VMPlaceS: A Generic Tool to Investigate and Compare VM Placement Algorithms

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ASCOLA Research Group
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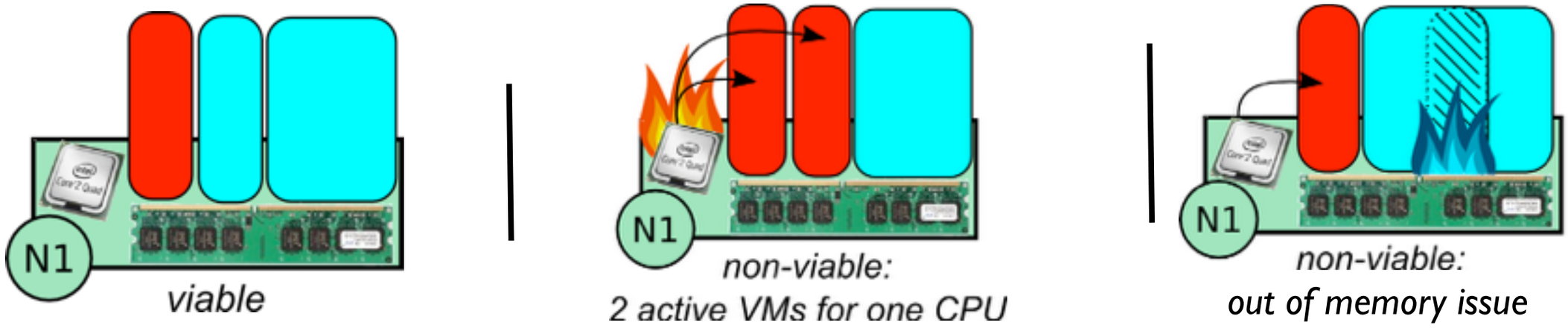
Agenda

- VM Placement Problem and challenges
- VMPlaces - a generic simulator to evaluate and compare VM placement strategies
- Use-case: Evaluation of three strategies aiming at mitigating CPU violations
- Conclusion/Future work

VM Placement Problem

- Fine management of resources: maximize the usage of CC resources while guaranteeing VM resource requirements (aka, SLAs)

- Find the ‘’right’’ mapping between needs of VMs and resources provided by PMs



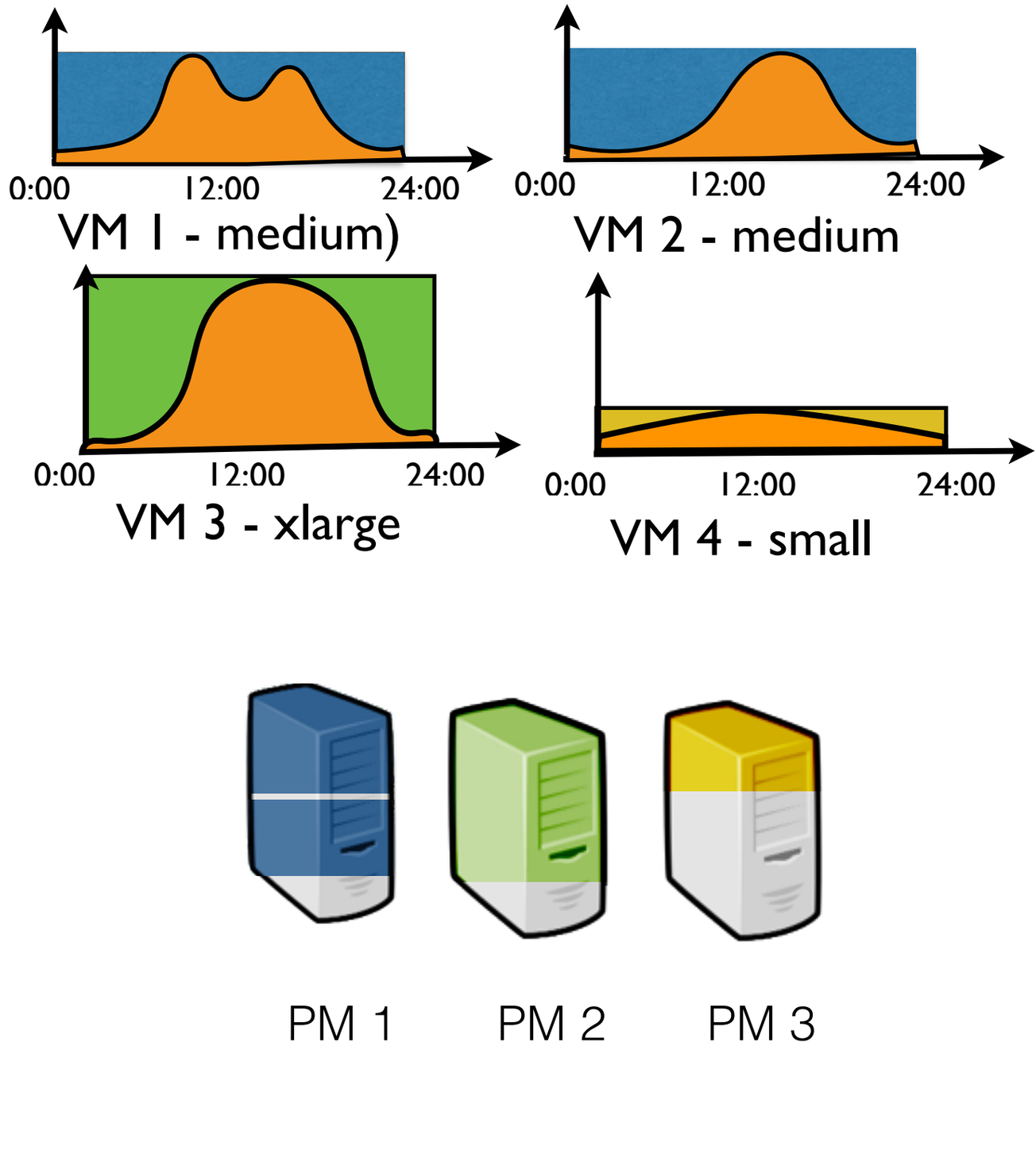
credits: F. Hermenier, OSDI poster session 2008

Challenge 1 - Fluctuations of VM Requirements

- Static placement policies (as delivered by most of the popular Cloud Computing management systems)

  ‘’Simple’’ but prevent CC providers to maximize the usage of CC resources (and thus their revenue)

- Advanced dynamic placement strategies to relocate VMs according to the scheduler objectives / available resources / waiting queue / ...



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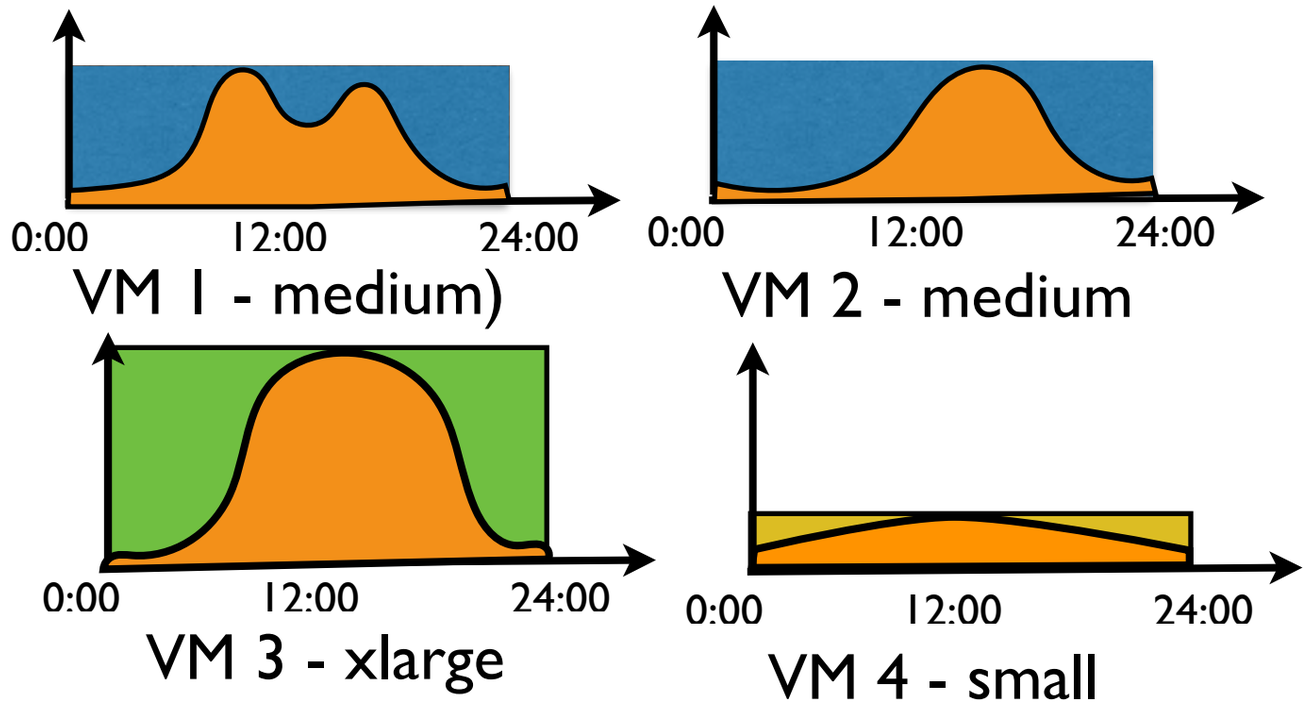

PM 1 PM 2

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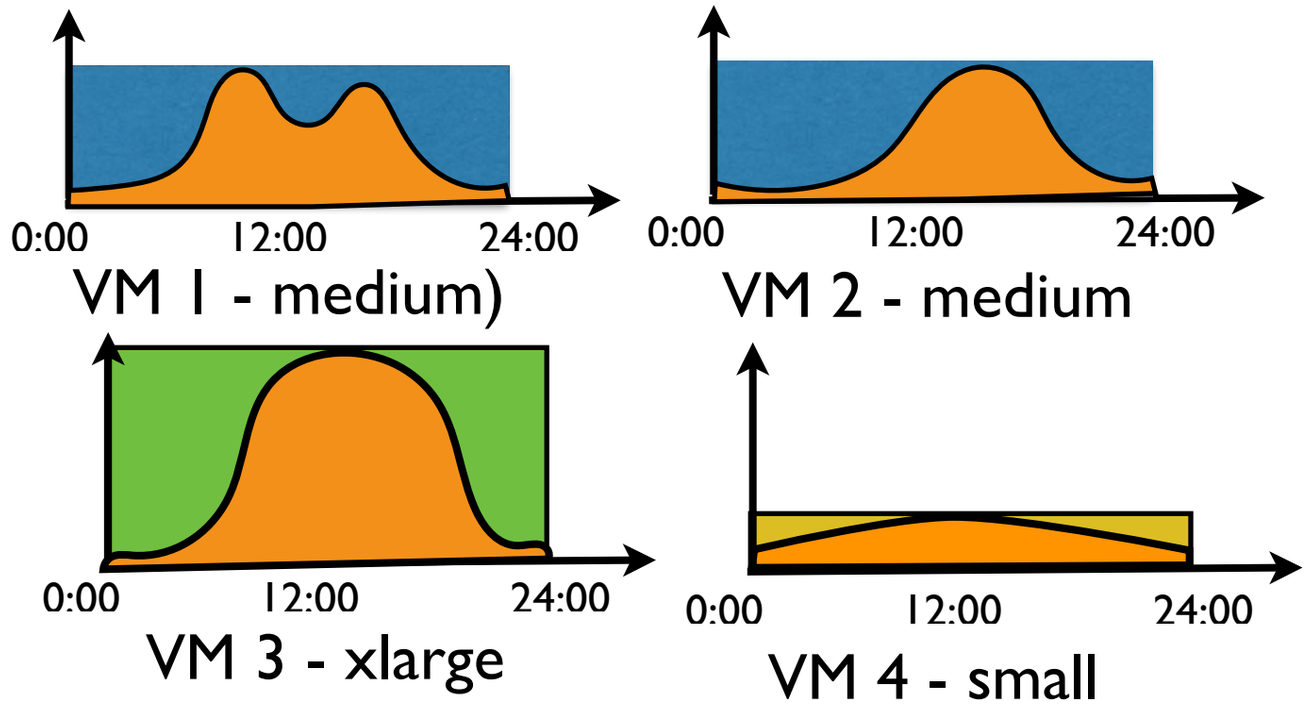

