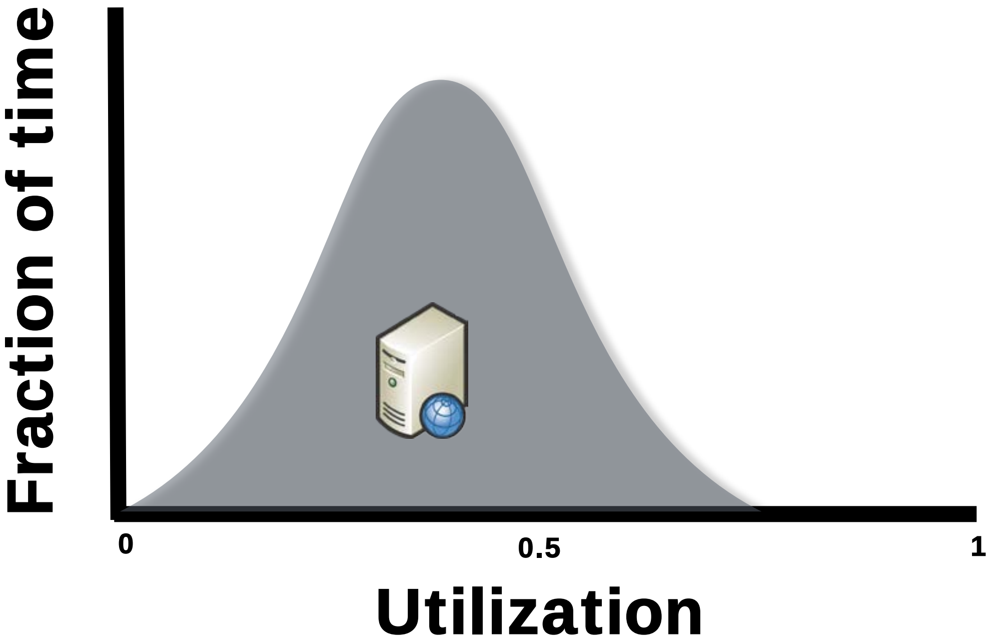
Accelerating Critical OS Services in Virtualized Systems with Flexible Micro-sliced Cores

Jeongseob Ahn*, Chang Hyun Park‡, Taekyung Heo‡, Jaehyuk Huh‡

* AJOU UNIVERSITY

‡ KAIST

Challenge of Server Consolidation



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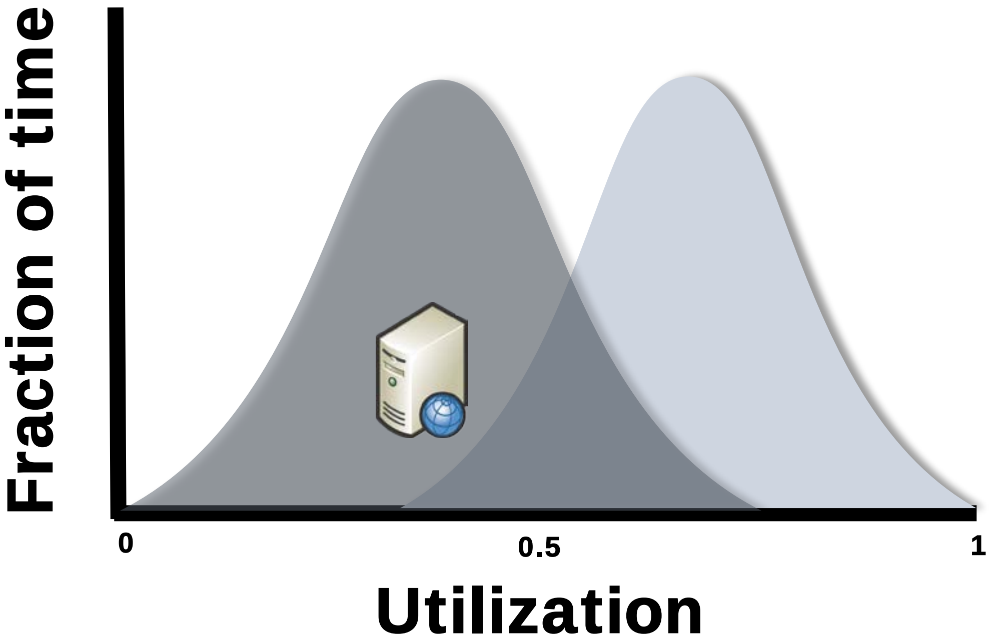

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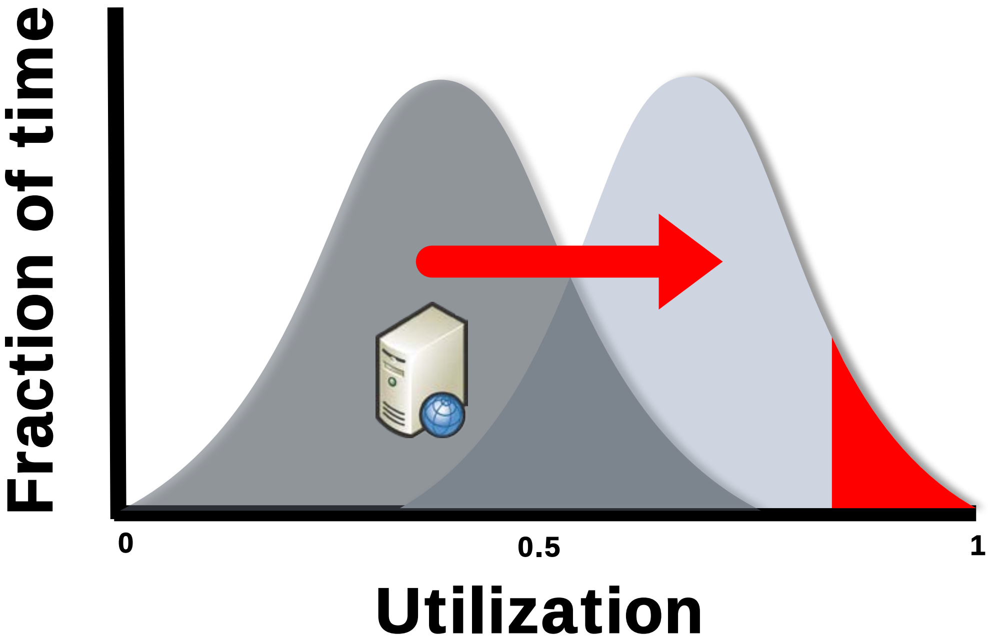

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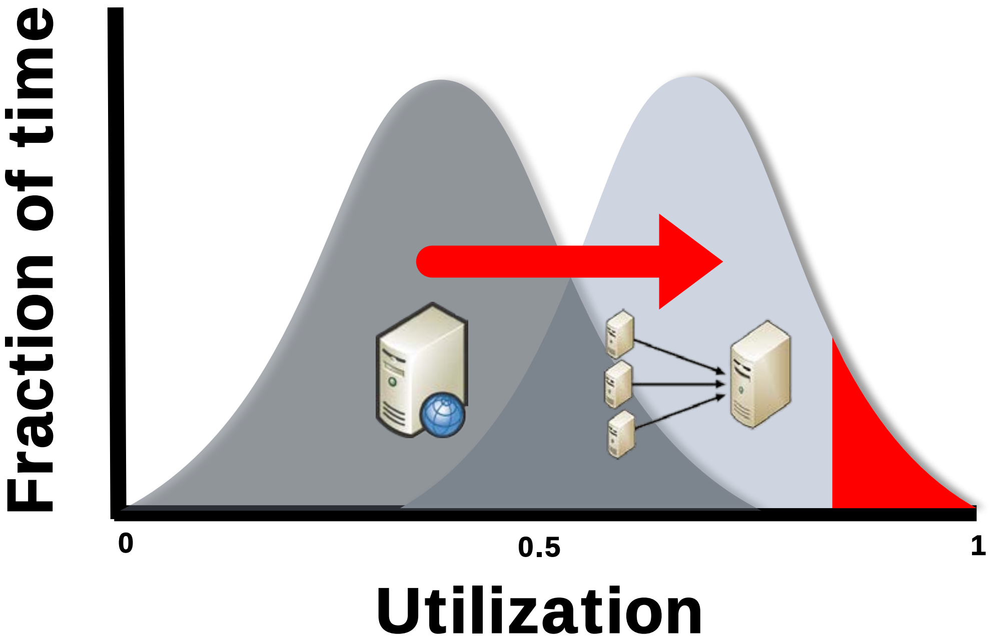

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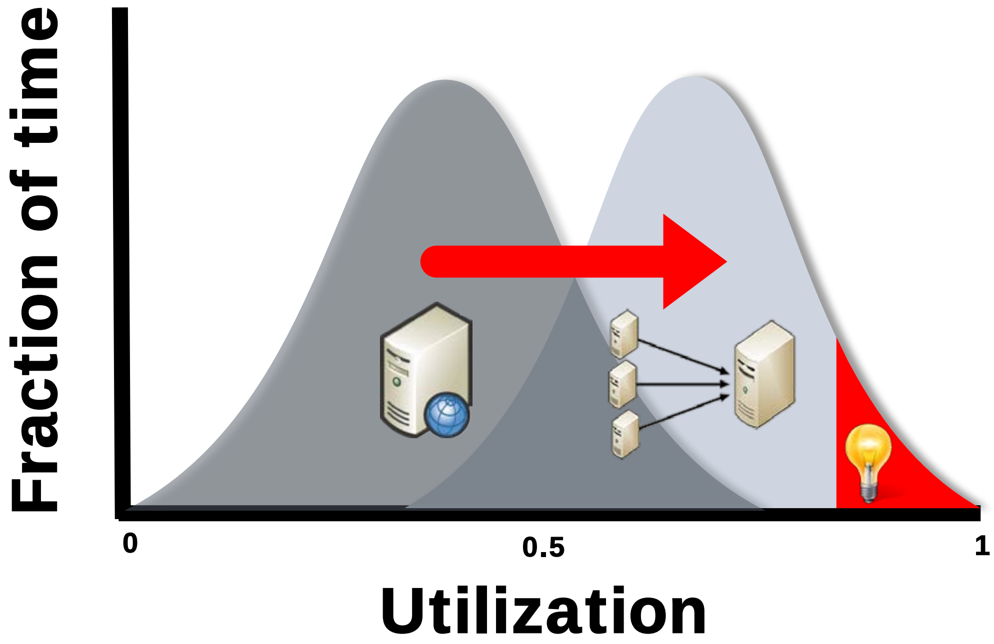

Consolidation improves system utilization

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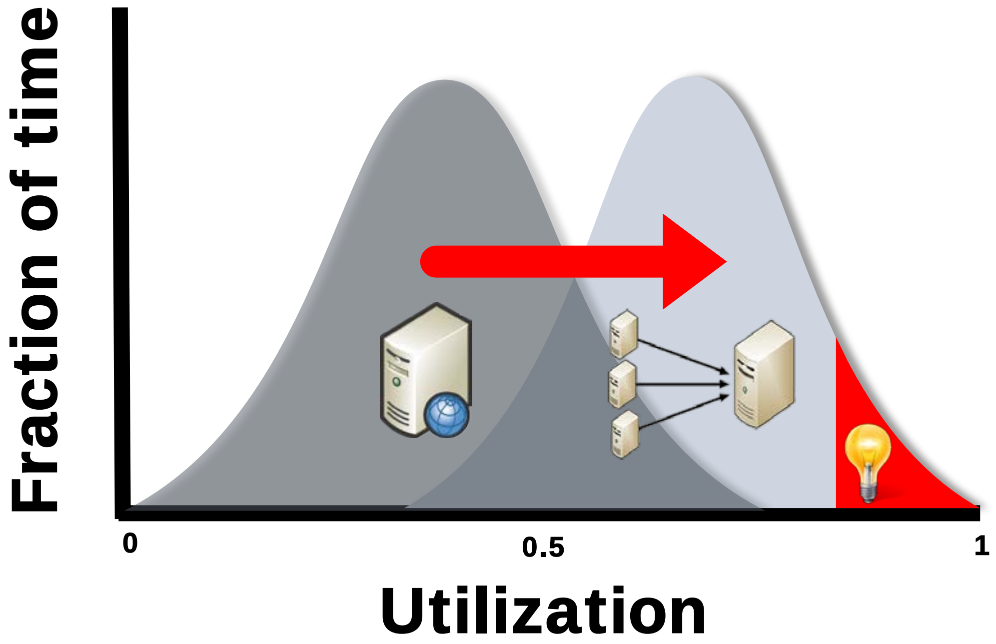

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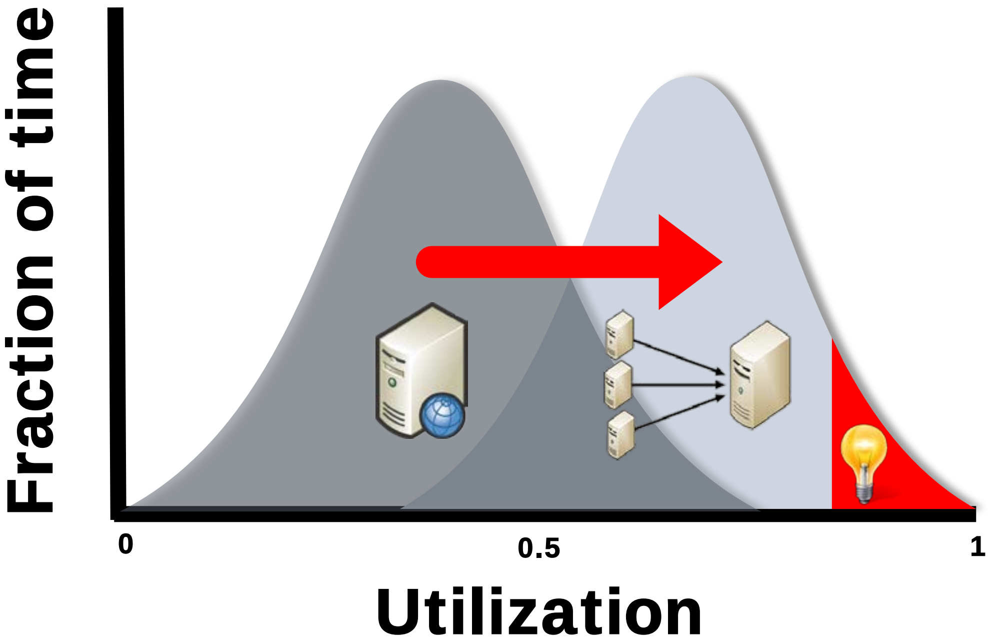

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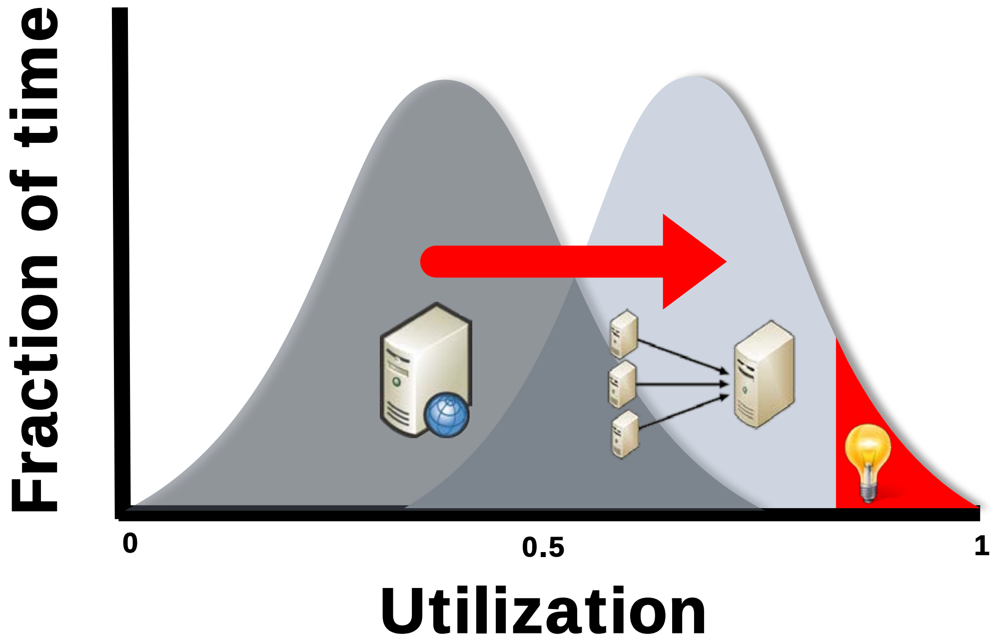

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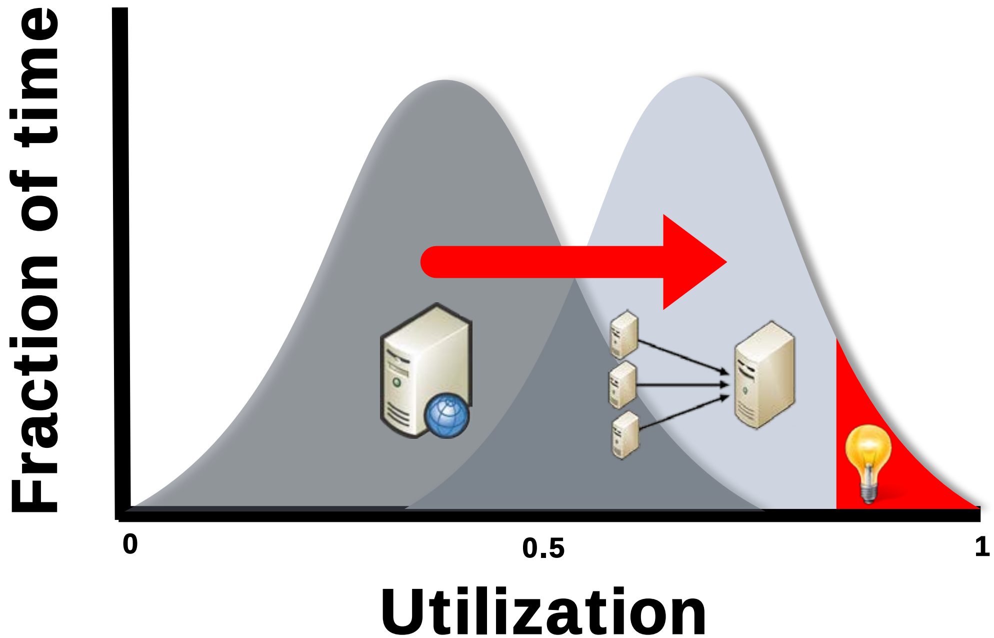

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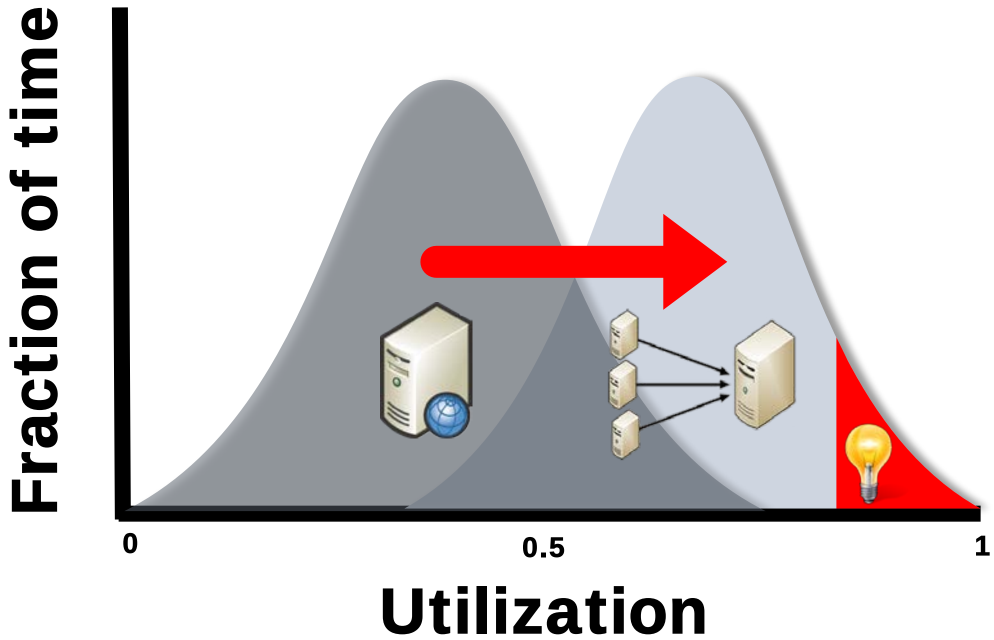

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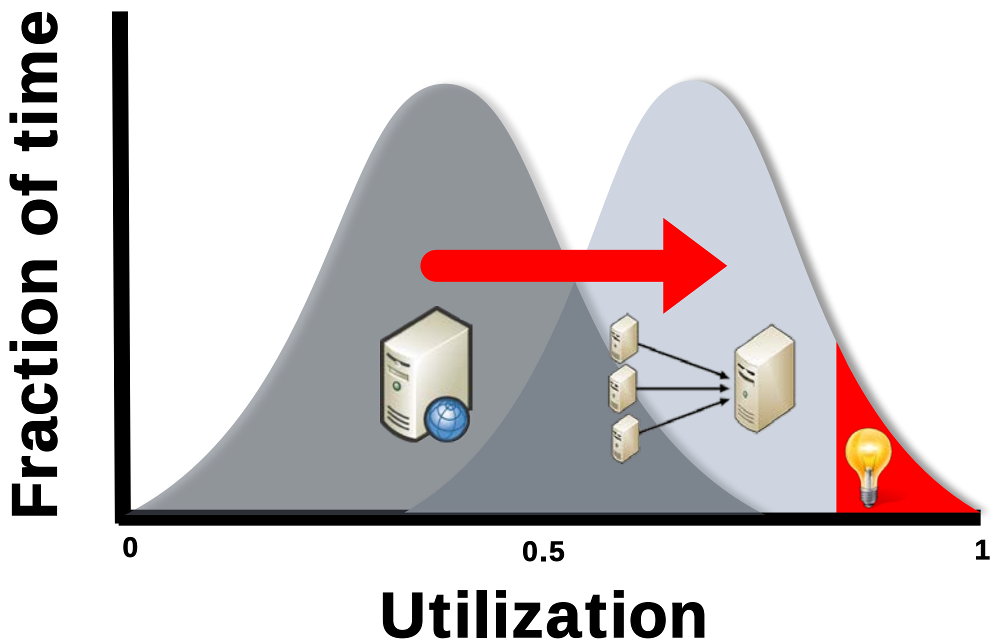

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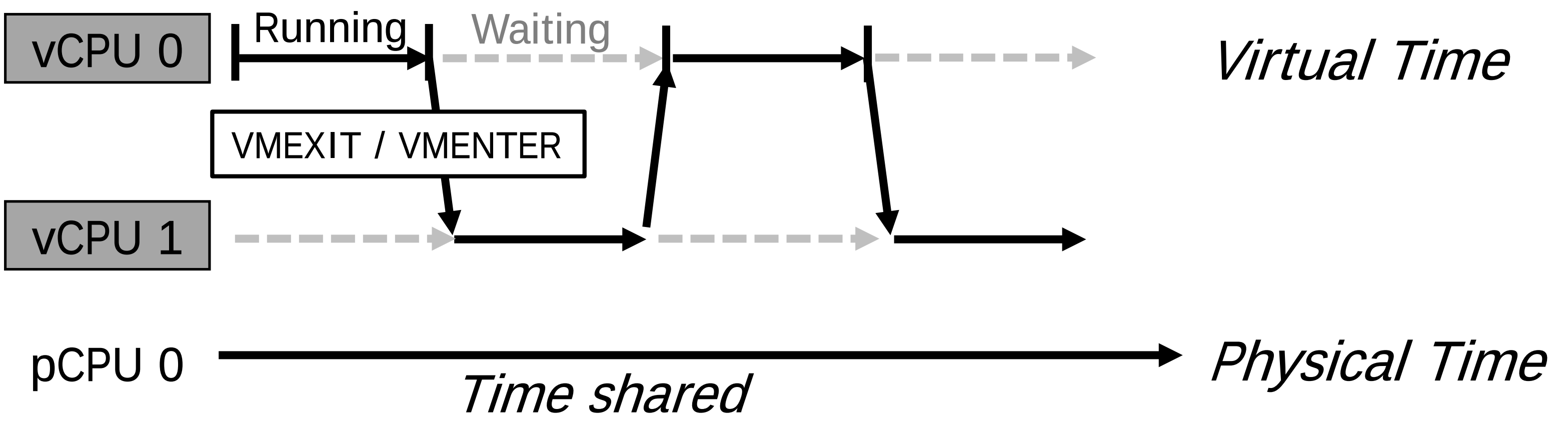
So, What Can Happen?

- Virtual time discontinuity



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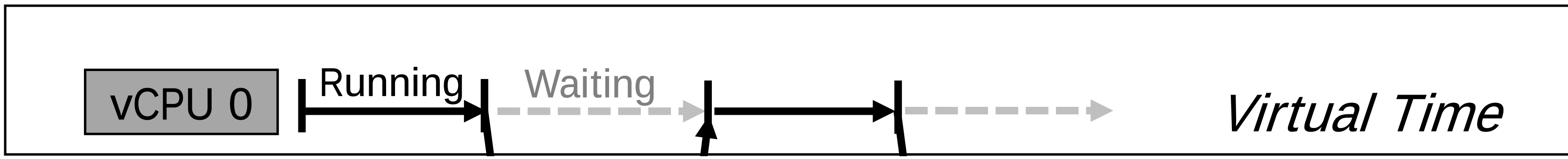

❶ Spinlock waiting time(`gmake`)

Kernel Component	Avg. waiting time (μsec)	
	solo	co-run*
Page reclaim	1.03	420.13
Page allocator	3.42	1,053.26
Dentry	2.93	1,298.87
Runqueue	1.22	256.07

** Concurrently running with Swaptions of PARSEC*

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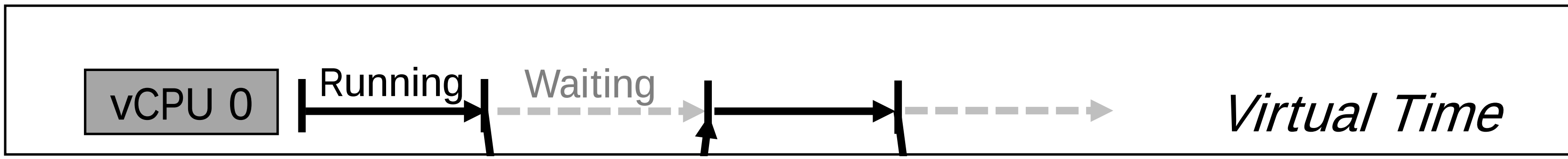

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dedup	solo	28	5	1927
	co-run*	6,354	7	74915
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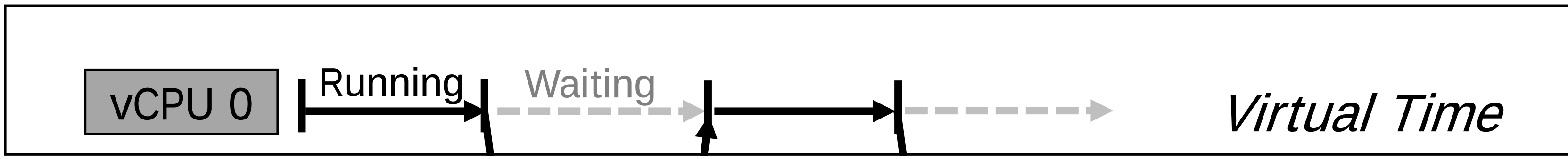

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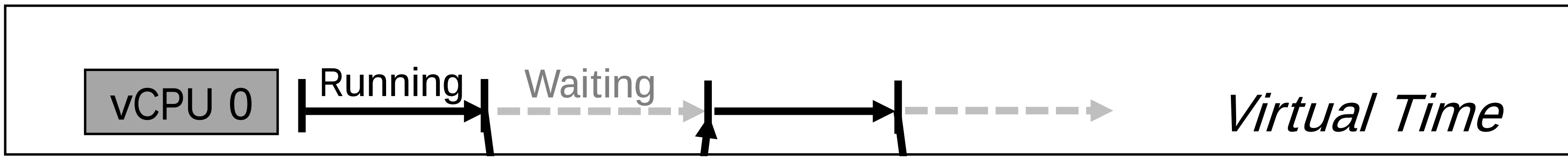

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❸ I/O latency & throughput (`iPerf`)

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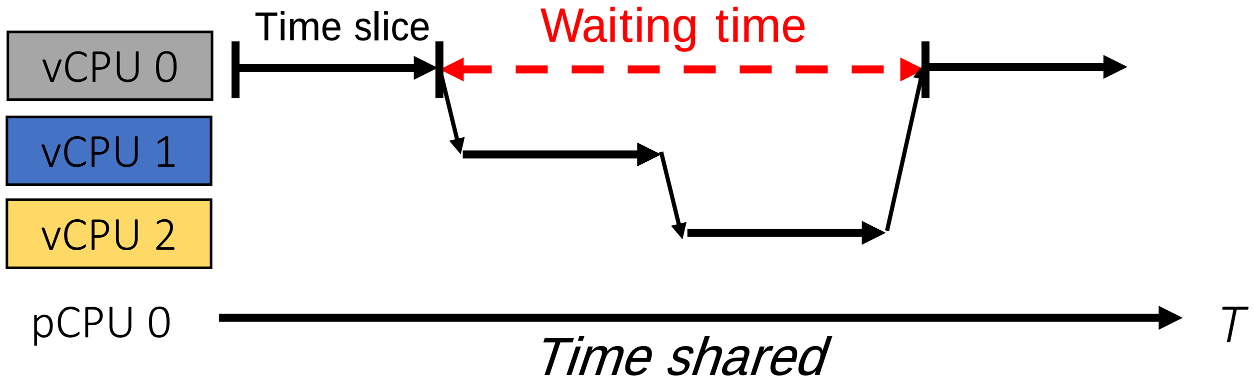
How about Shortening Time Slice?



