Dynamically Provisioning Isolation in Hierarchical Architectures

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TECHNISCHE
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Problem Definition

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Side channels

Covert channels

https://www.flickr.com/photos/inkvision/2868388856

http://jeffberezny.com/wp-content/uploads/2014/02/passing-paper-notes-in-class.jpg

Attacks

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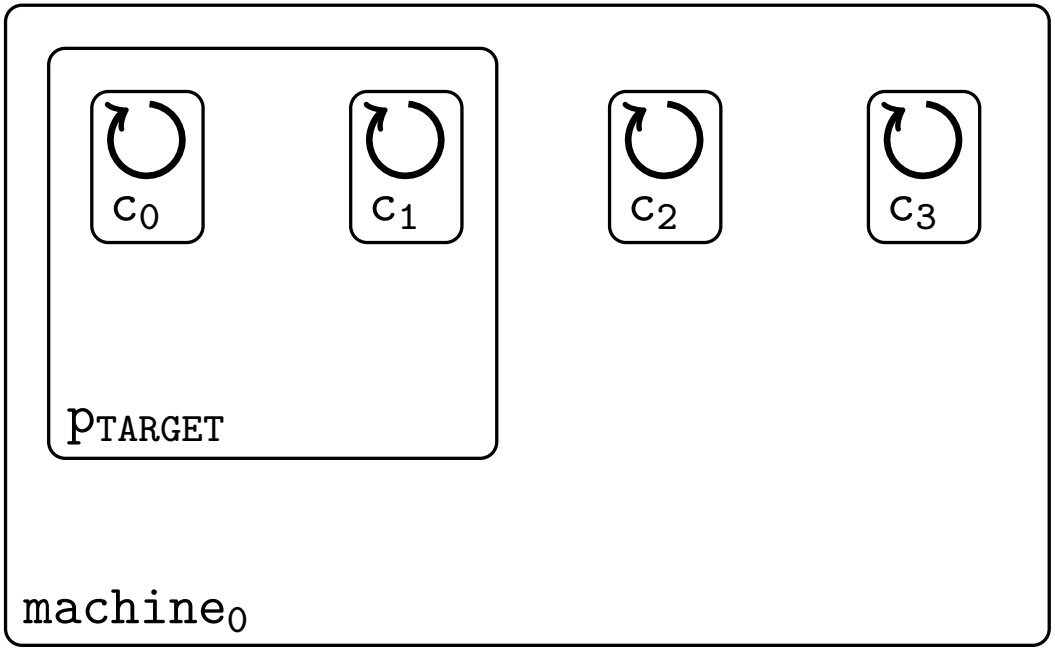

Attacks

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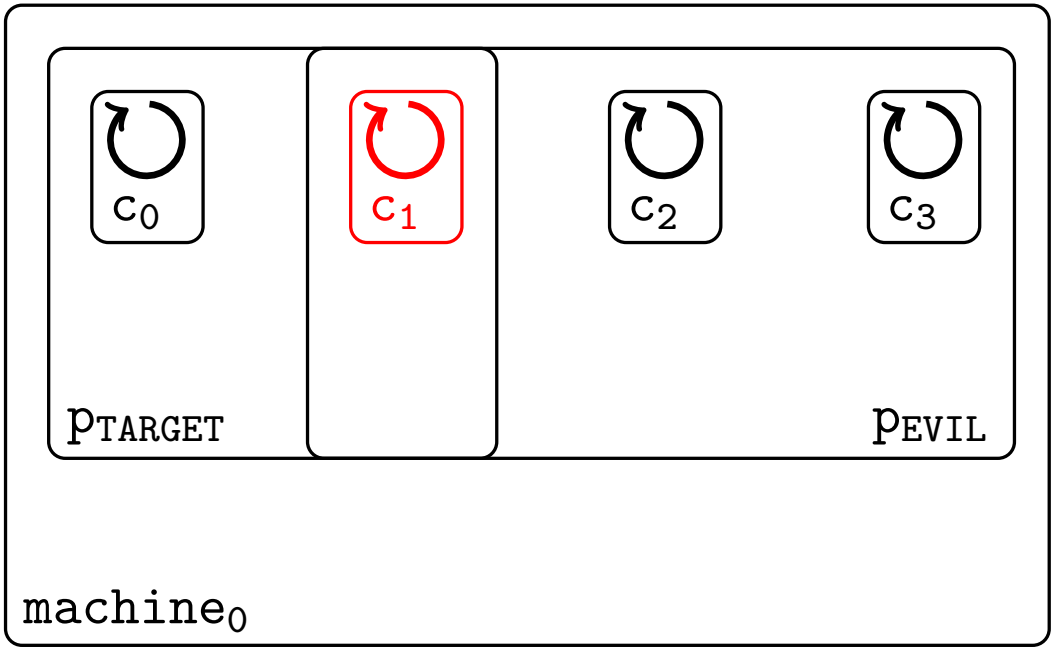