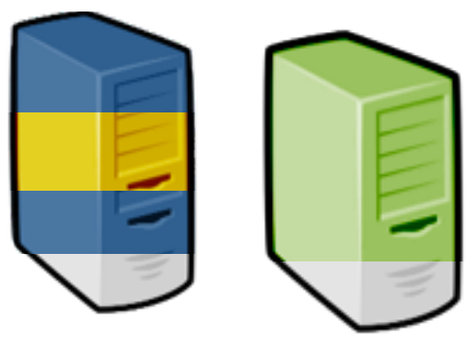

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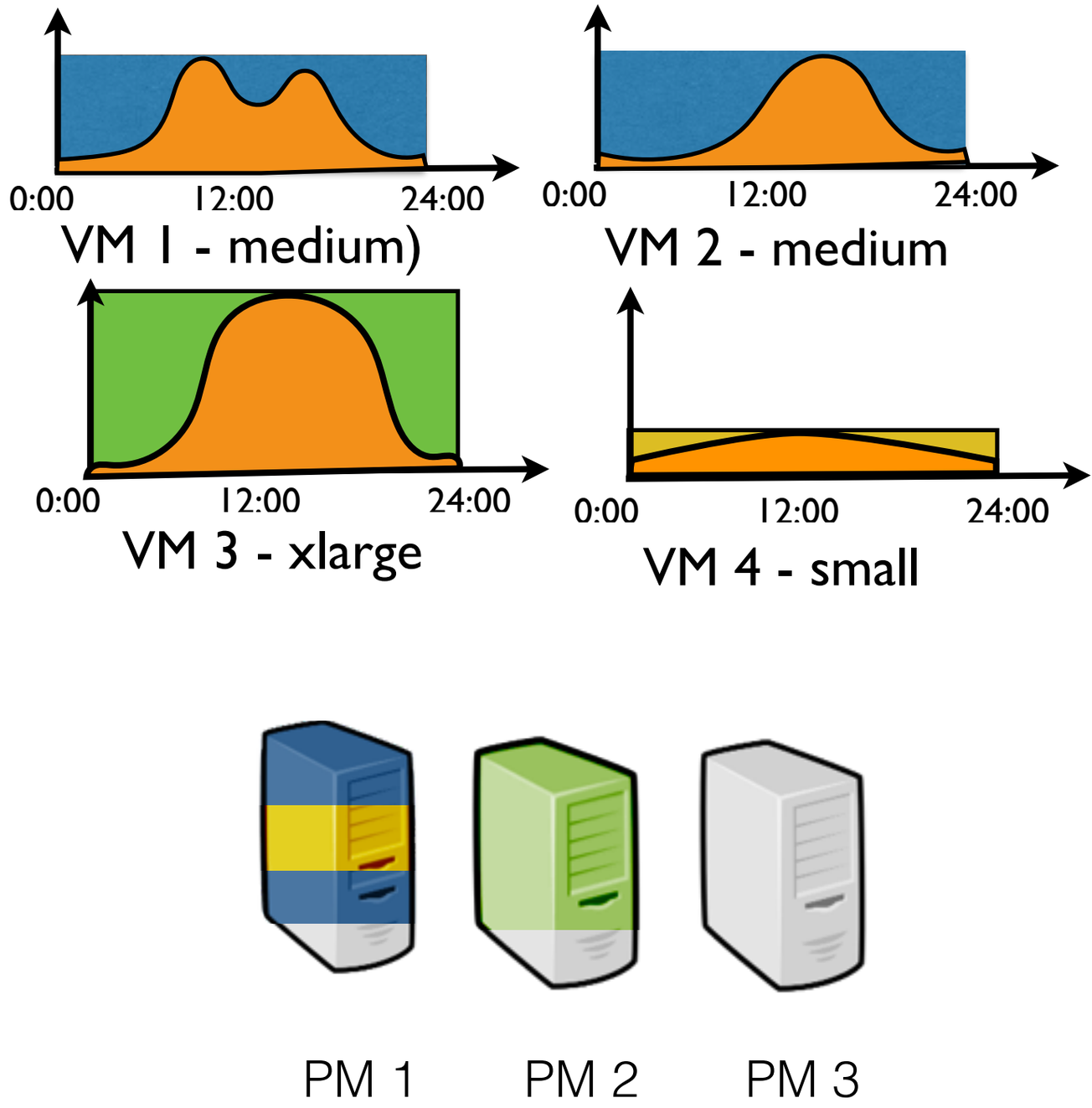

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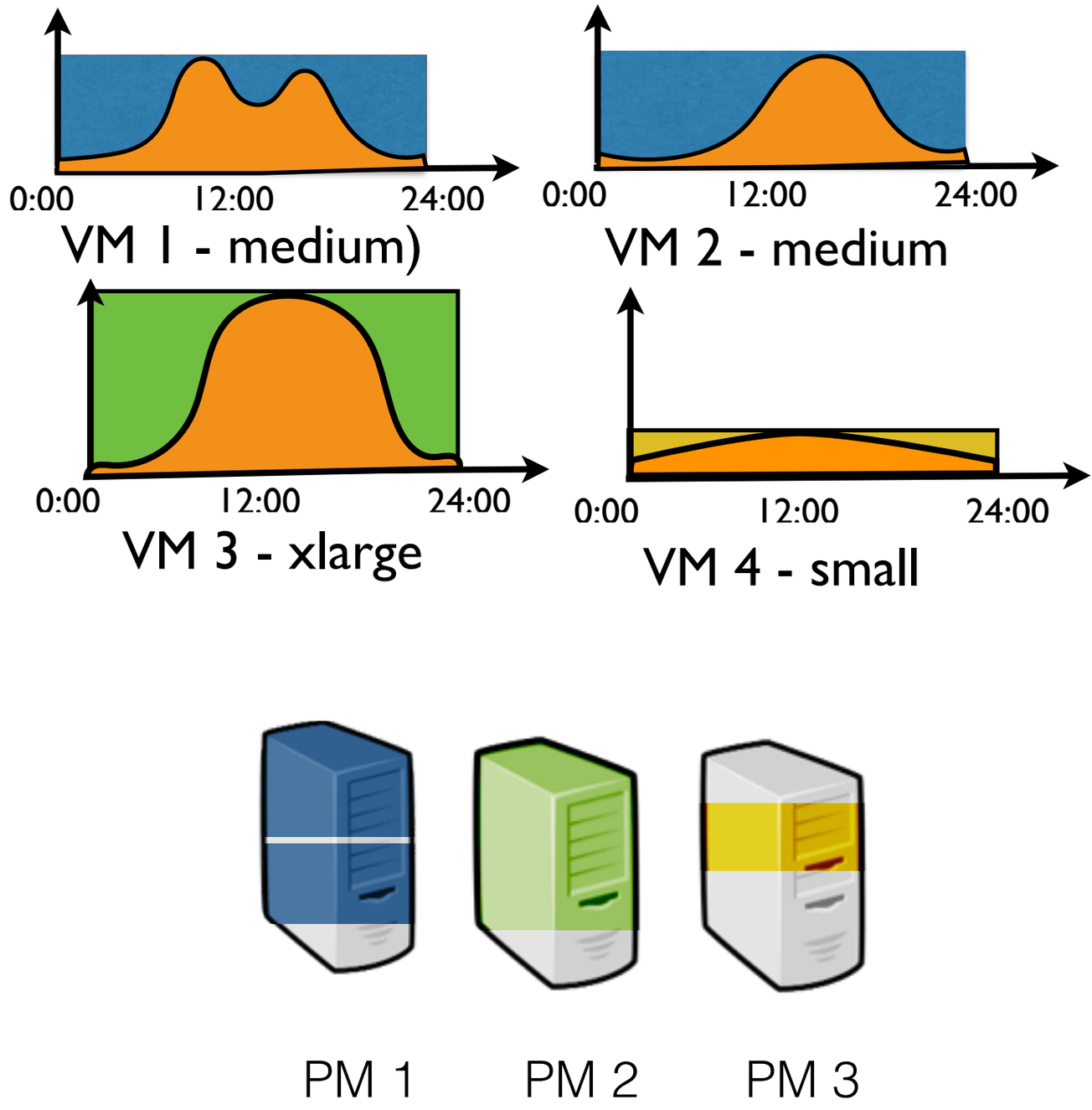

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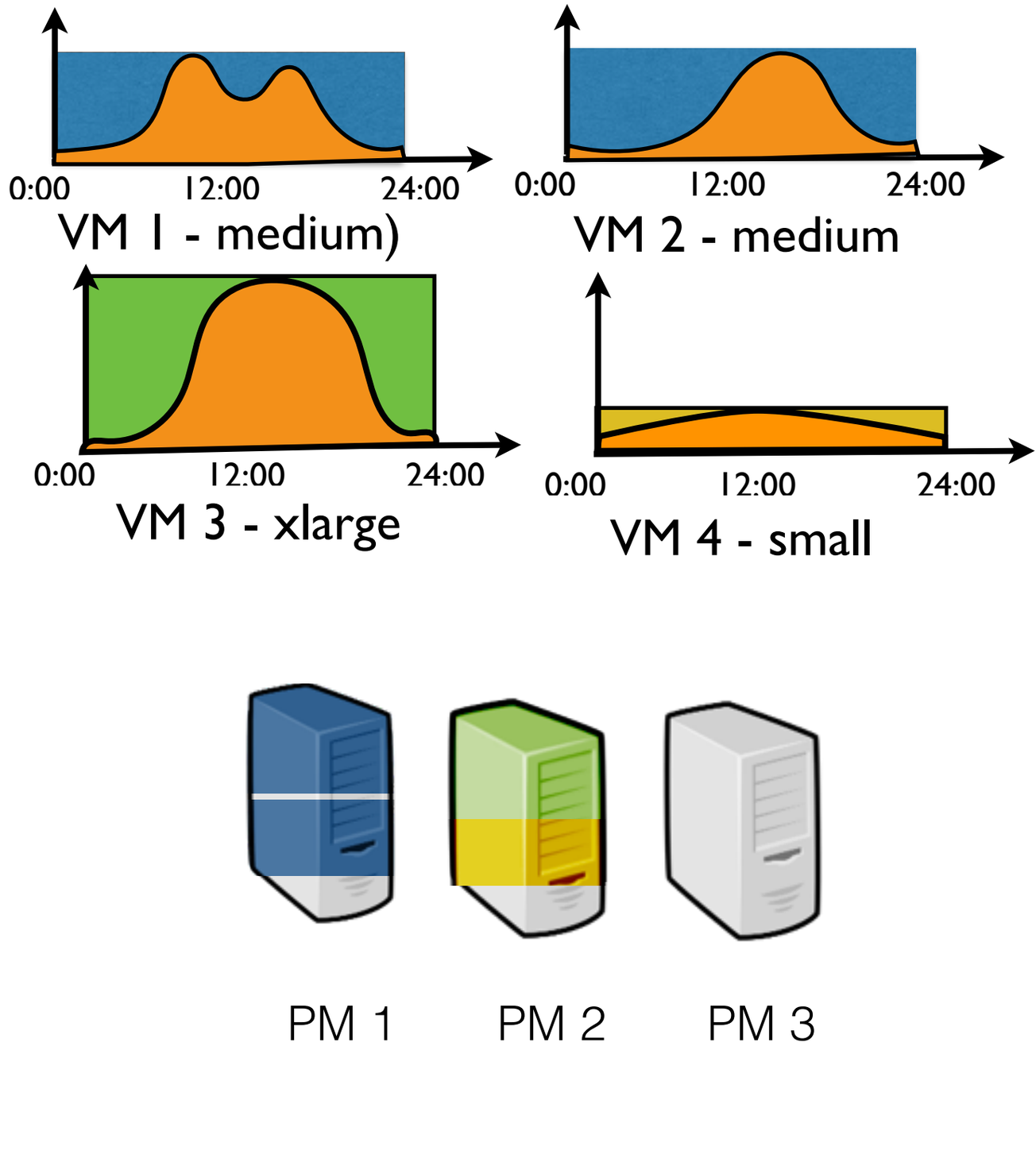
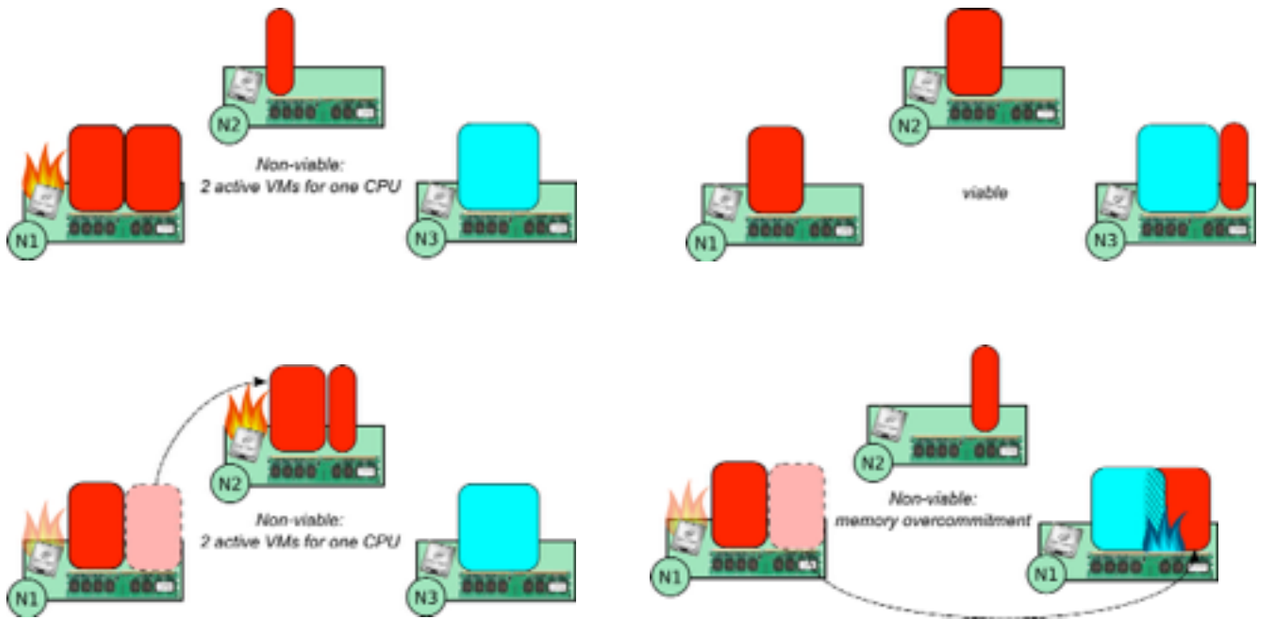
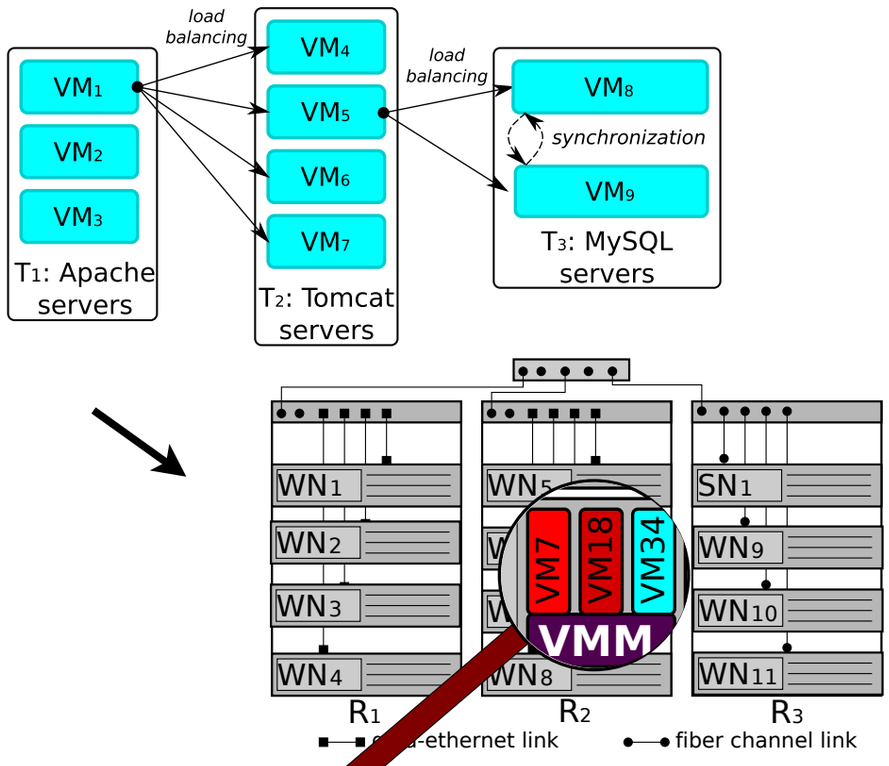