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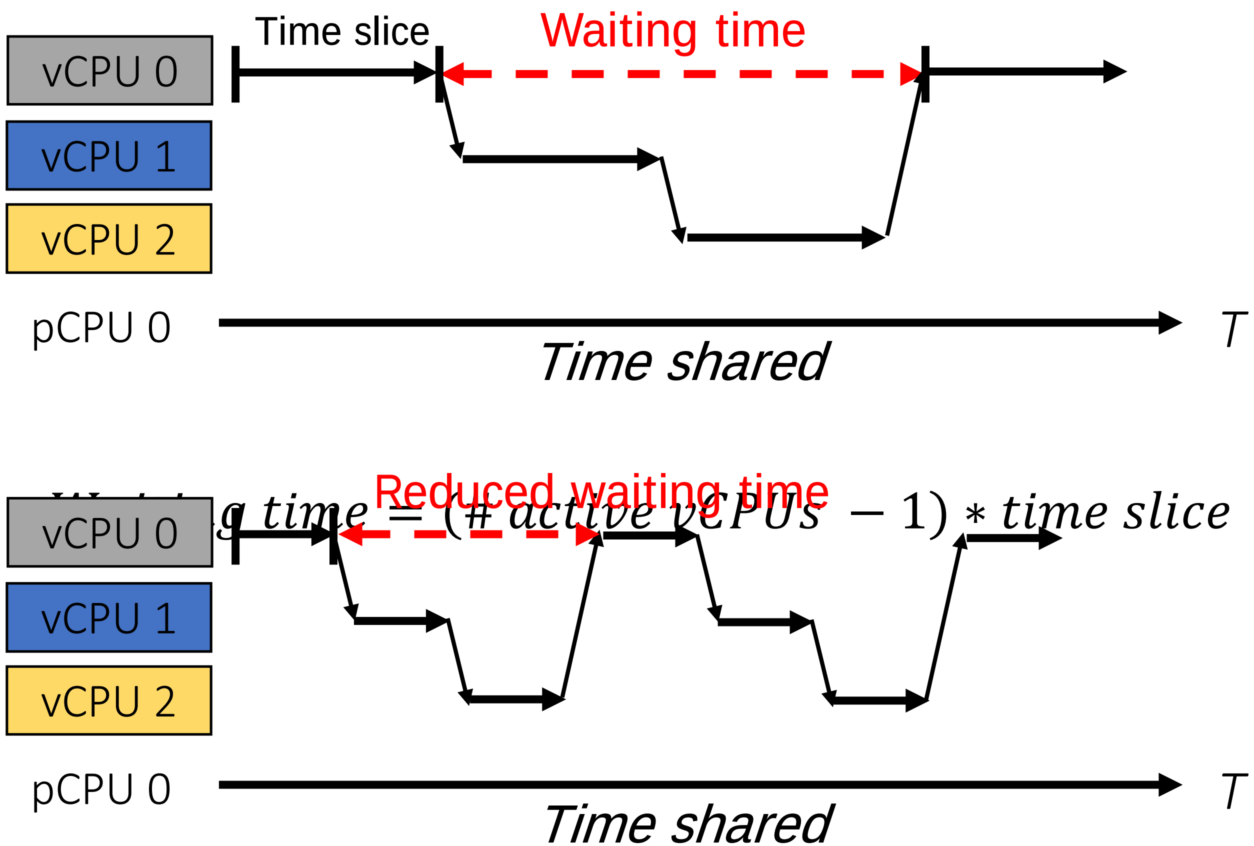

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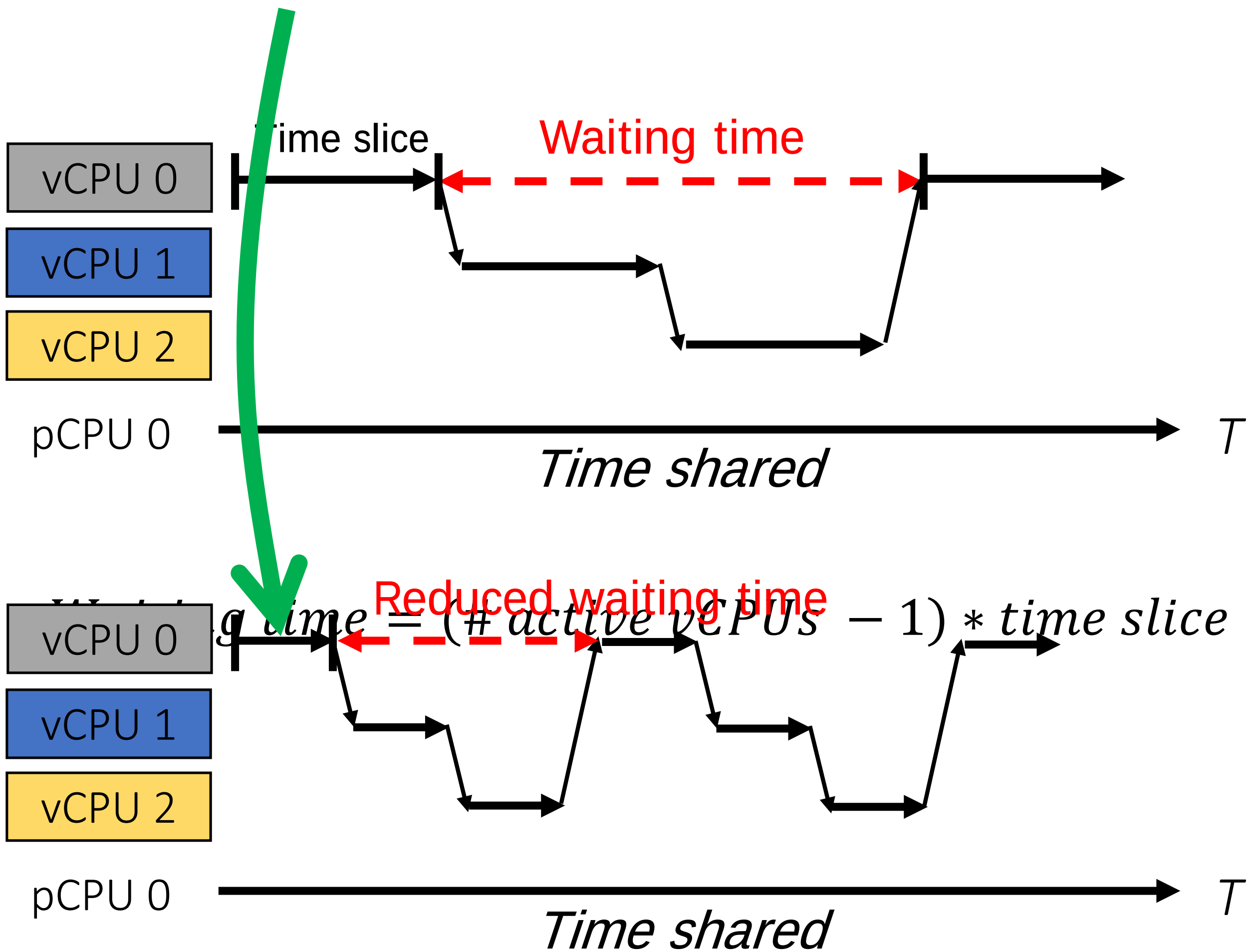

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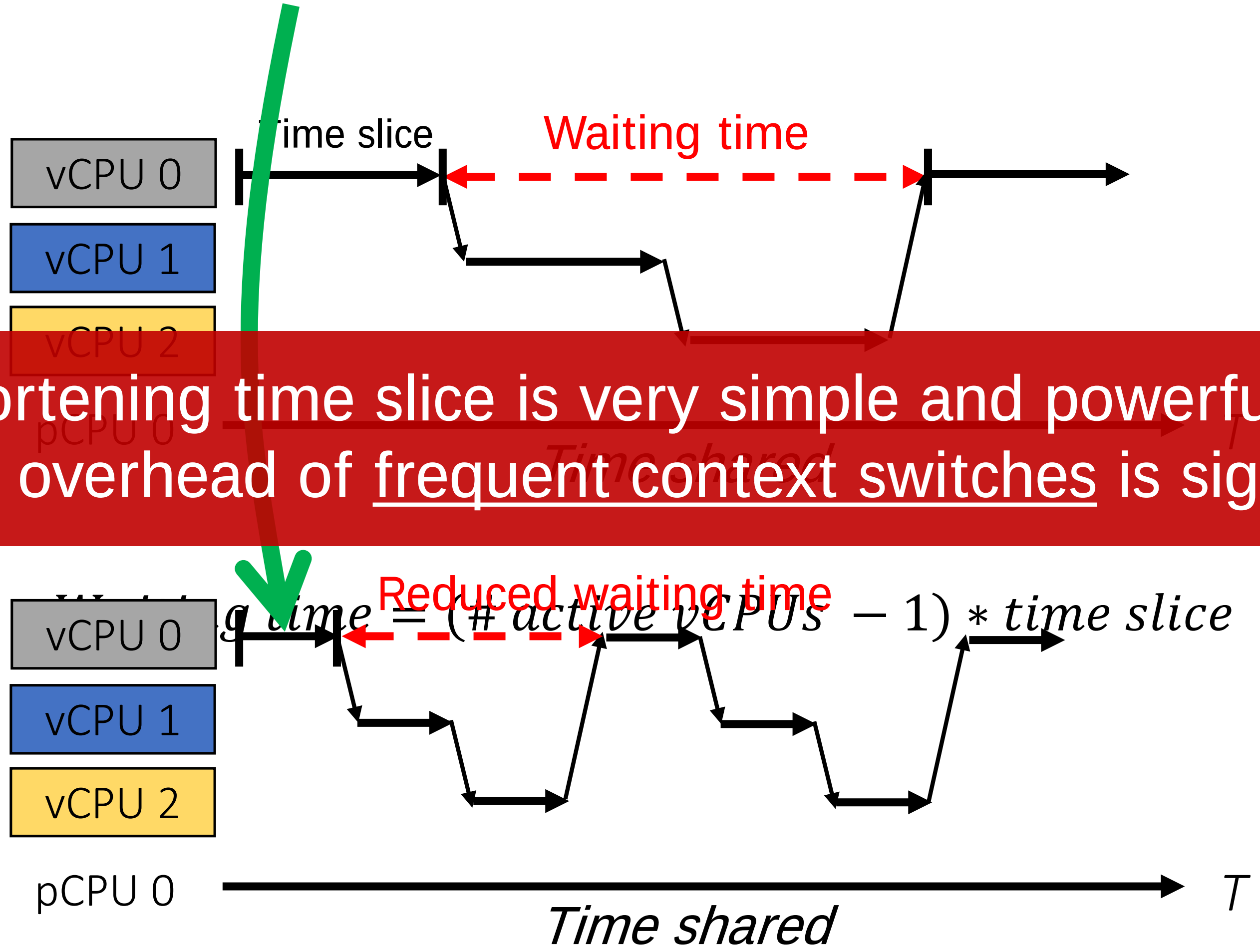

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Shortening time slice is very simple and powerful, but the overhead of <u>frequent context switches</u> is significant

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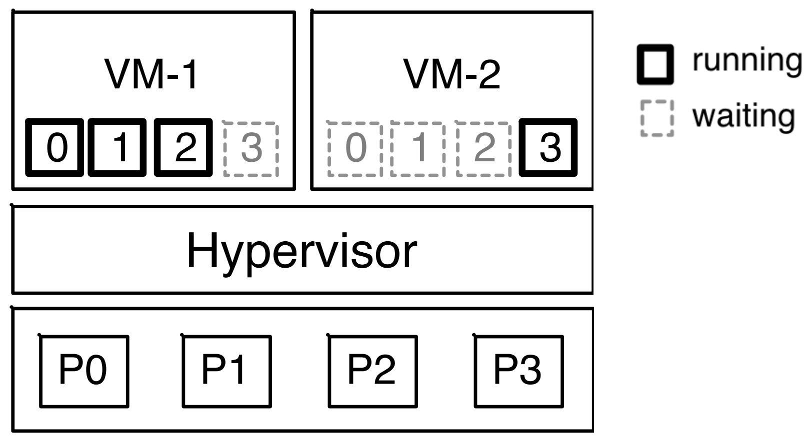

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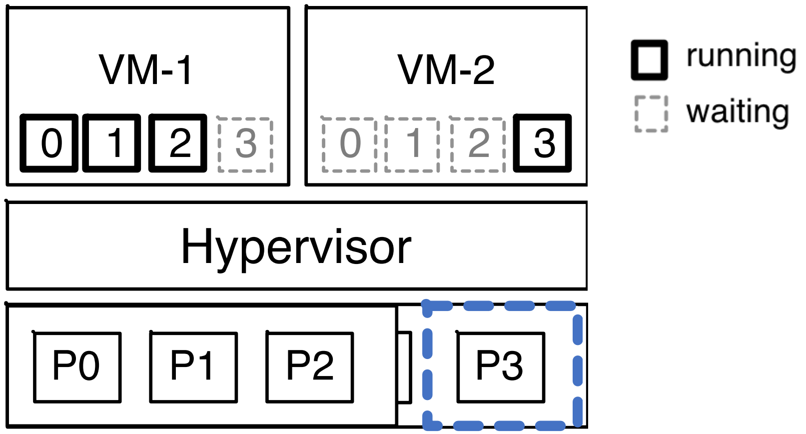
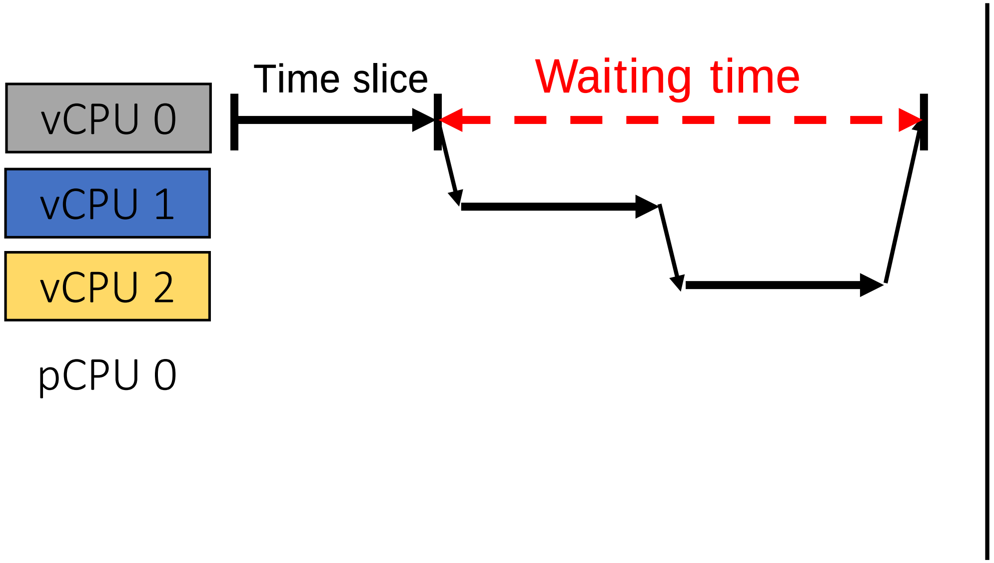


❶ Normal pool



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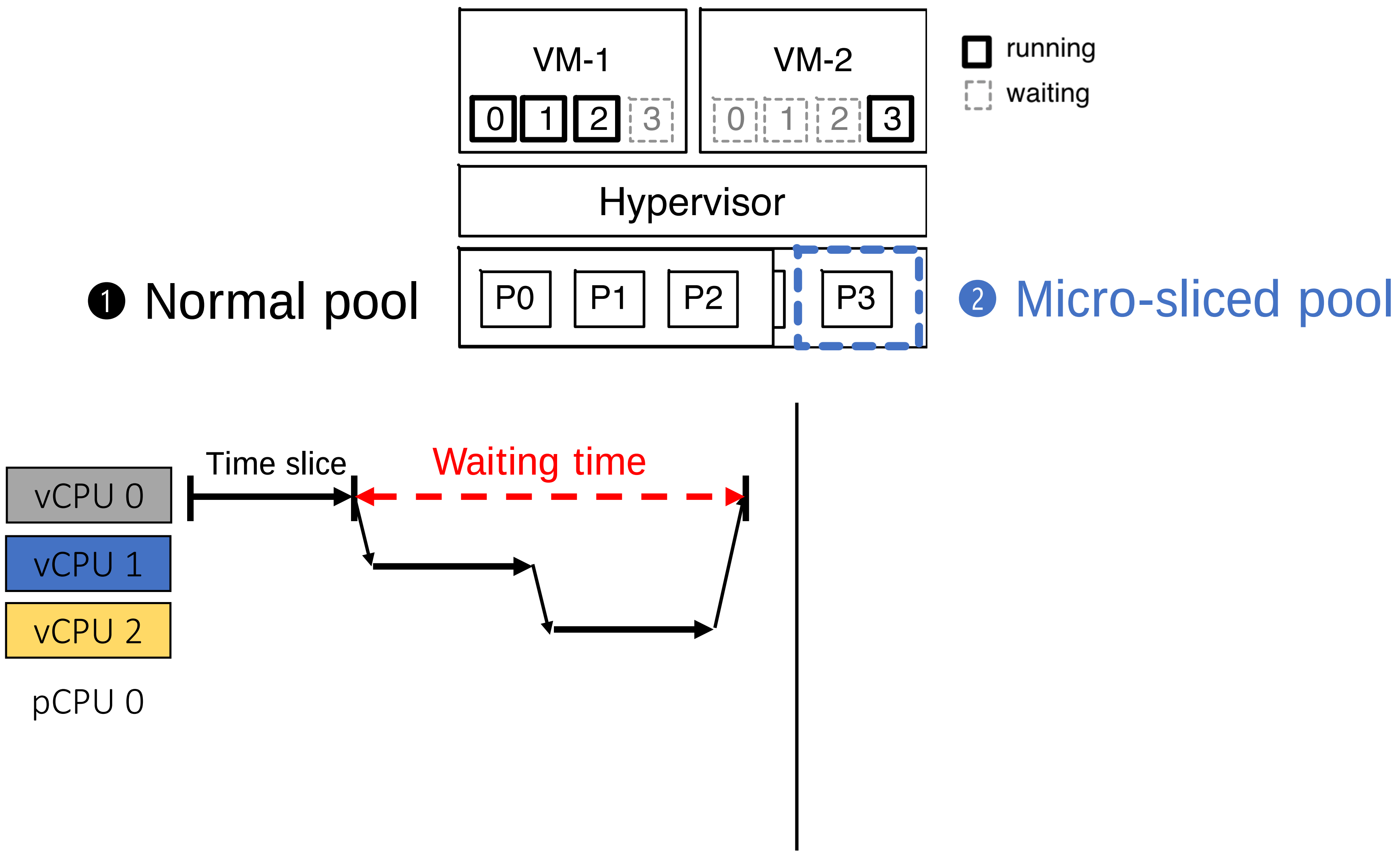

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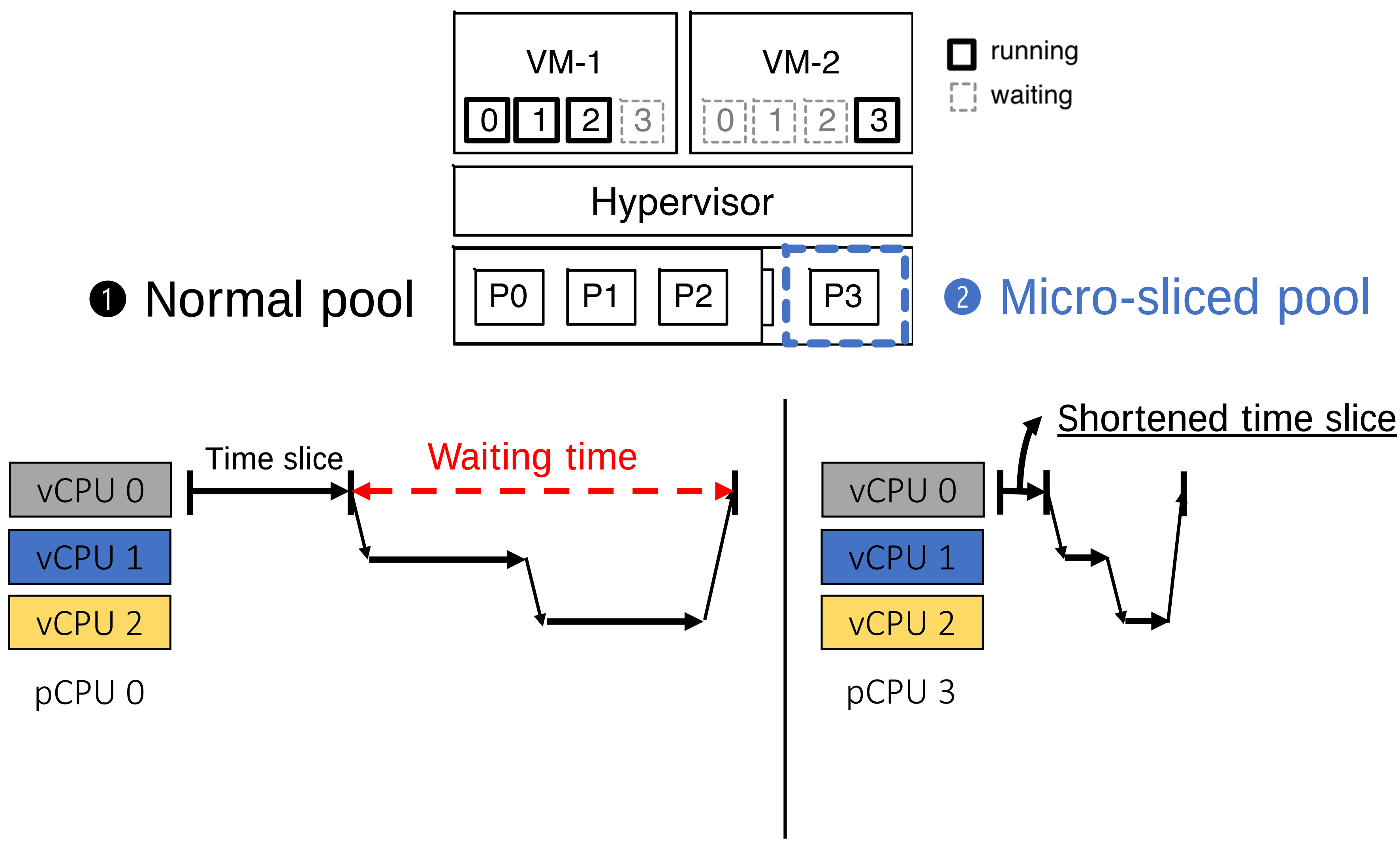

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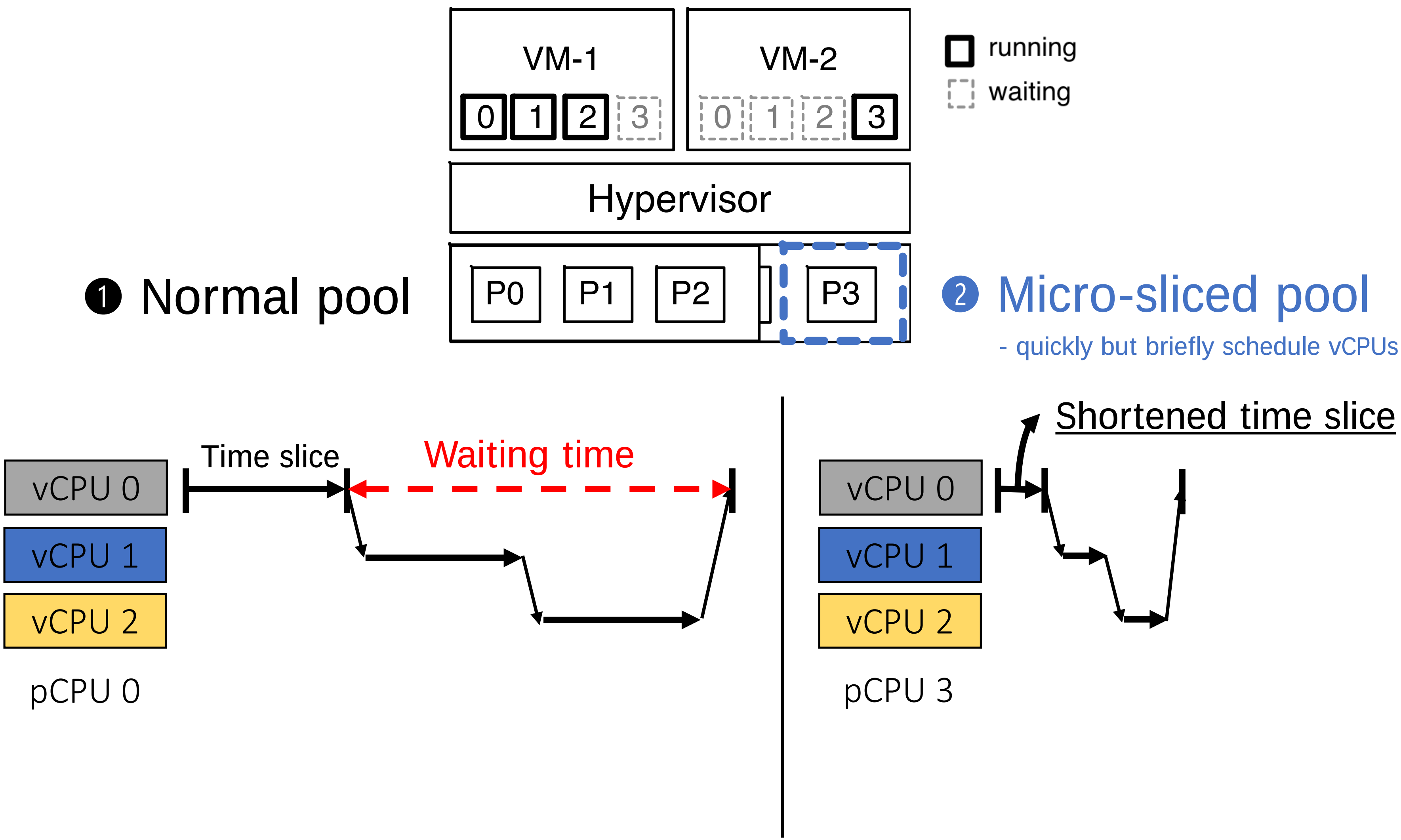

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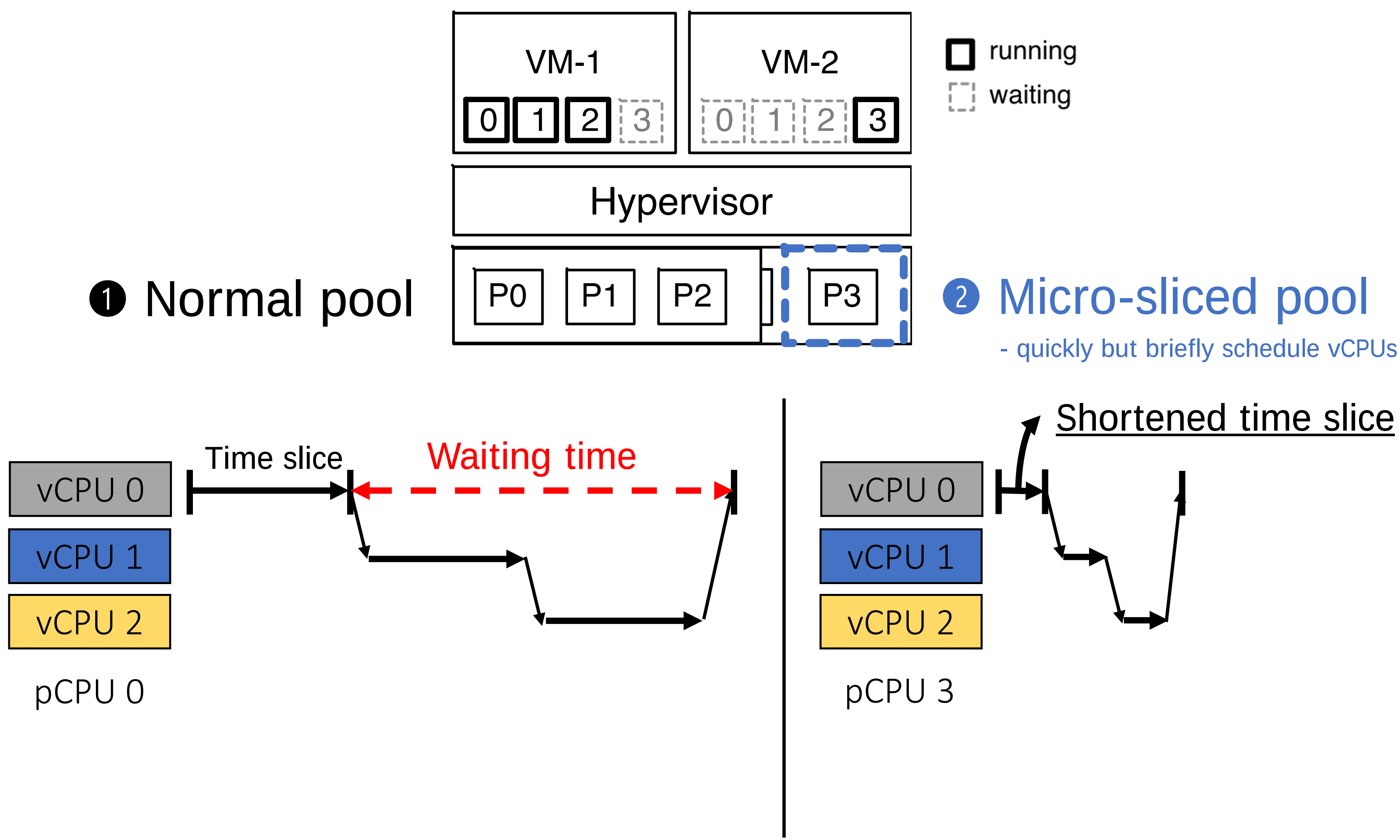

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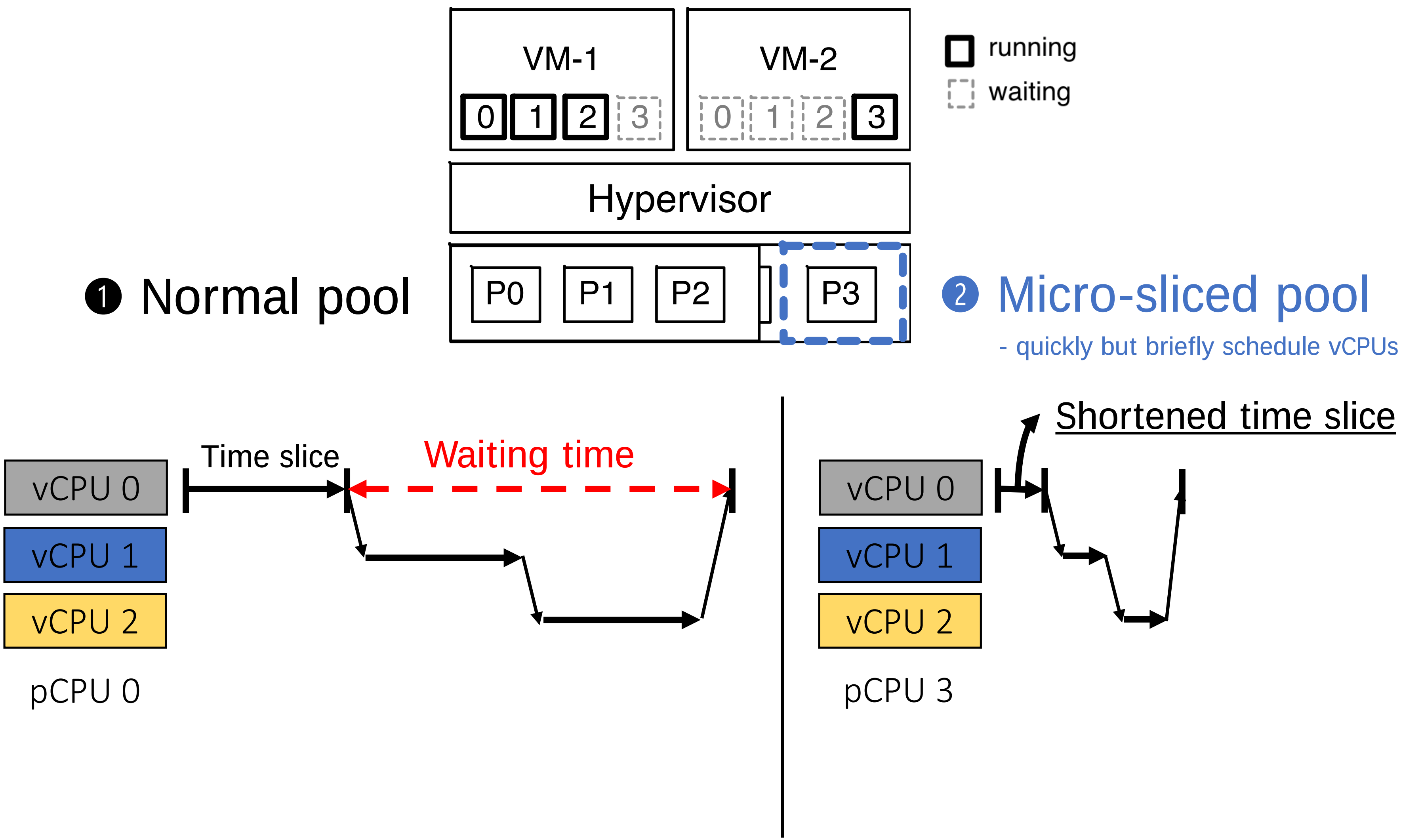

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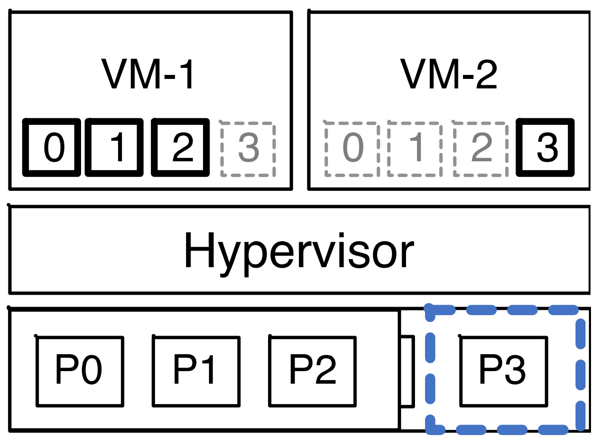
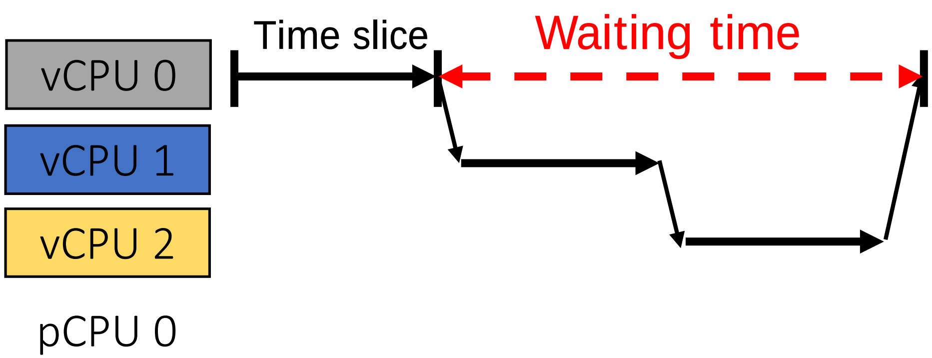


