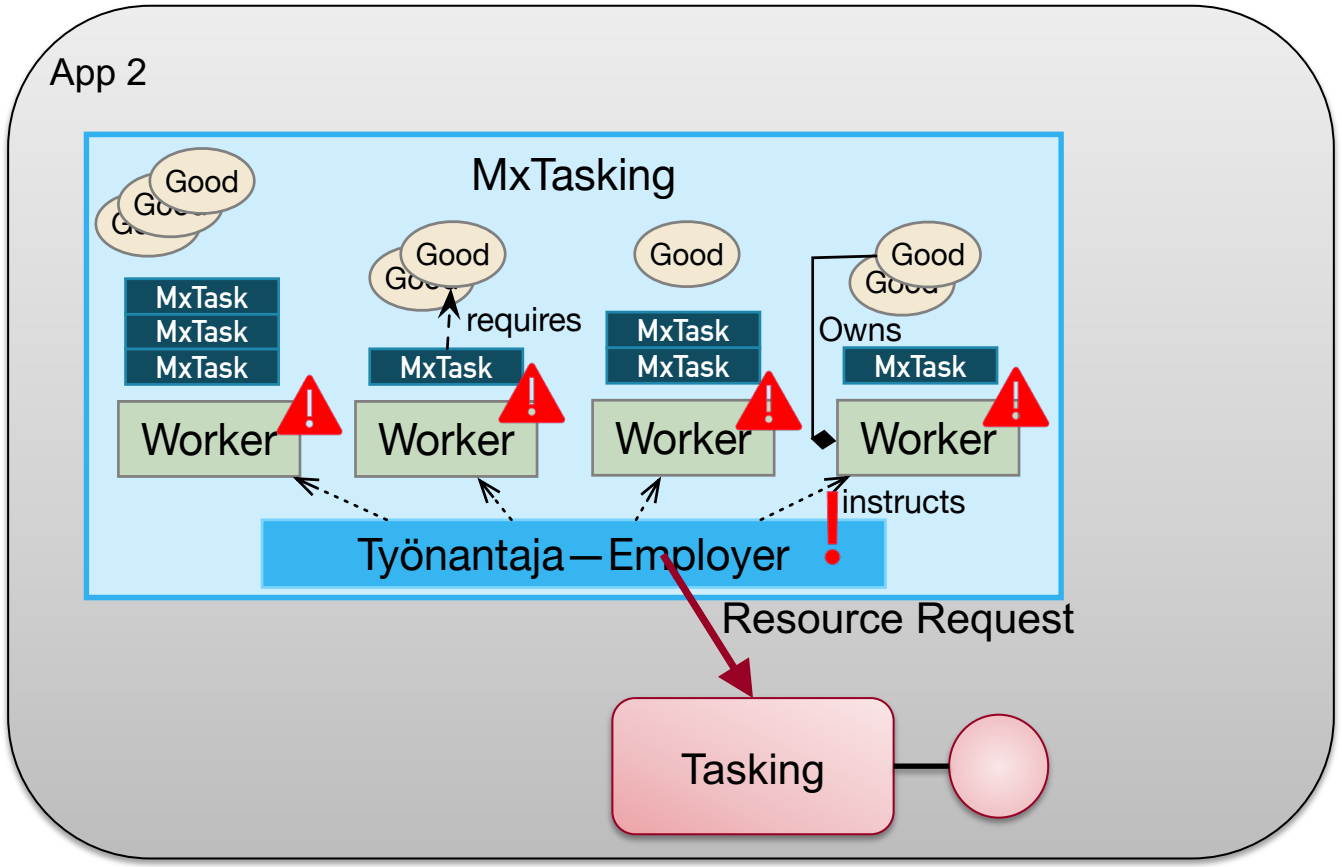

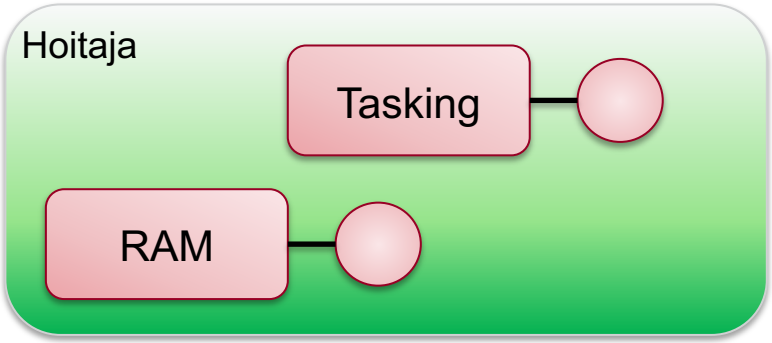

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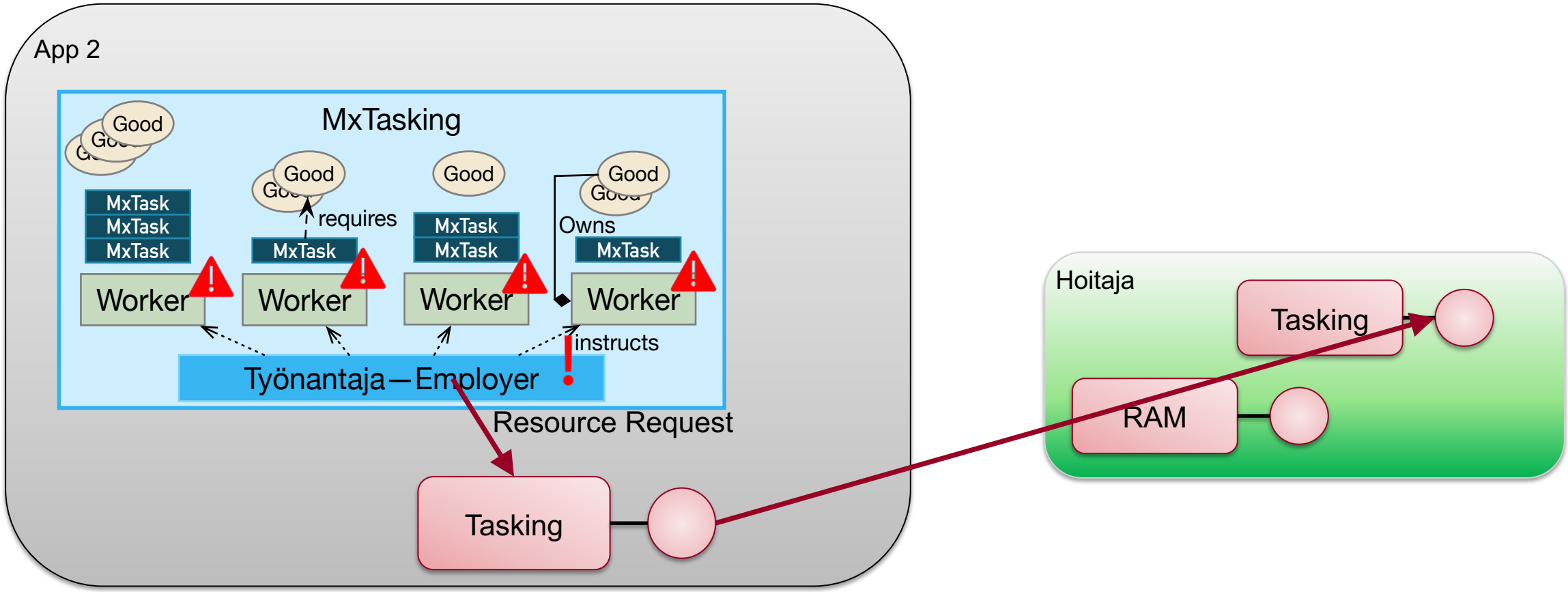