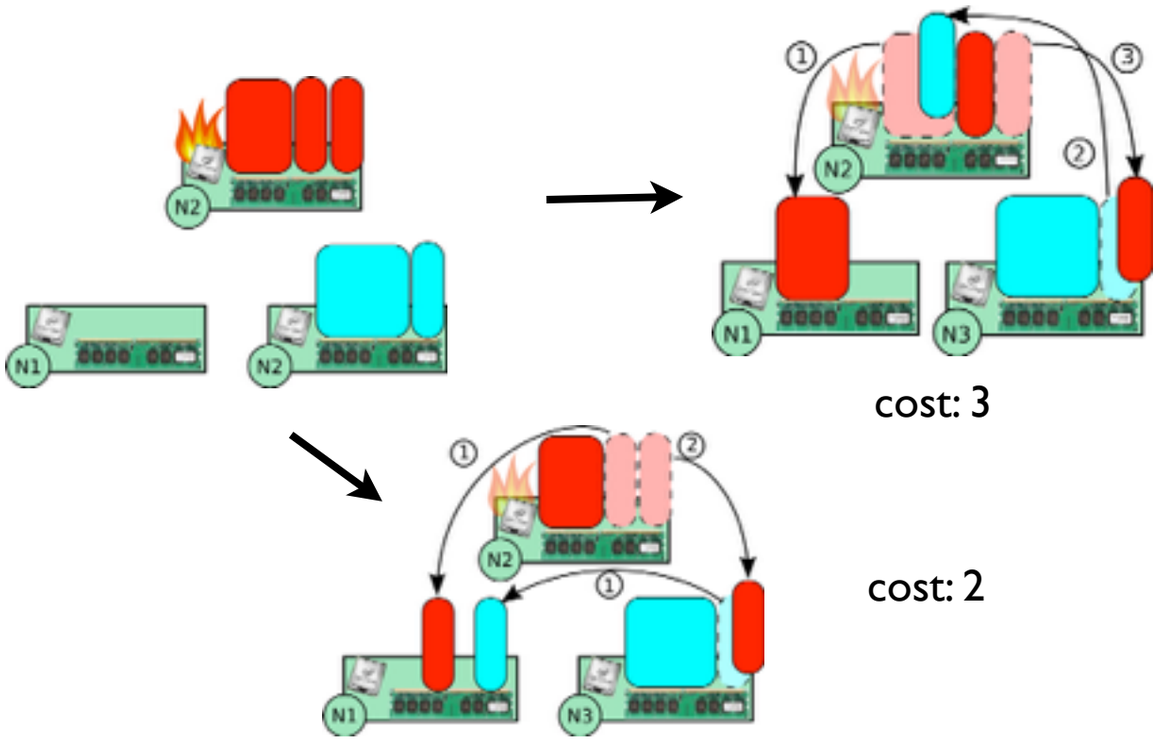
Challenge 2 - Manipulation constraints



Non-viable manipulations - SLA violations

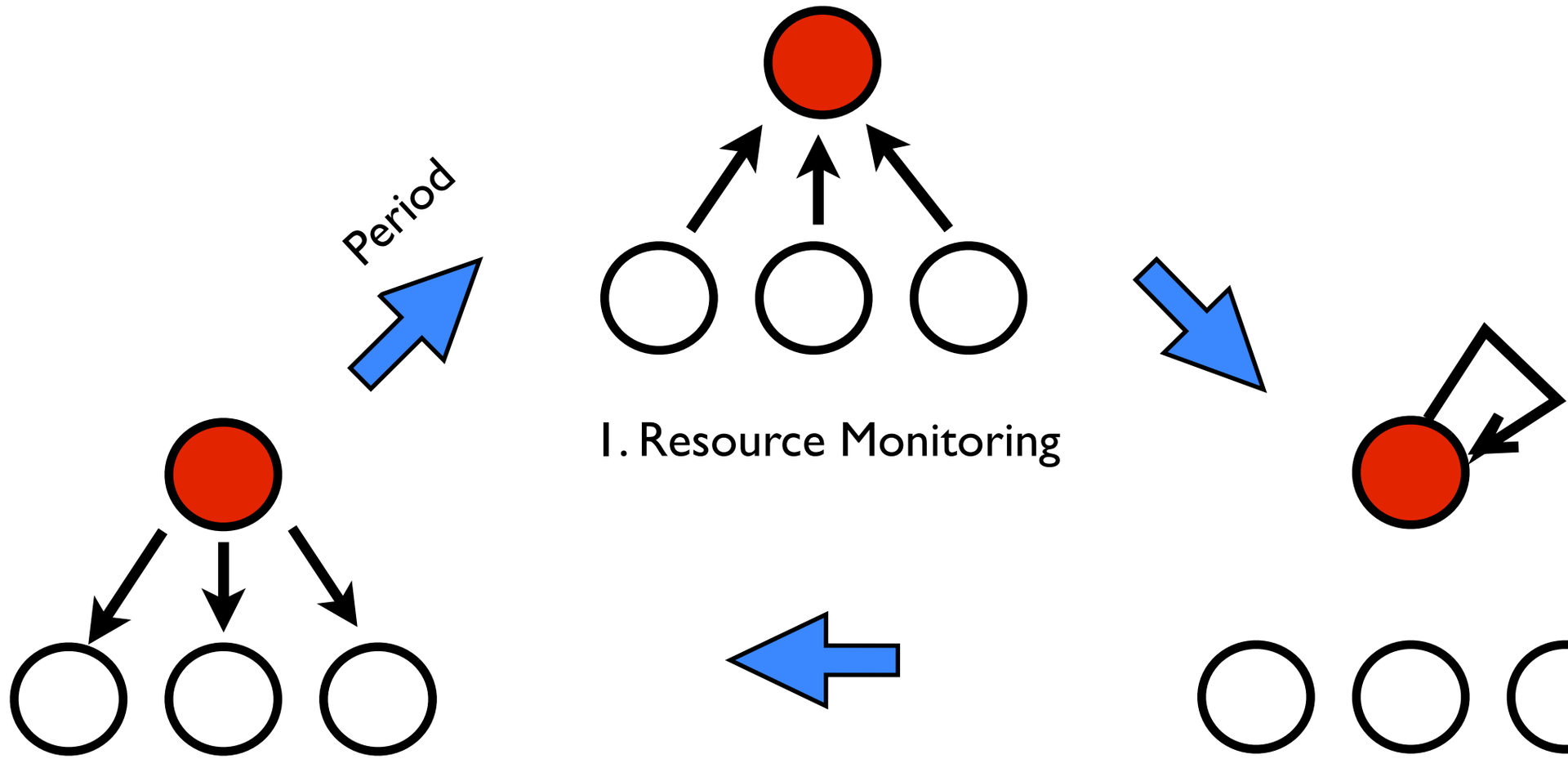


- Optimize the mapping according the needs of VMs, **their placement constraints** and the resources provided by PMs



credits: F. Hermenier, Sophia Antipolis University, www.btrplace.org

Challenge 3 - Reactivity/Scalability Criteria



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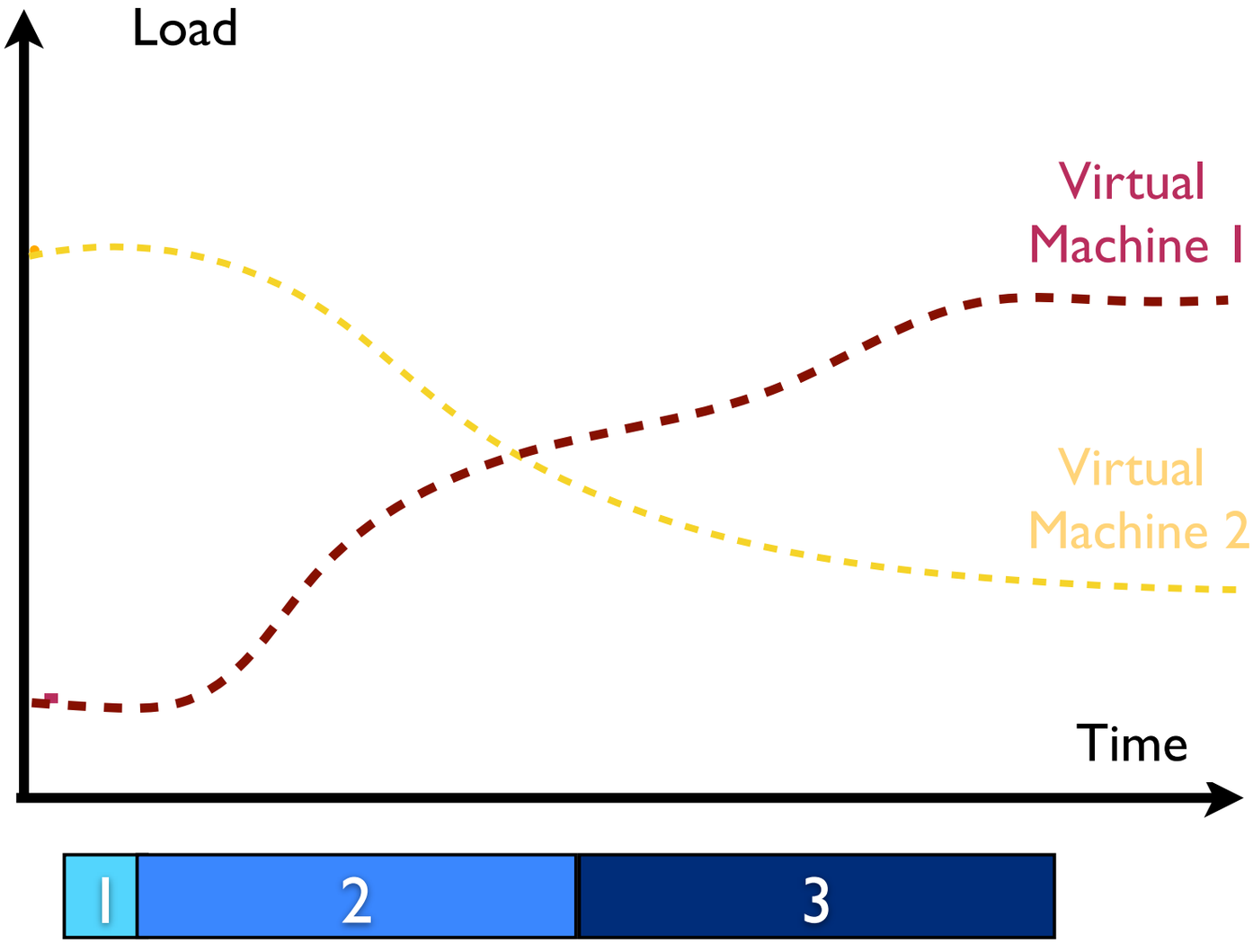

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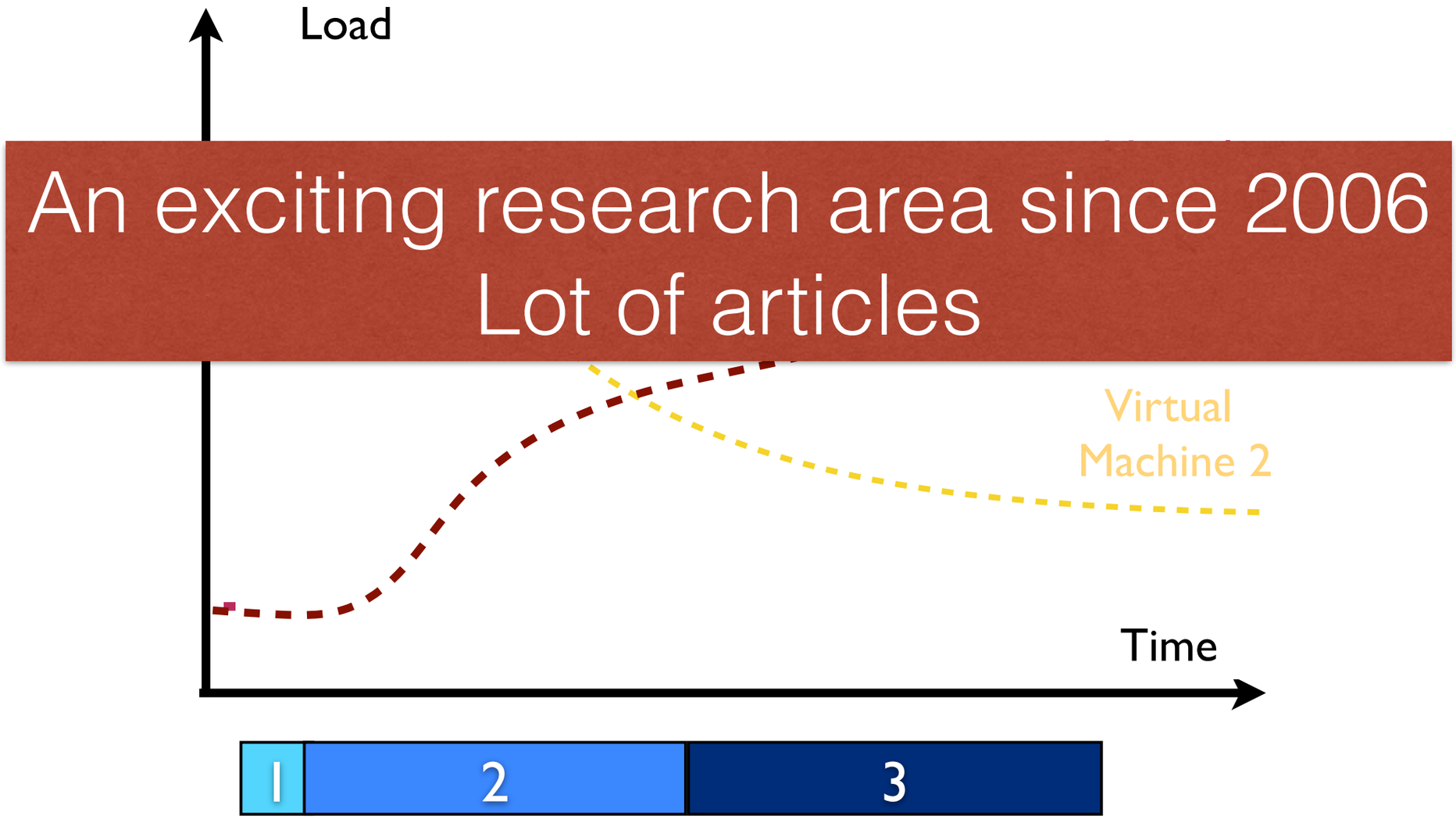