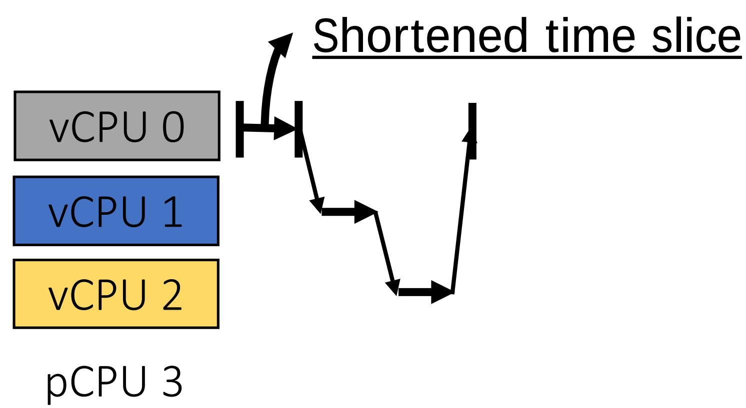
running
waiting

❶ Normal pool

❷ Micro-sliced pool

- quickly but briefly schedule vCPUs





Serving the main work of applications

Serving critical OS services to minimize the *waiting time*

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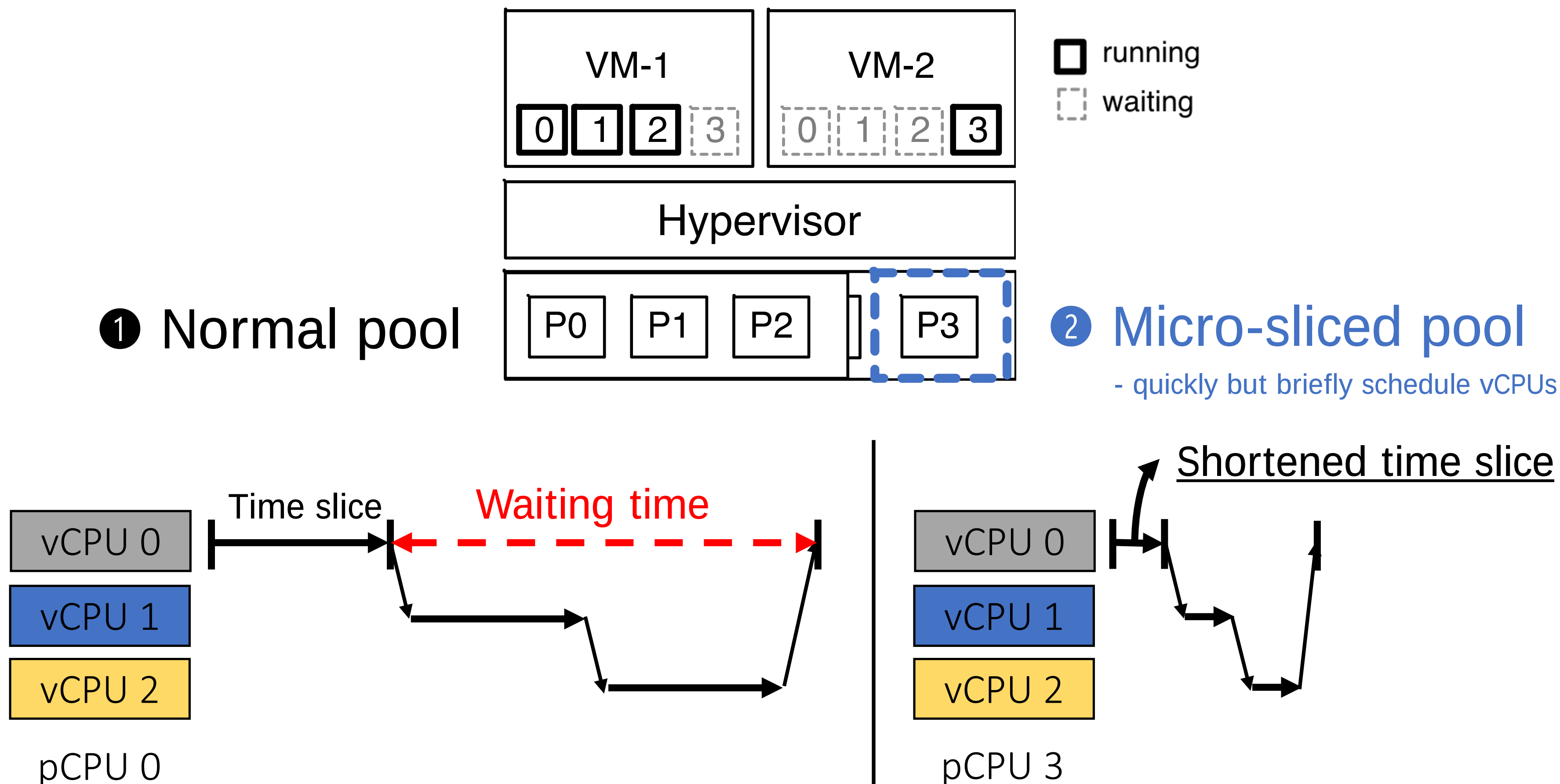

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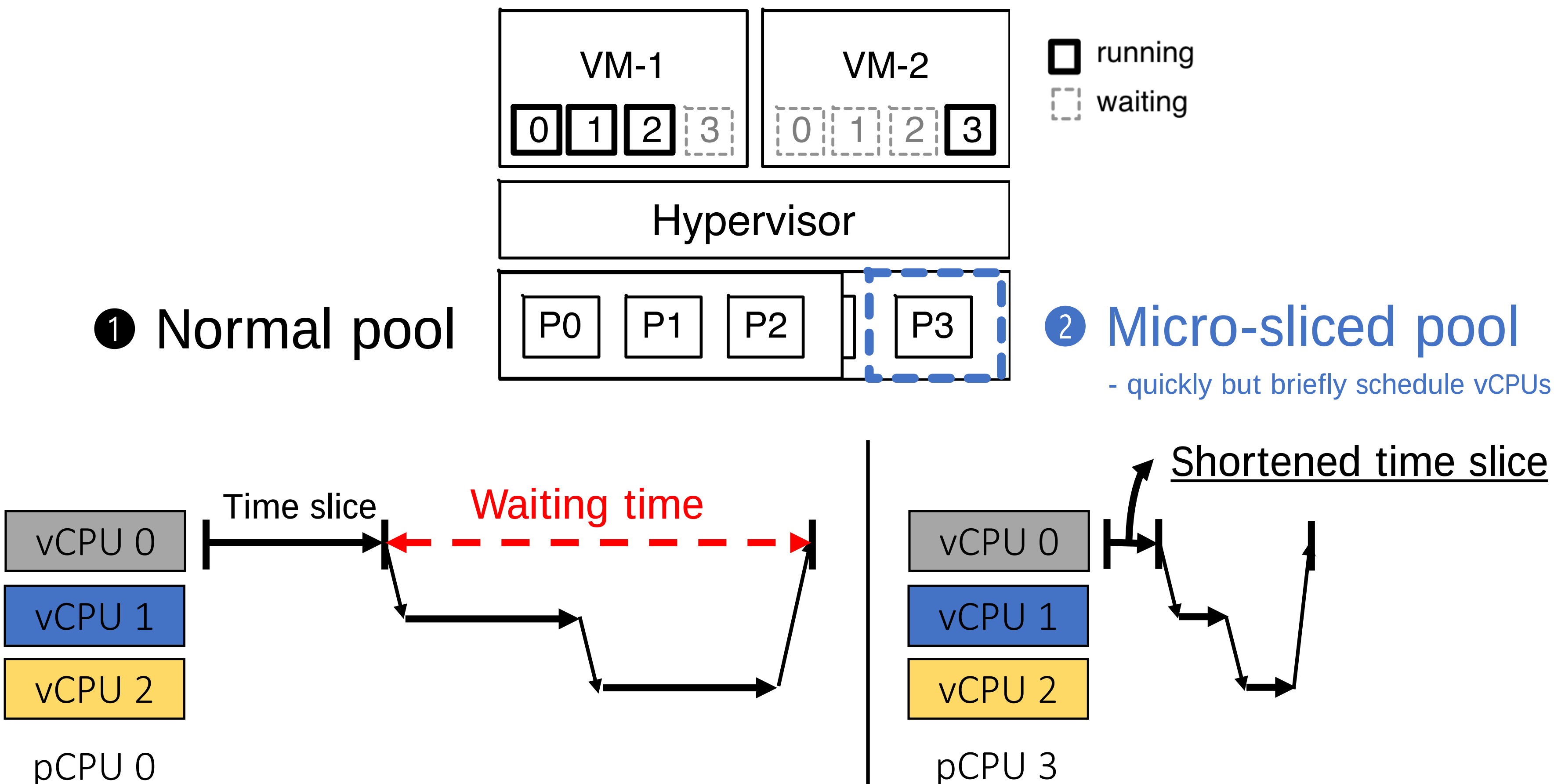

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Challenges in Serving Critical OS Services on Micro-sliced Cores

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1. Precise detection of urgent tasks

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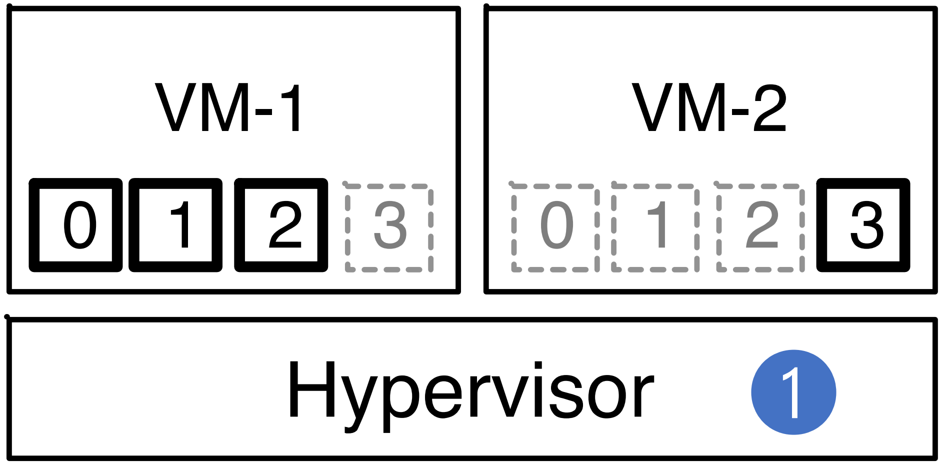
3. Dynamic adjustment of micro-sliced cores

Detecting Critical OS Services



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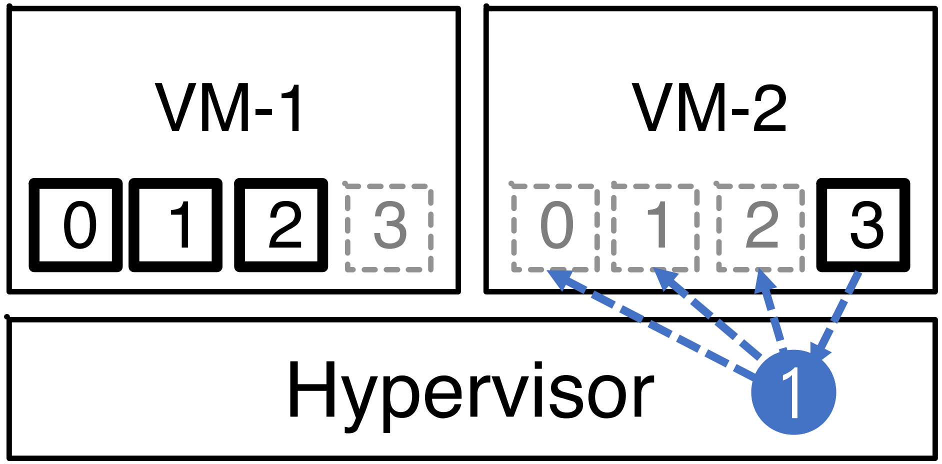
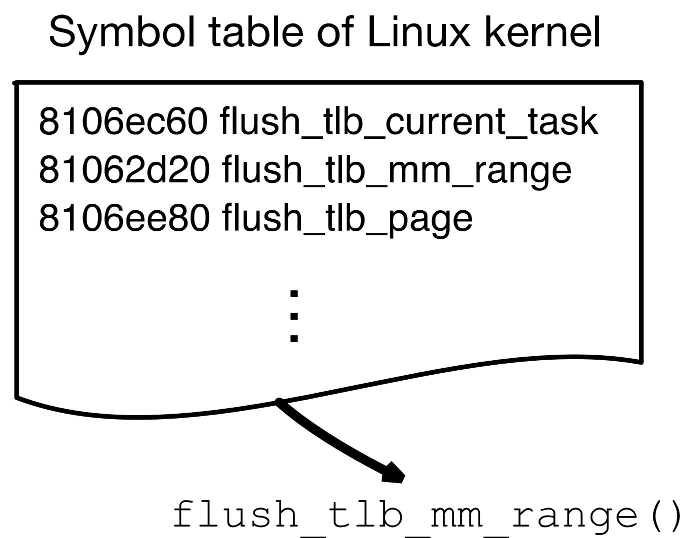


Examining the instruction pointer (a.k.a PC) whenever a vCPU yields its pCPU



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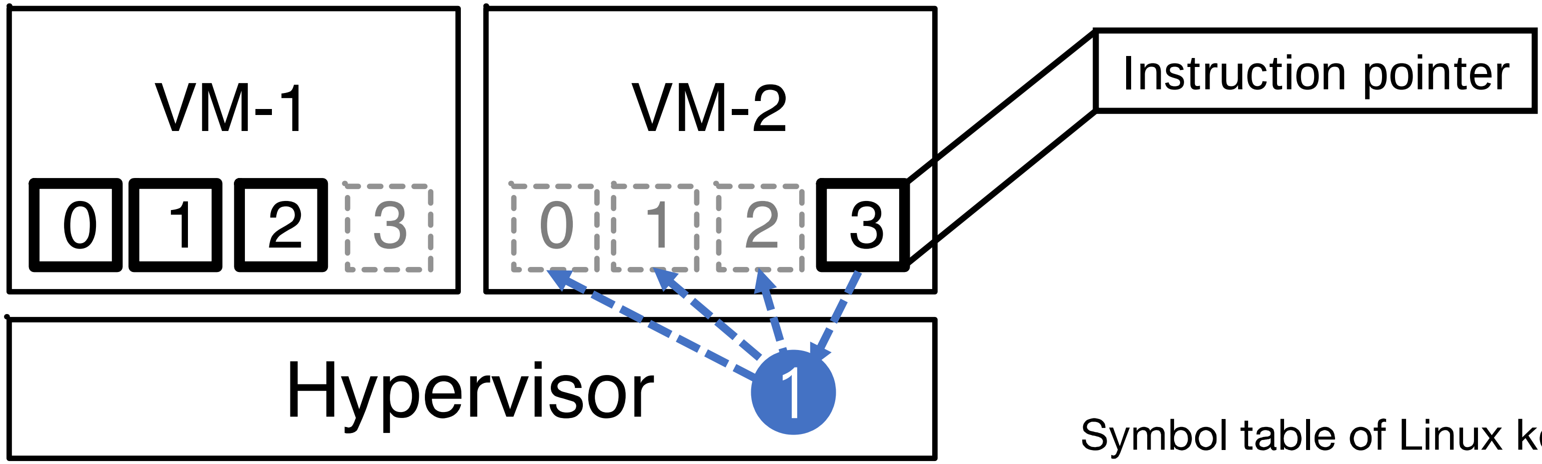

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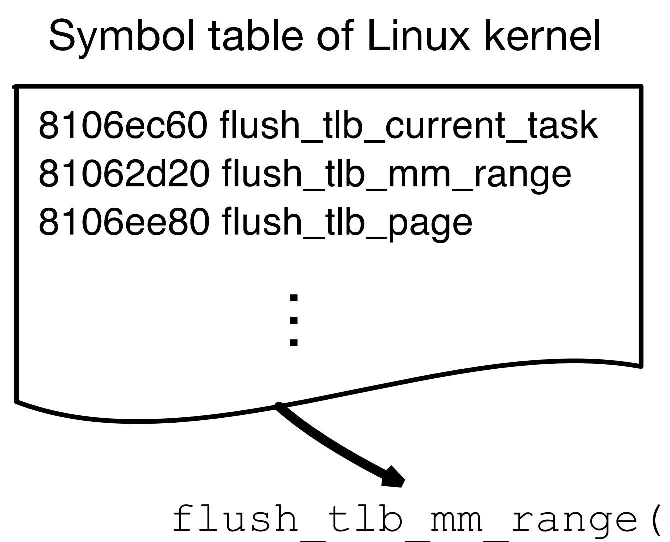

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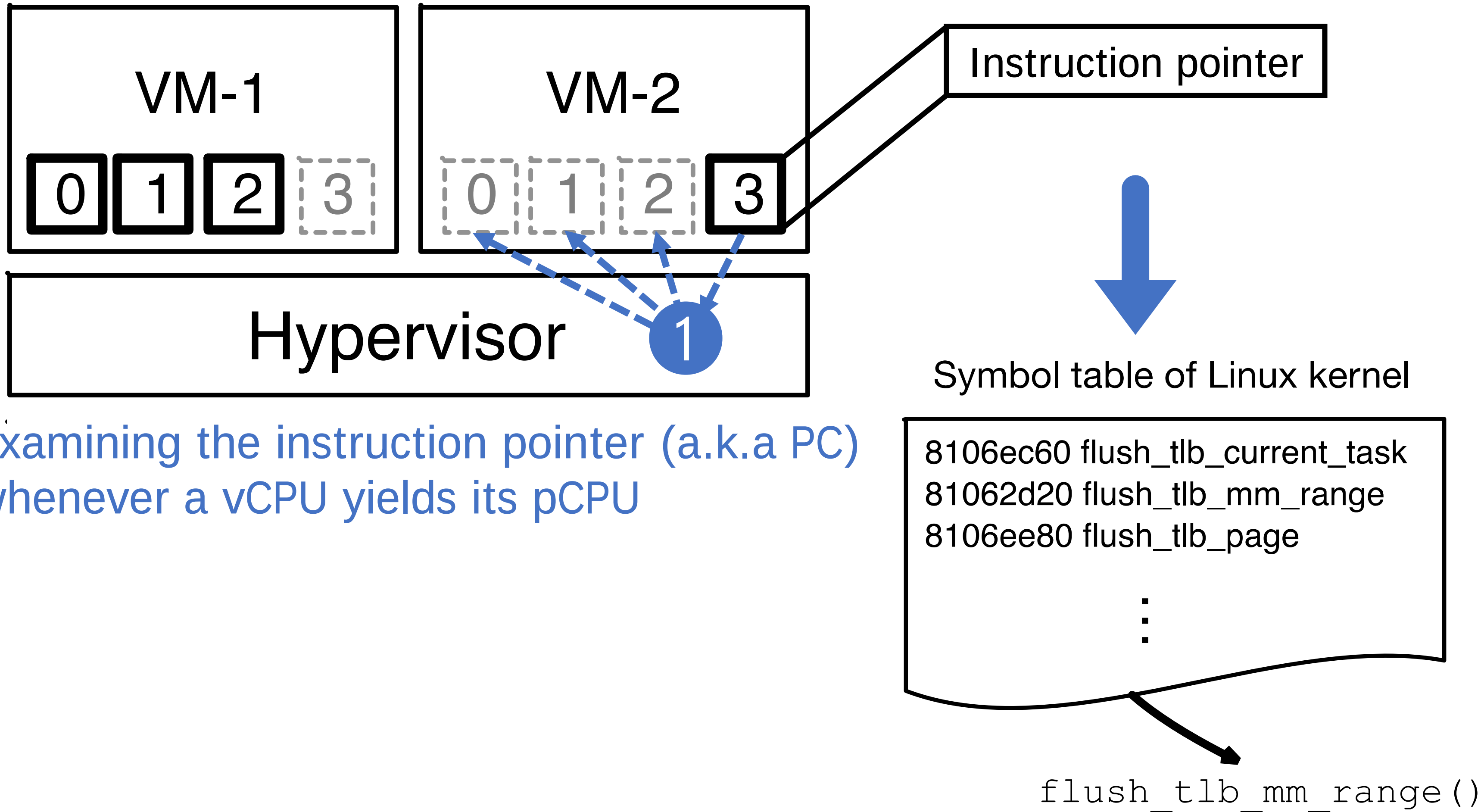

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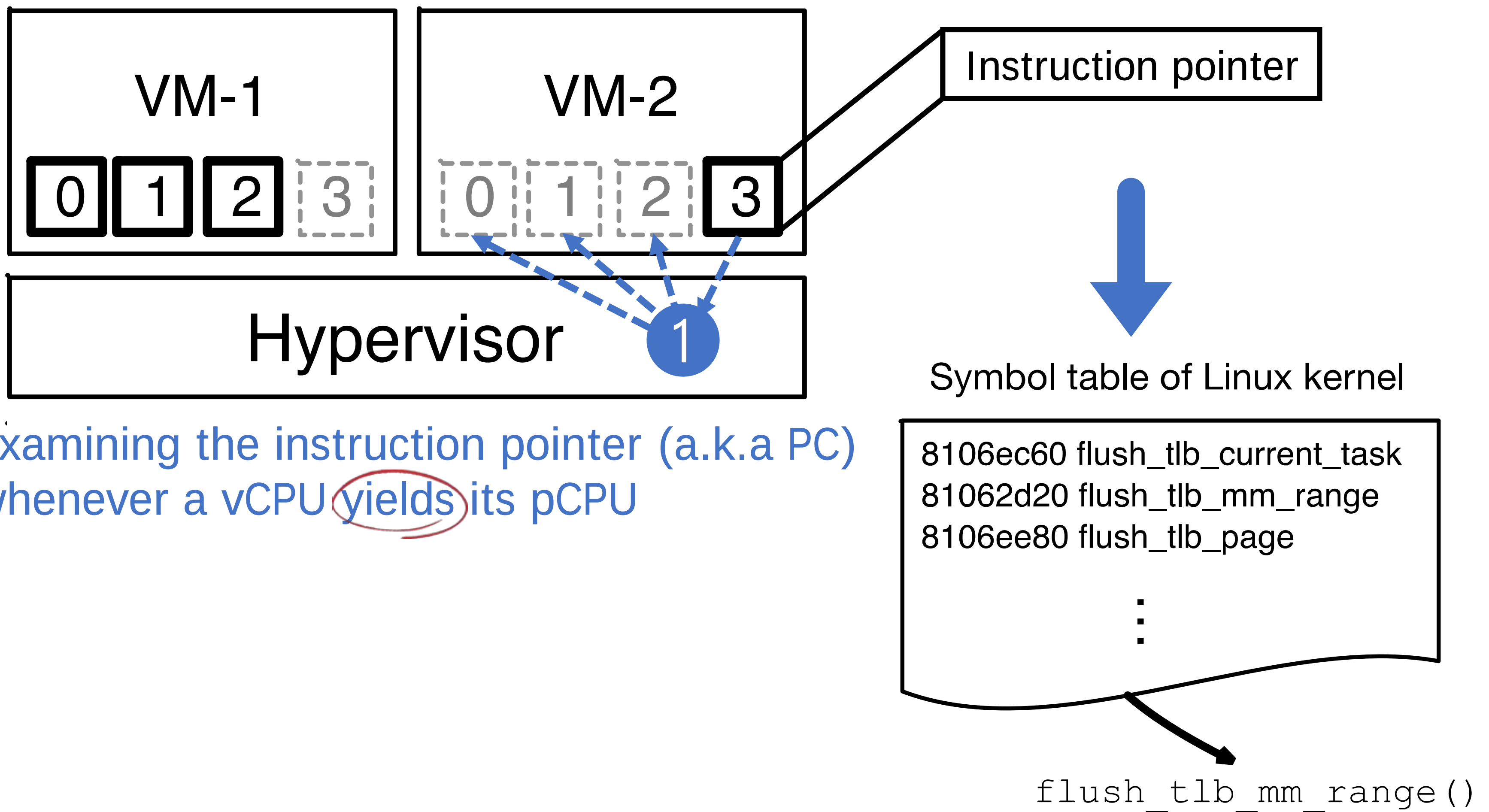

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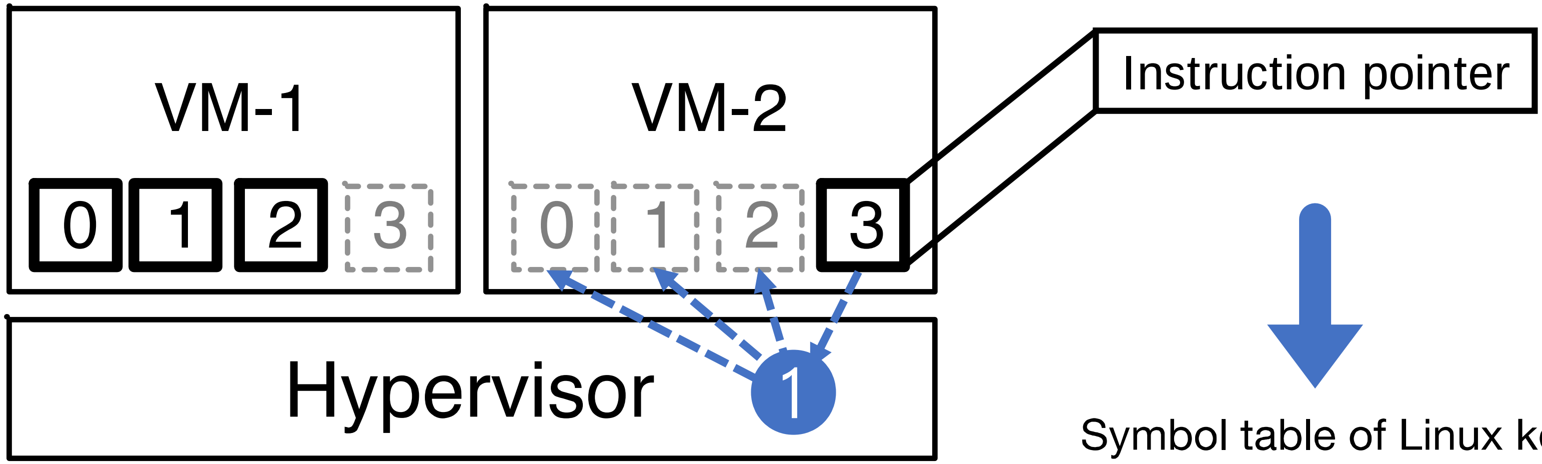

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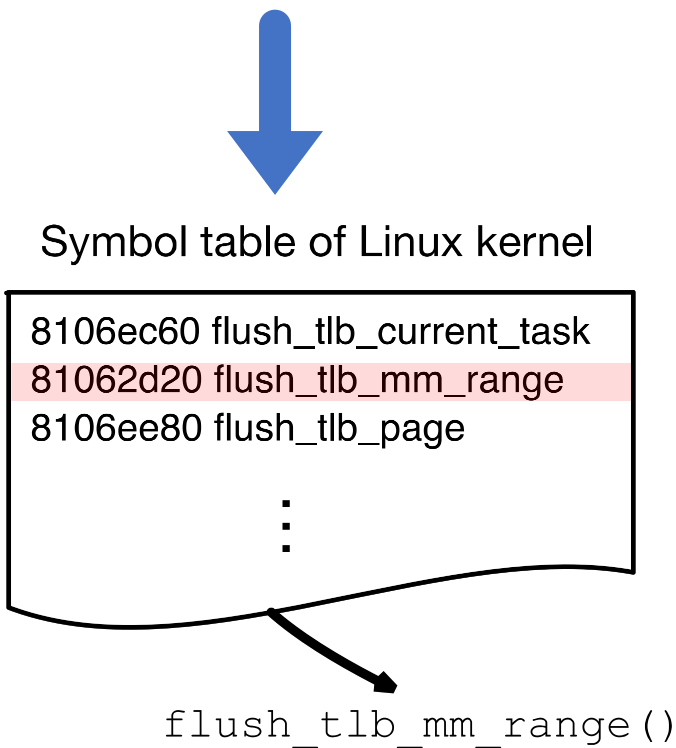

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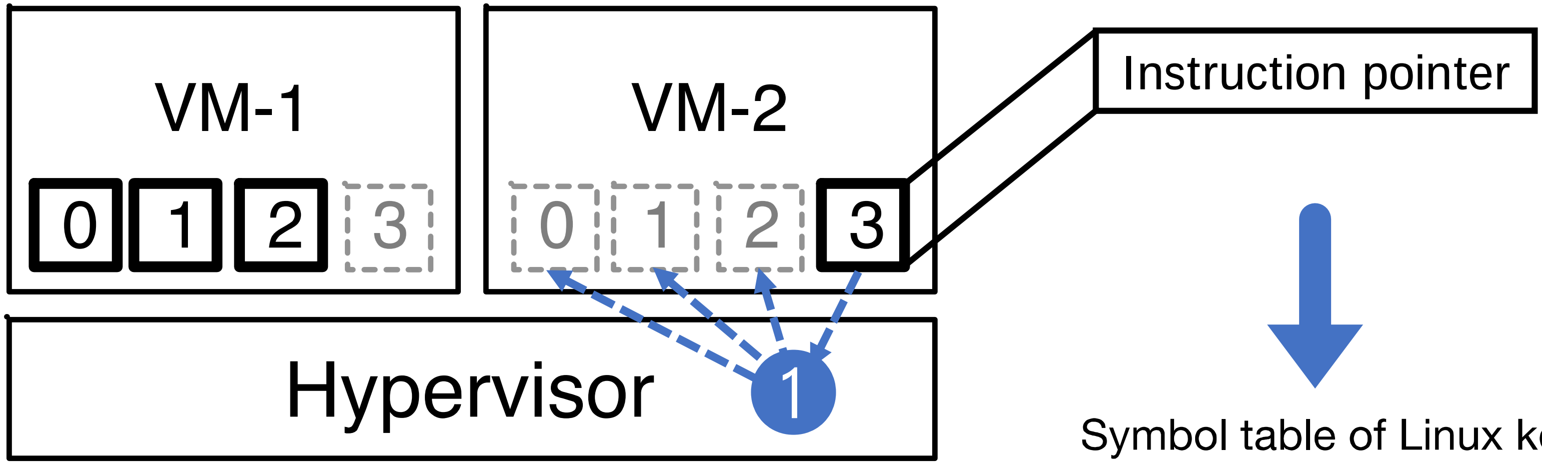

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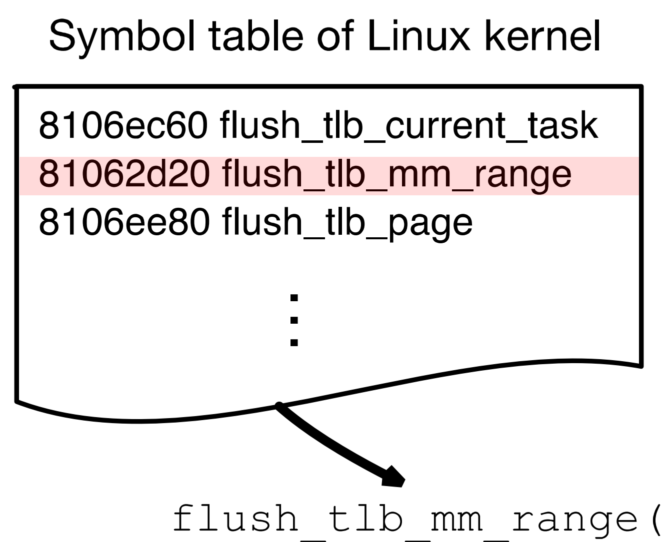

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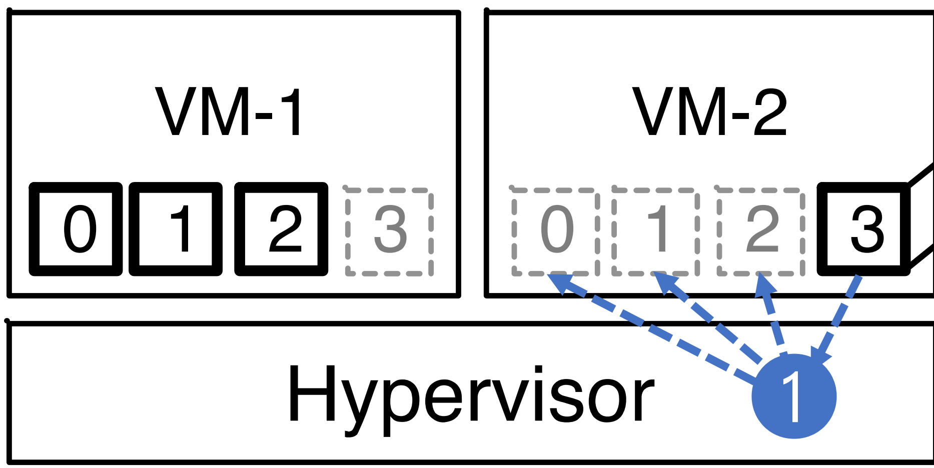

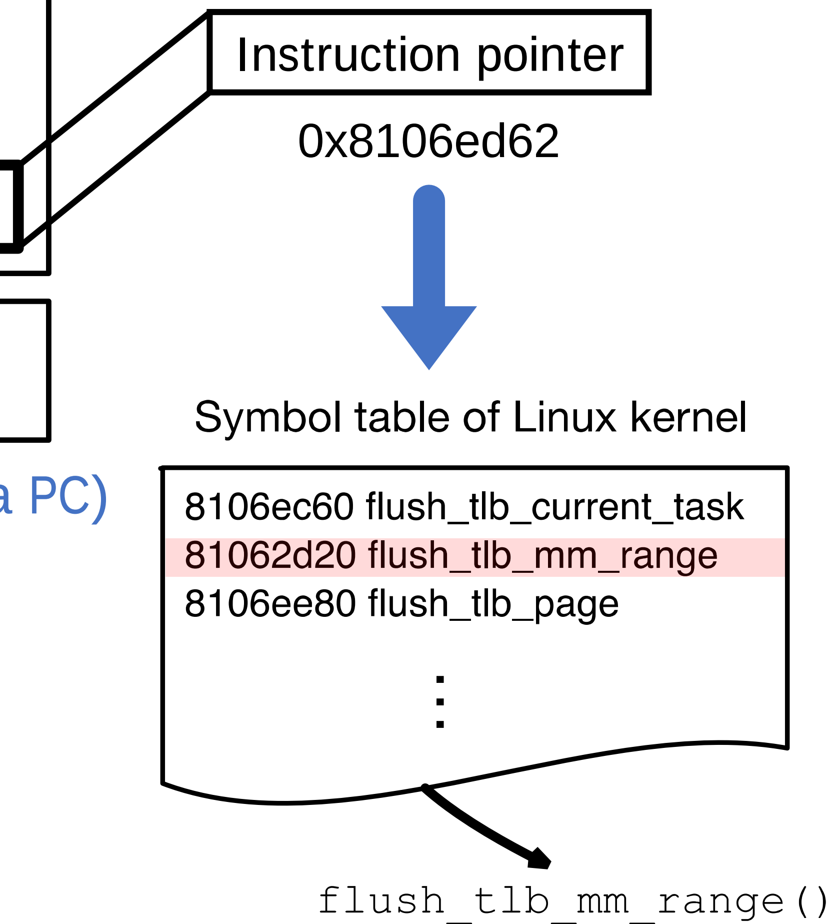

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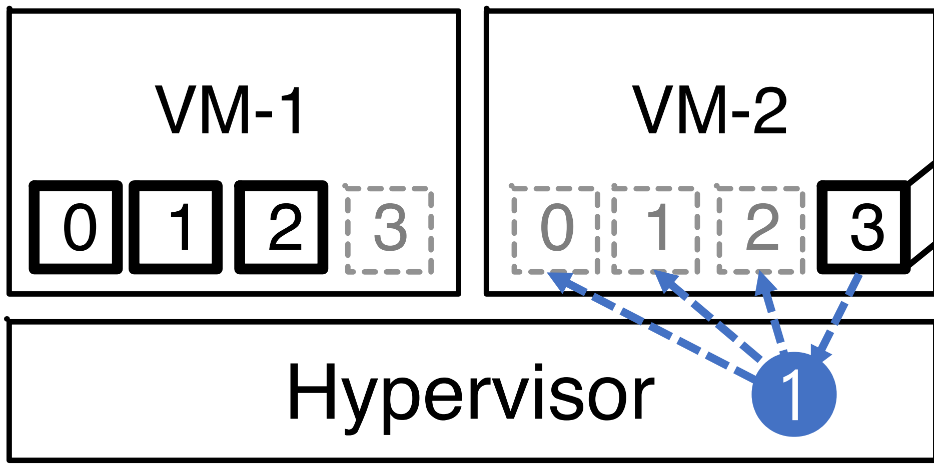