Core-level attacks
(AES key inference, ElGamal path detection)

Attacks

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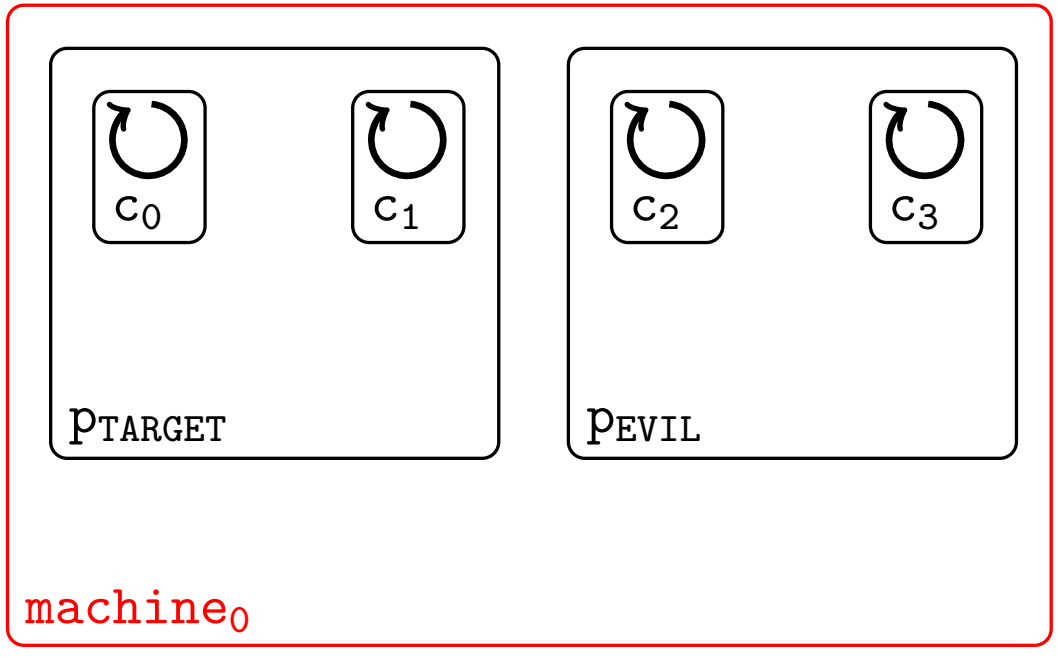

Machine-level attacks
(memory bus covert channel, branch predictor, `/proc` monitoring)