VM Placement Algorithms

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A mathematical programming approach for server consolidation problems in virtualized data centers [PDF] from tum.de
B Speitkamp, M Bichler - Services Computing, IEEE ..., 2010 - ieeexplore.ieee.org
Abstract—Today's data centers offer IT services mostly hosted on dedicated physical servers. **Server** virtualization provides a technical means for **server consolidation**. Thus, multiple virtual servers can be hosted on a single **server**. **Server consolidation** describes ...
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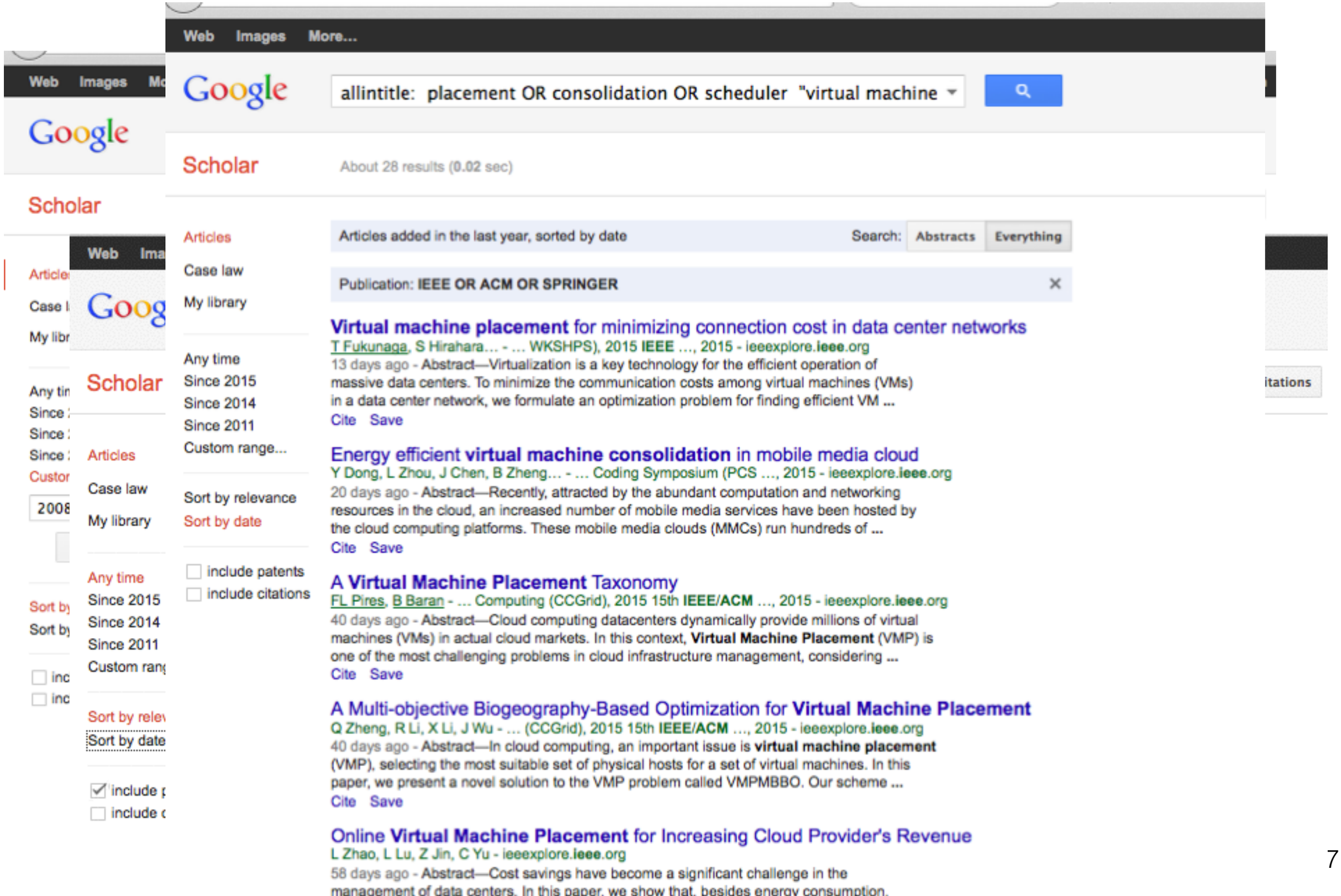
VM Placement Algorithms



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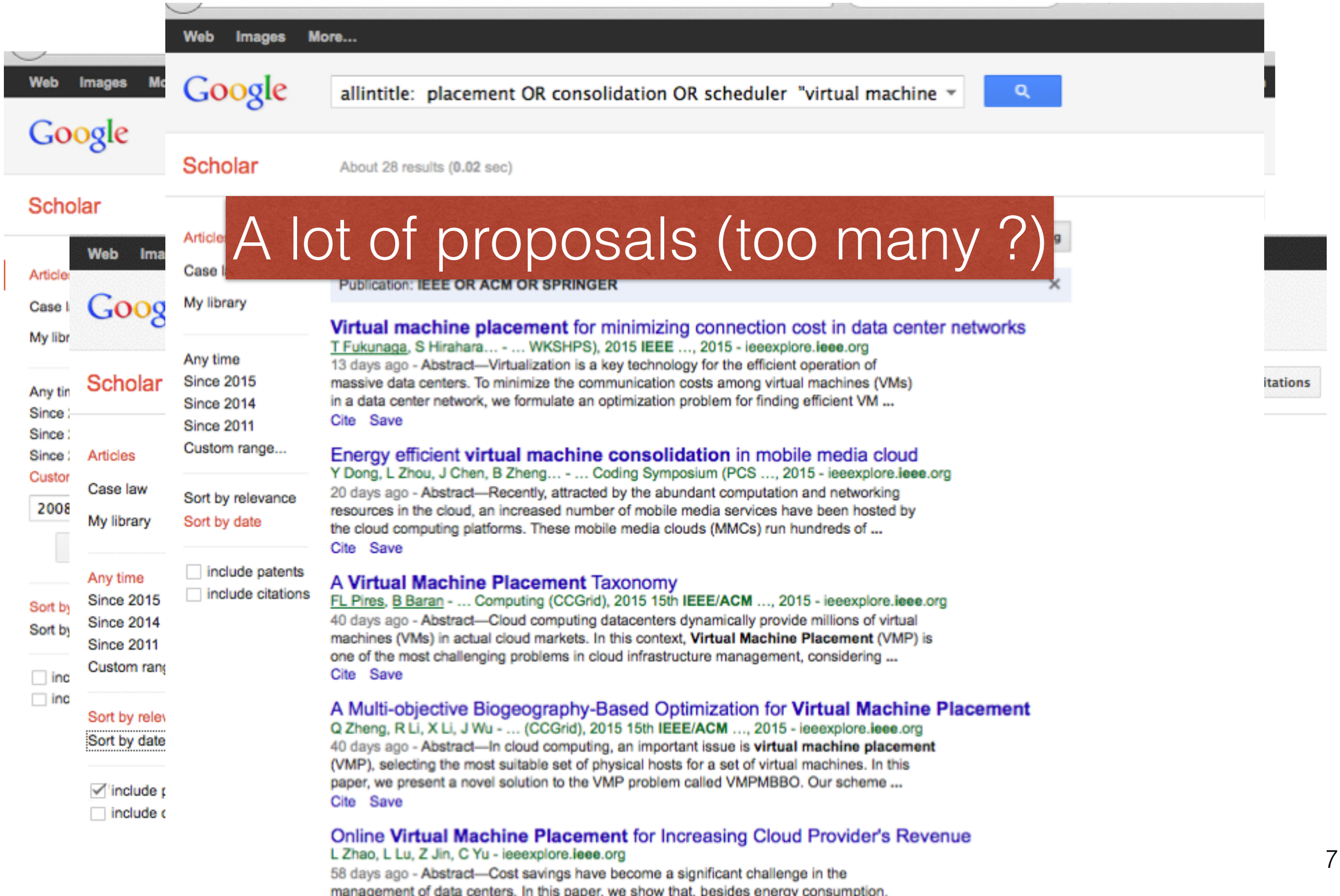

A lot of proposals (too many ?)

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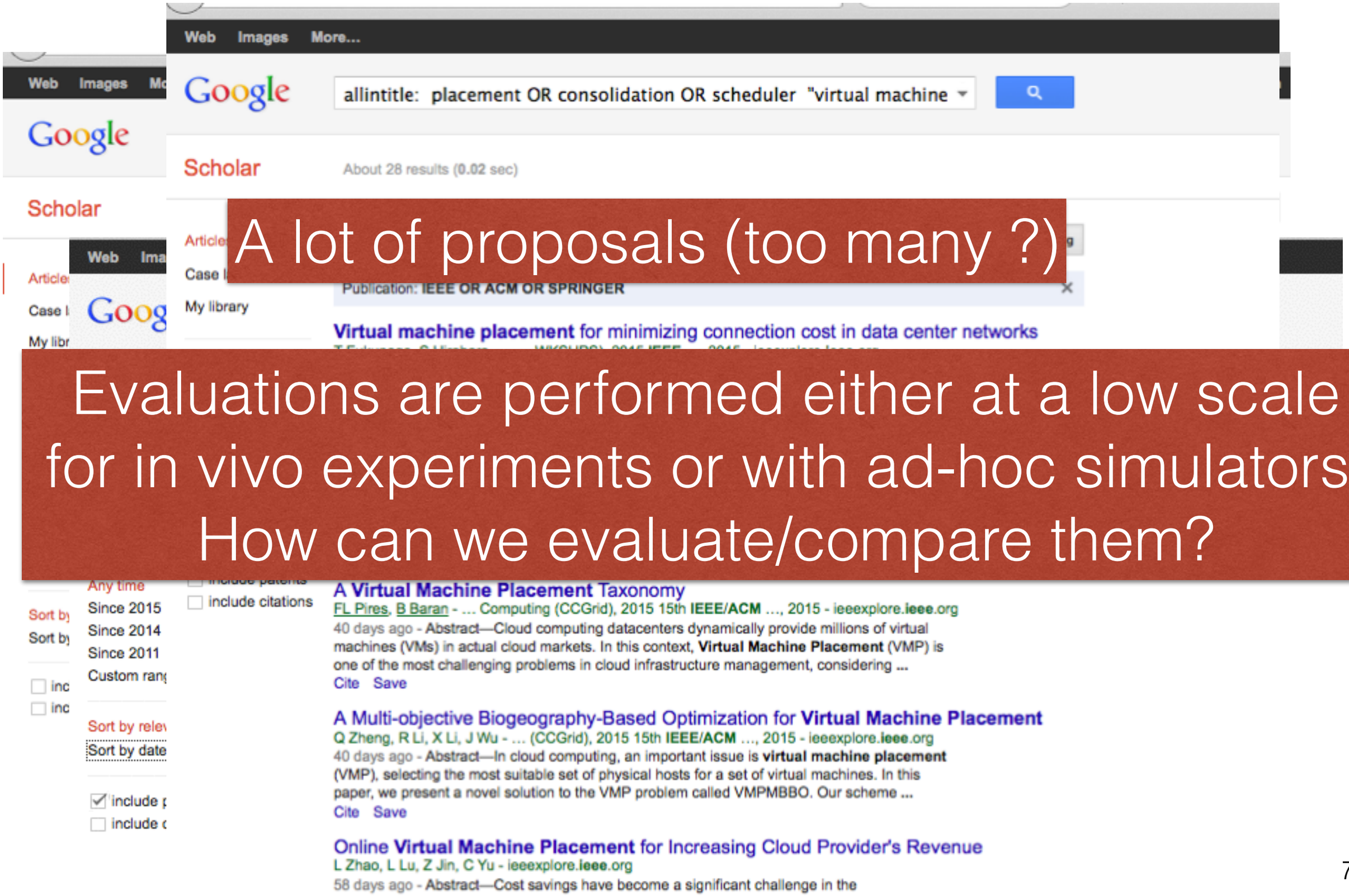

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Evaluations are performed either at a low scale for in vivo experiments or with ad-hoc simulators. How can we evaluate/compare them?