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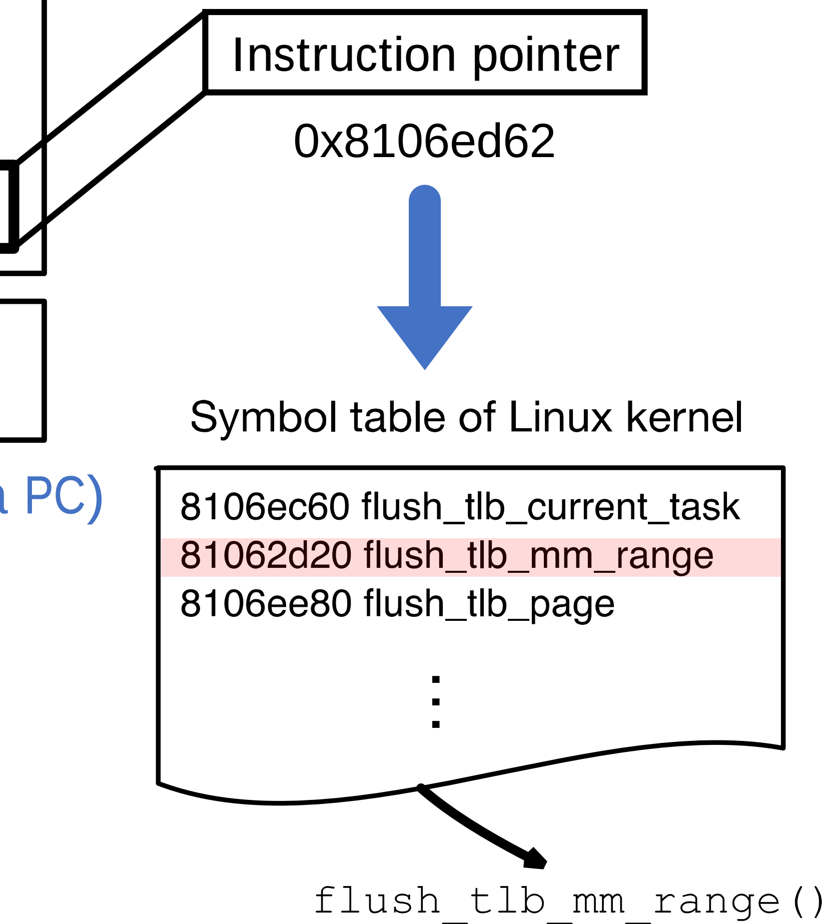

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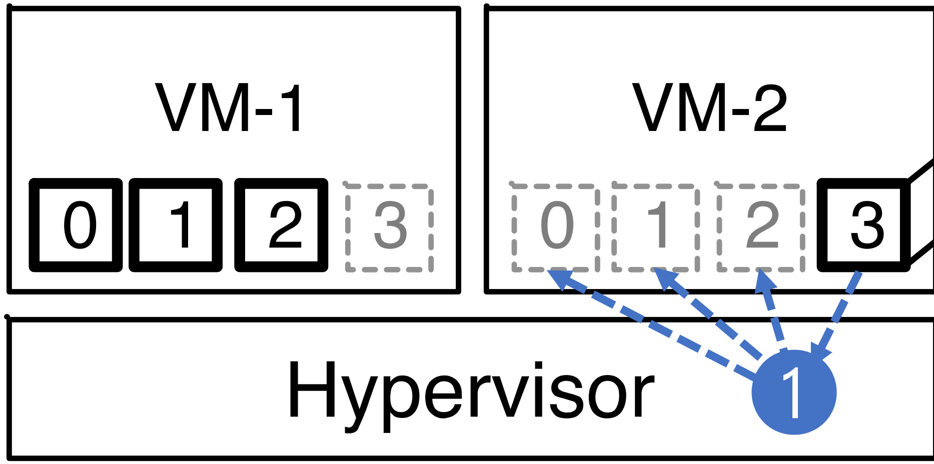

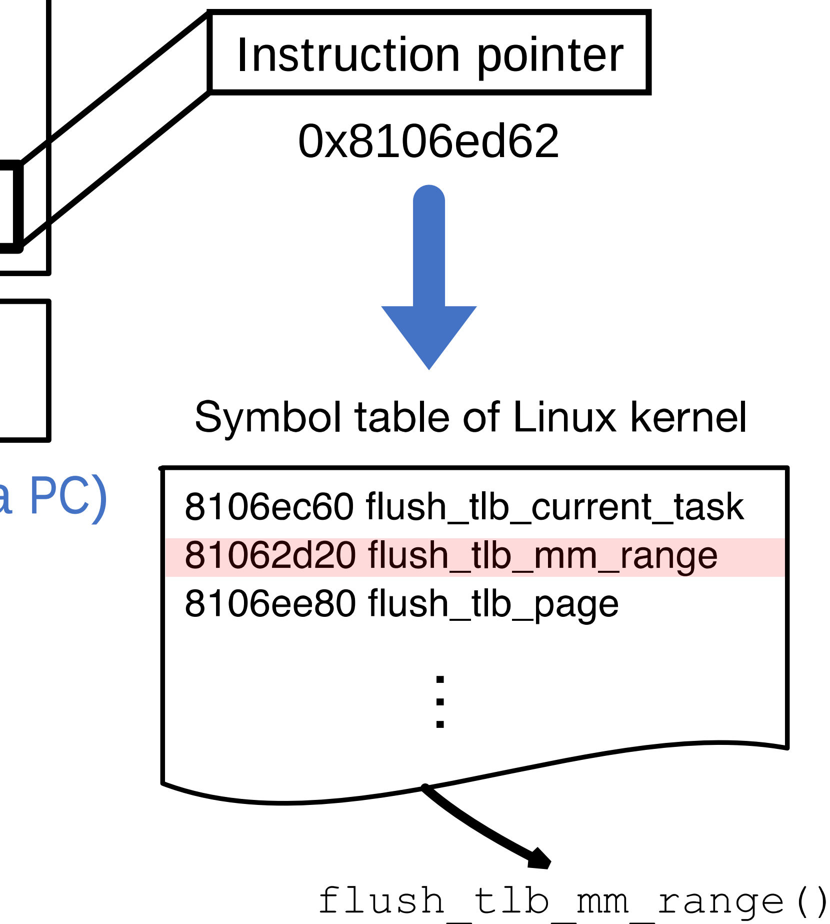

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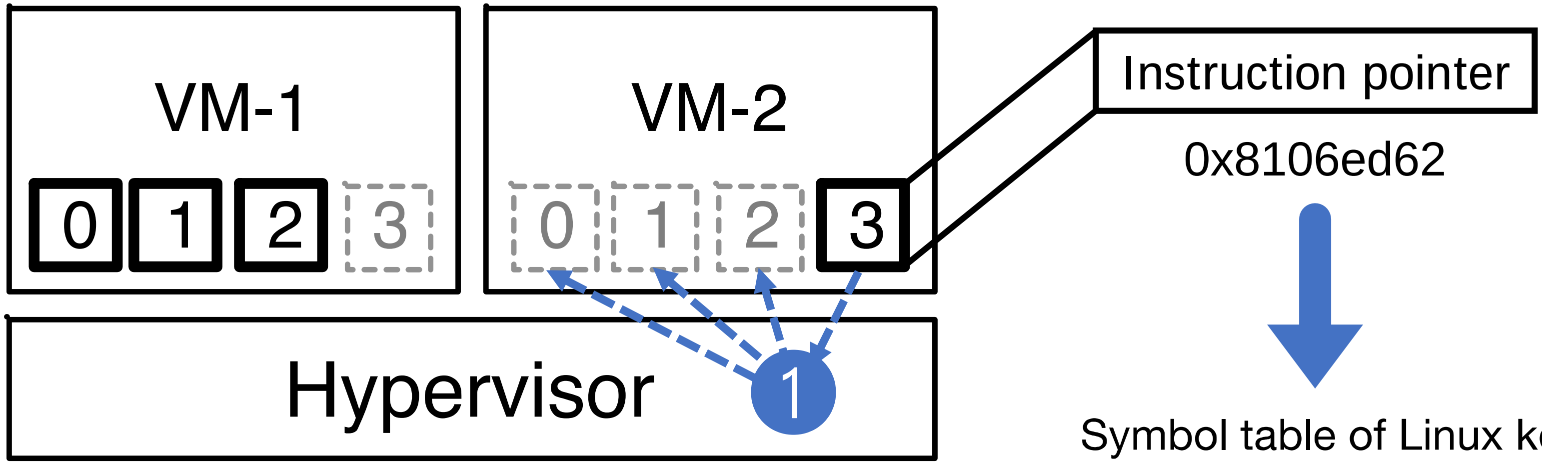

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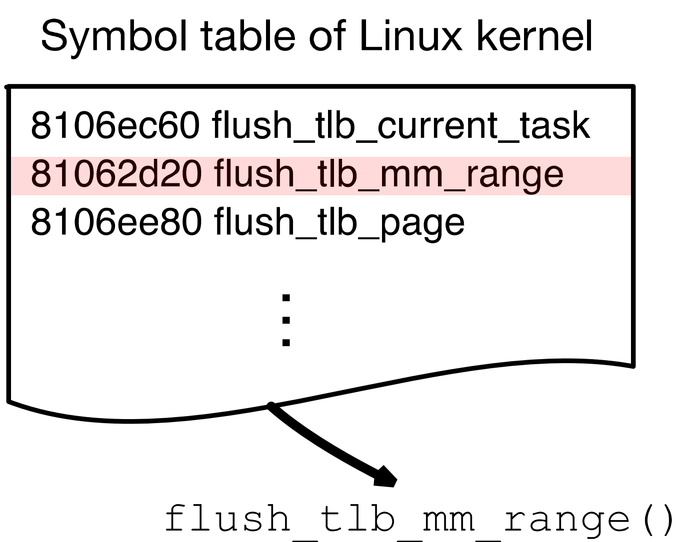
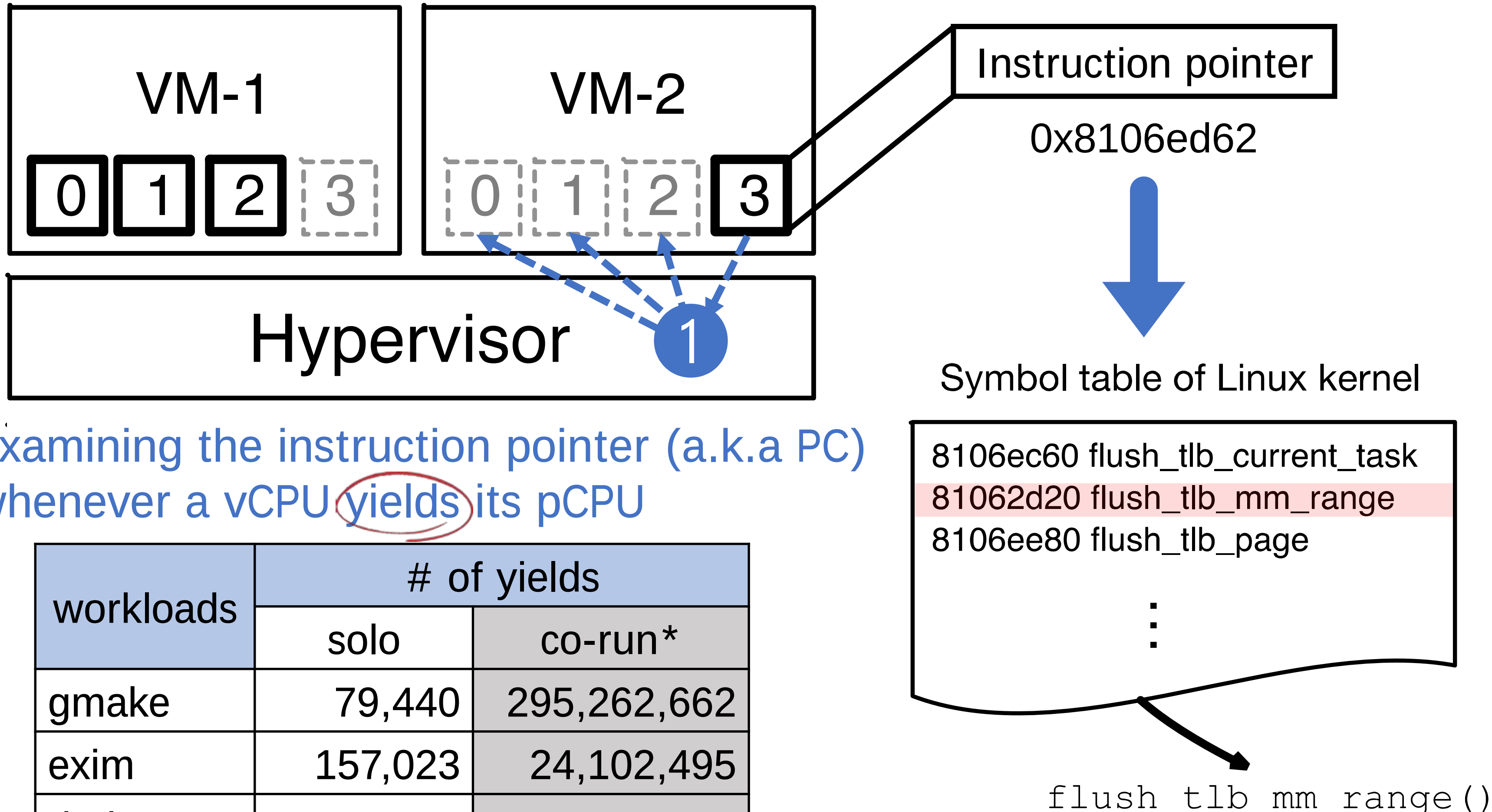


May need to inspect vCPU siblings

Detecting Critical OS Services



Examining the instruction pointer (a.k.a PC) whenever a vCPU yields its pCPU

workloads	# of yields	
	solo	co-run*
gmake	79,440	295,262,662
exim	157,023	24,102,495
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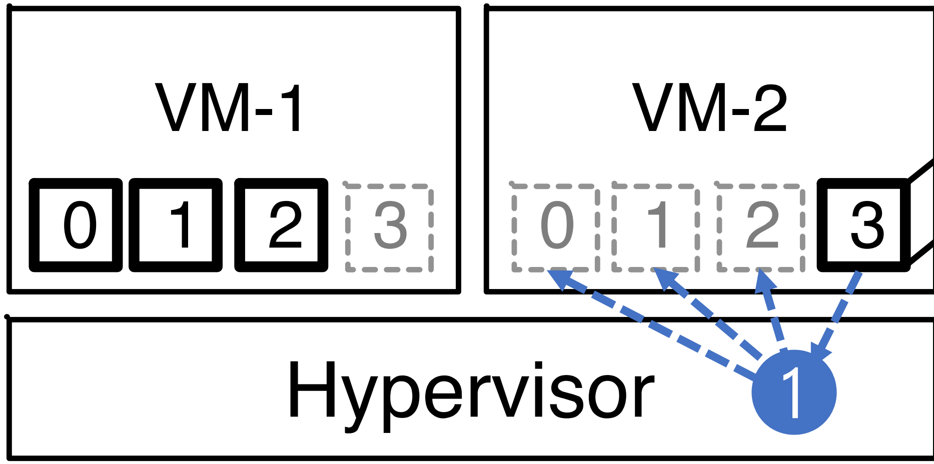

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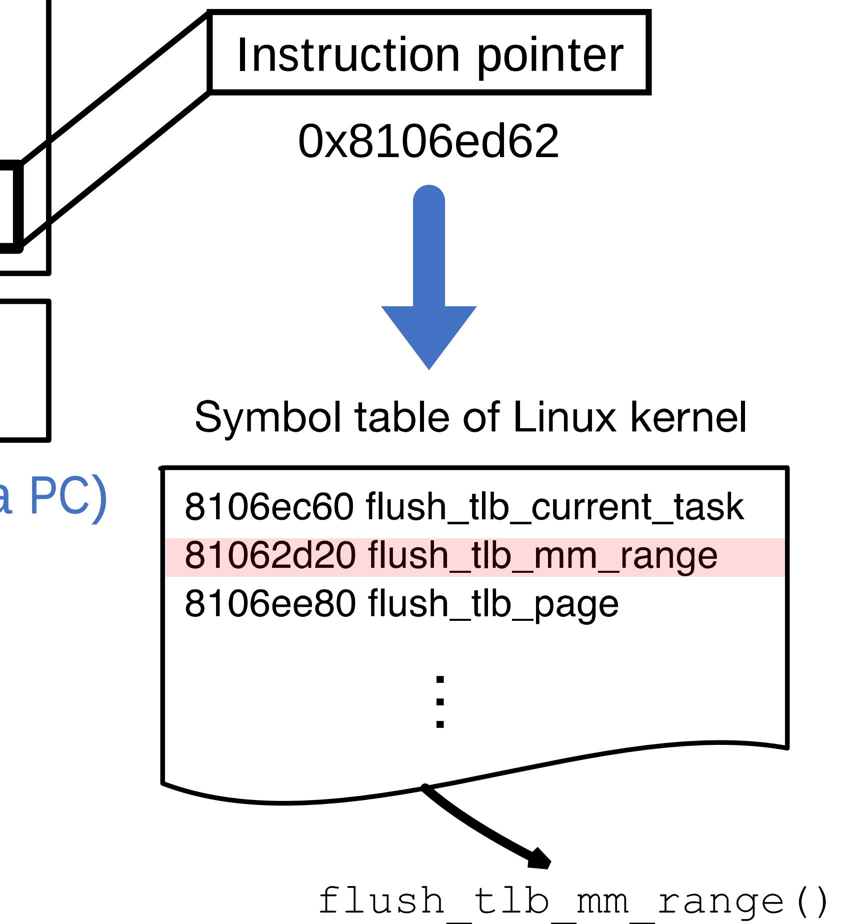

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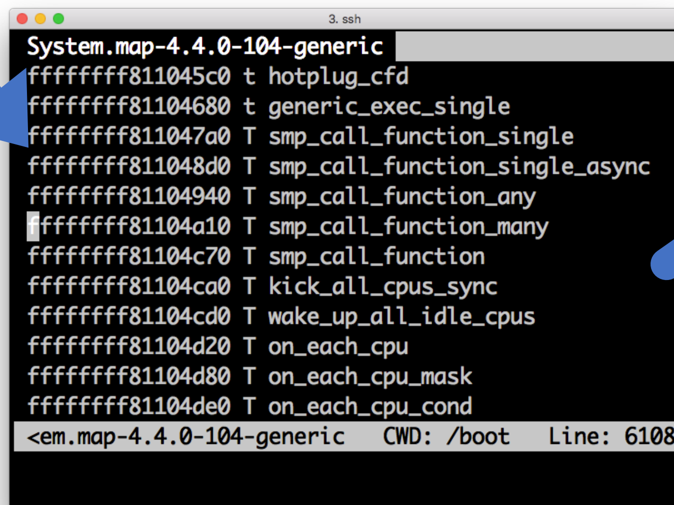
Profiling Virtual CPU Scheduling Logs

- Investigating frequently preempted regions

vCPU scheduling trace
(w/ `Inst. Pointer`)



Kernel symbol tables

Critical Guest OS Components

Module	Operation

sched	`scheduler_ipi()`
	`resched_curr()`
	…

mm	`flush_tlb_all()`
	`get_page_from_freelist()`
	…

irq	`irq_enter()`
	`irq_exit()`
	…

spinlock	`__raw_spin_unlock()`
	`__raw_spin_unlock_irq()`
	…

In our paper, you can find the table in details

Profiling Virtual CPU Scheduling Logs

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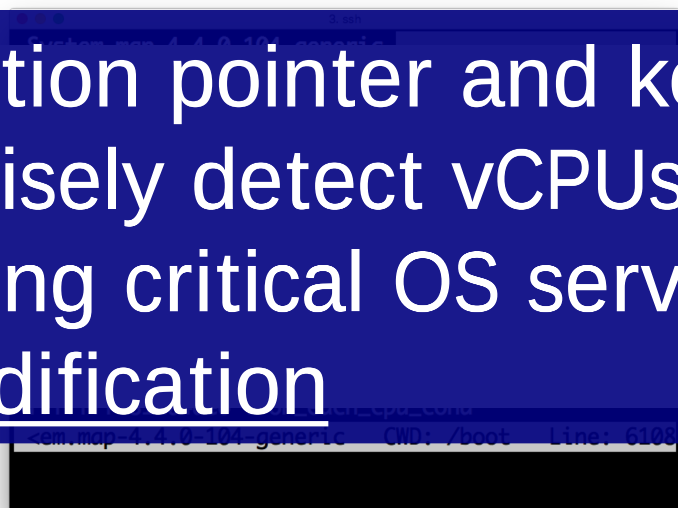

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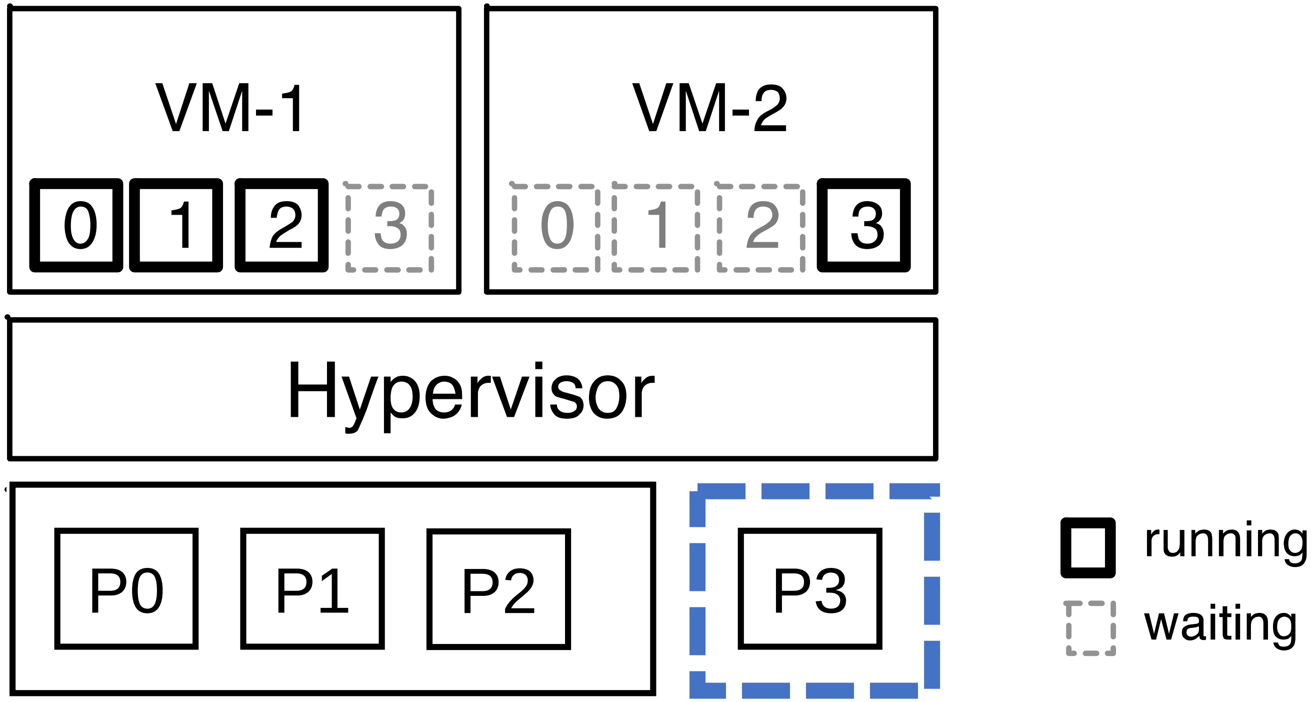
Instruction pointer and kernel symbols enable to precisely detect vCPUs preempted while executing critical OS services <u>without guest OS modification</u>

Accelerating Critical Sections



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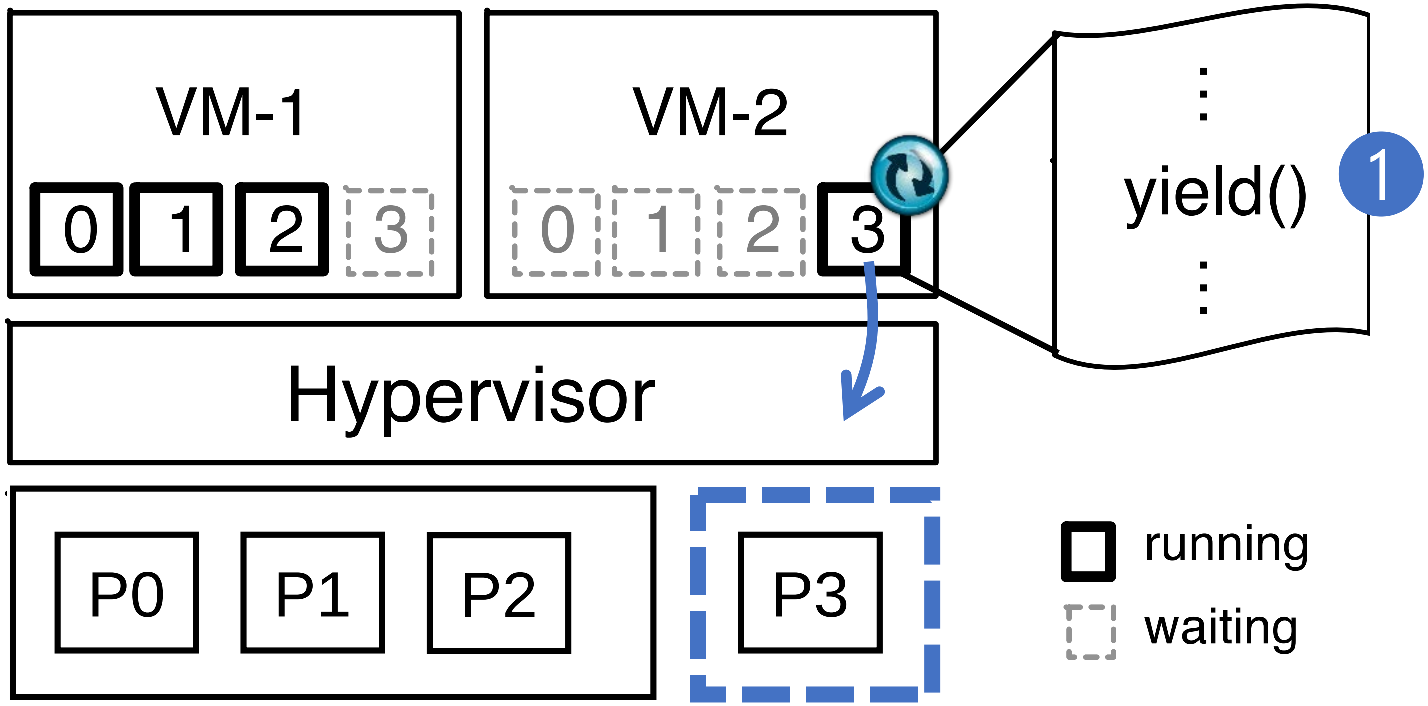

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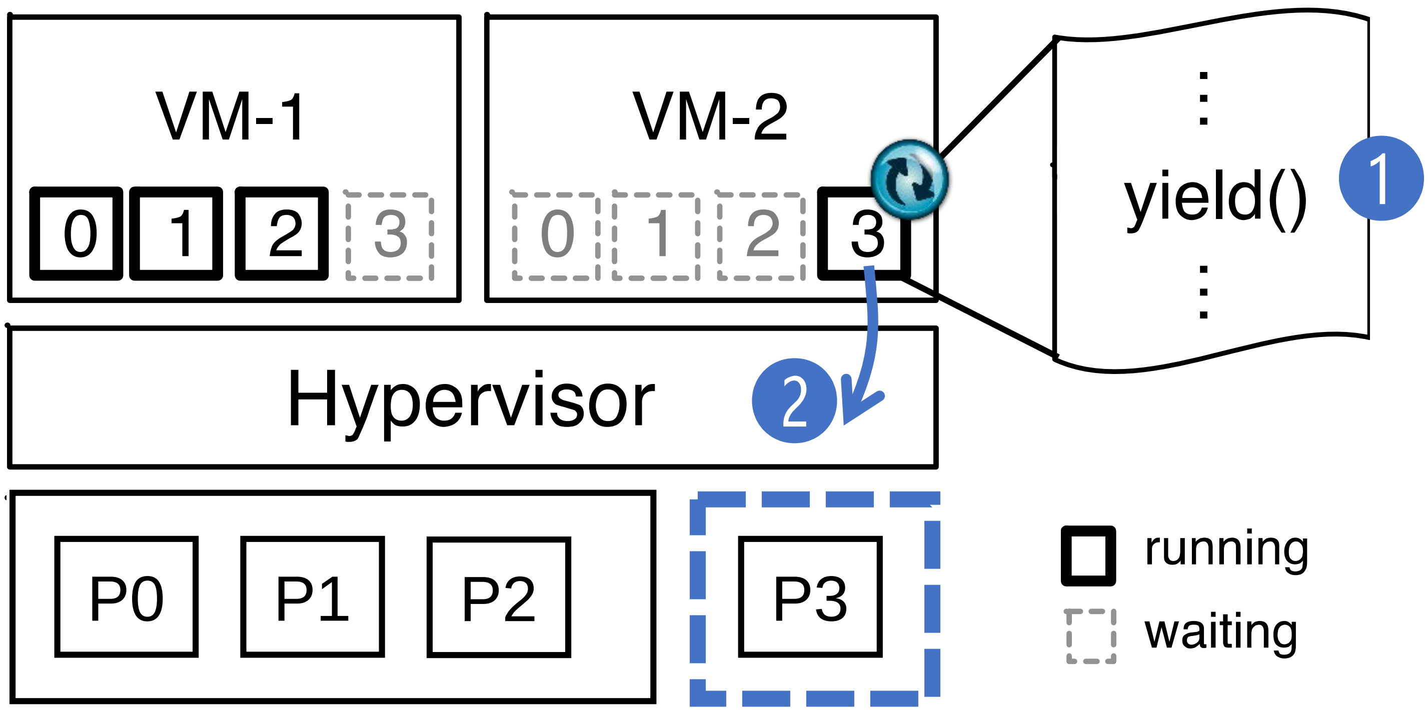

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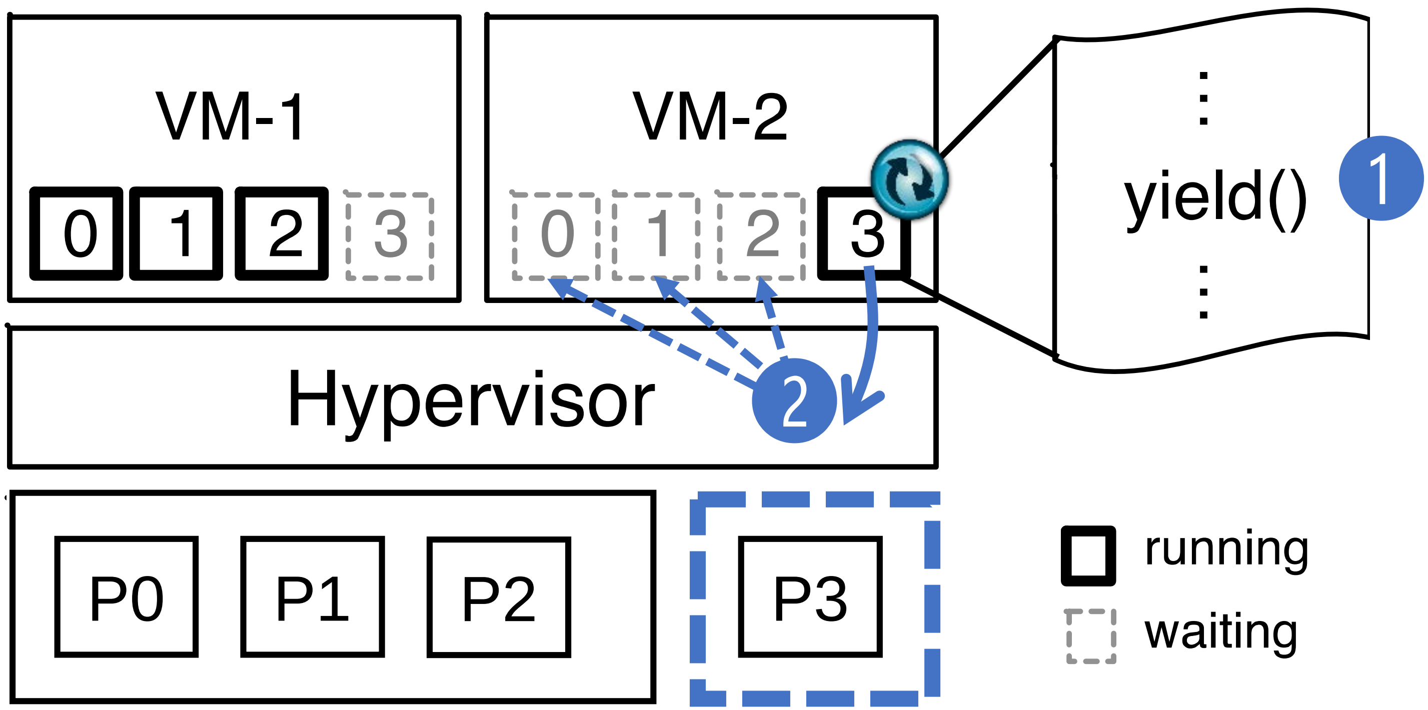