Attacks

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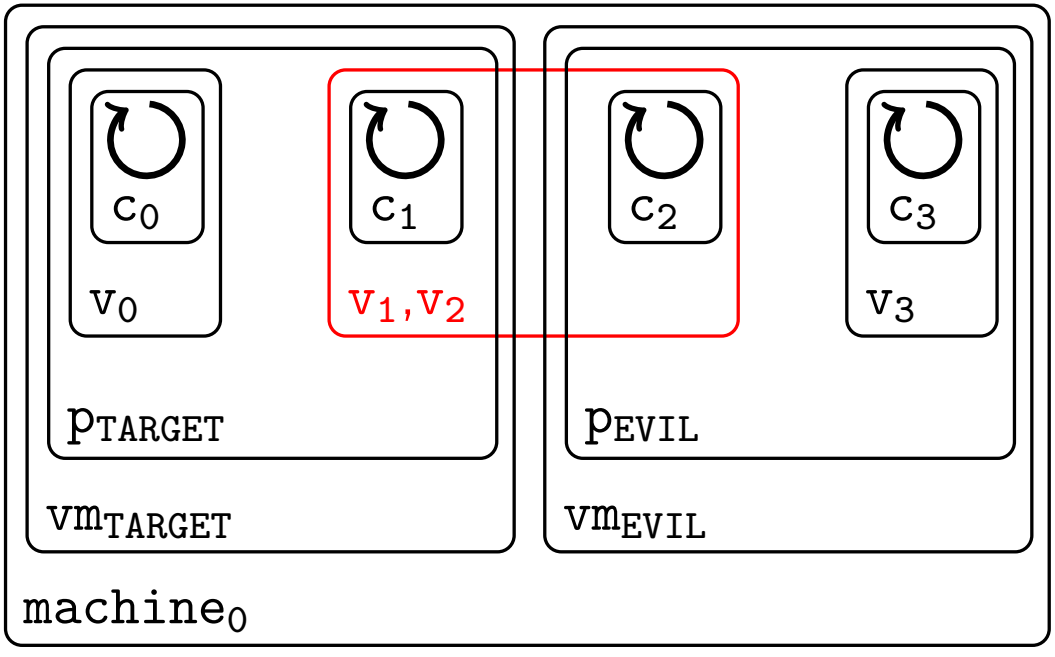

Cross-VM attacks
(VCPU sharing, scheduler attacks, core-level attacks)

Attacks

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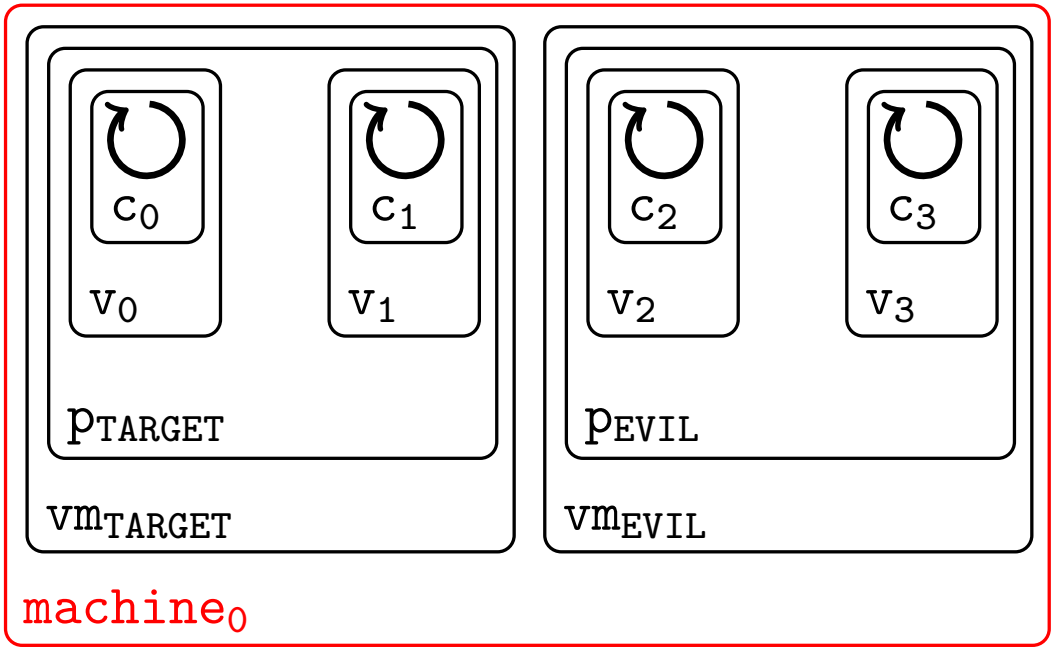