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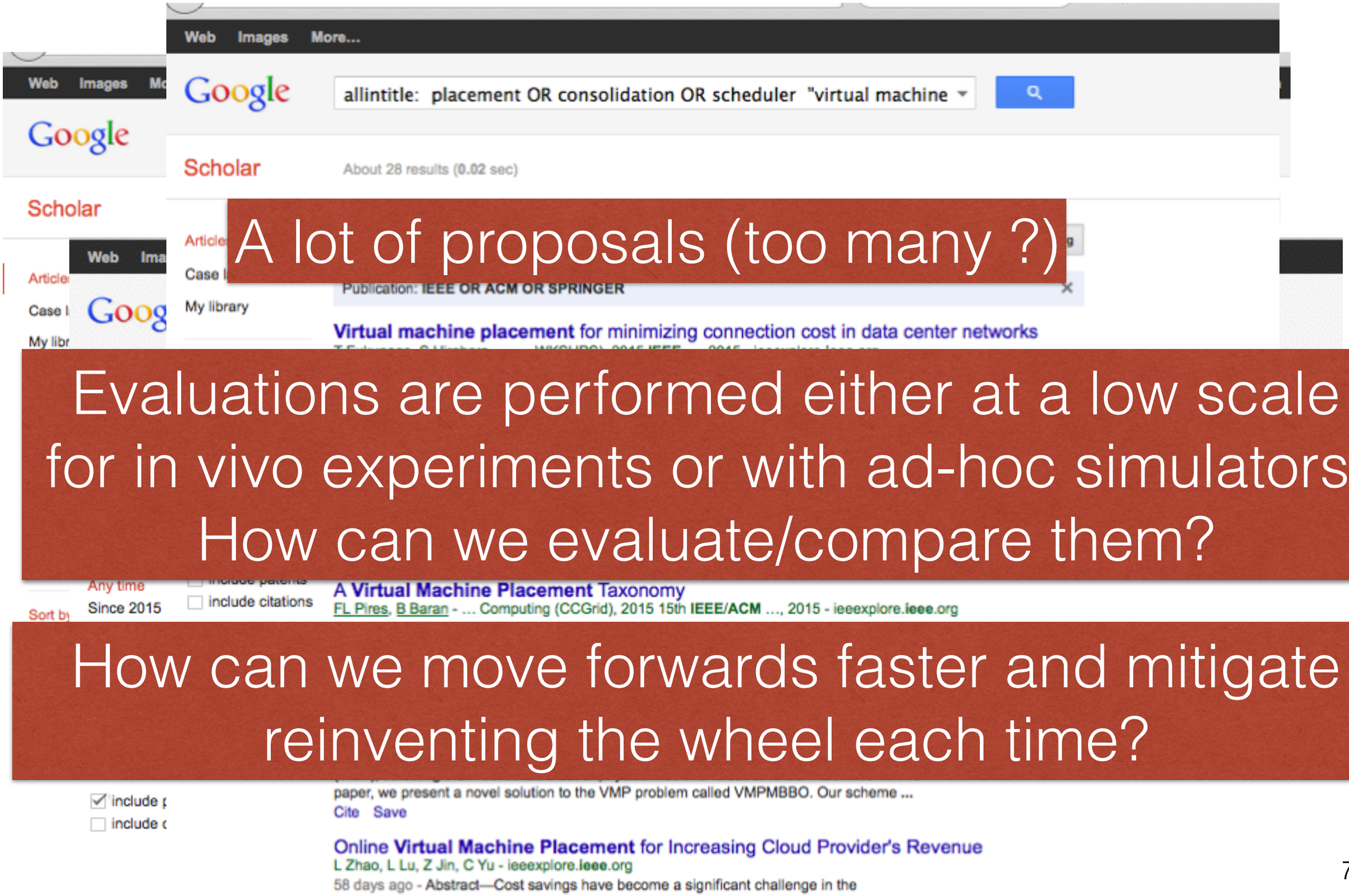

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Evaluations are performed either at a low scale for in vivo experiments or with ad-hoc simulators. How can we evaluate/compare them?

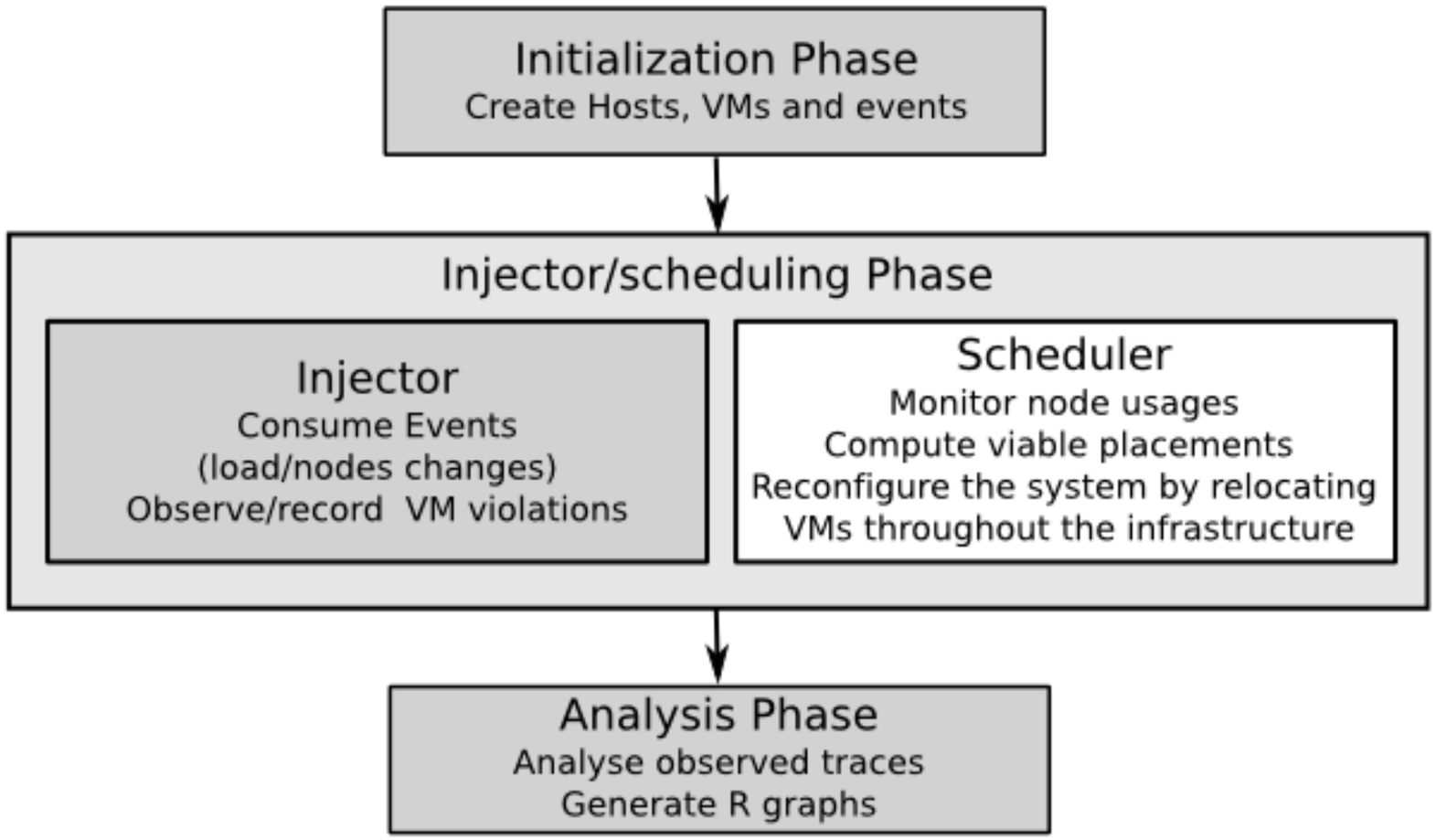
How can we move forwards faster and mitigate reinventing the wheel each time?

VM PLACEment Simulator

- A dedicated simulator to
  - Evaluate/compare VM placement policies at large-scale
  - Relieve researches of the burden of dealing with VM creations and workload fluctuations
- Leveraging latest SimGrid VM extensions
  - Enabling researchers to control VMs in the same manner as in the real world (*e.g.*, create/destroy, start/shutdown, suspend/resume and migrate)
  - Accurate live migration model (implementing the pre-copy strategy) The time and the resulting traffic of a migration is computed by taking into account competition arising in the presence of resource sharing and the memory refresh rate [CloudCom2013].

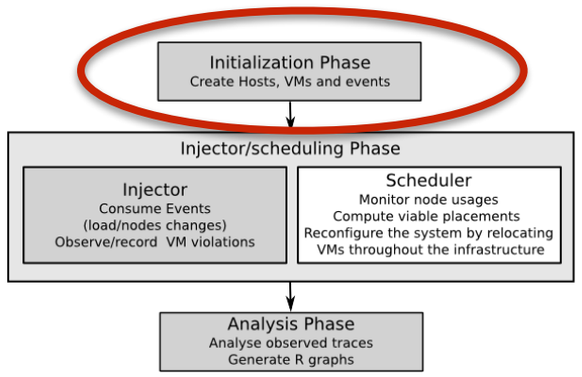
VMPlaceS - Overview

- A three steps simulation



- Researchers develop their scheduling algorithm in JAVA (or SCALA) using the SimGrid MSG API and a more abstract interface (XHost, XVM and SimulatorManager)

VMPlaceS - Initialization Phase



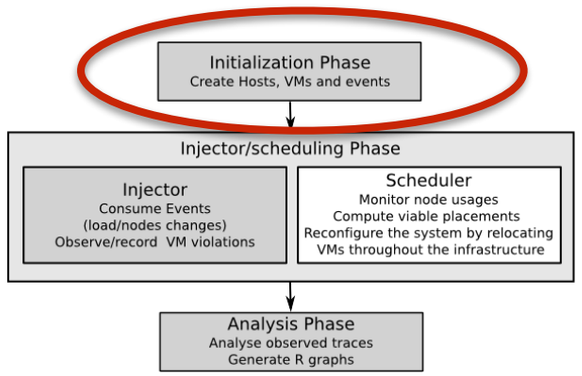
- Simulated infrastructure
  - Defined as input parameters : p hosts, s host(s), n VMs
  - Hosts are organized in forms of topologies (clusters being the most common ones but more complex structures can be defined to investigate federated scenarios for instance)

- VMs
  - Defined as input parameters through classes: **`nb_cpus:ramsize:net_bw:mig_speed:mem_speed`**
  - Assigned in a round robin fashion to the p hosts
  - VMs starts with a CPU consumption of 0 evolving during the simulation according to the events injection

VM Classes definitions

small-1:1:1024:125:125:80
medium-1:2:4096:125:125:40
medium-2:2:4096:125:125:60
medium-3:2:4096:125:125:80
large:4:8192:125:125:60
xlarge:8:16384:125:125:50

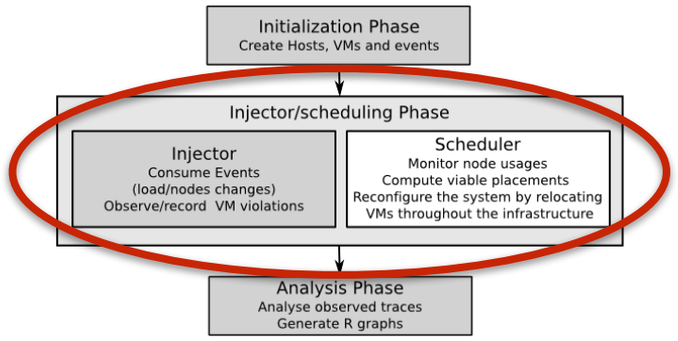
VMPlaceS - Events Generation



- Generation of the events queue at the end of the initialization phase
  - CPU load change events
    - Generated in order to change the load of each VM every `t` seconds on average (`t` being a random variable following an exponential distribution with rate λt)
    - The CPU load evolves according to a Gaussian distribution (defined by μ and σ)
  - Node apparition/removal events have been added since the submission (other events can be easily added for instance to stress other dimensions).
- Once the global event queue is ready and the VMs have been started, the evaluation of the scheduling mechanism can start for the given duration.

VMPlaceS - Injector/Scheduling Phase

- Injector



  - It consumes the events

  - Changes on the cpu load lead to SLA violations but also modify the time to migrate VMs from one PM to another one.

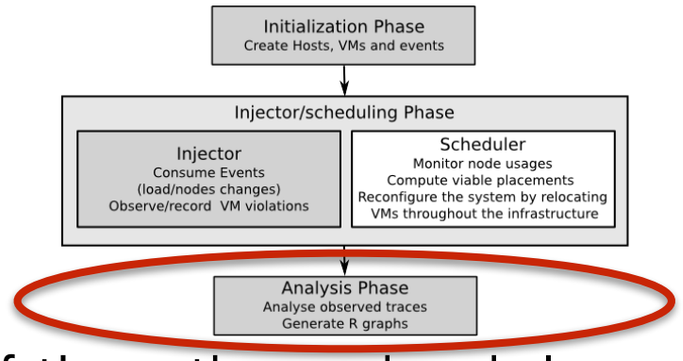
- Scheduler

  - Implemented by researchers/end-users

  - The computation phase of the VMPP is really performed (i.e., VMPlaces really invokes the scheduler)

  - Apply reconfiguration plans by invoking resume/suspend/ migrate operations of SimGrid.

VMPlaceS - Trace Analysis

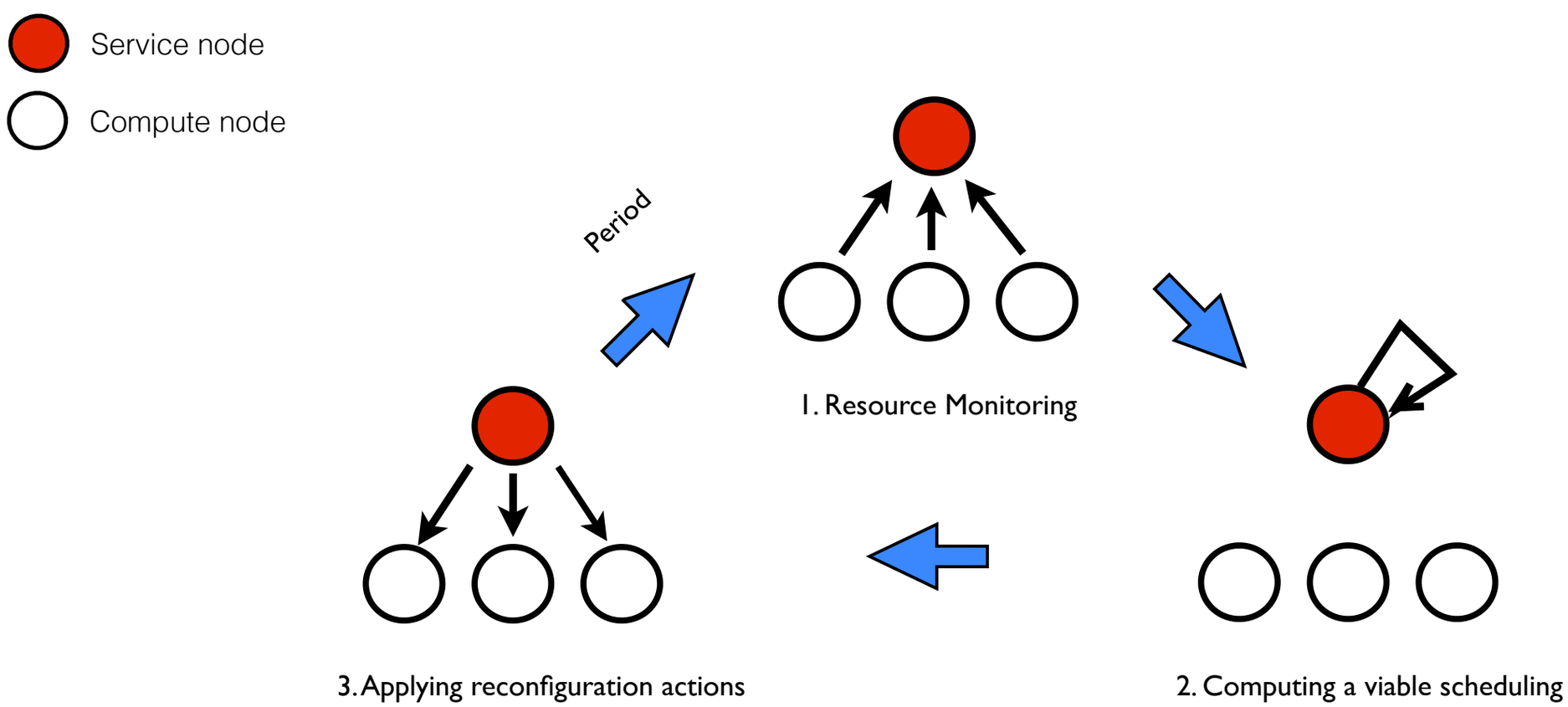


- VMPlaces records several metrics
  - load of VMs/hosts, number of migrations, number of time the scheduler has been invoked, number of times it succeeds or fails to resolve non viable violations, …