❶ Yield occurring

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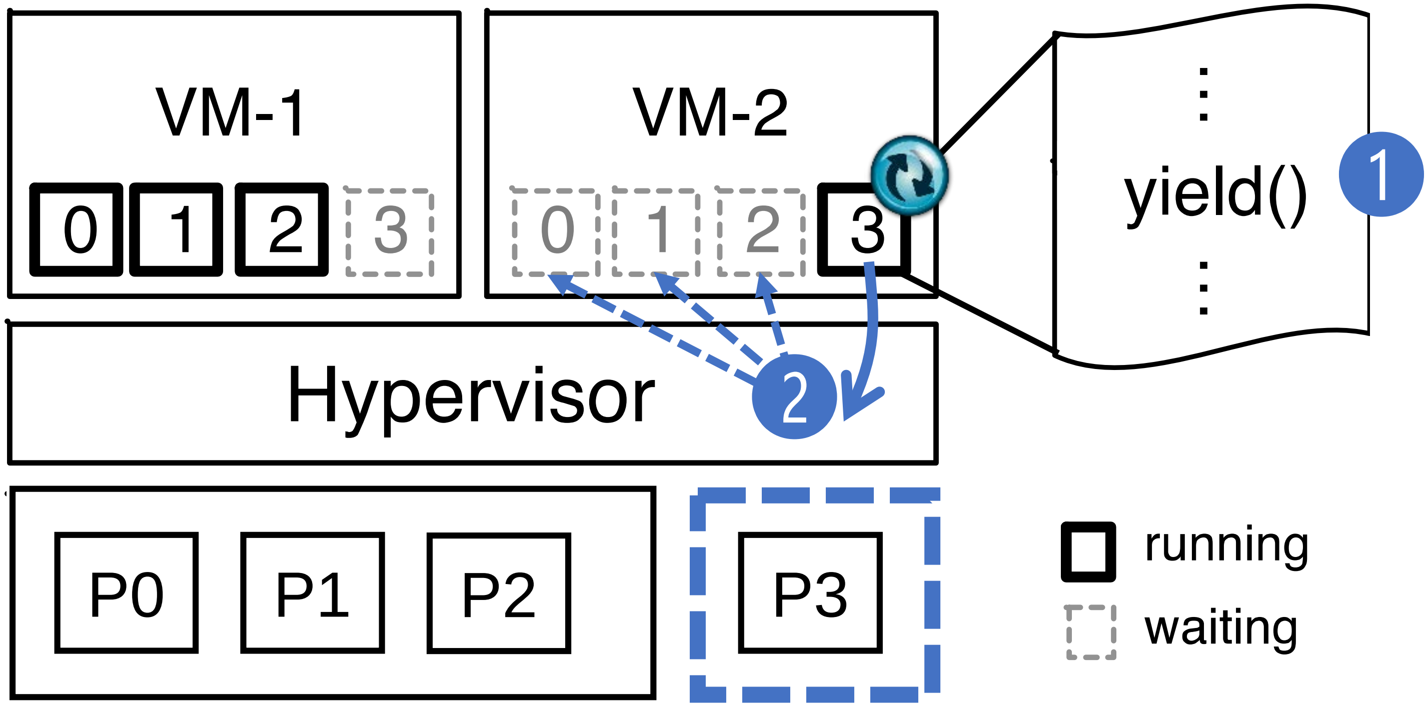

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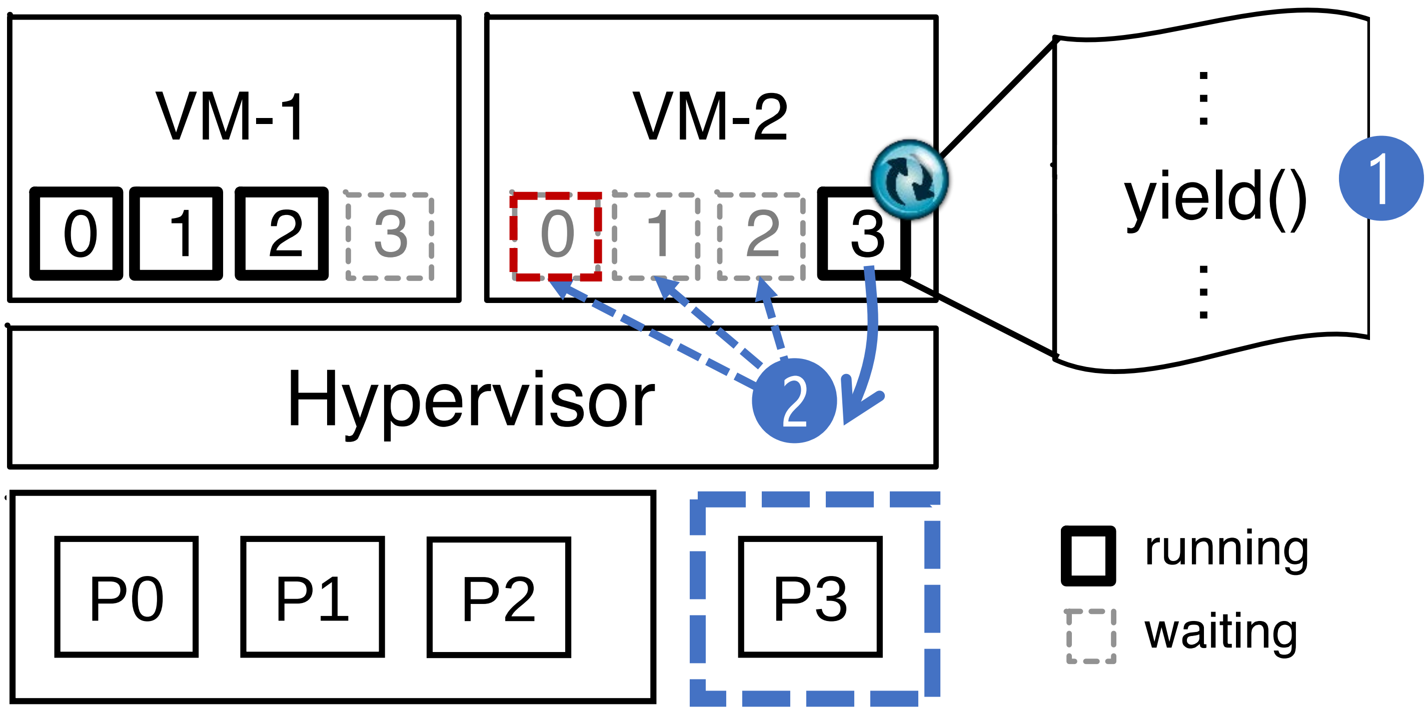

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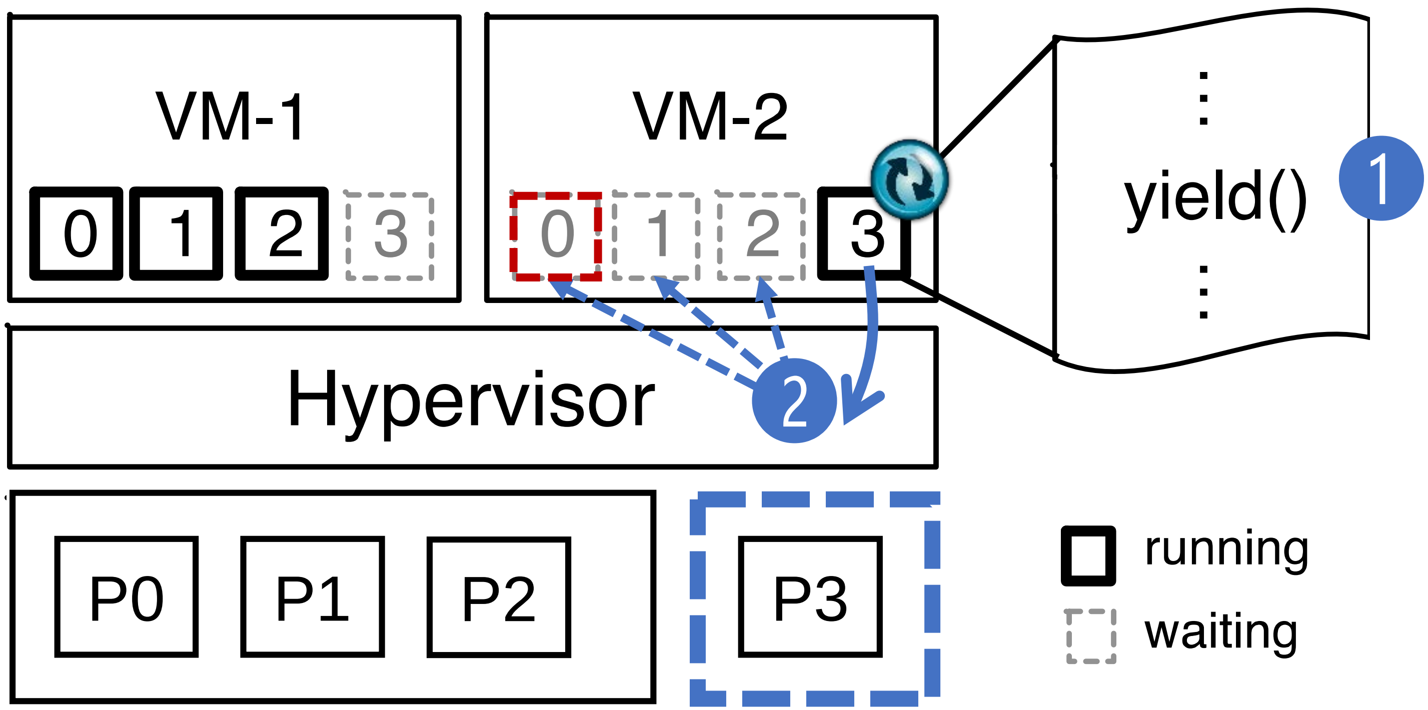

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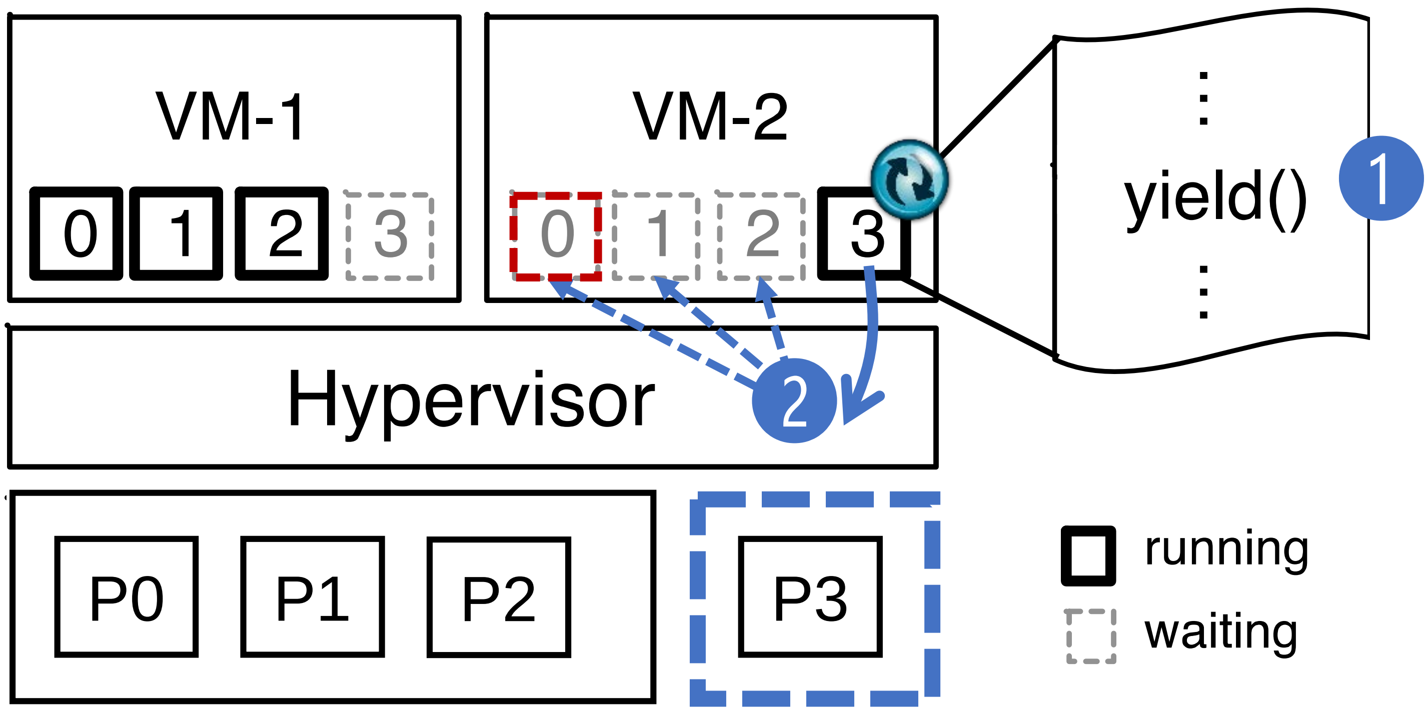

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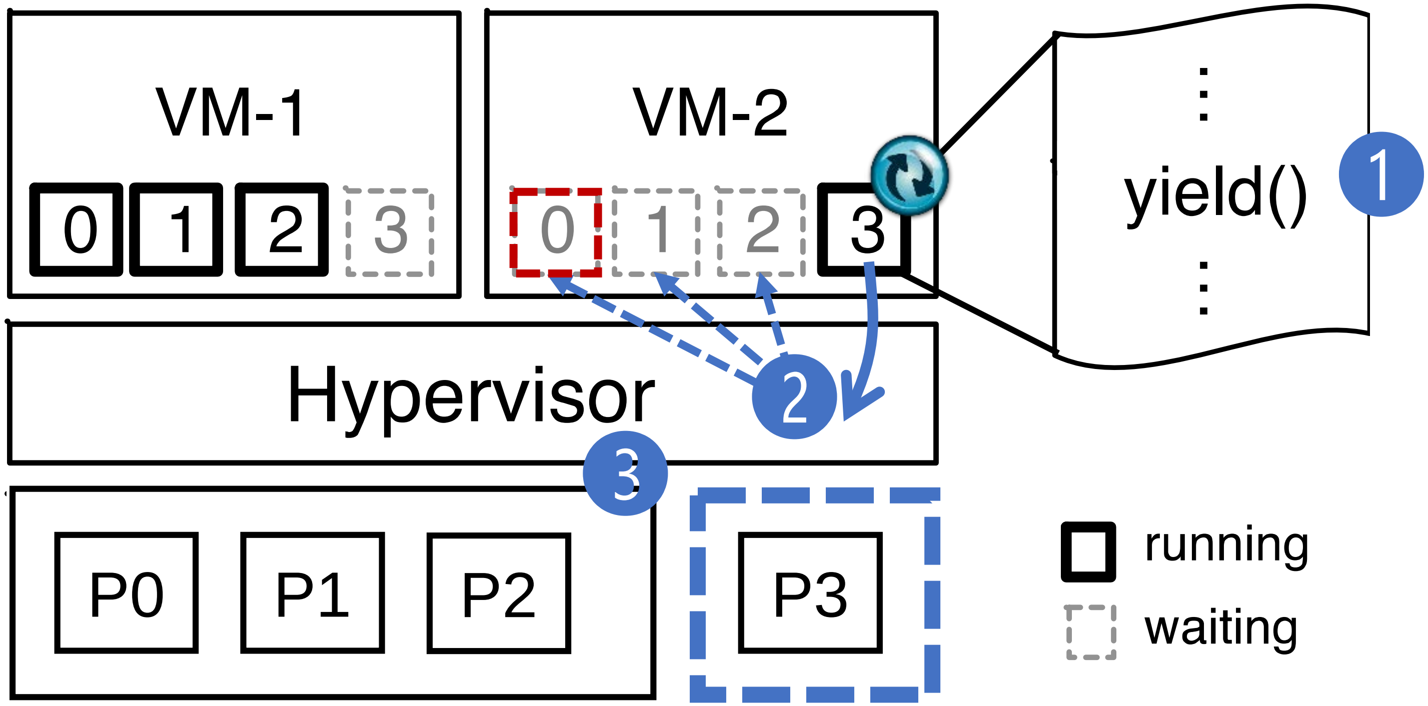

❶ Yield occurring
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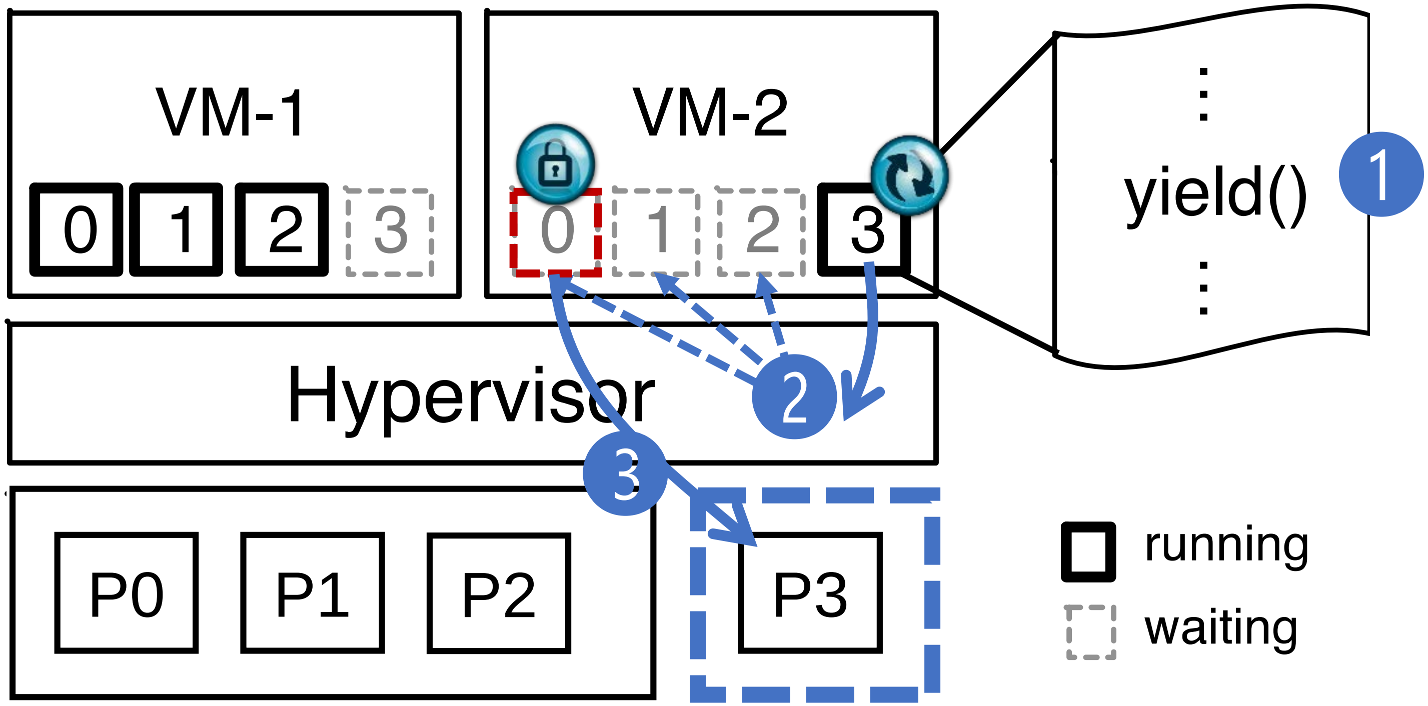
❸ Scheduling the selected vCPU on the micro-sliced pool

Accelerating Critical Sections



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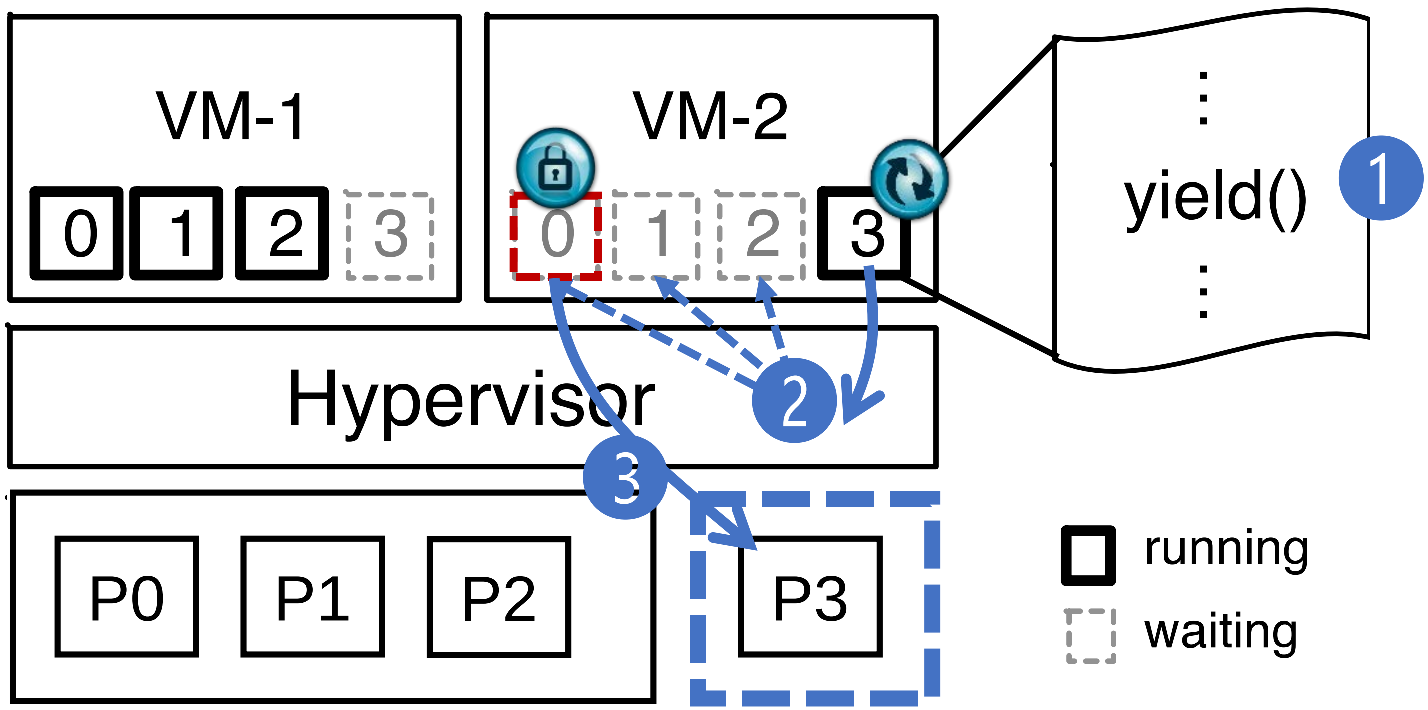

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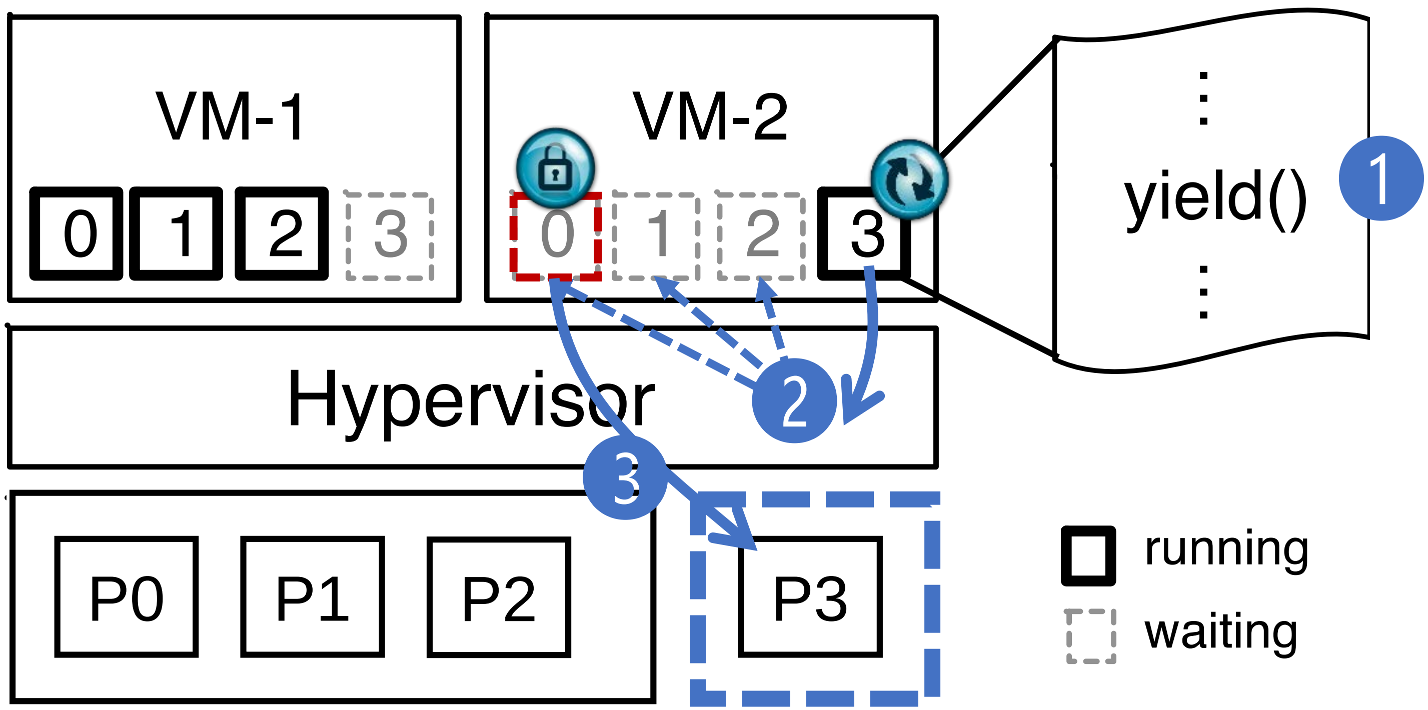

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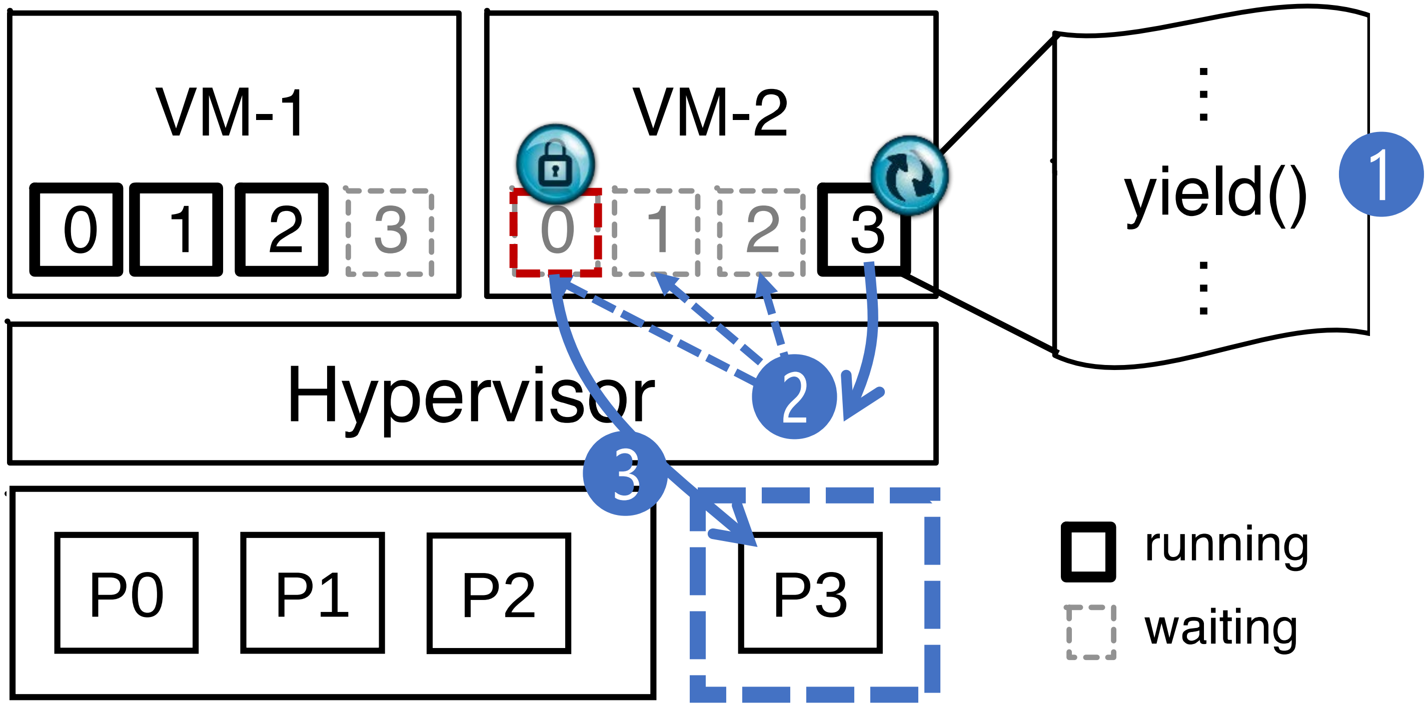

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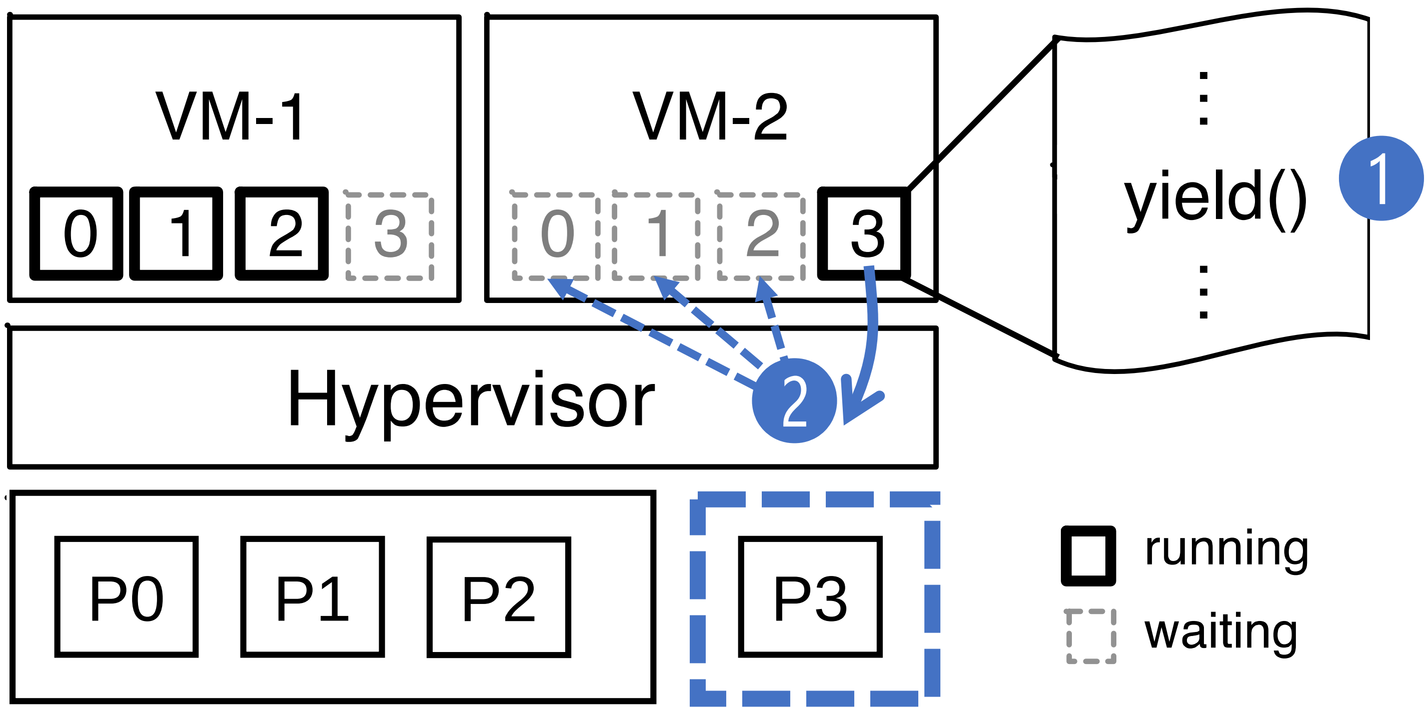
Accelerating Critical TLB Synchronizations