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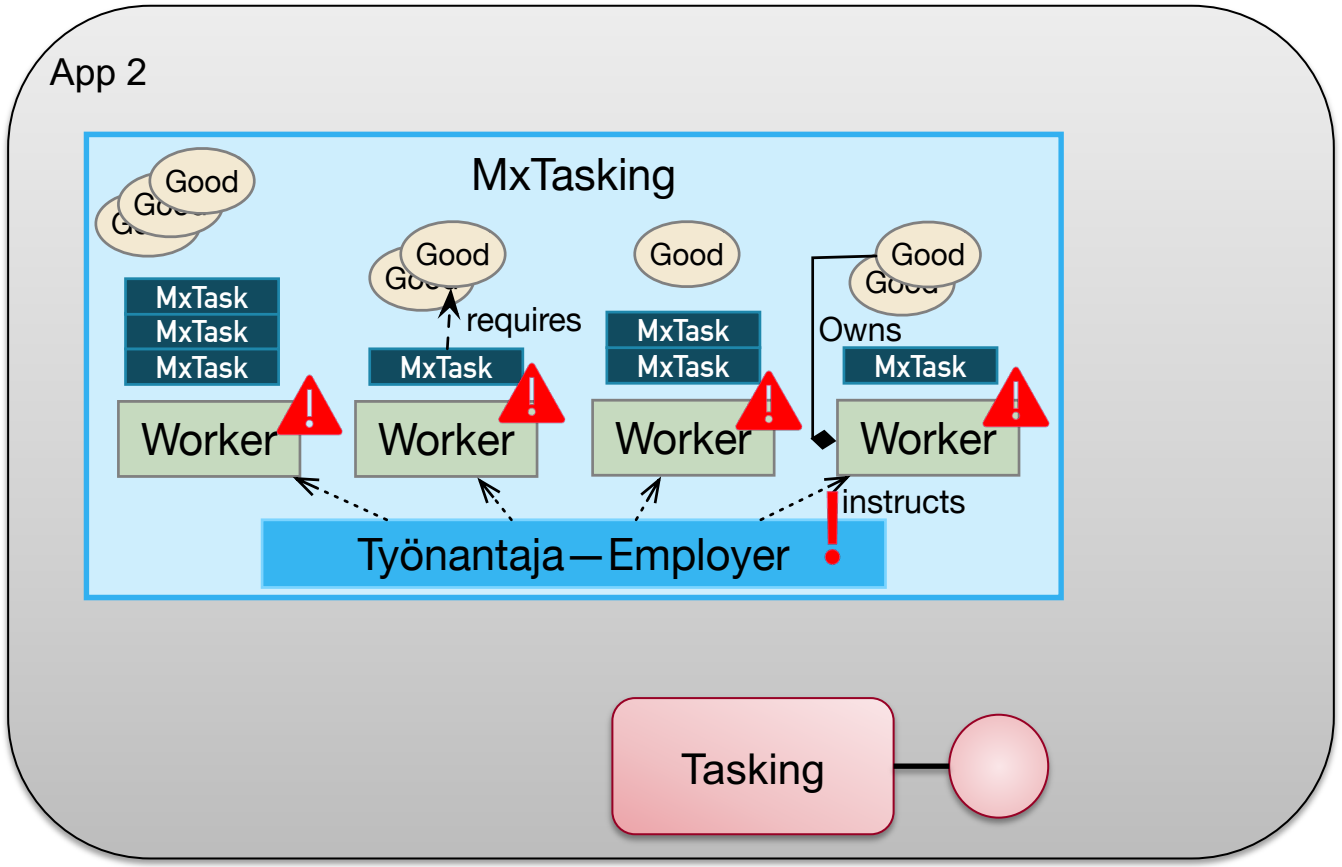