- Using an extending version of SimGrid's TRACE module
- Delivering a JSON trace file which is then consumed by R to deliver tables/graphs
  - Duration of violations per VMs, PMs and overall (**μ** and **σ**), Duration of scheduling computation/reconfiguration phases (**μ** and **σ**), …

VMPlaceS Accuracy

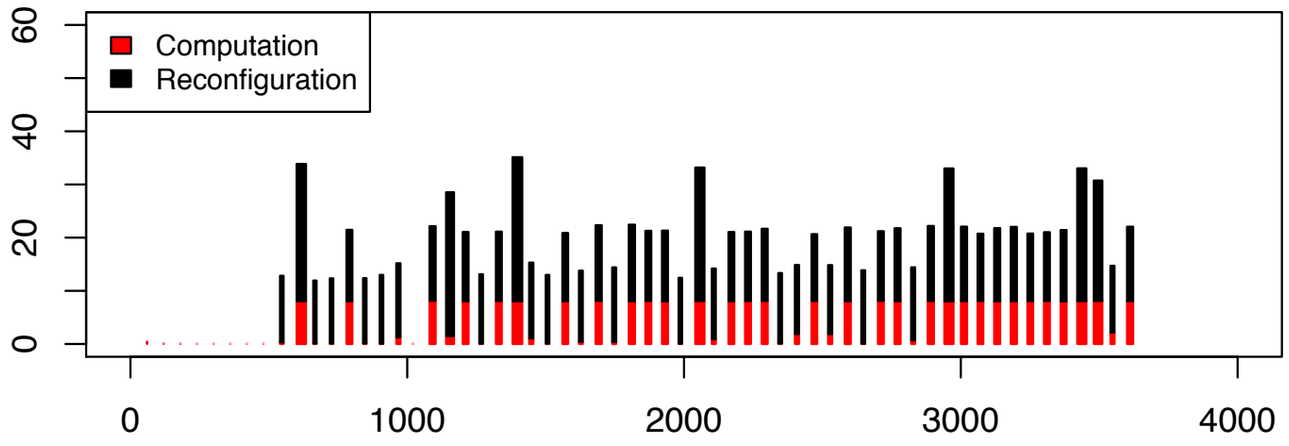
- Implementation of a dedicated version of VMPlaceS on Grid'5000
- Implementation of the Entropy proposal [VEE'09] in both systems
  - Scheduling algorithm based on the Choco solver (Constraint Programming)



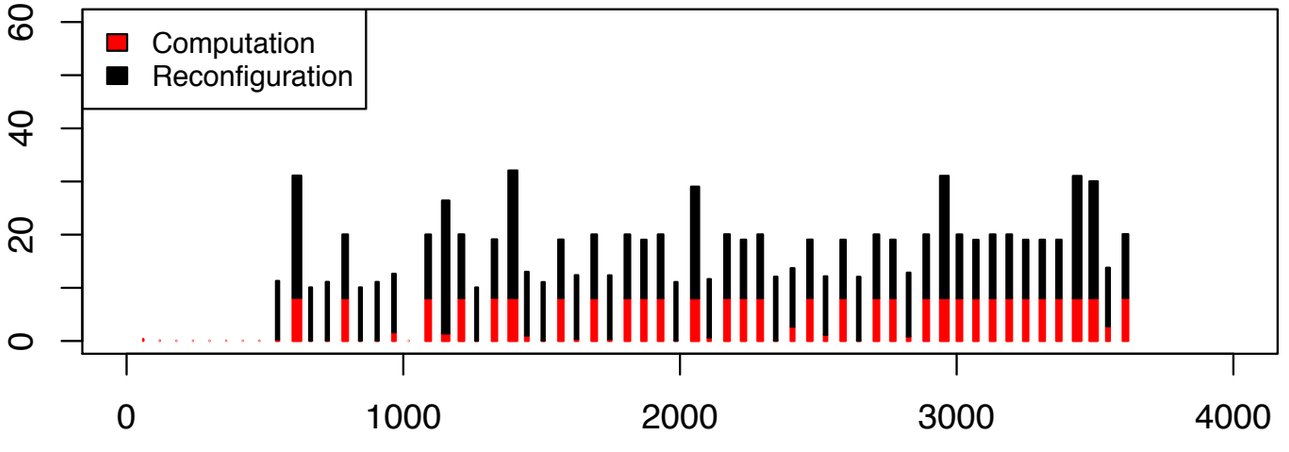
VMPlaceS Accuracy

- Comparison of the executions in both worlds (in vivo / simulated)
  - 32PMs, 4 cores/16GB/1Gbps per PM
  - VMs based on classes: 1:1GB:1Gbps:1Gbps:x with x varies between 0 and 80%
  - 192 VMs (6 per node) . $\lambda t=\#VMs/300$ $\mu=60$ and $\sigma=20$
  - The scheduling algorithm has been invoked every 60 seconds over a 3600 seconds execution
  - a dedicated tool to inject the load in each VM running on top of G5K according to the events consumed by the injector

Grid'5000



VMPlaceS



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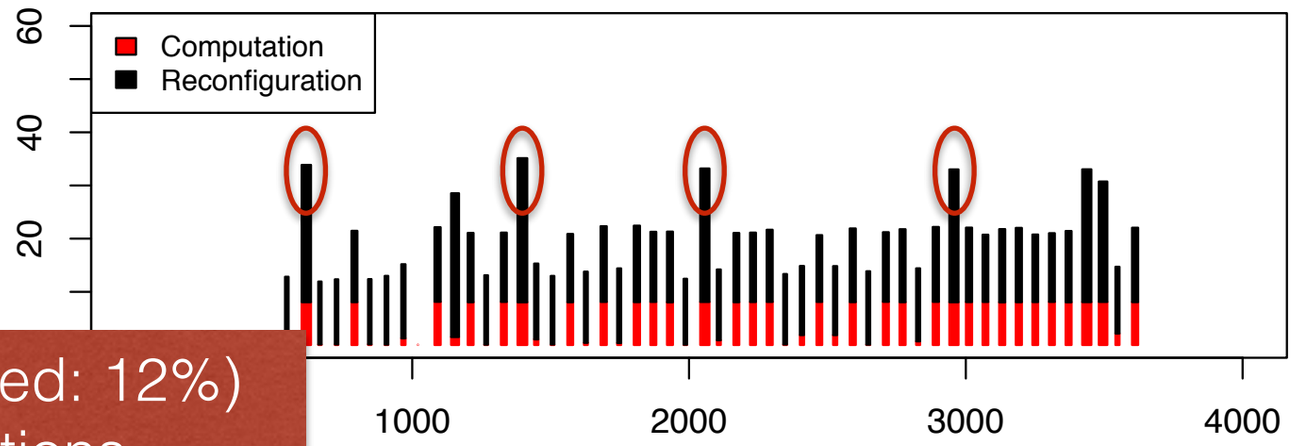
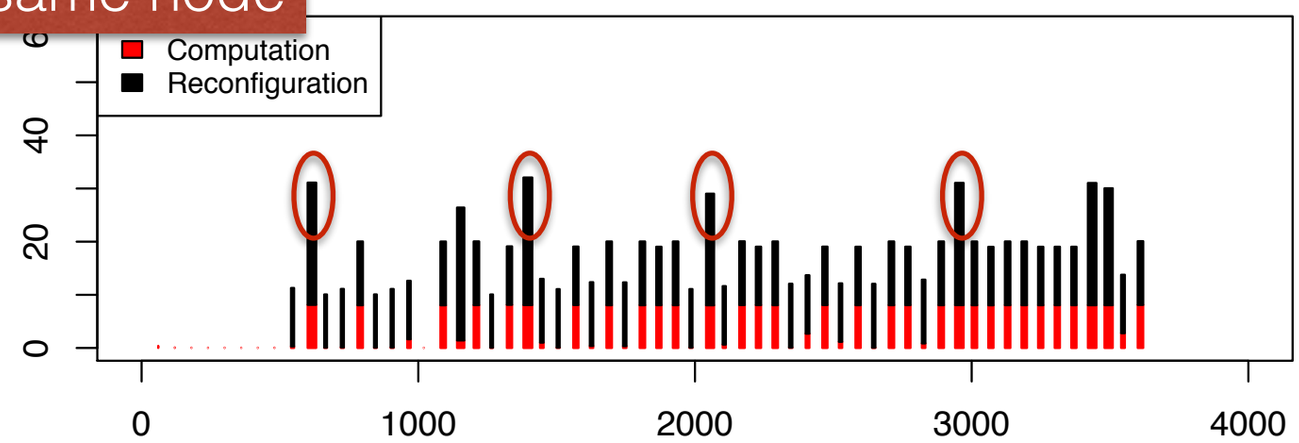


Difference between 6% and 18% (med: 12%)
Worst case when multiple migrations
are performed simultaneously to the same node

VMPlaceS

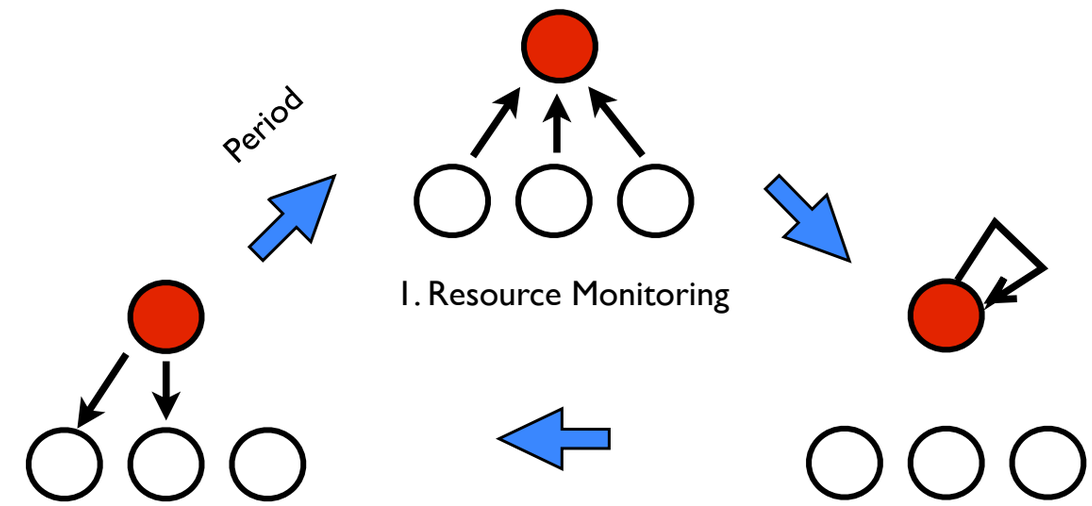


A First Use-Case

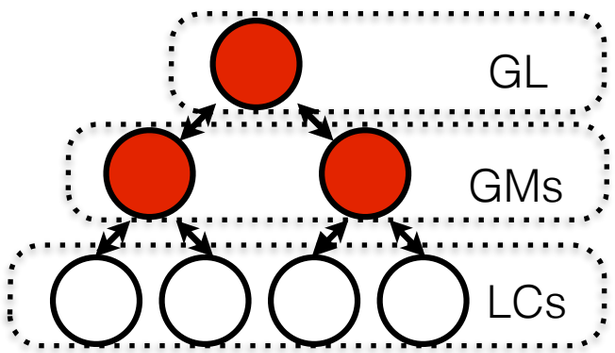
- To illustrate how different strategies can be evaluated/compared
- Three strategies aiming at mitigating CPU violations
  - Centralized (the Entropy proposal, [VEE'09])
  - Hierarchical (The Snooze proposal, [CCGRID'12])
  - Distributed (The DVMS proposal, [CCPE'12])
- For the sake of simplicity, the same scheduling algorithm has been used in each policy [VEE'09]