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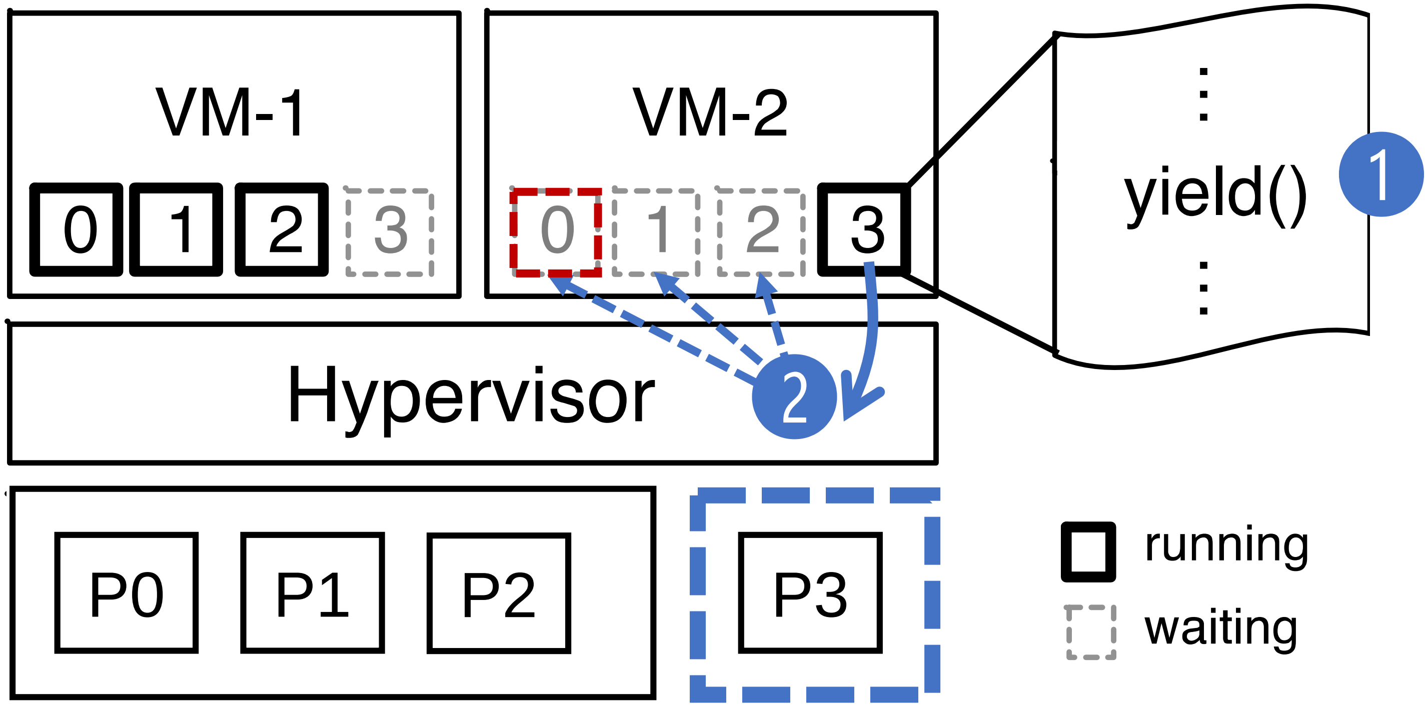

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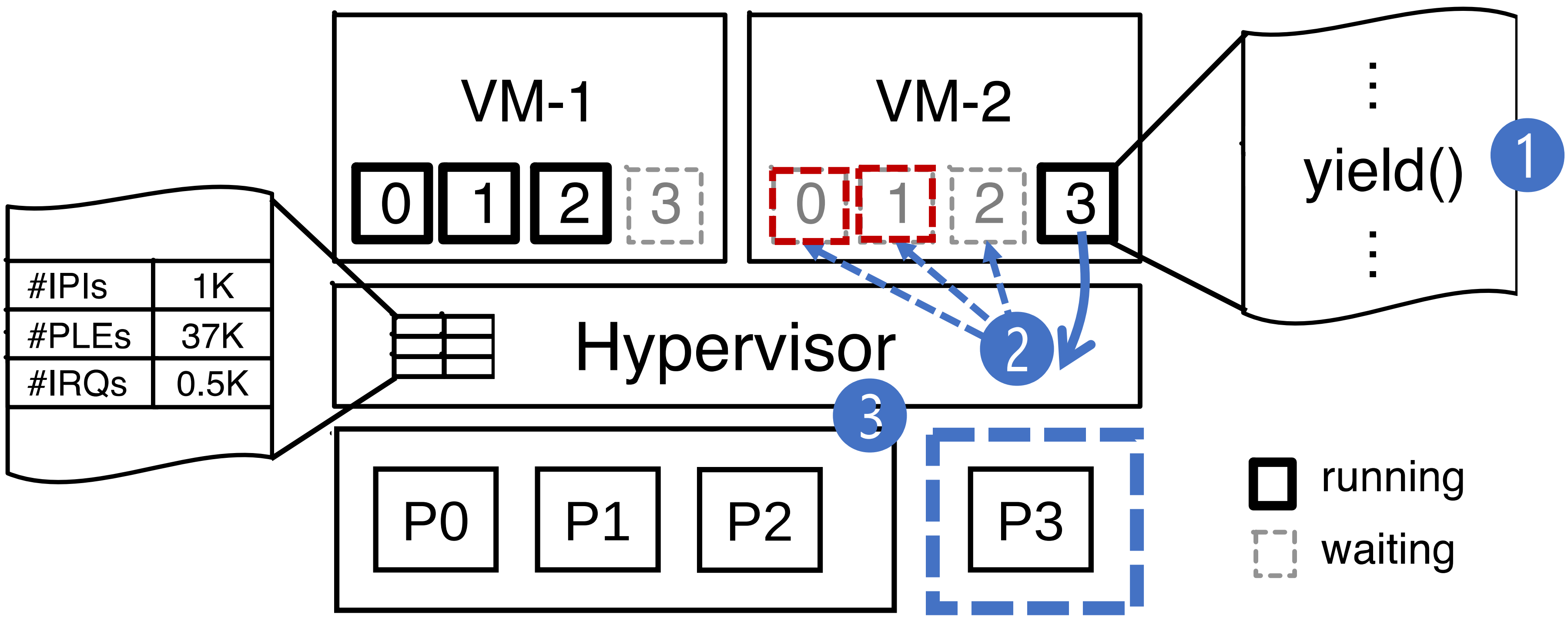

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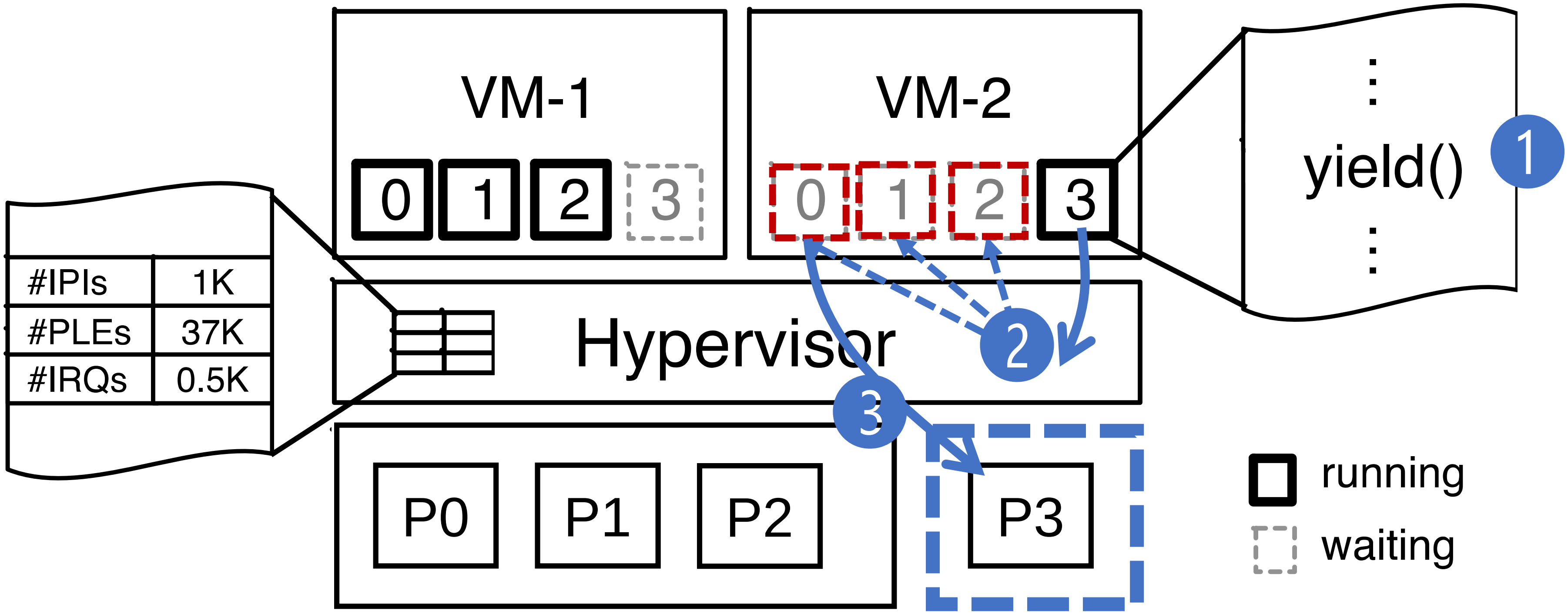

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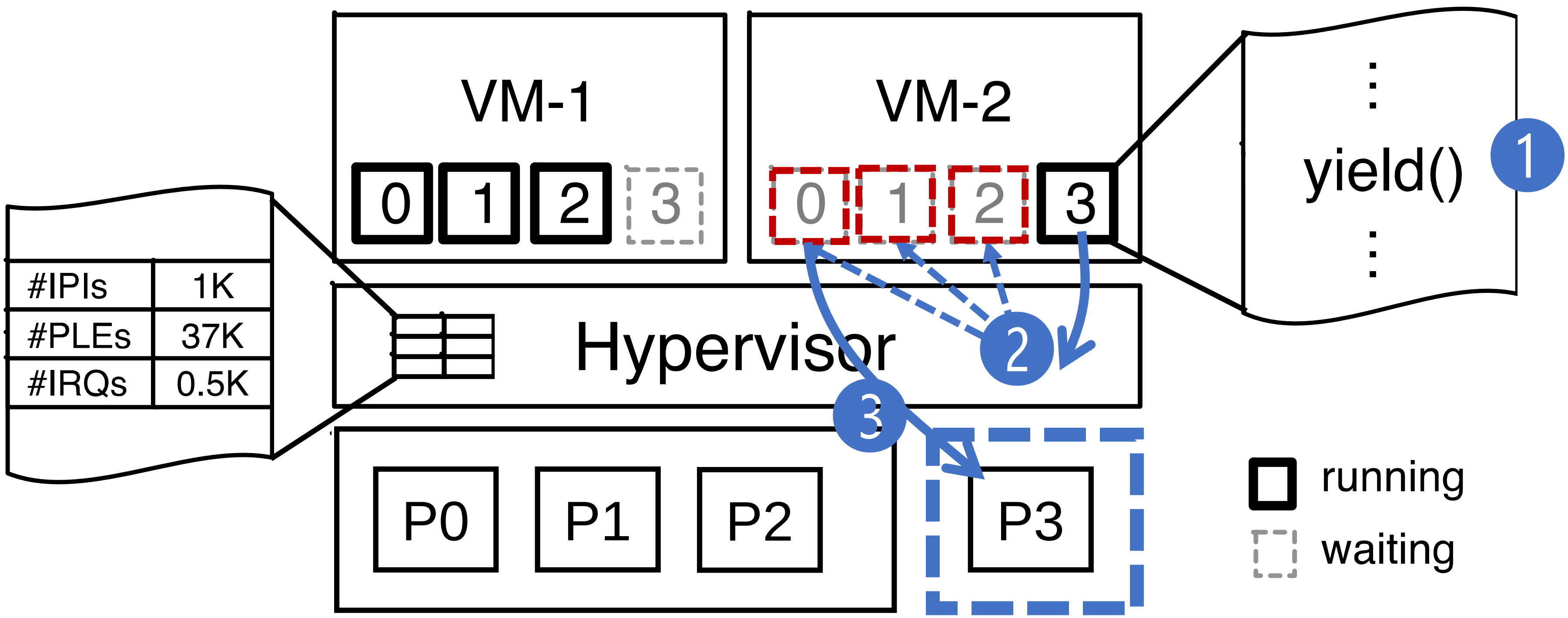

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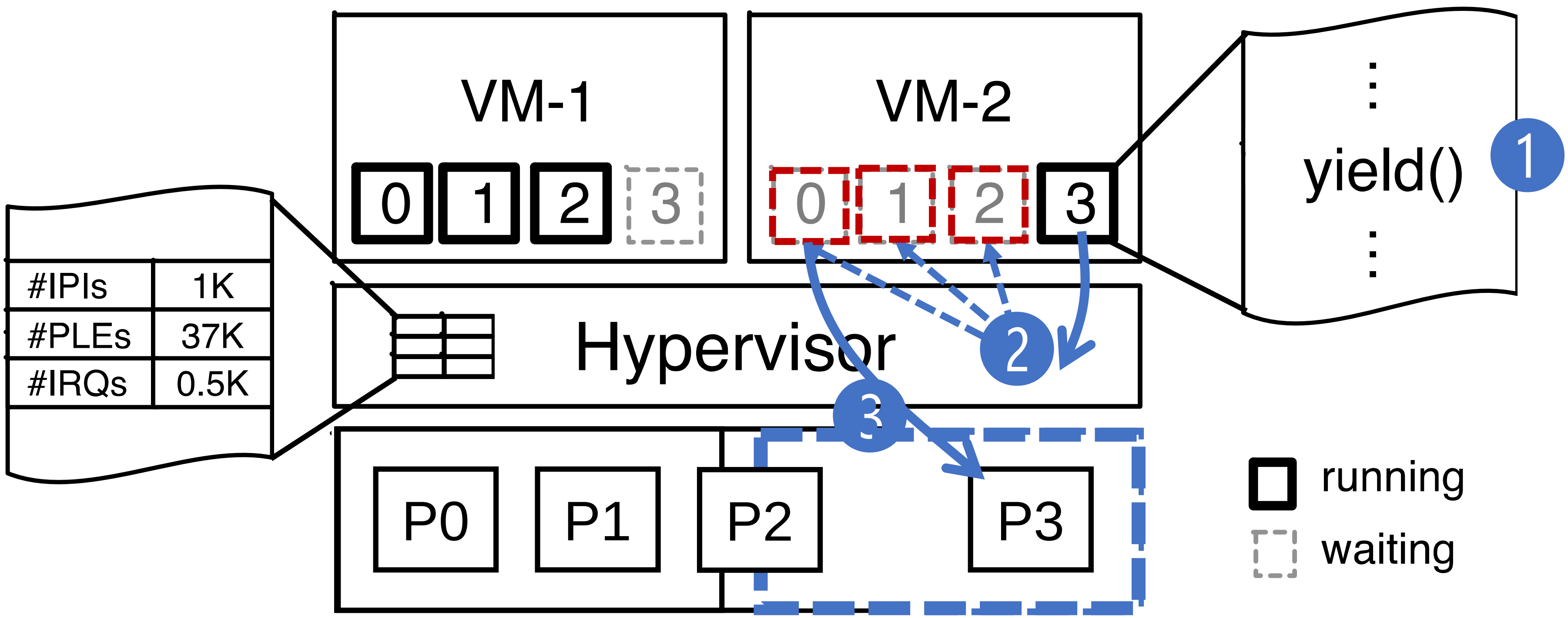

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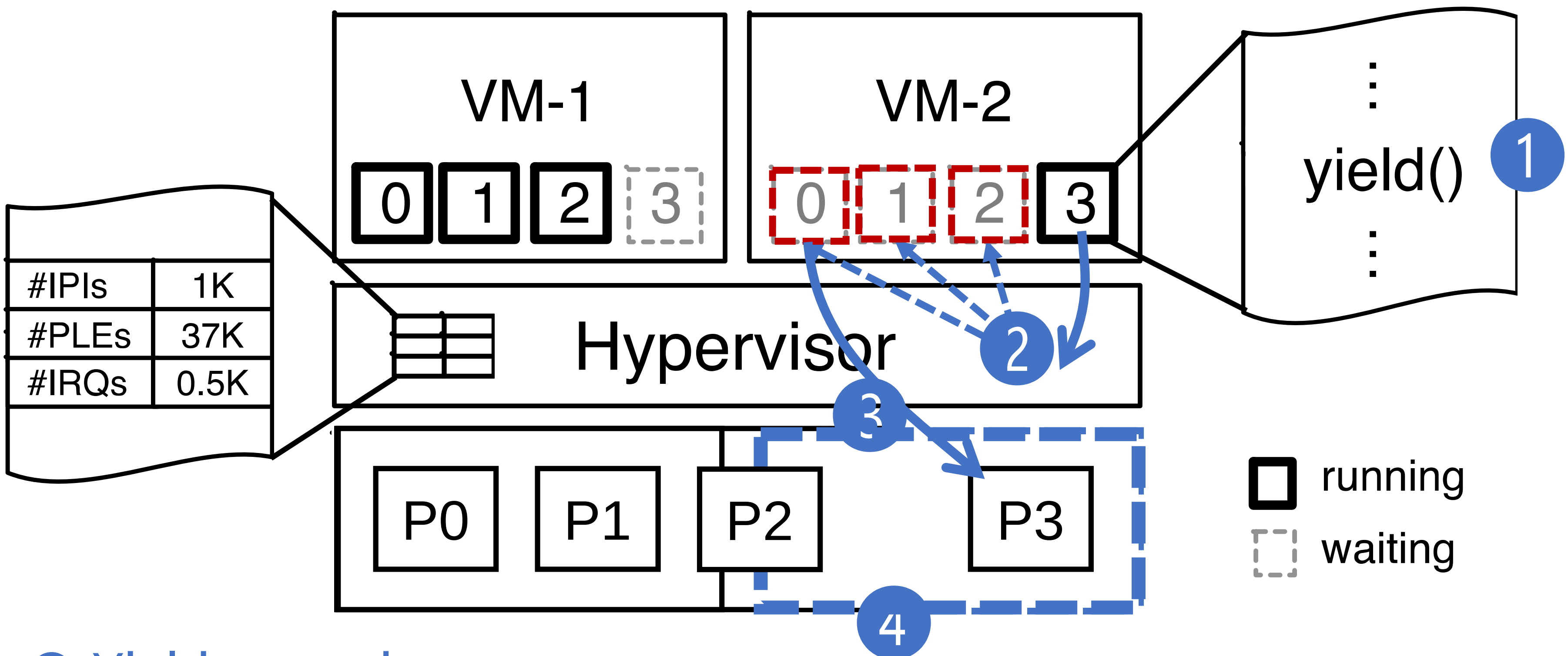

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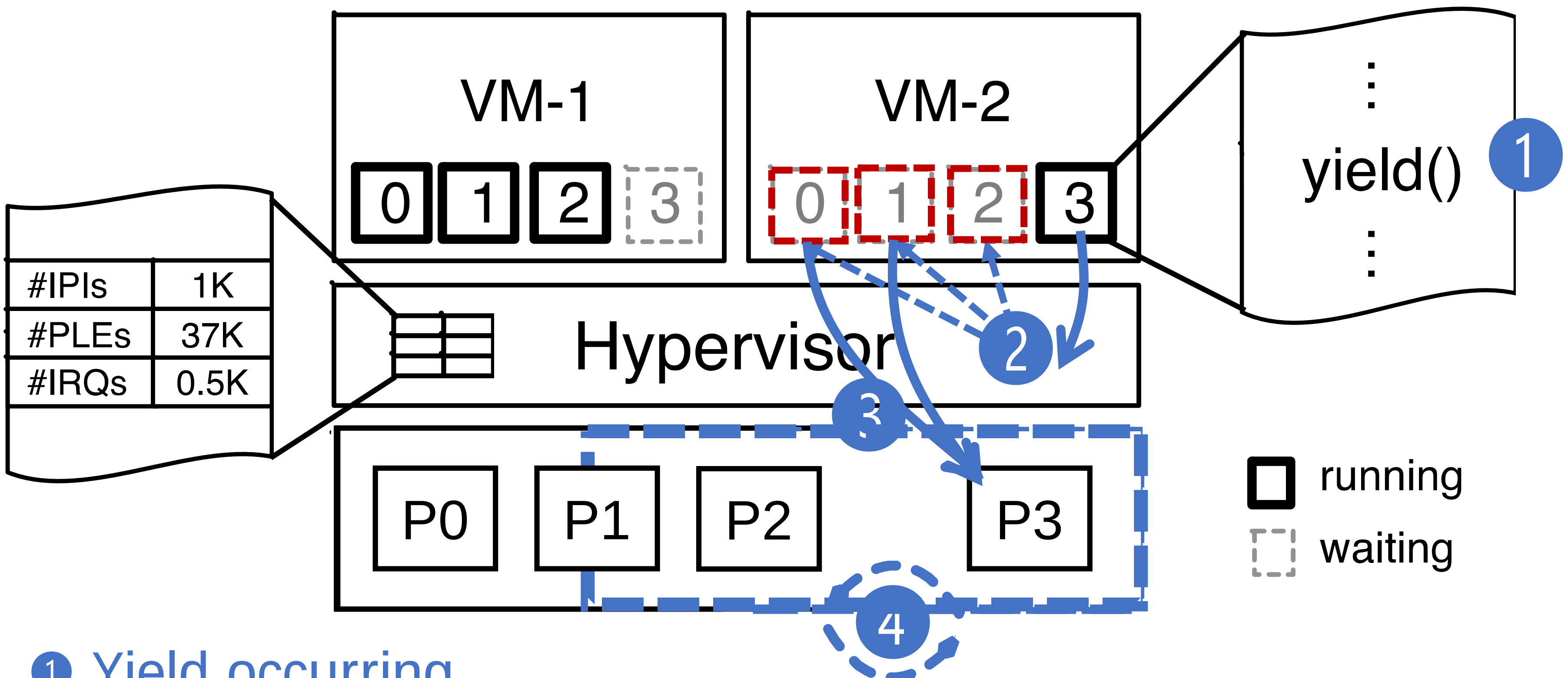

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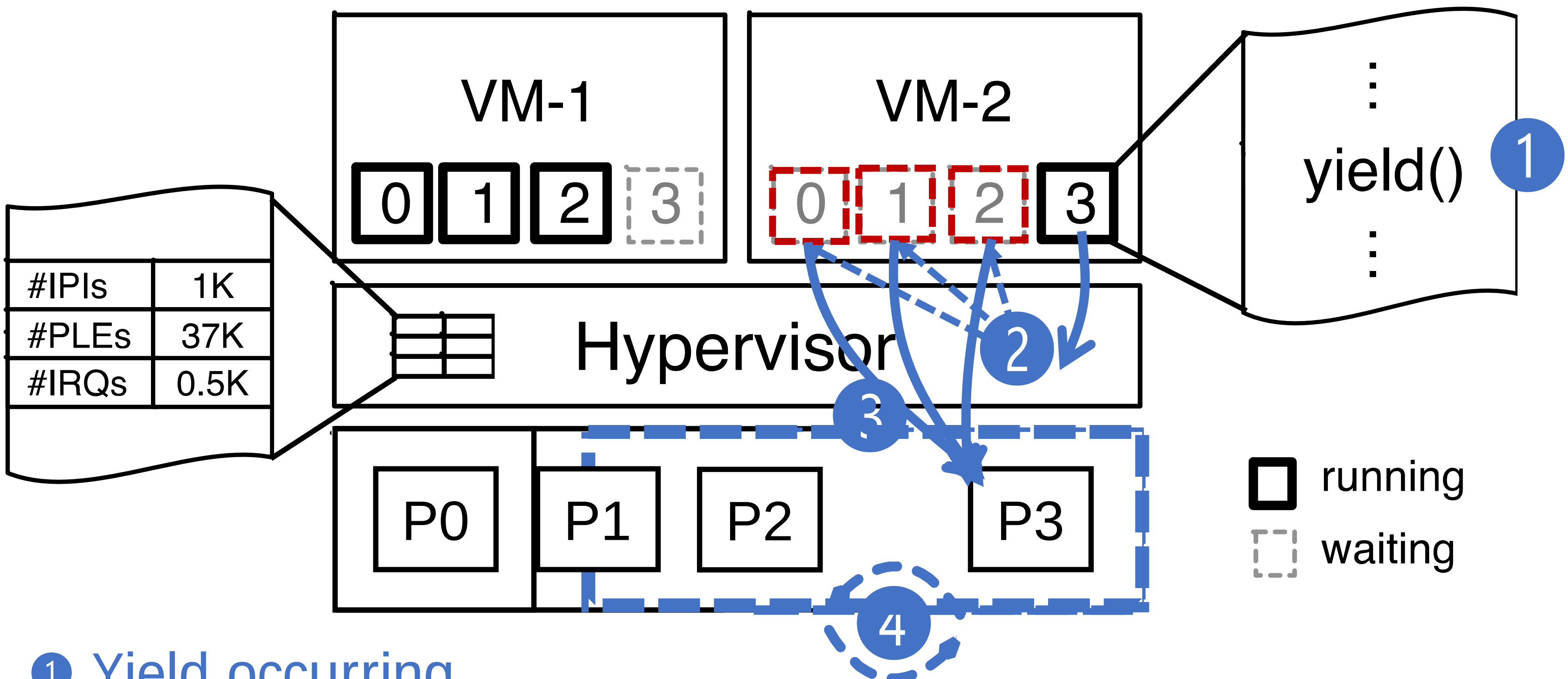

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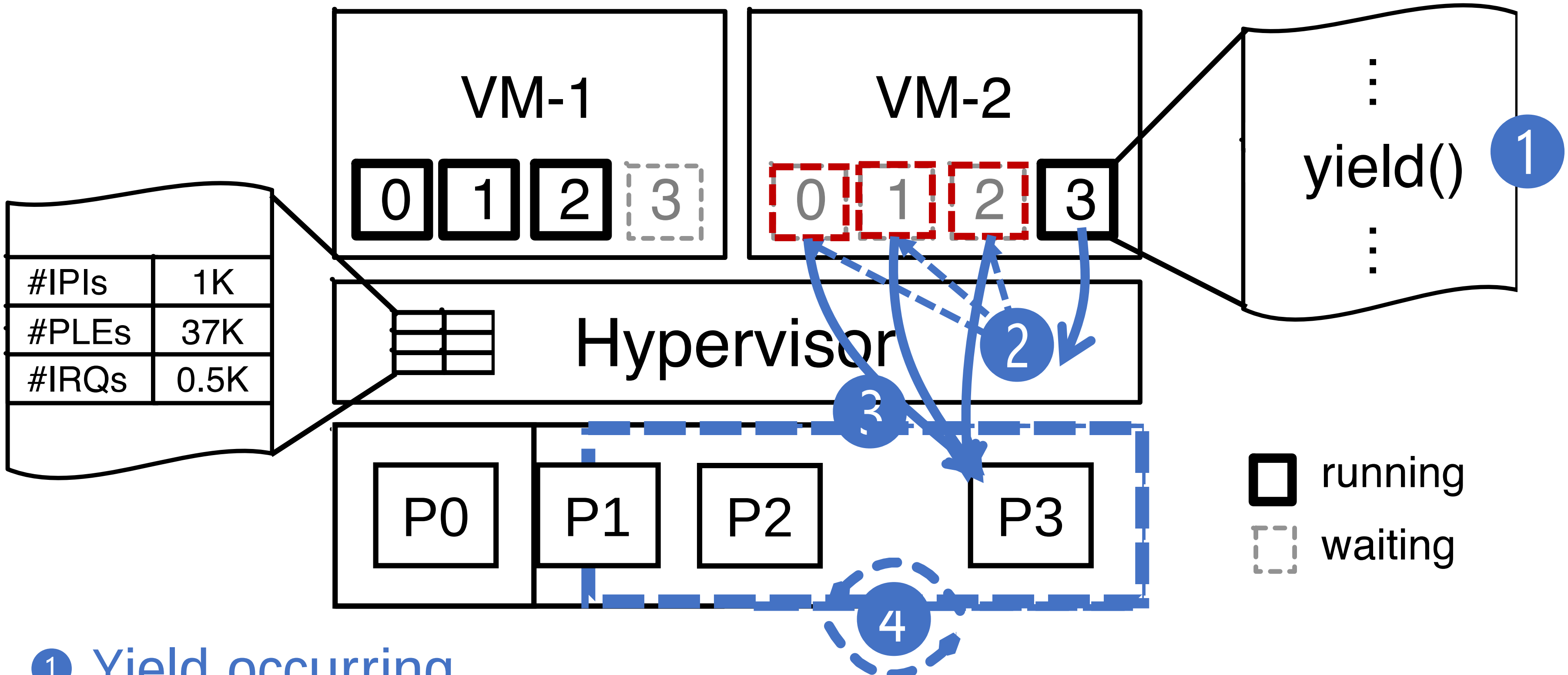

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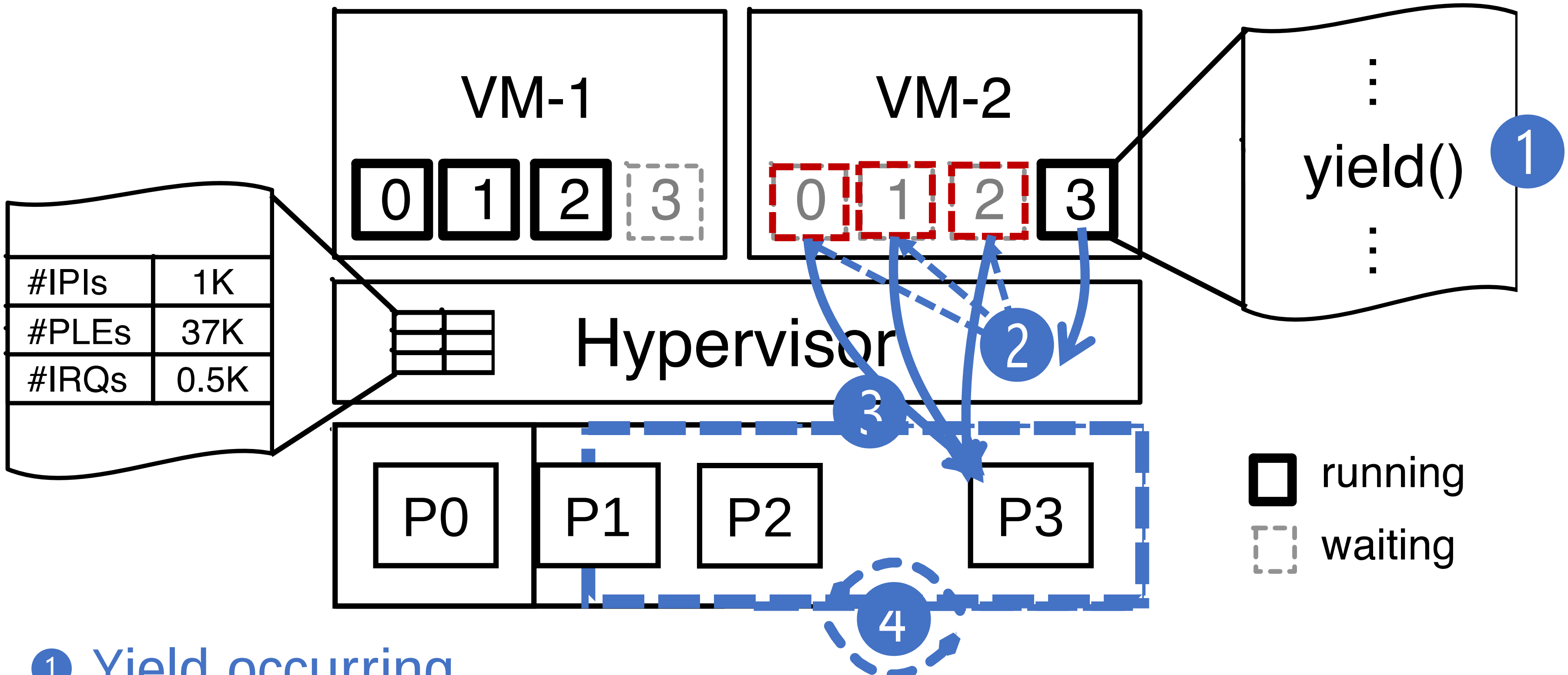