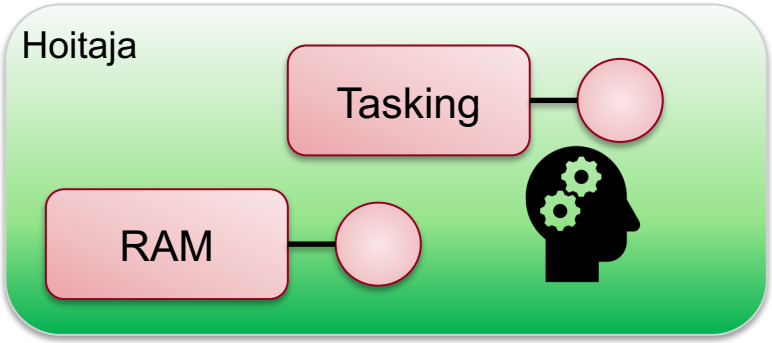
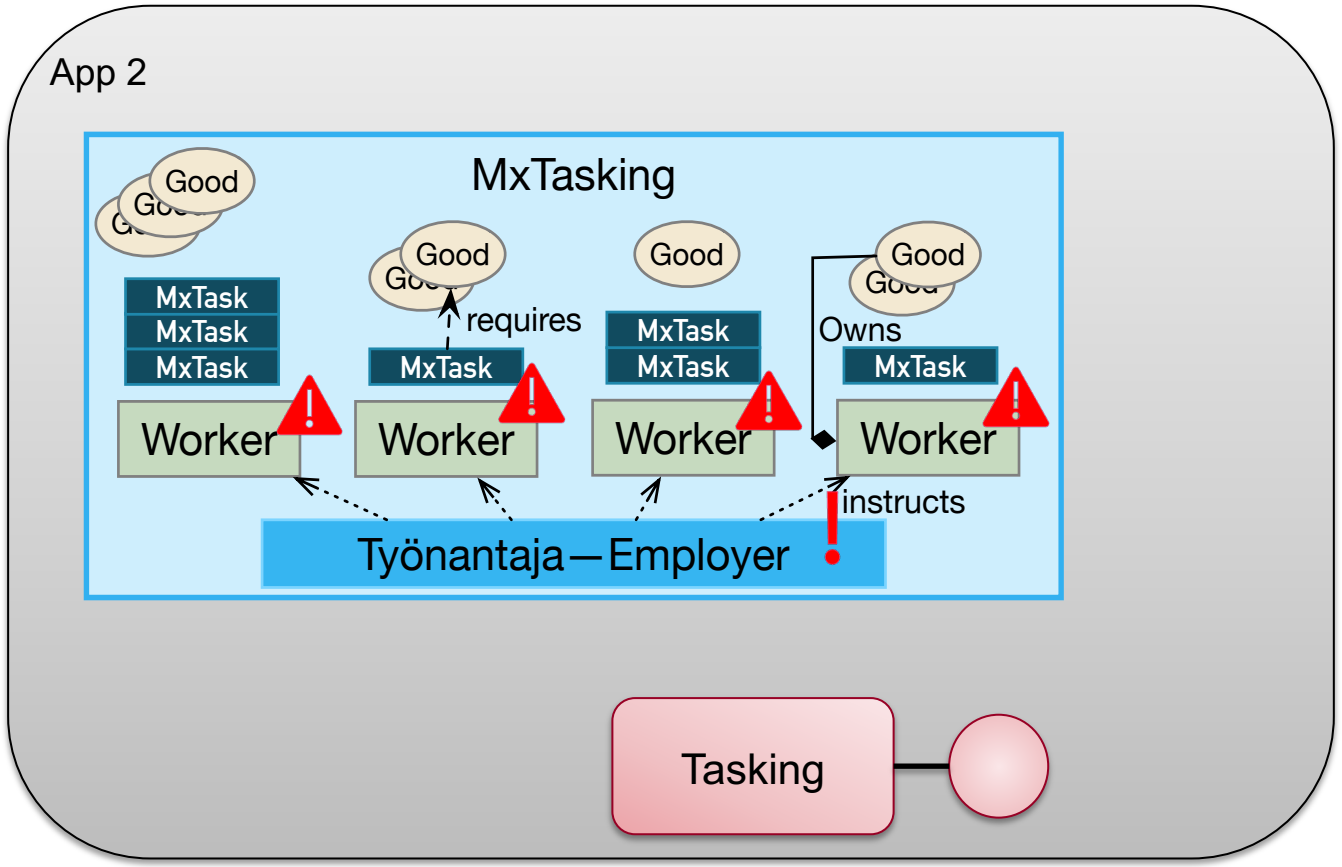
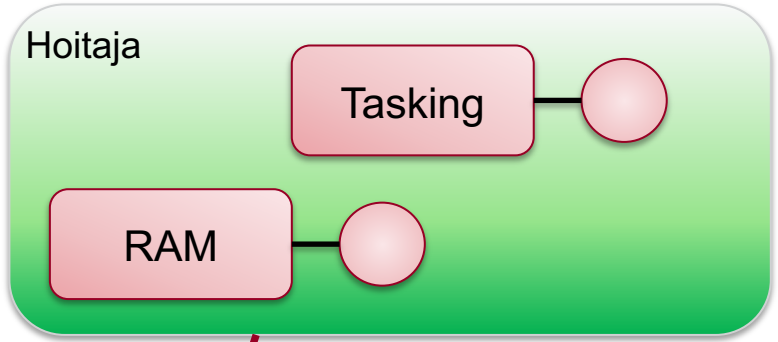