Implemented Strategies - Overview

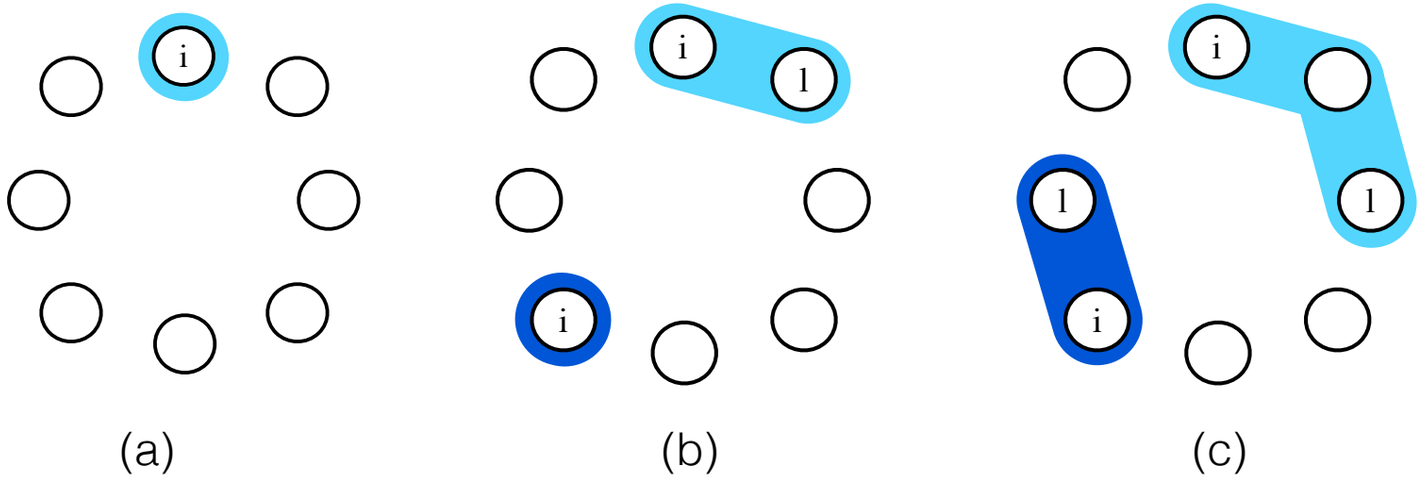
- Centralized

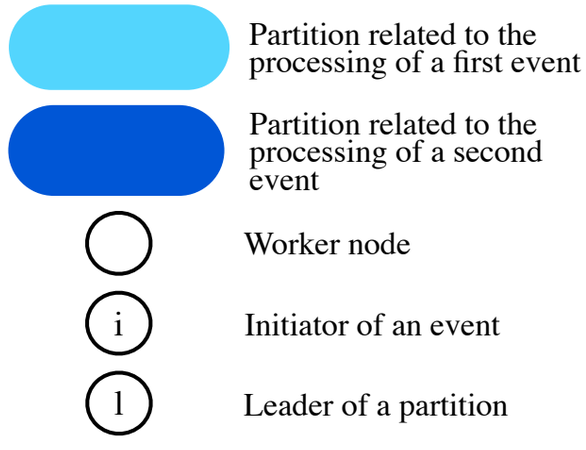


- Hierarchical



- Distributed





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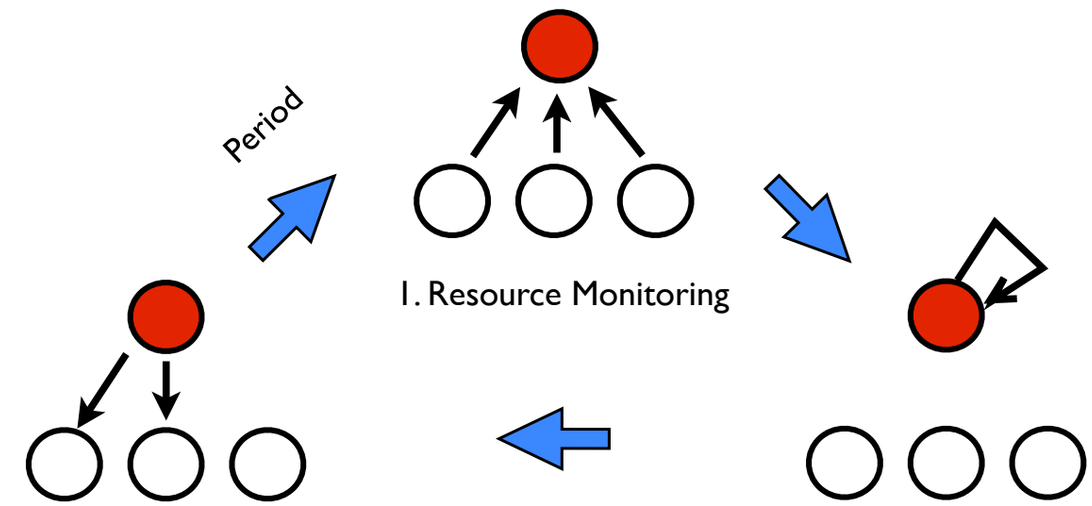
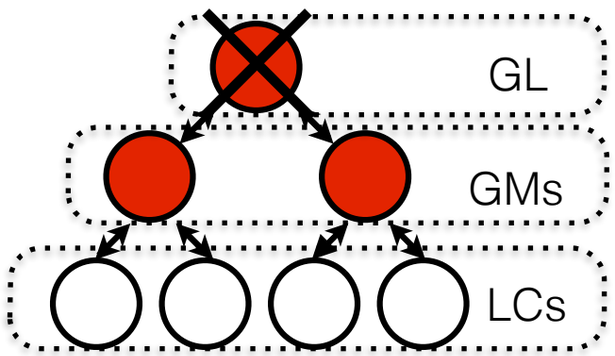
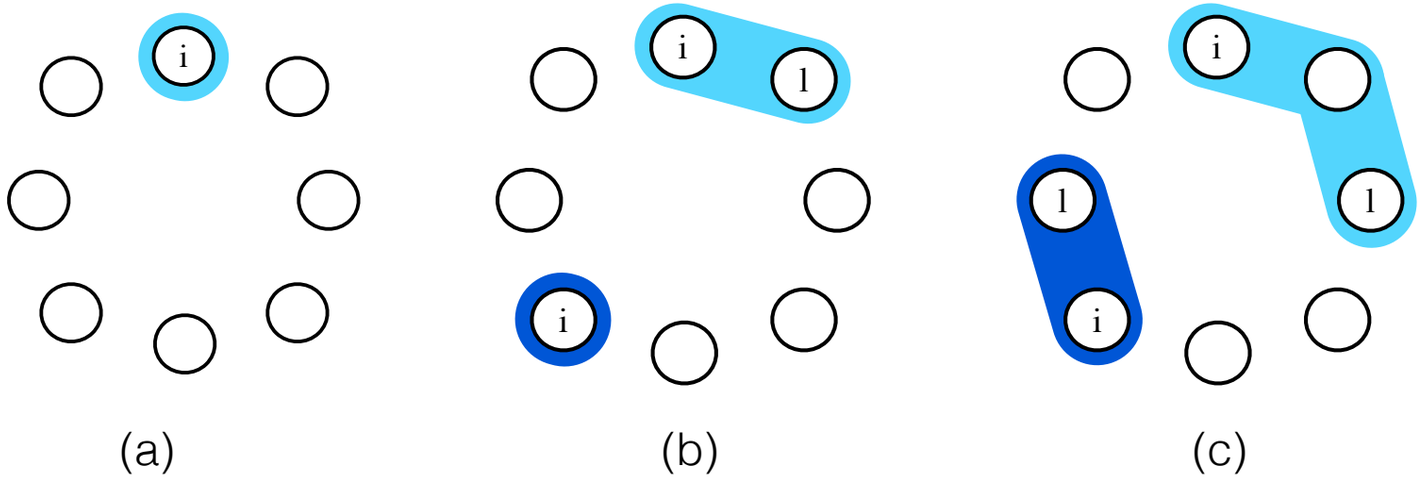
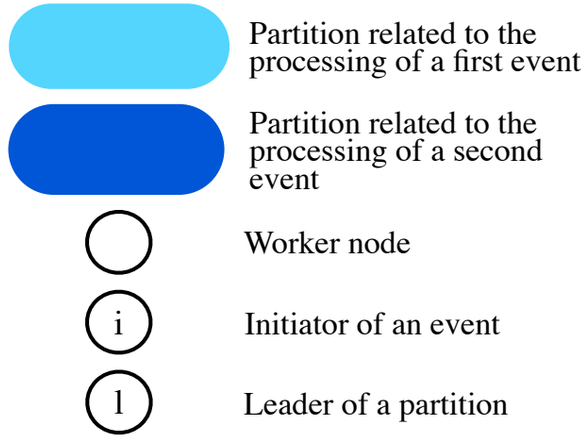


- Hierarchical



- Distributed





Entropy/Snooze/DVMS Analysis

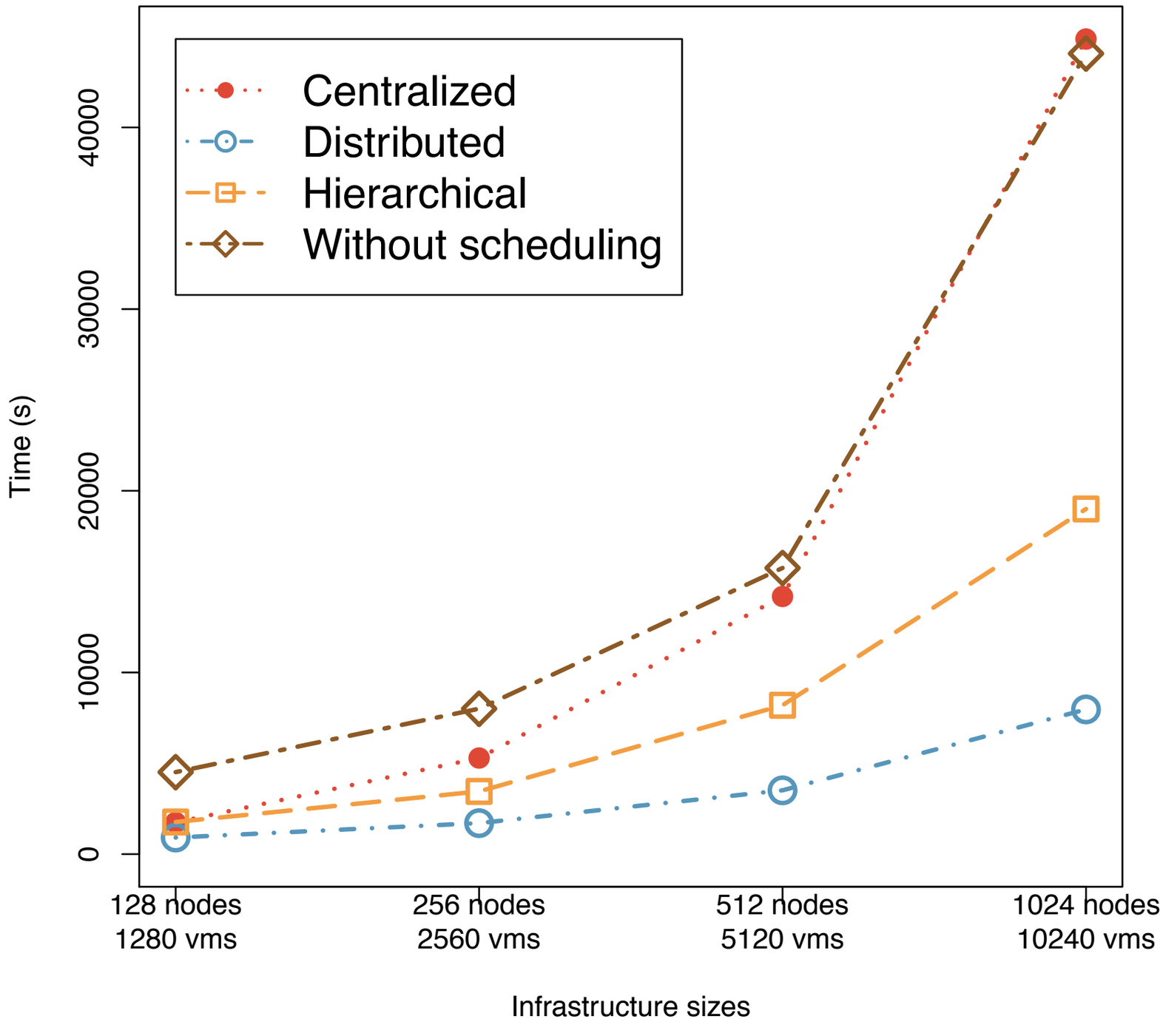
- Simulation Input parameters

  - PMs: 8 cores, 32GB, 1Gbps, 7 cores are considered.
    VMs: 1:1GB:1Gbps:1Gbps:x with x varies between 0 and 80%
    10 VMs per PM
    Cluster infrastructure composed of 128, 256, 512, 1024 PMs

    λt=#VMs/300 μ=60 and σ=20
    Duration: 1800 seconds
    (stationary state reached after 20 min, global cluster load 85%)

  - For Entropy and Snooze additional simulated PMs have been provided (one GM per 32 PMs)
    period 30 seconds.

Entropy/Snooze/DVMS Analysis



Cumulated violation time

Entropy/Snooze/DVMS Analysis

Infrastructure size	Duration of **violations** ($\mu \pm \sigma$)		
	Centralized	Hierarchica	
128 nodes	21.26 ± 13.55	21.07 ± 12.32	9.55 ± 2.57
256 nodes	40.09 ± 24.15	21.45 ± 12.10	9.58 ± 2.5
512 nodes	55.63 ± 42.26	24.54 ± 16.95	9.57
1024 nodes	81.57 ± 86.59	29.01 ± 38.14	

DVMS outperforms the others !?

Infrastructure size	Duratio		Distributed
128 n		± 4.63	0.29 ± 0.03
		2.65 ± 4.69	0.25 ± 0.02
	29.14	2.83 ± 4.98	0.21 ± 0.01
	.41 ± 50.35	2.69 ± 4.92	0.14 ± 0.01

1./ Can we find a good partitioning size for Snooze ?

2./ What would be the benefit for Snooze of a reactive approach?