Hypervisor-level attacks
(fingerprinting, memory deduplication, machine-level attacks)

Attacks

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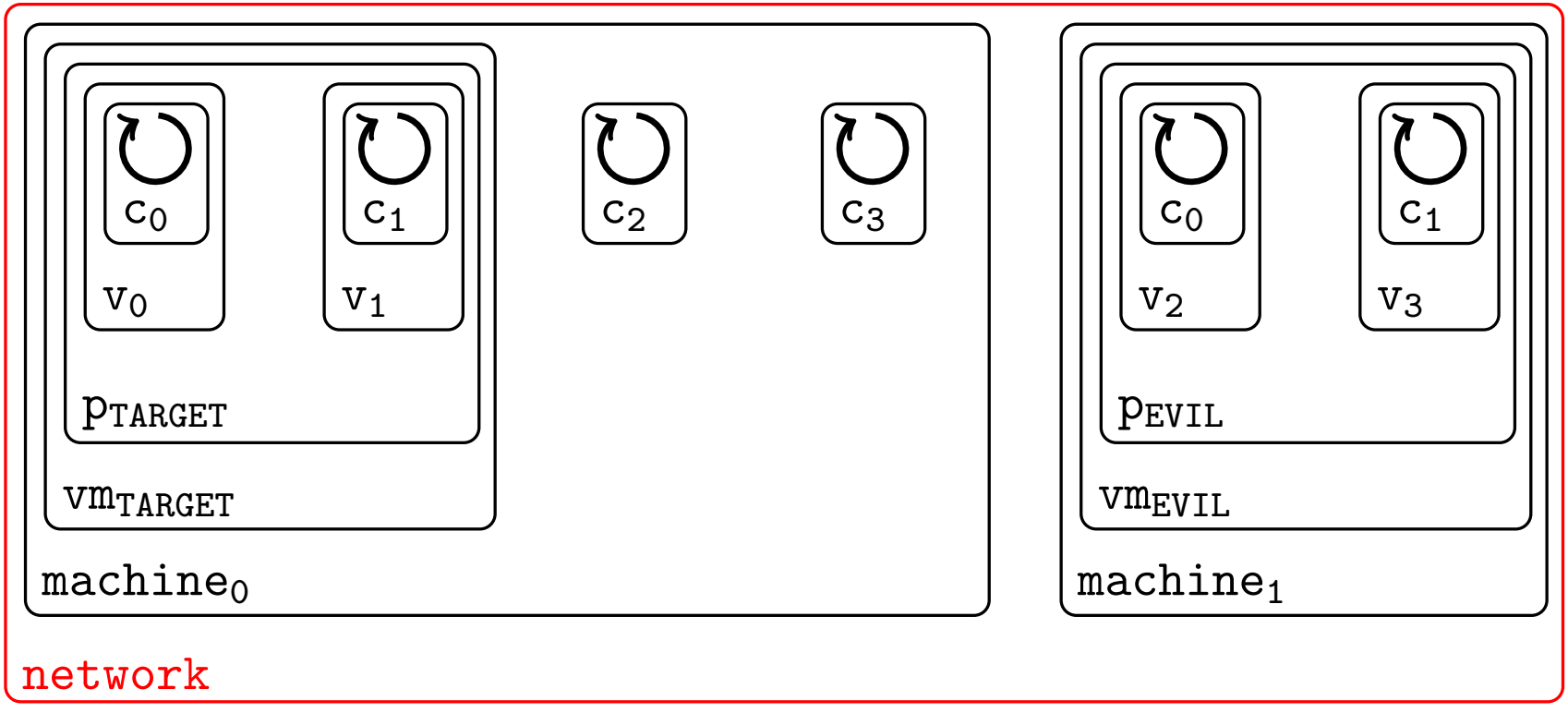

Network-level attacks
(OSI layer hiding, remote timing attacks)

Attacks

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Observation

Channels are scoped.