Compute new allocation

Resource Allocation Negotiation

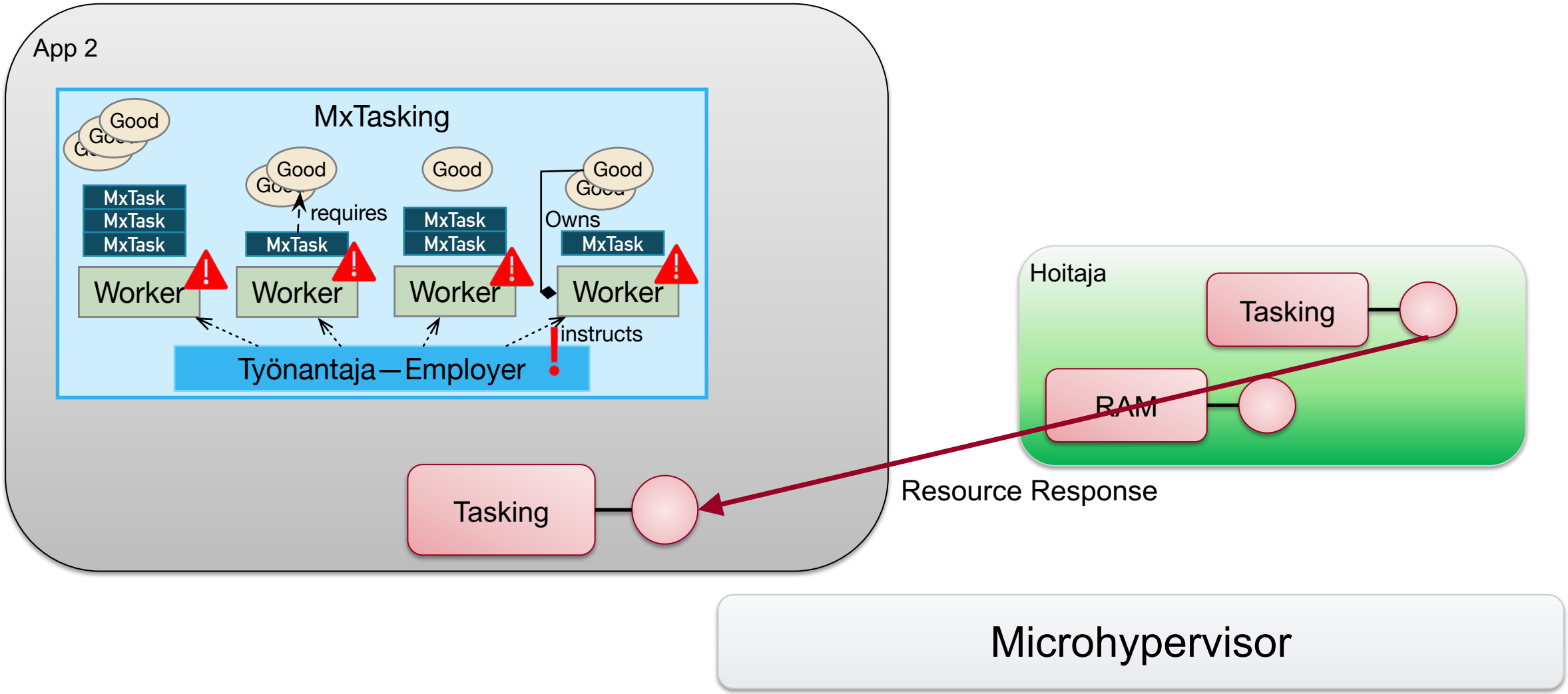




Change allocation

Microhypervisor

Resource Allocation Negotiation