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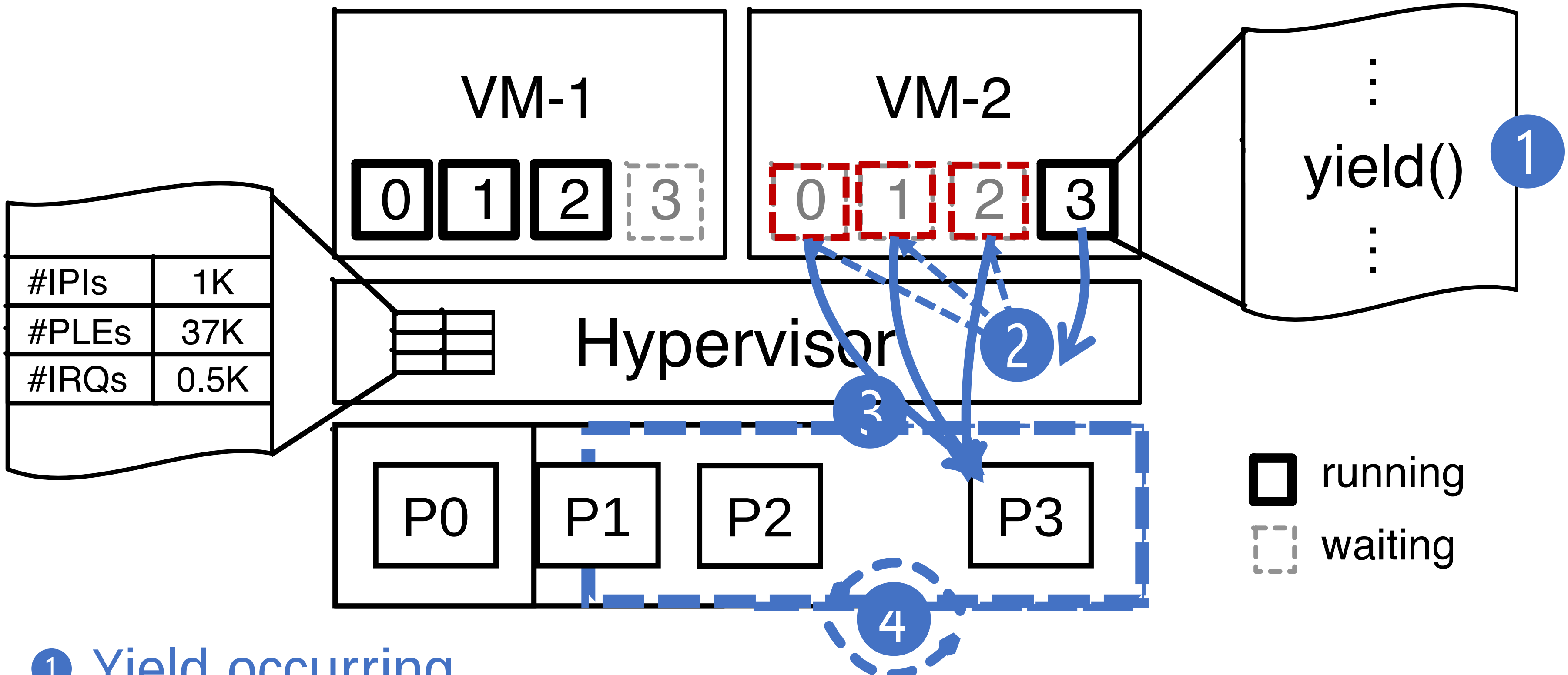

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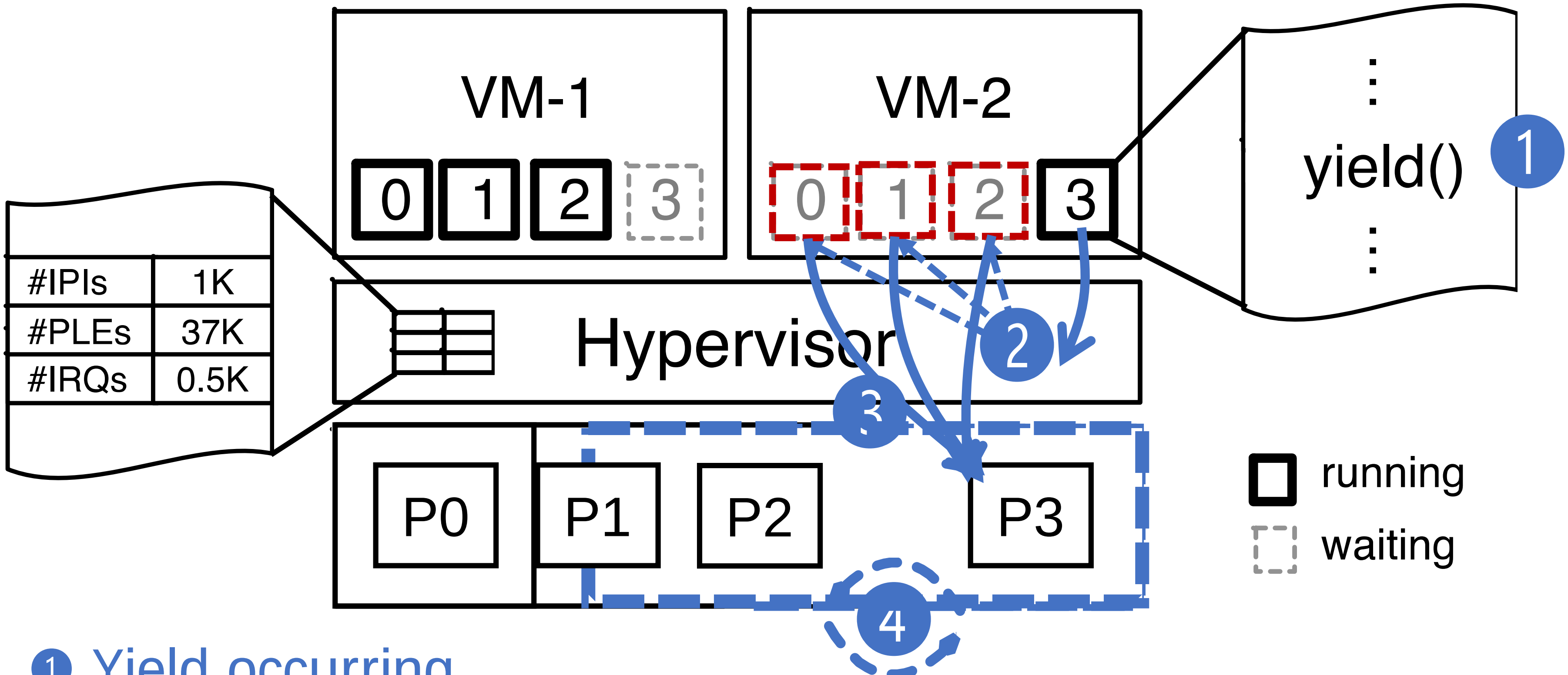

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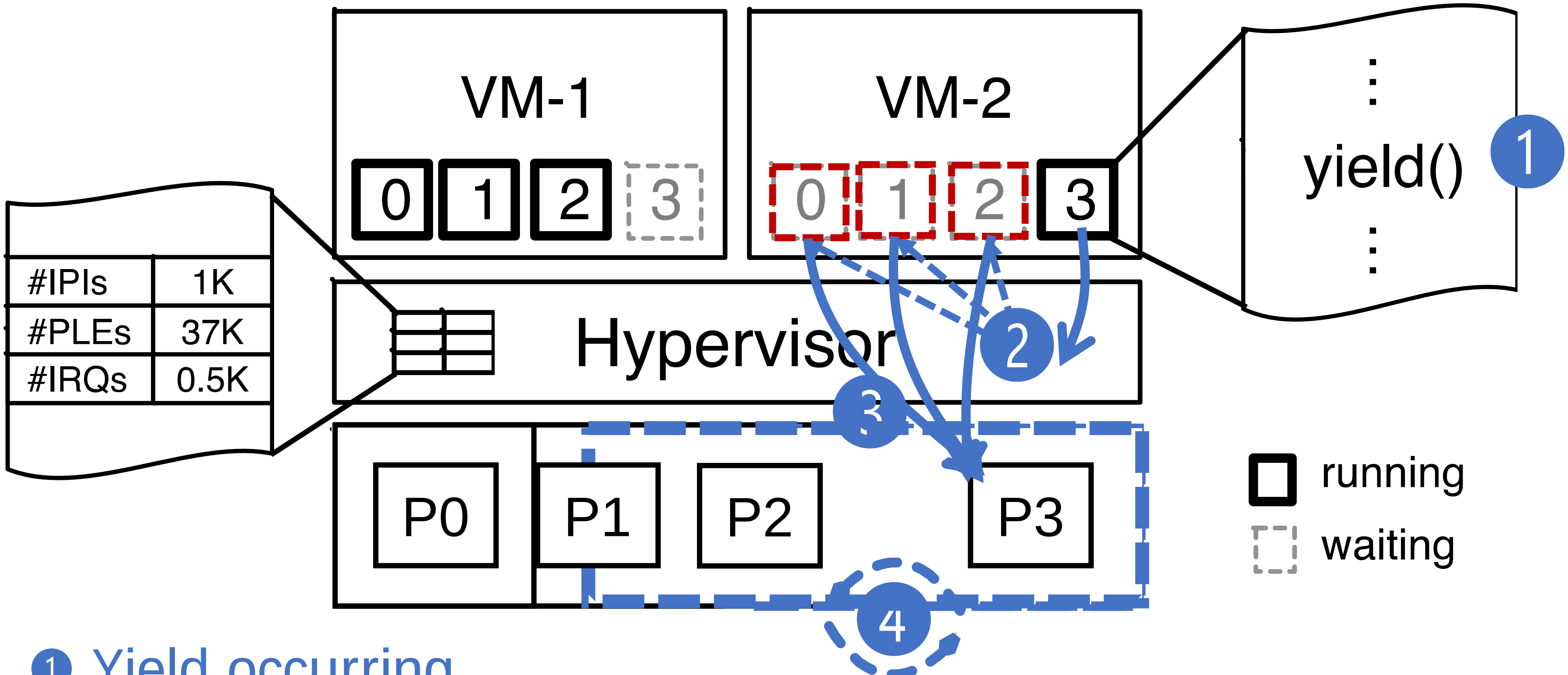

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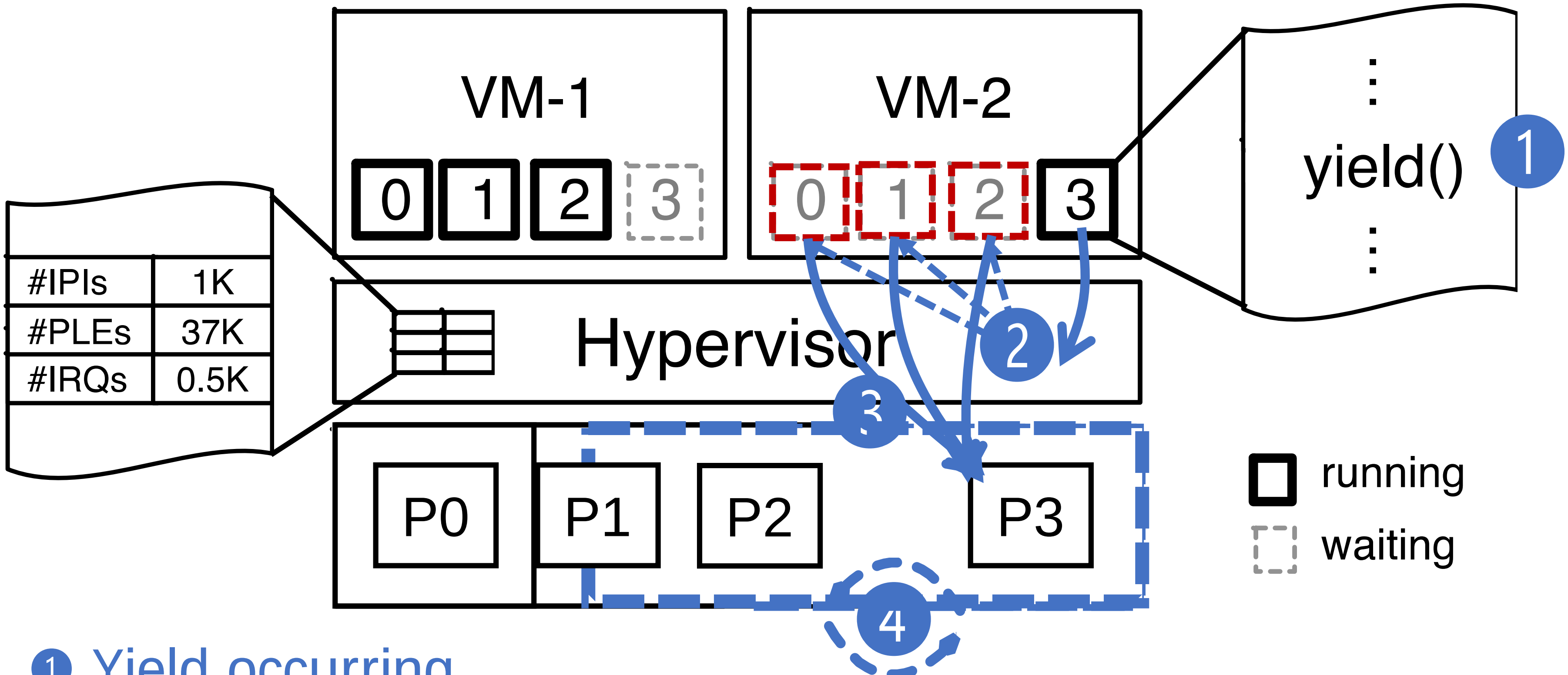

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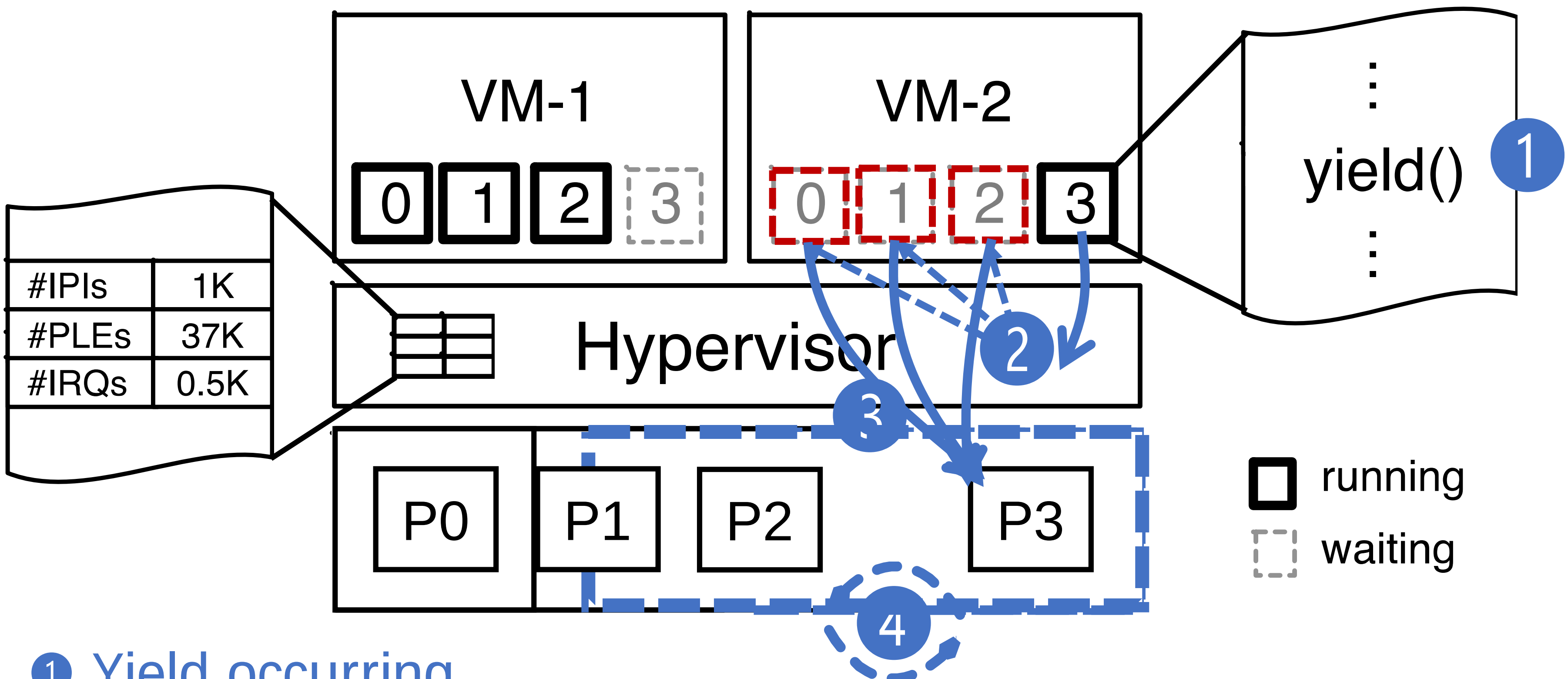

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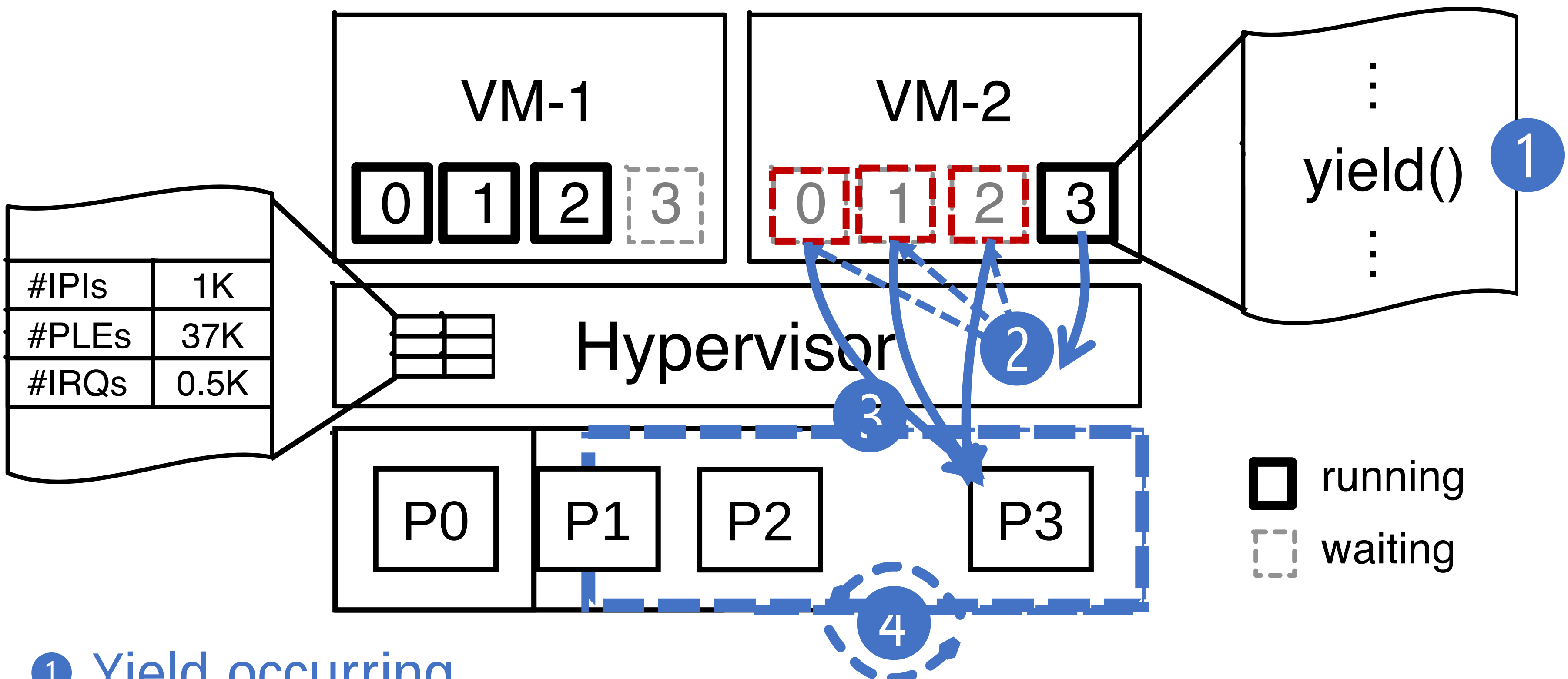

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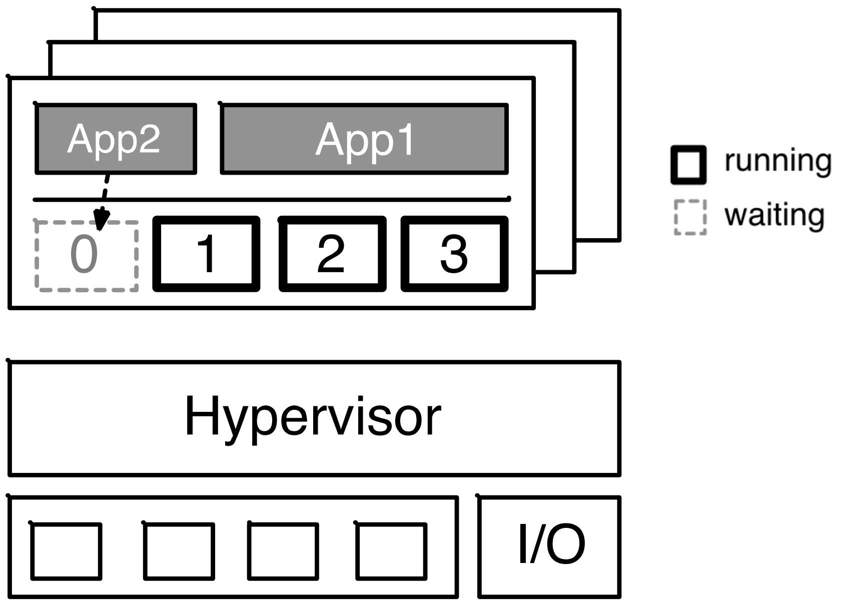
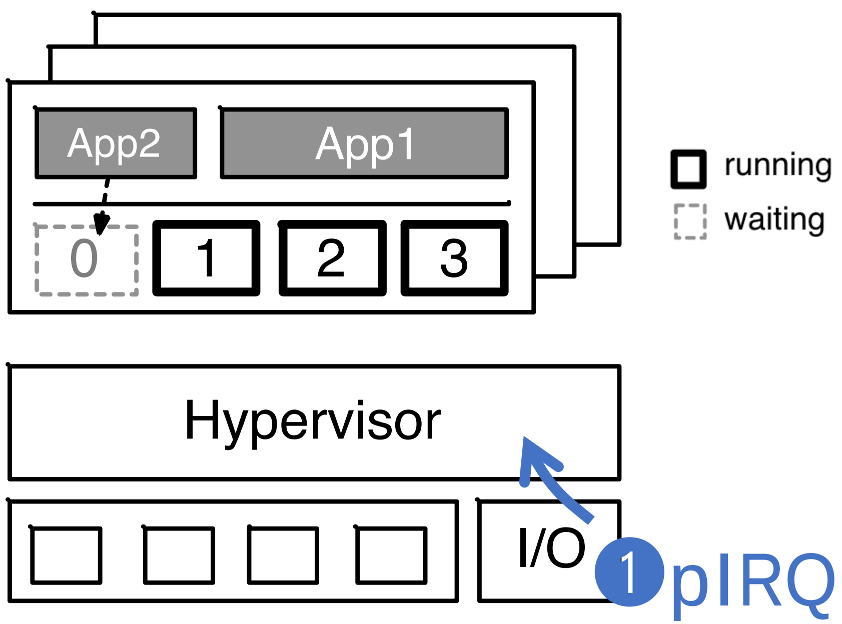
Detecting Critical I/O Events



I/O handling consists of a chain of operations involving potentially multiple vCPUs

Detecting Critical I/O Events



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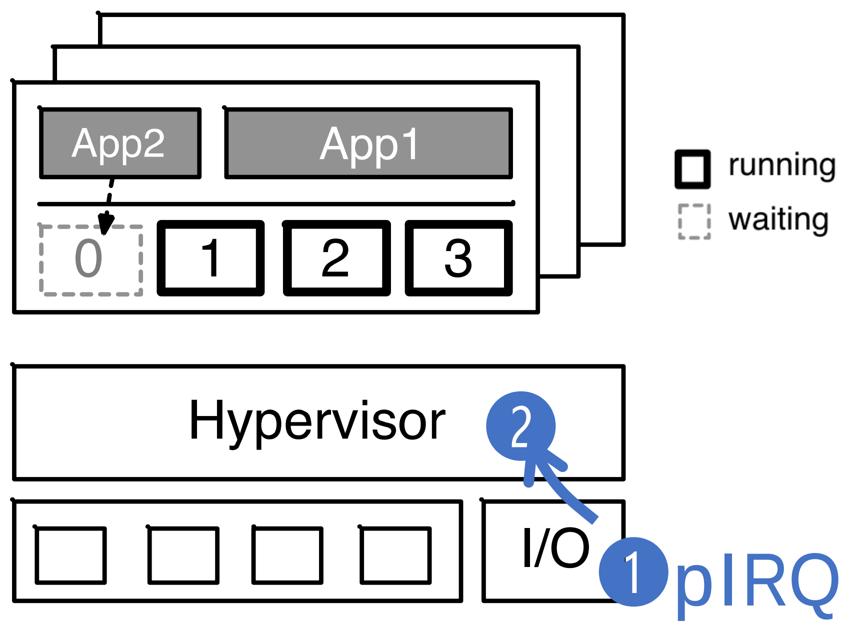

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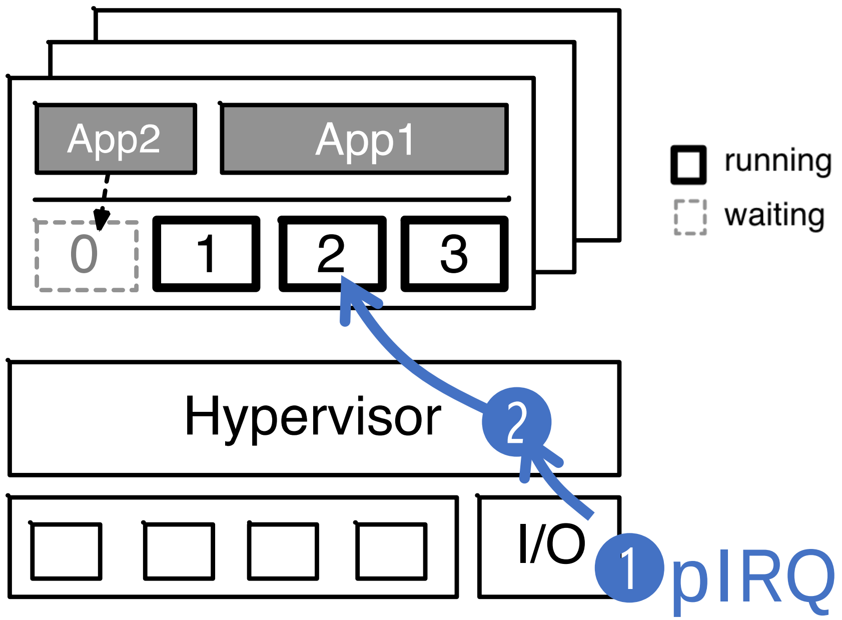

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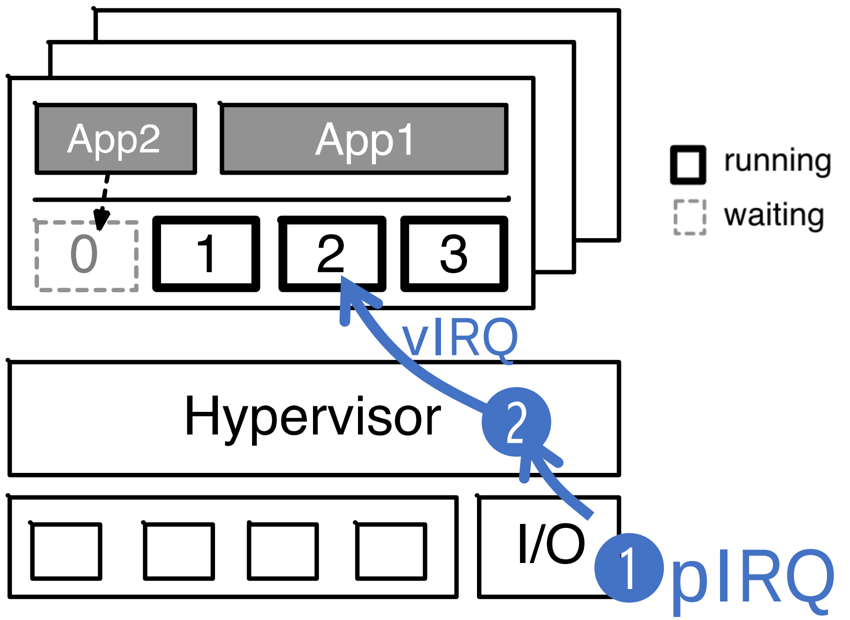

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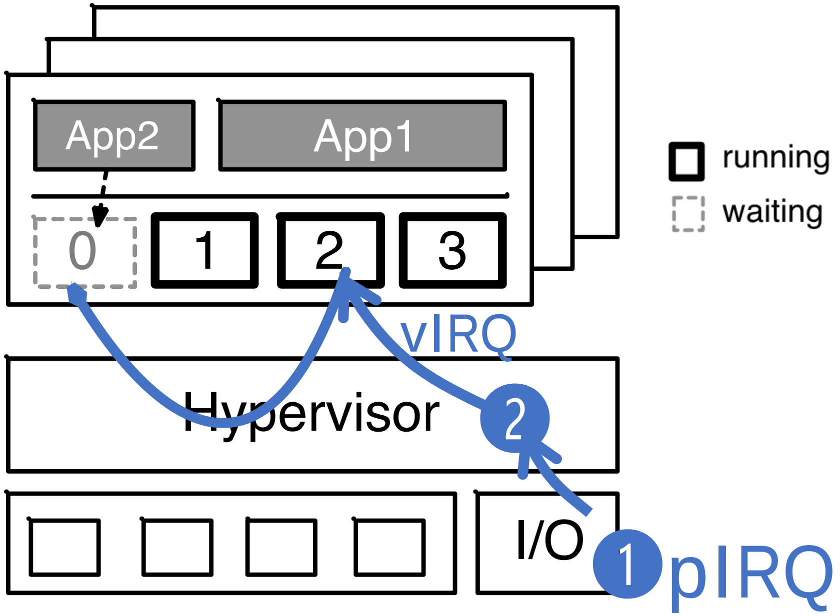

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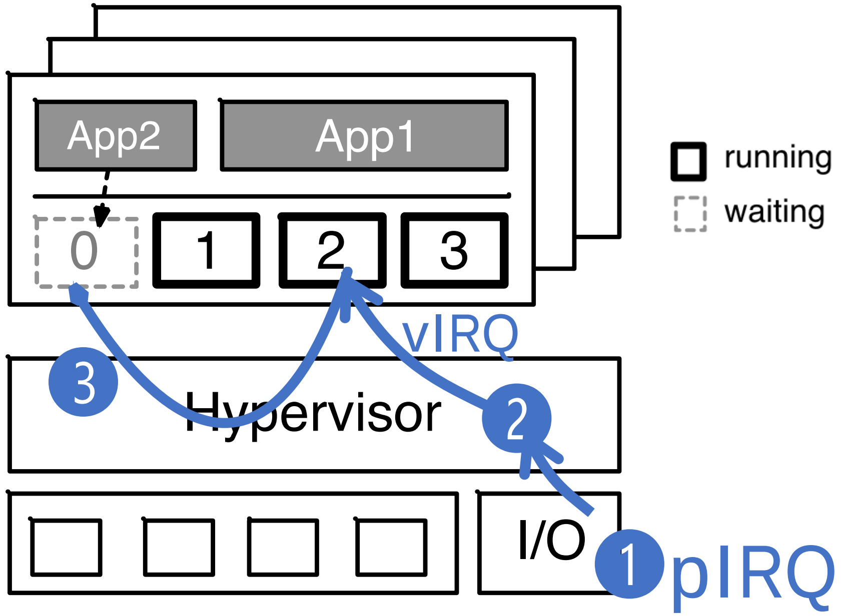

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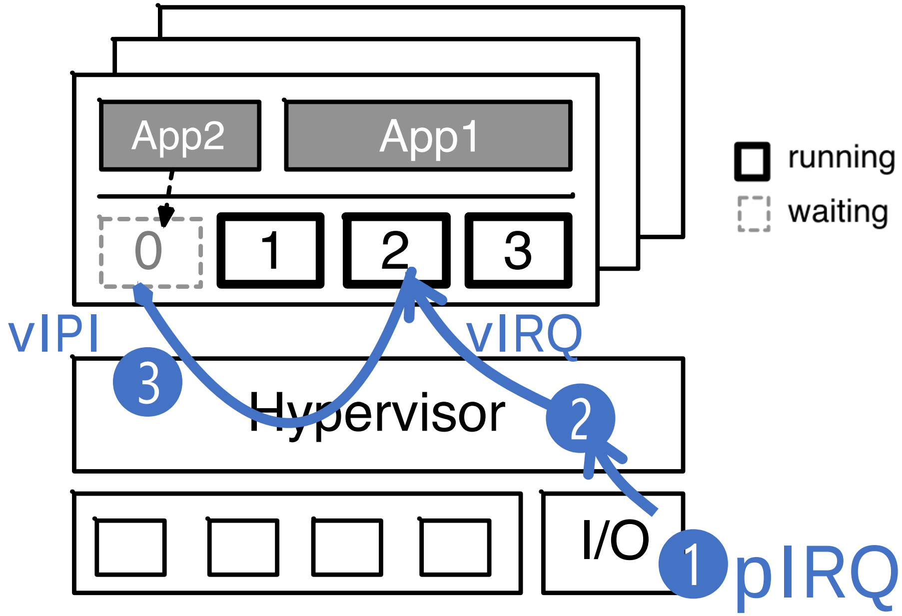