Aim

Isolate entities at a granularity matching a perceived threat

- Isolate **on demand** rather than statically
- Finer granularity $\rightarrow$ better utilisation

Aim

Isolate entities at a granularity matching a perceived threat

- Isolate **on demand** rather than statically
- Finer granularity $\rightarrow$ better utilisation
- Note: focus is on *hard isolation*

Approach

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Look into migration at several system levels:

- Move **processes** between CPUs, vCPUs and OS environments
- Move **virtual machines** between physical machines

Enhance approach via additional technologies:

- Hardware event counters
- Post-copy migration
- Process containers

Implementation

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Developed the SafeHaven framework

- Networks of *agent* and *probe* processes

  Agents control migrations

  Probes serve as event sources

- Interface with **cpusets**, **criu** and **libvirt**
- Originally in C, now in Erlang

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Two case studies:

- Machine-wide covert channel by Wu et al.
- Multi-level moving target defense

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Case Study – Machine-Wide Covert Channel

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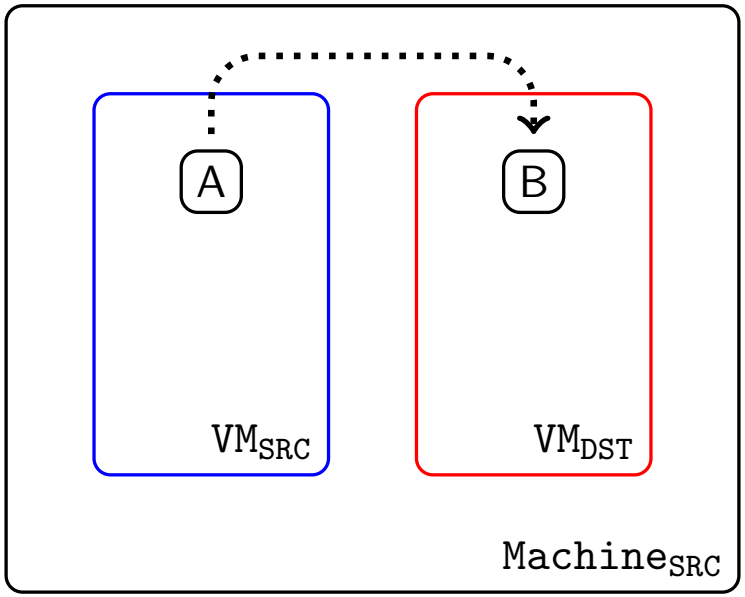