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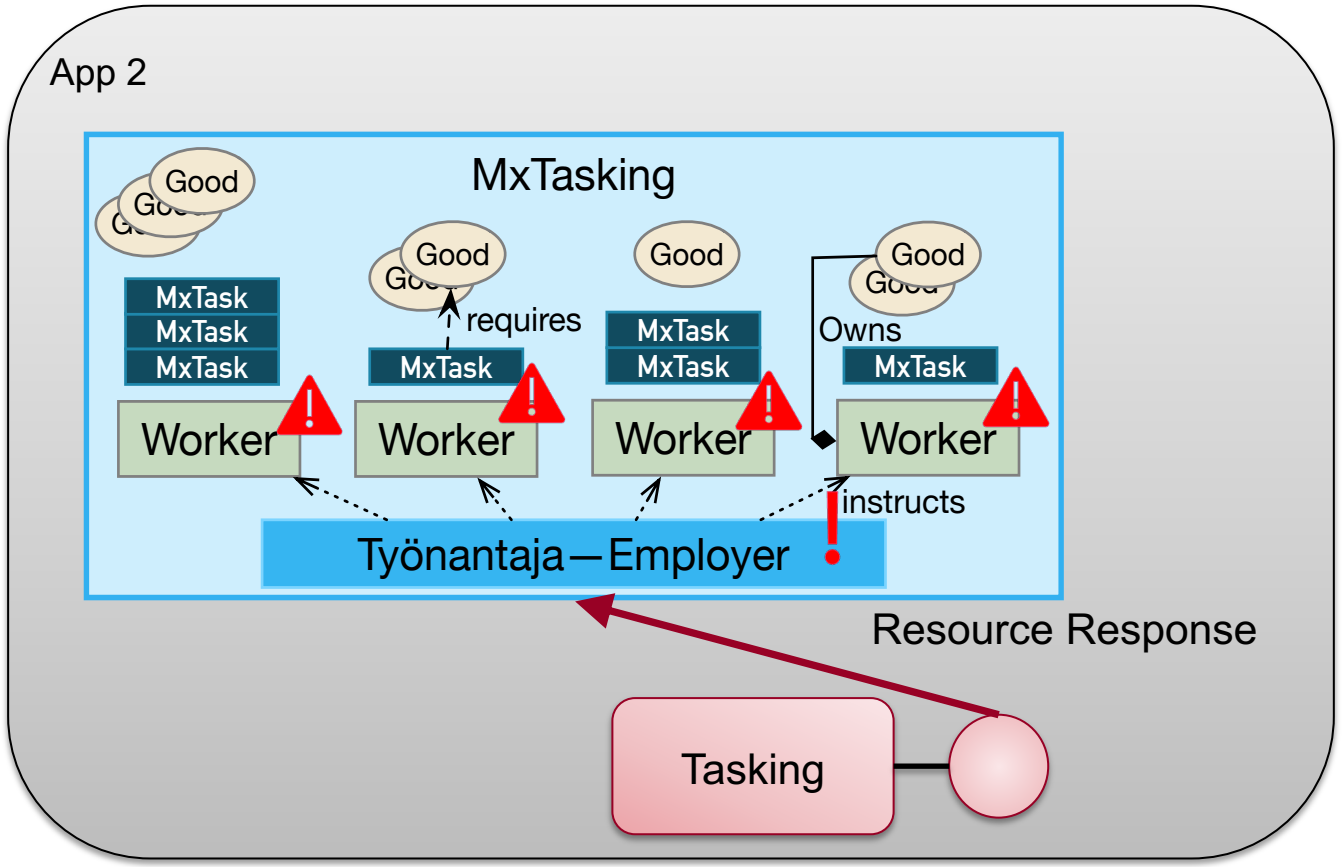
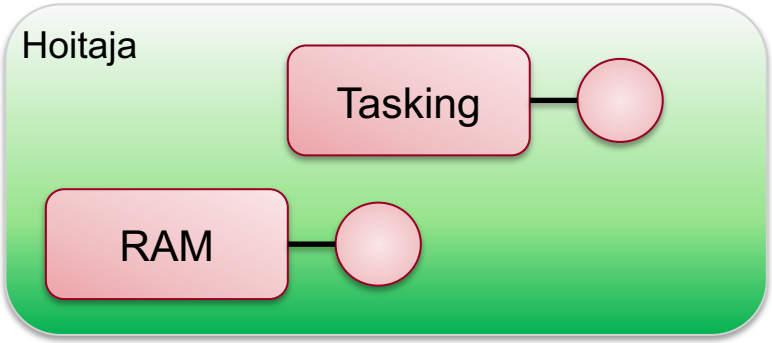
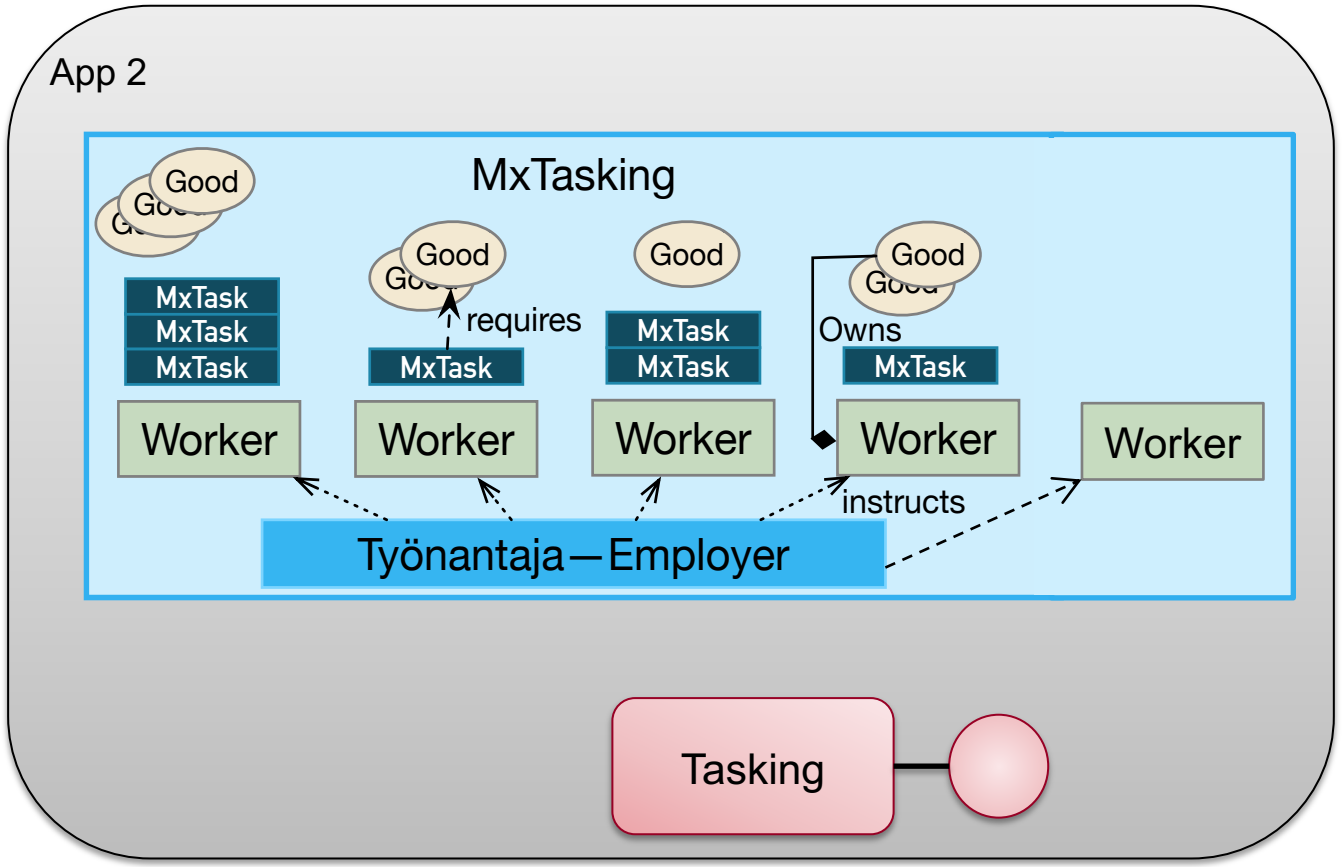
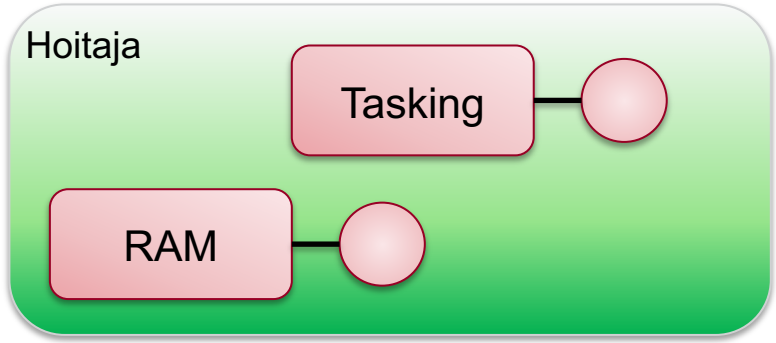