Infrastructure size	Duration of **reconfigurations** ($\mu \pm \sigma$)		
	Centralized	Hierarchical	Distributed
128 nodes	10.34 ± 1.70	10.02 ± 0.14	10.01 ± 0.11
256 nodes	10.26 ± 1.45	10.11 ± 0.83	10.01 ± 0.08
512 nodes	11.11 ± 3.23	10.28 ± 1.50	10.08 ± 0.82
1024 nodes	18.90 ± 7.57	10.30 ± 1.60	10.04 ± 0.63

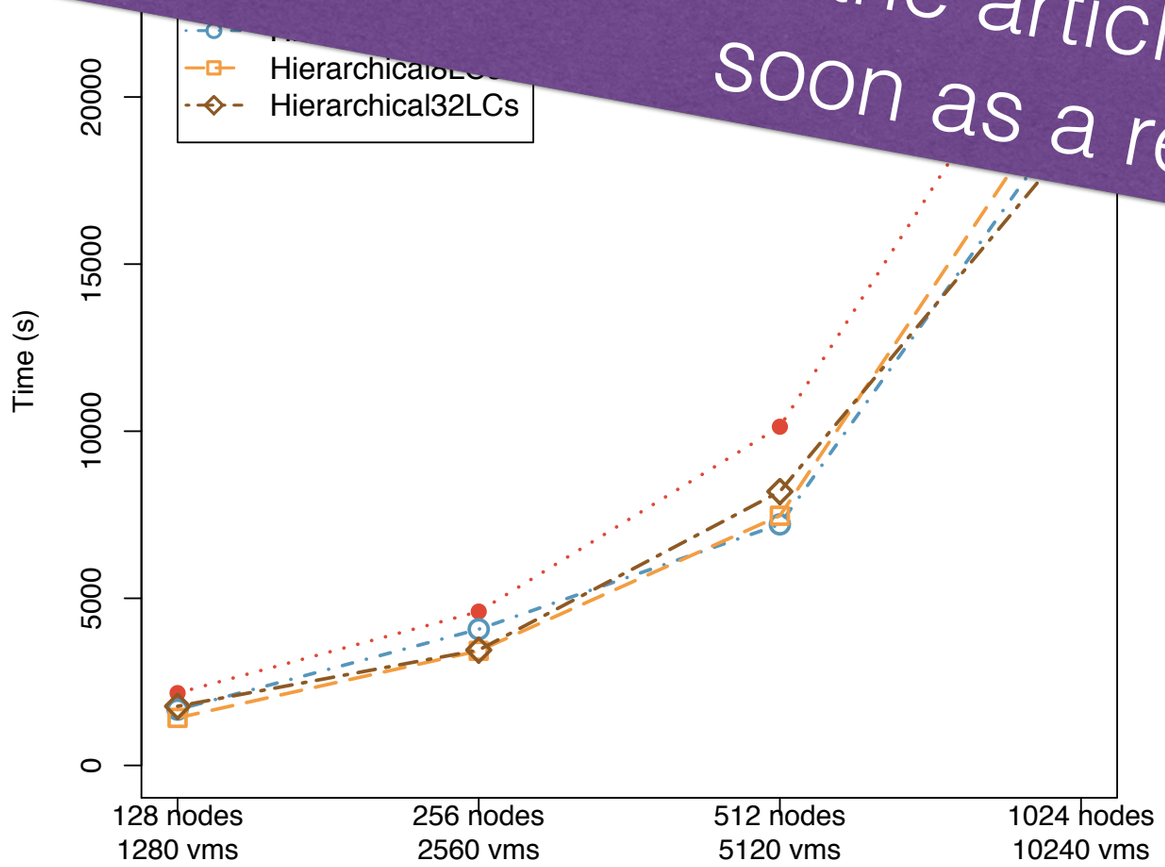
While the centralized approach does not scale, both phases are constant from the time viewpoint for the two other approaches

Investigate Variants

- Evaluate the impact of having smaller partitions in Snooze

but partitions grow from 2 LCs to 32 LCs per GM

Other variants and possible improvements (not addressed in the article but available on demand and soon as a research report)



Cumulated violation time

512	
1024	173

Infra. Size	Duration of the **computations** ($\mu \pm \sigma$)			
	2 LCs	4 LCs	8 LCs	32 LCs
128	0.16 ± 1.23	0.34 ± 1.81	0.58 ± 2.40	2.53 ± 4.62
256	0.18 ± 1.31	0.42 ± 1.99	0.66 ± 2.50	2.65 ± 4.69
512	0.15 ± 1.20	0.33 ± 1.78	0.67 ± 2.54	2.83 ± 4.98
1024	0.19 ± 1.37	0.42 ± 2.02	0.89 ± 2.90	2.69 ± 4.91

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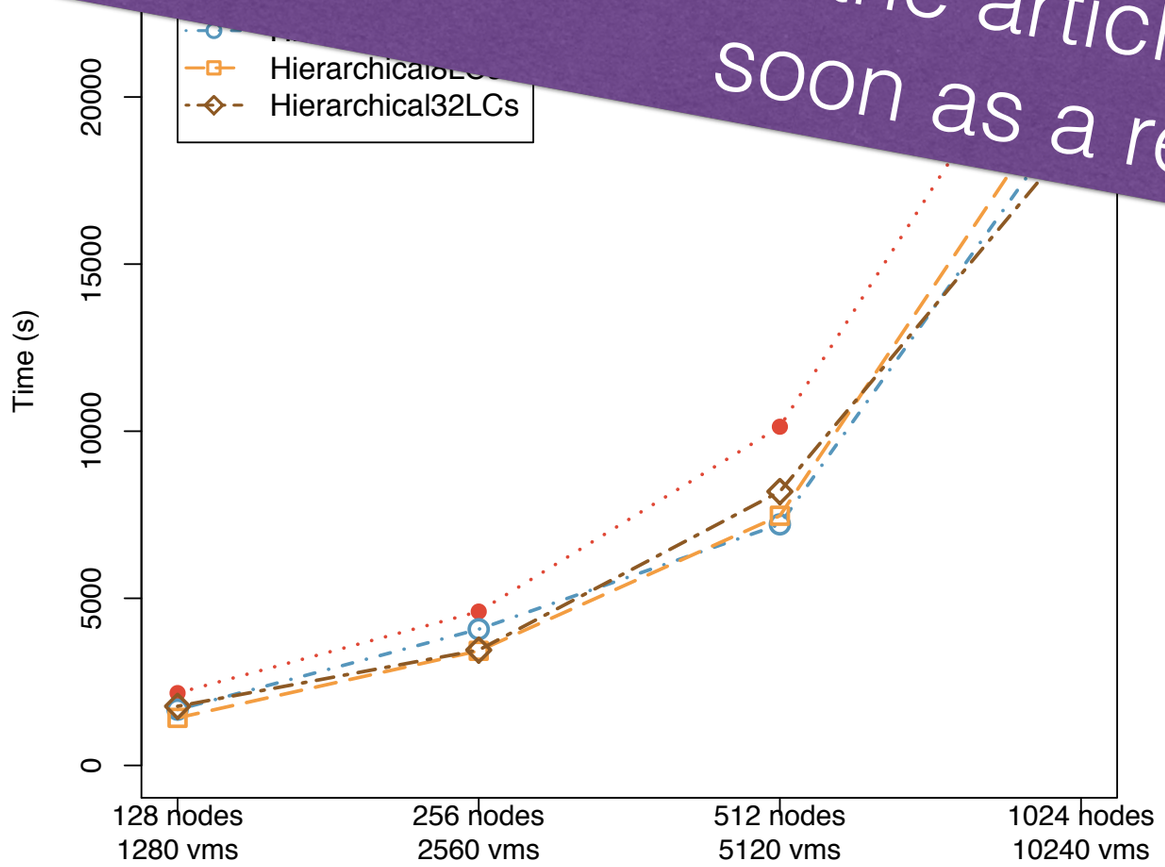

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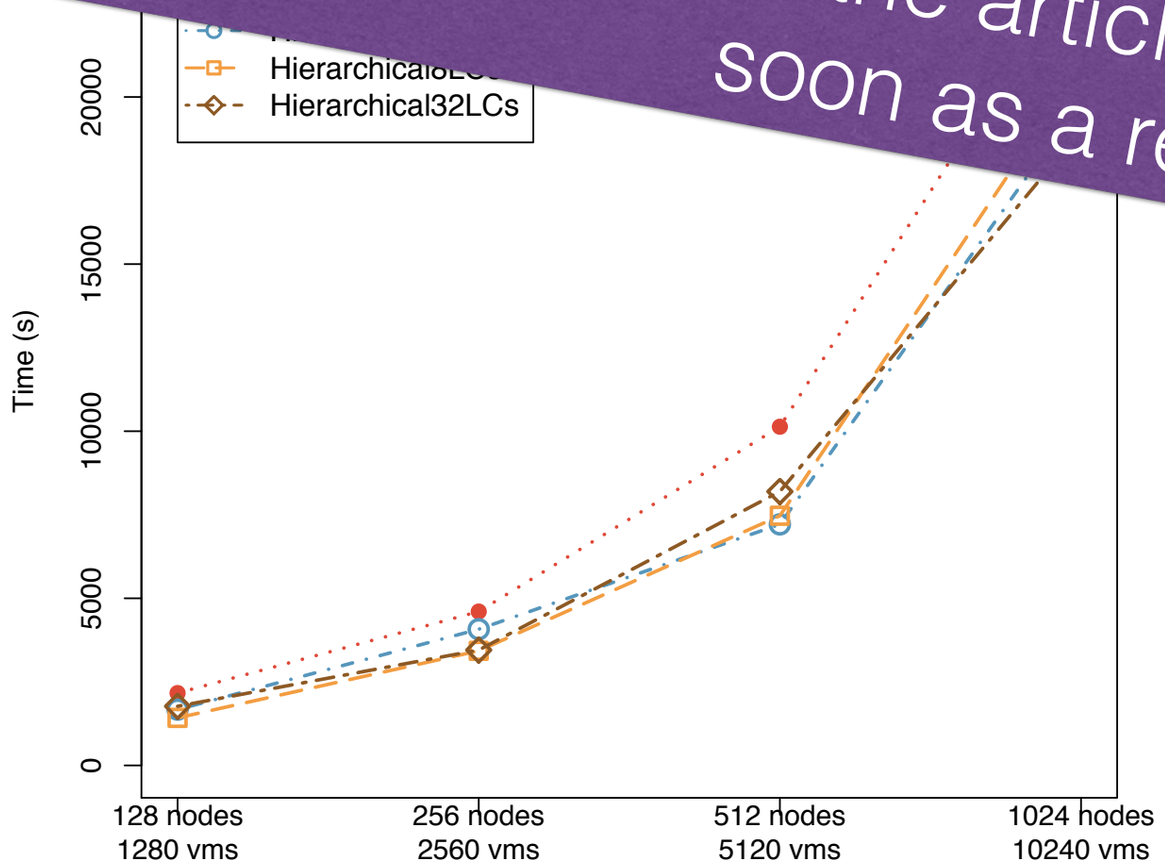

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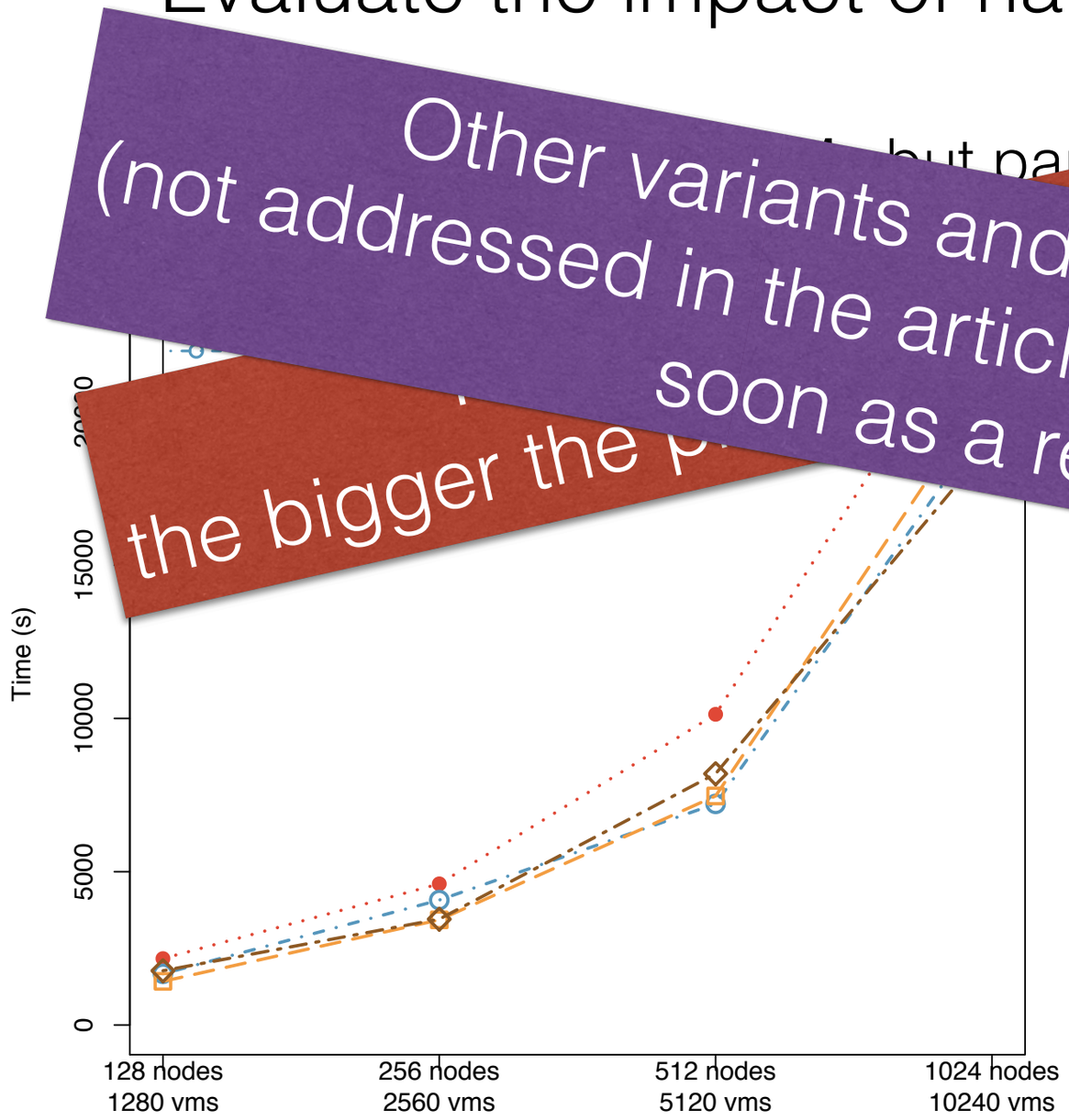

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ge of the partition, find a viable solution

the bigger the p

VMPlaceS - Conclusion

- Difficulties to conduct relevant evaluation of VM placement strategies (in vivo conditions, lot of metrics to monitor, scalability/reactivity, …)

- VMPlaceS, a framework providing

  - Programming support for the definition of new VM placement strategies
    Execution support for their accurate simulation at large scale
    Means to analyze the collected traces

  - Available online (with the three aforementioned strategies)
    http://beyondtheclouds.github.io/VMPlaceS/

- On-going and future work

  - New events: node apparition/removal (memory/network load changes soon)
    VM boot time, VM image migrations
    Injection of addition VMs on-the-fly

Thanks

adrien.lebre@inria.fr

http://beyondtheclouds.github.io