Process A attempts to communicate with B via a covert channel

- Misaligned atomic accesses causes bus lock
- Modulate access times

Case Study – Machine-Wide Covert Channel

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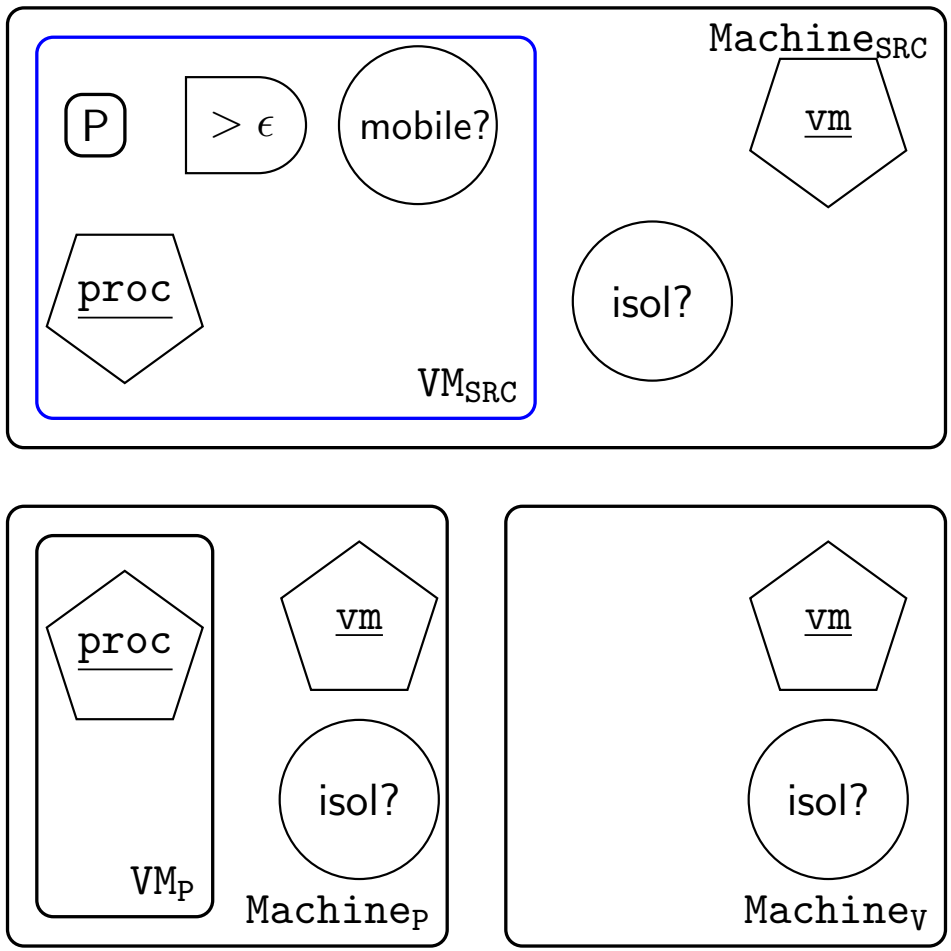

Case Study – Machine-Wide Covert Channel

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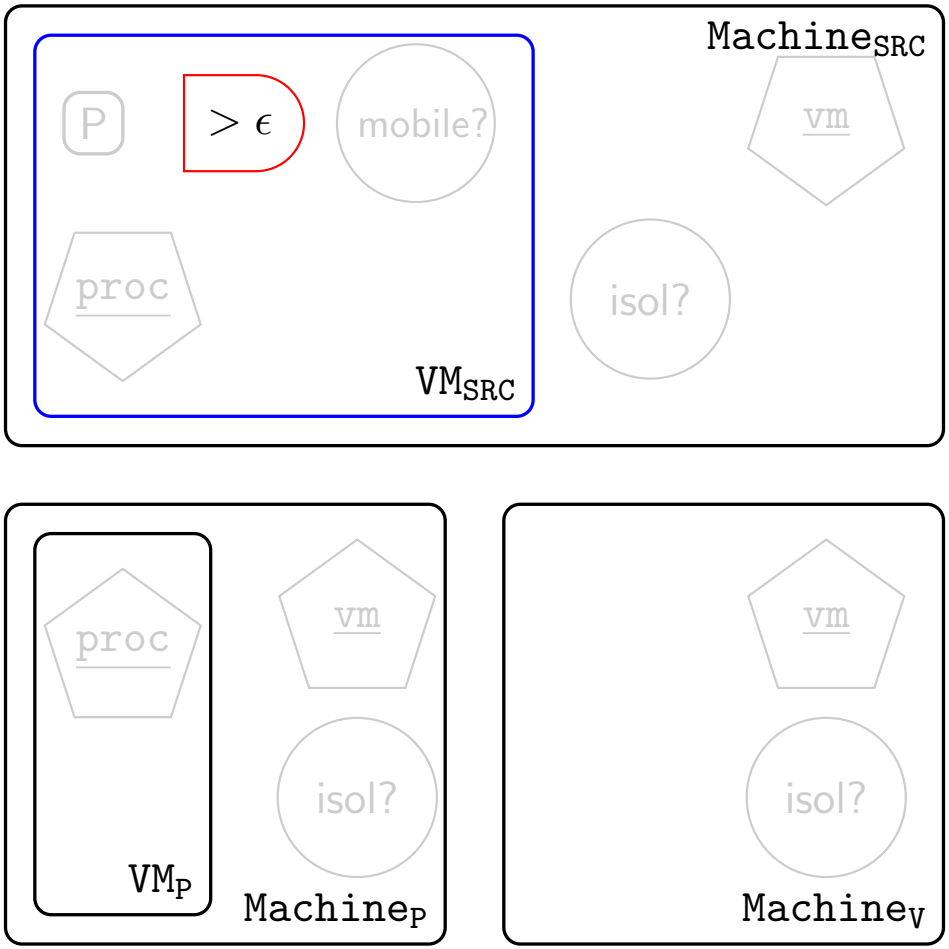