Microhypervisor

Resource Allocation Negotiation





Microhypervisor

Summary

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  - While increasing resource utilization to save costs

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  - Must optimize performance and minimize interference of workloads
  - While increasing resource utilization to save costs
- Traditional OSes lack interface to communicate resource demands of workloads accurately
  - => Often, over- and under-provisioning of resources leading to waste and overloads
- The MxKernel architecture provides a remedy to these challenges
  - With dynamic resource containers for workloads and their tasks
  - MxTasks as verbose control flow abstraction
  - Component-based architecture allowing for tailored resouce management within workloads

Thank you for your attention

Prototypical implementation of the MxKernel Architecture

- github.com/mmueller41/genode
- github.com/mmueller41/NOVA

EalánOS

- github.com/jmuehlig/mxtasking
- dbis.cs.tu-dortmund.de

MxTasking

Get in touch

Embedded Software Systems

- ess.cs.uos.de
- www.uni-osnabrueck.de

SPP2037 SCALABLE DATA MANAGEMENT FOR FUTURE HARDWARE

- mxkernel.org
- dfg-spp2037.org

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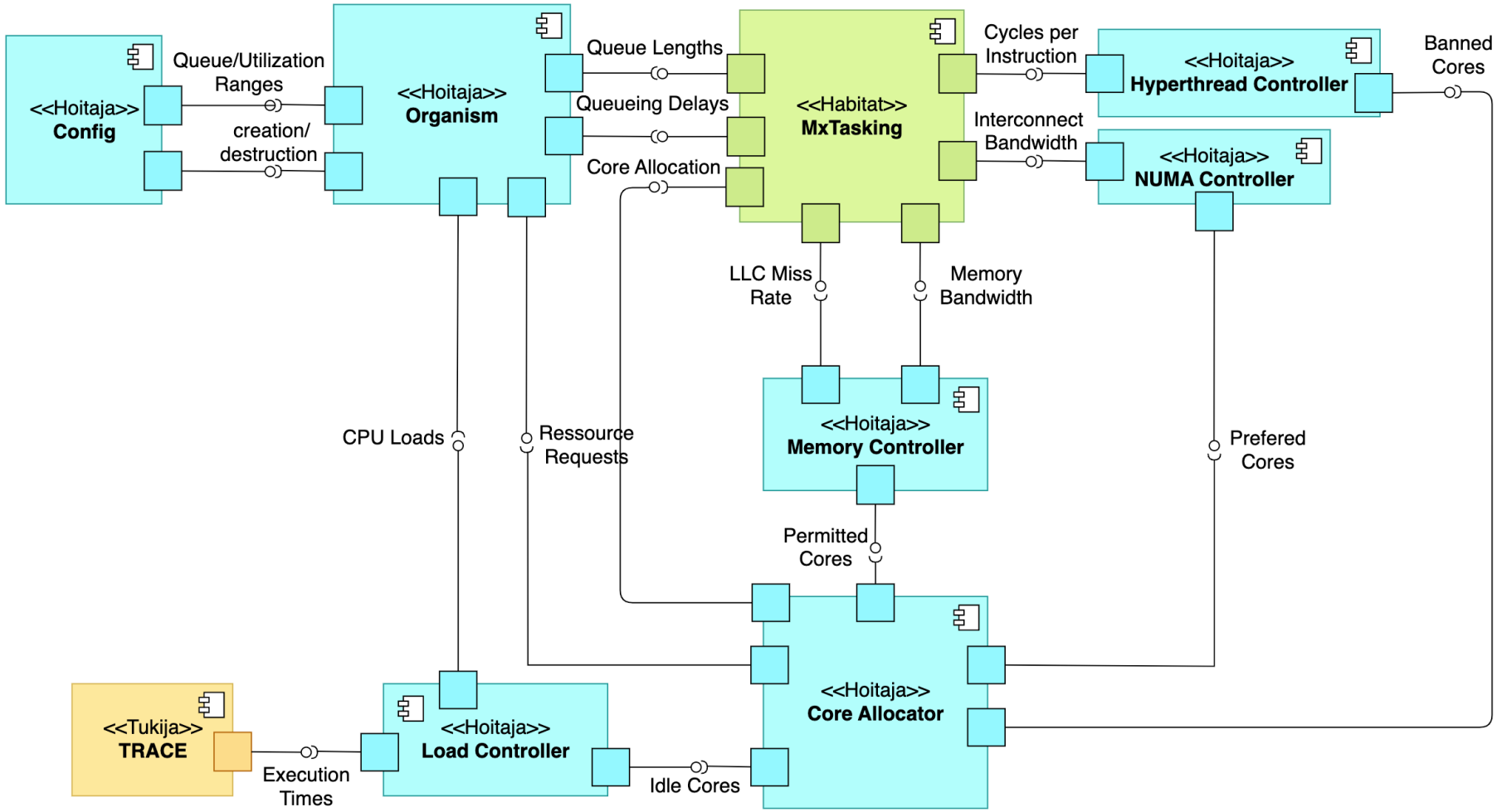
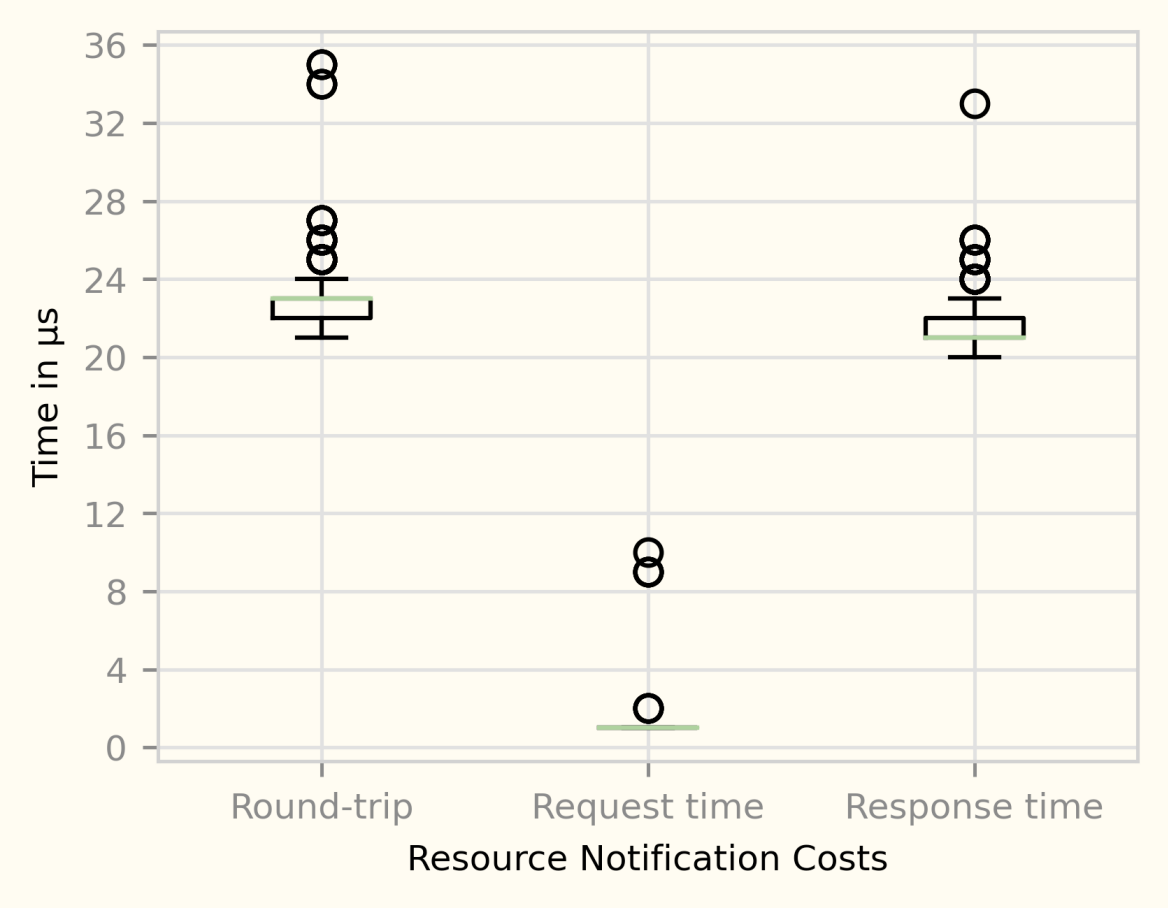
Hoitaja's Architecture