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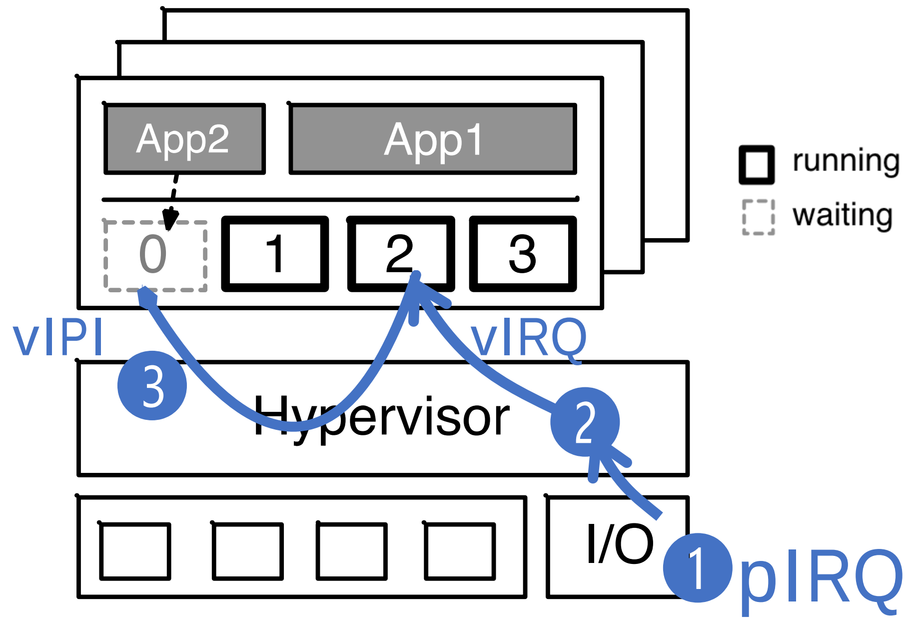
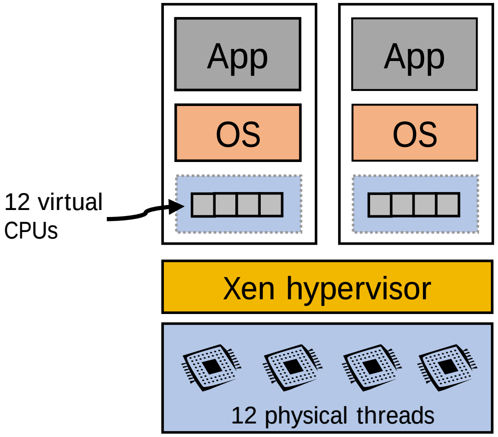


I/O handling consists of a chain of operations involving potentially multiple vCPUs

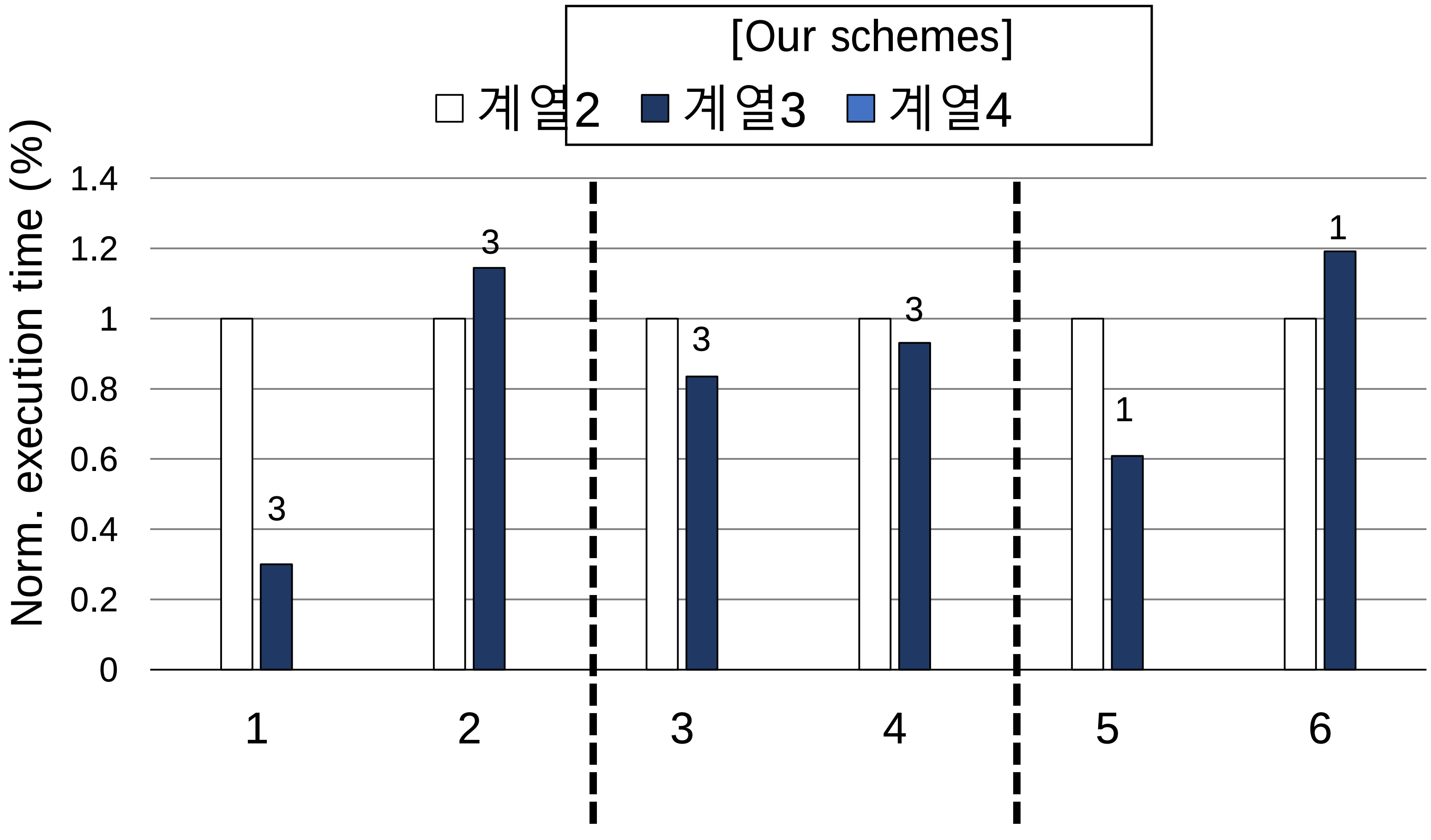
Experimental Environments

- Testbed
  - 12 HW threads (Intel Xeon)
  - 2 VMs with 12 vCPUs for each
  - Xen hypervisor 4.7
- Benchmarking workloads
  - `dedup` and `vips` from PARSEC
  - `exim` and `gmake` from MOSBENCH
- Pool configuration
  - Normal: 30ms (Xen default)
  - Micro-sliced: 0.1ms



2-to-1 consolidation ratio

Performance of Micro-sliced Cores



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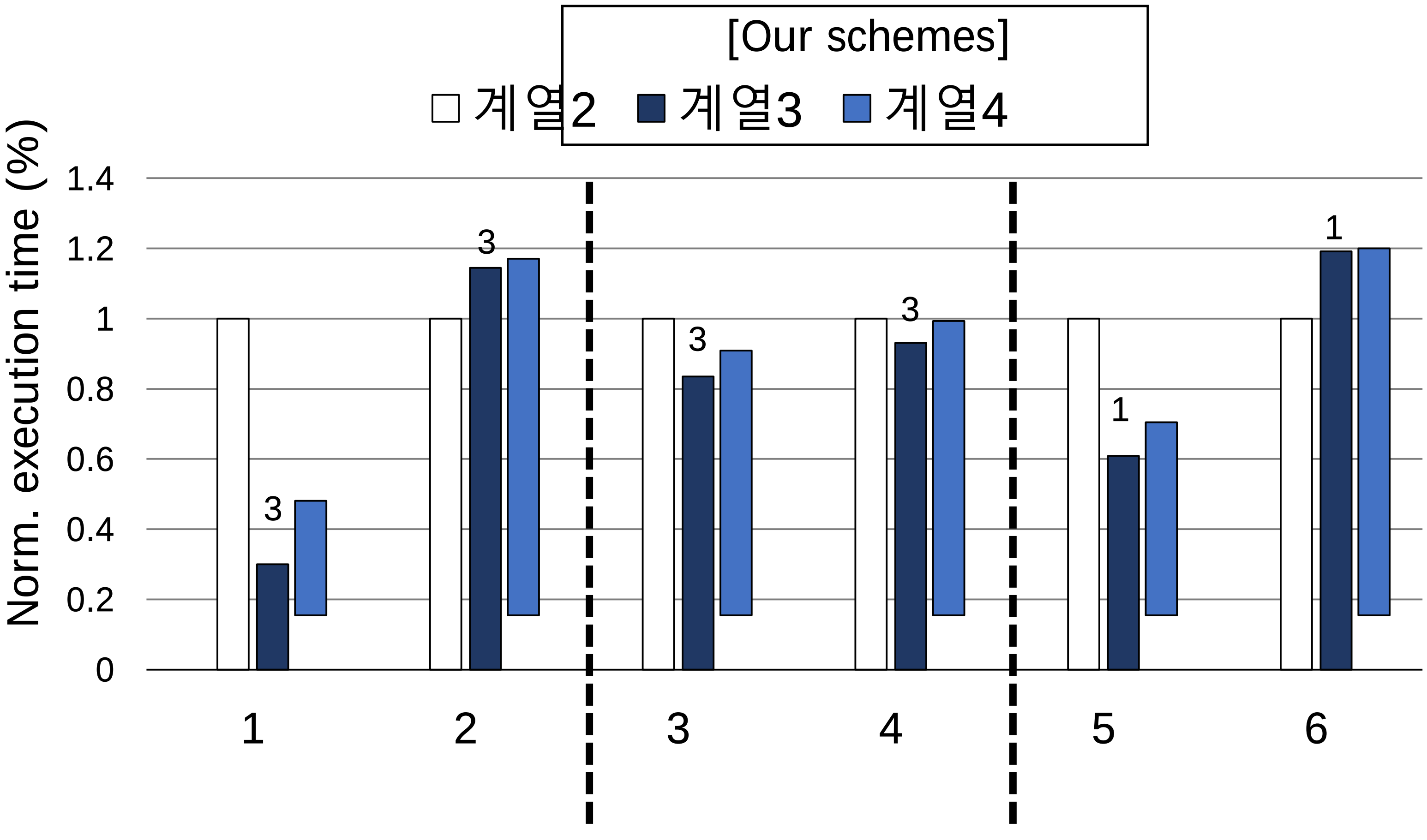

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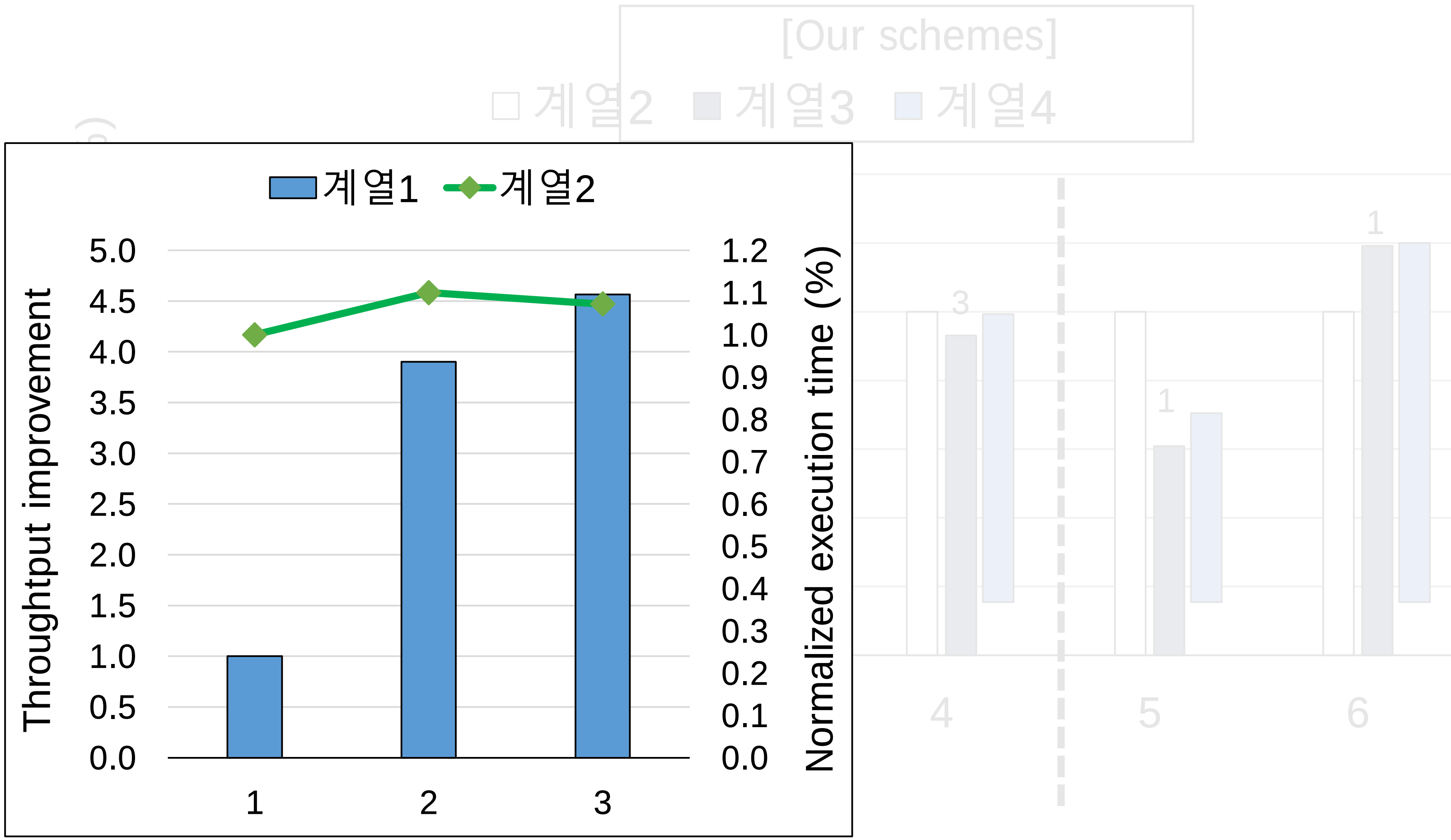

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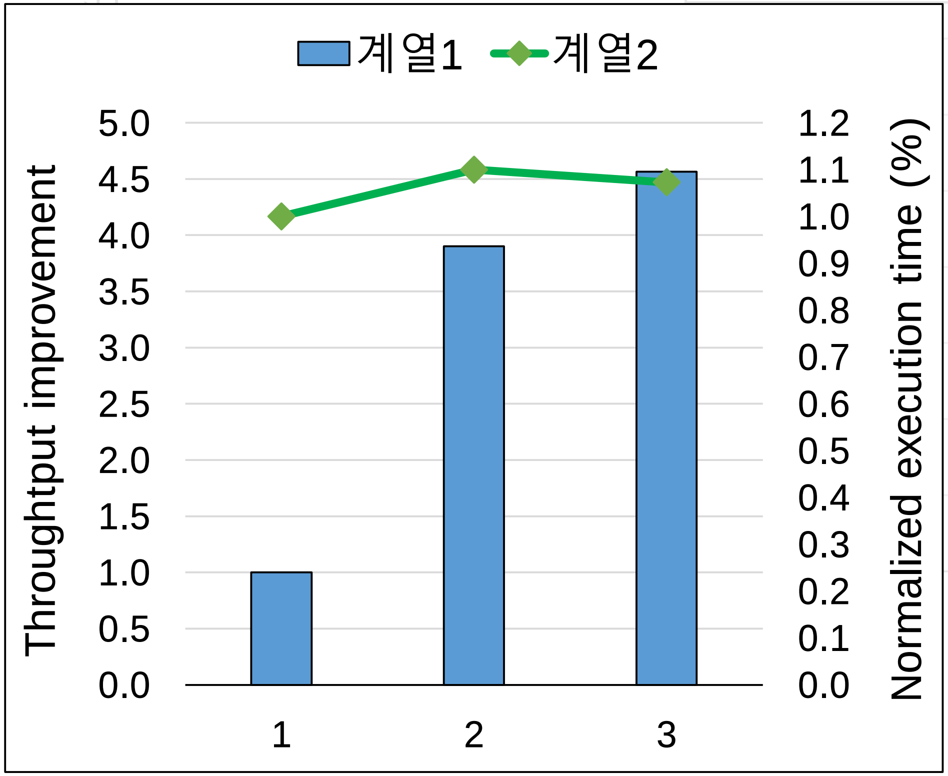

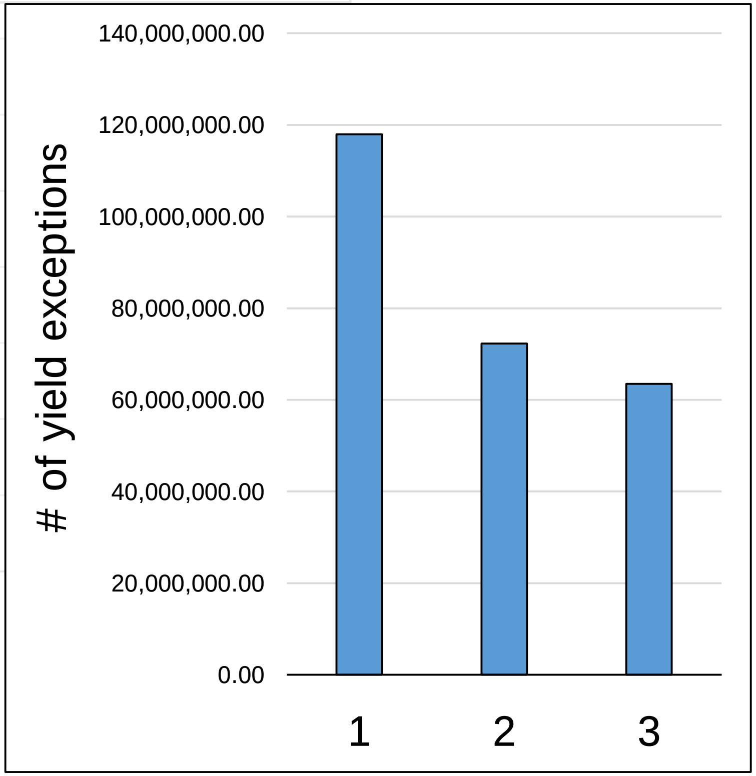

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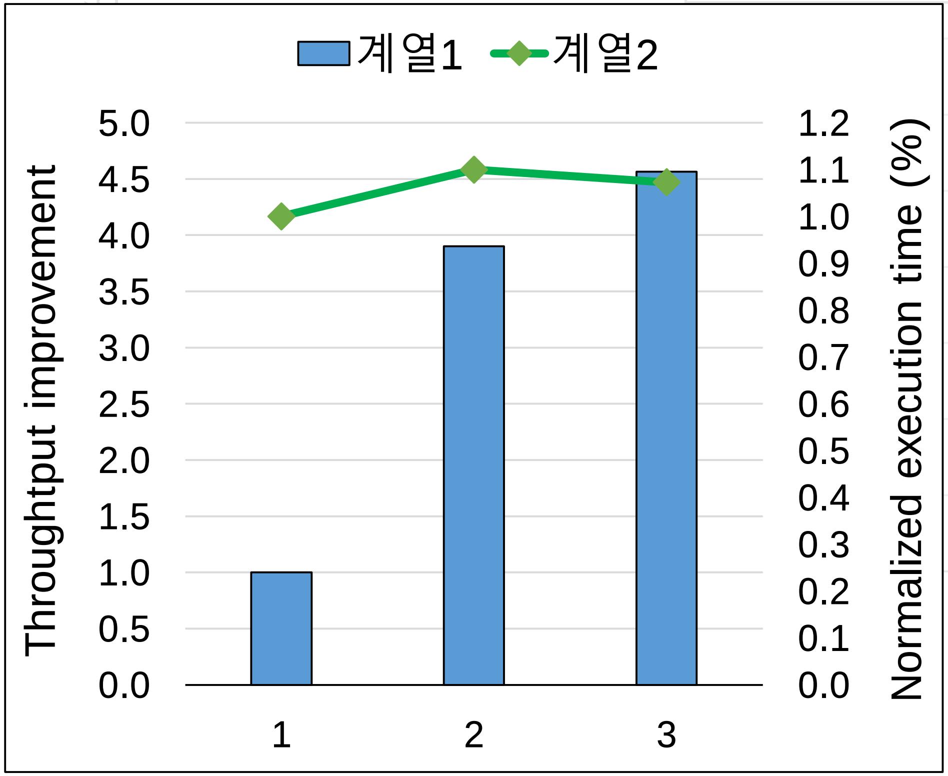

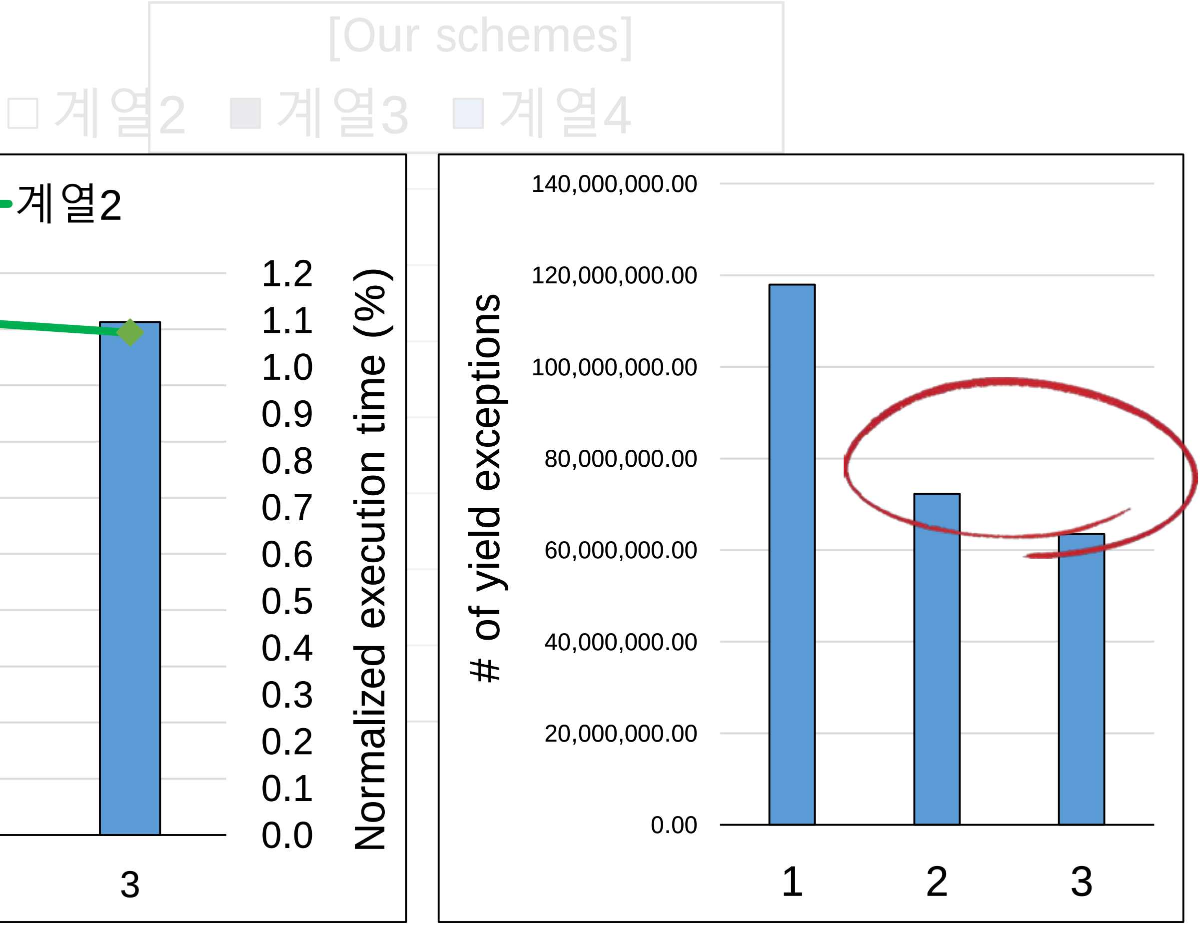

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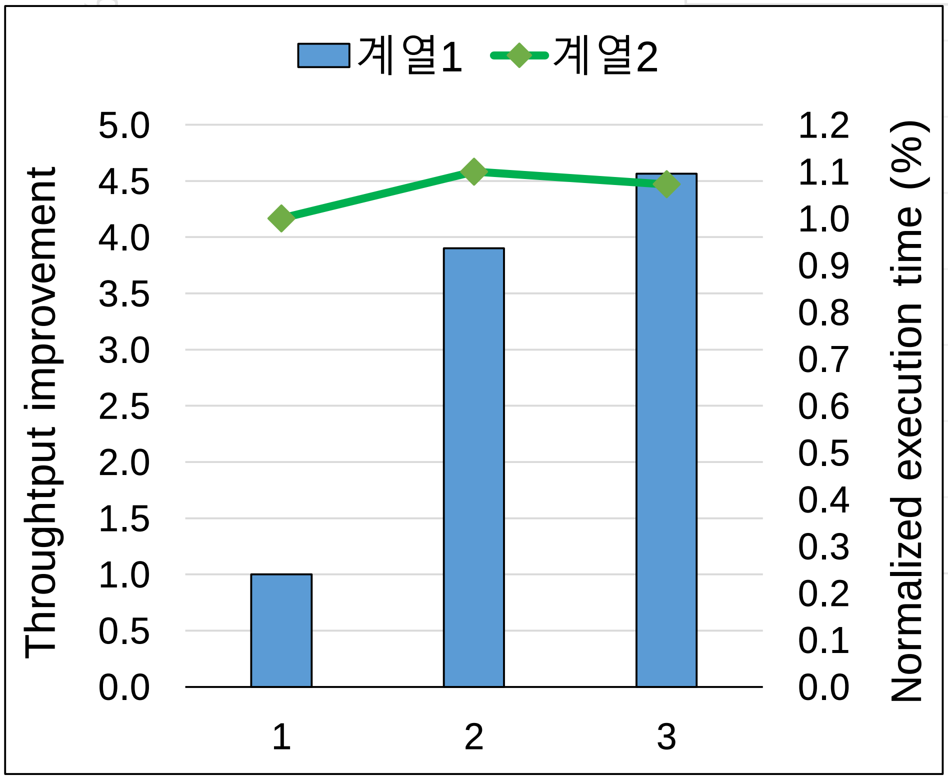
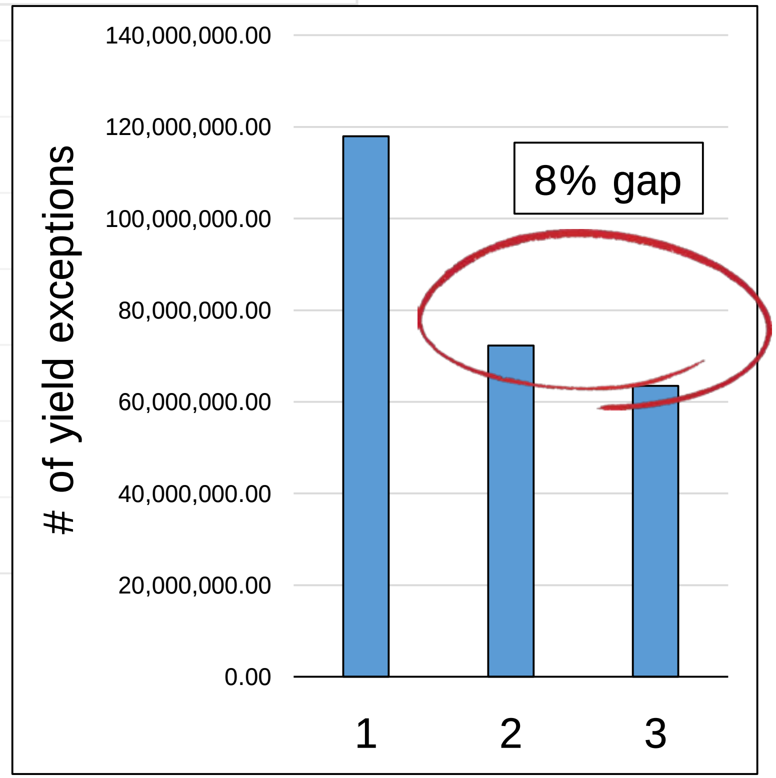
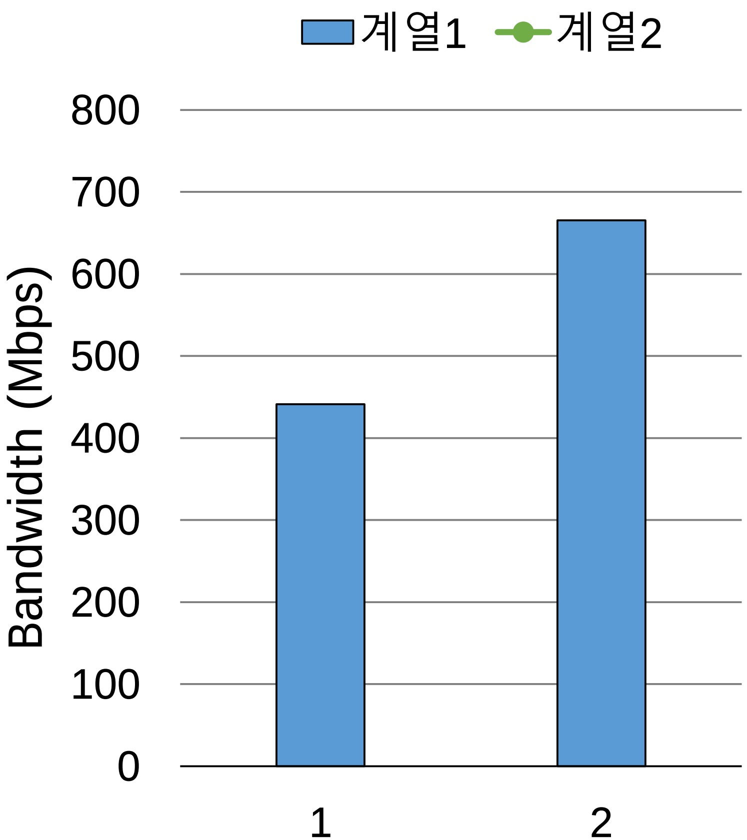


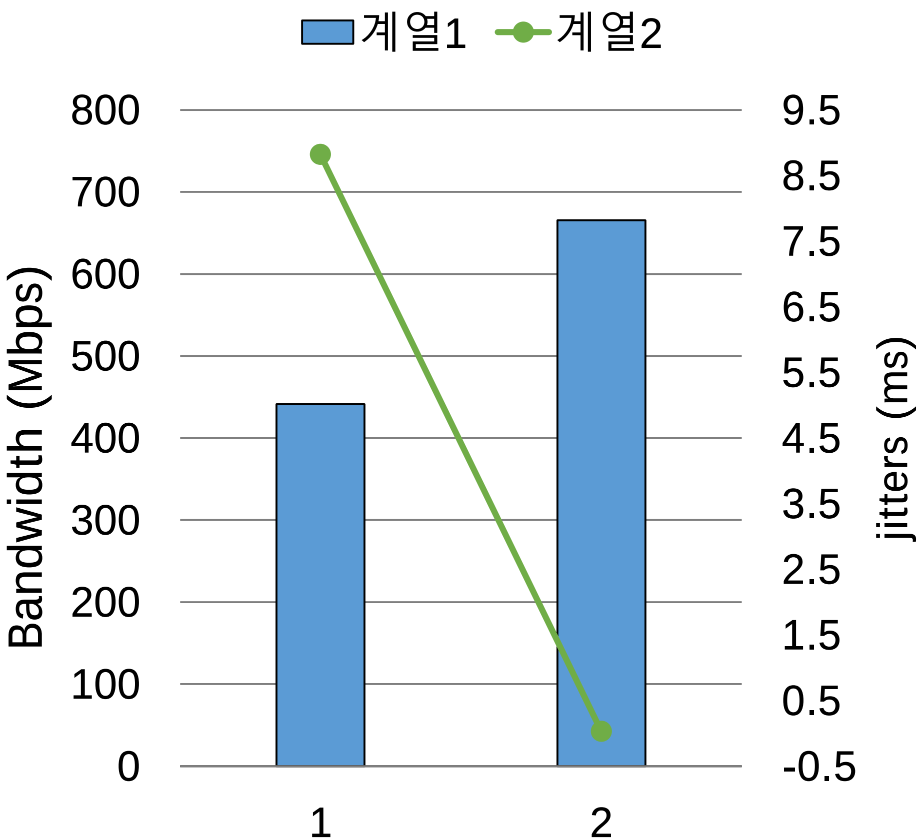


I/O Performance



	Workloads
VM-1	iPerf lookbusy
VM-2	lookbusy

I/O Performance



	Workloads
VM-1	iPerf lookbusy
VM-2	lookbusy

Conclusions

- We introduced a new approach to mitigate the virtual time discontinuity problem
- Three distinct contributions
  - Precise detection of urgent tasks
  - Guest OS transparency
  - Dynamic adjustment of the micro-sliced cores
- Overhead is very low for applications which do not frequently use OS services

Thank You!

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Accelerating Critical OS Services in Virtualized Systems with Flexible Micro-sliced Cores

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