Preliminary Evaluation: Notification Mechanism



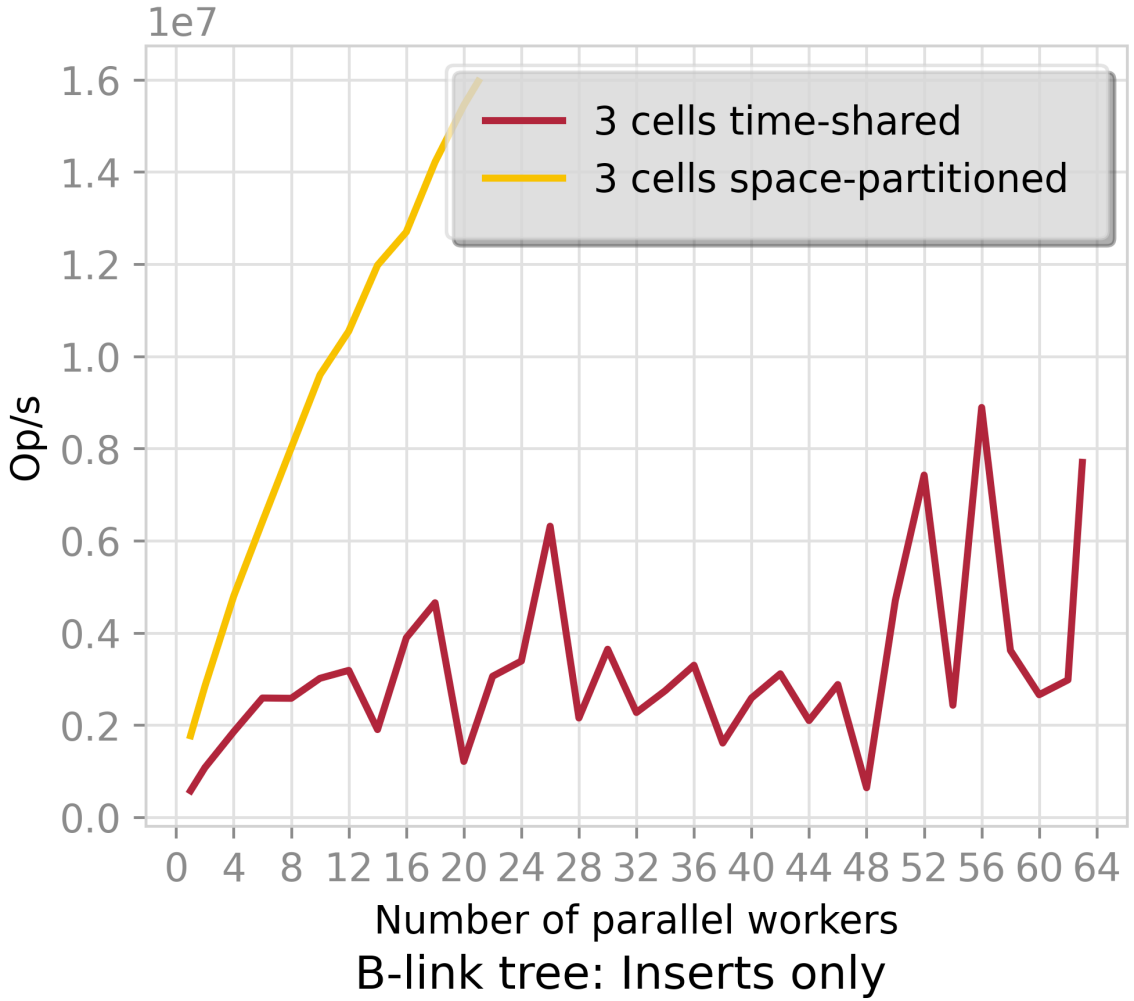
- Hoitaja sends notification to cell, cells sends acknowledege when notification received
- 5000 notifications total
- 10ms interval between notifications

Example: B-link tree benchmark

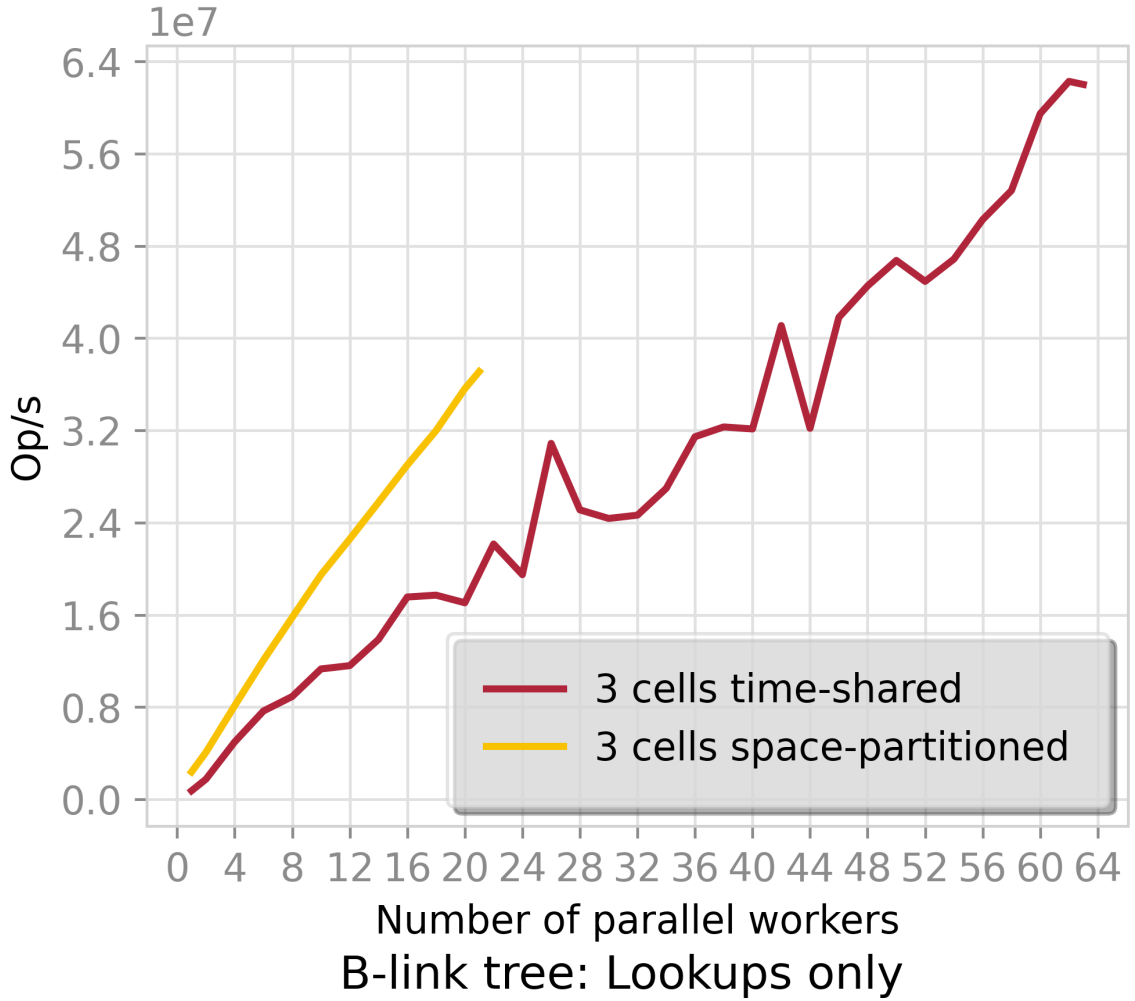
- Investigate how **throughput** of benchmark is **affected** when we run **multiple instances**
  - On the **same** set of CPU cores
  - On a **disjunct** set of CPU cores
- **Which** scenario will yield the **higher** throughput at the respective **maximum** of cores?

- B-link trees are a wide-spread **datastructure** for **indexing** in **database** systems.
- The B-link tree benchmark is based on **YCSB**, a **common benchmark** for **key-value stores**.

Example: Results



B-link tree: Inserts only



B-link tree: Lookups only