Probe (Hardware counter)

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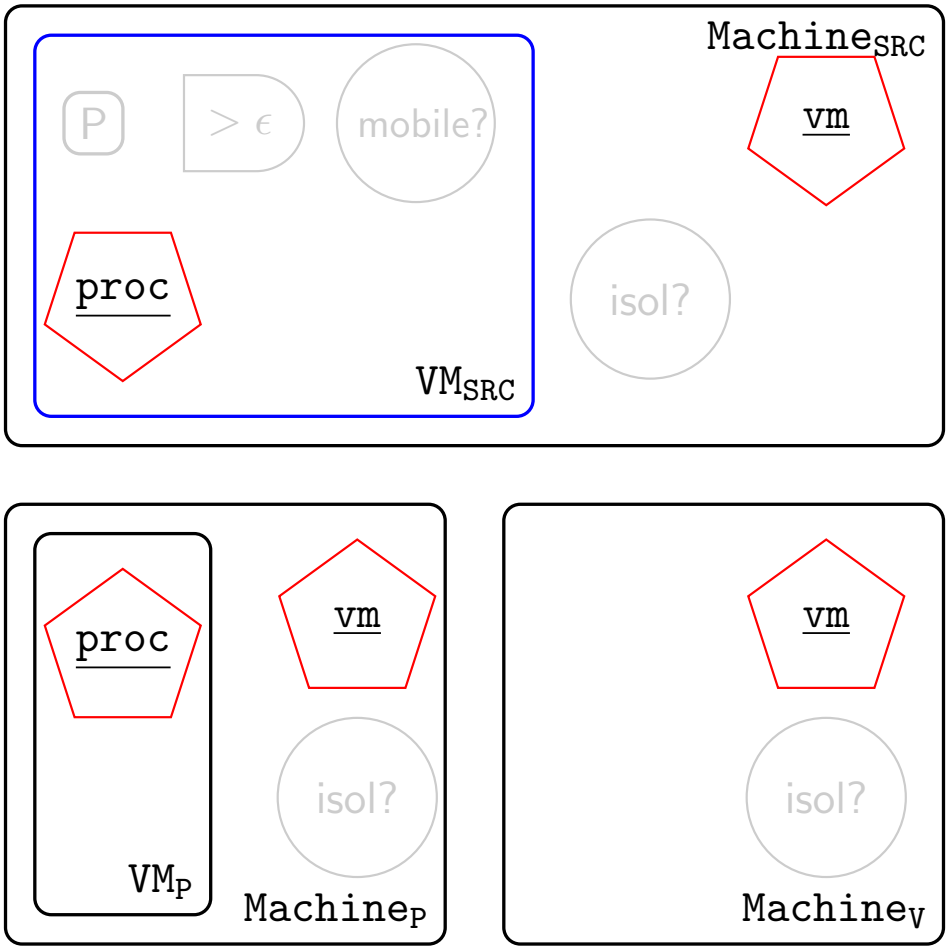

Agents

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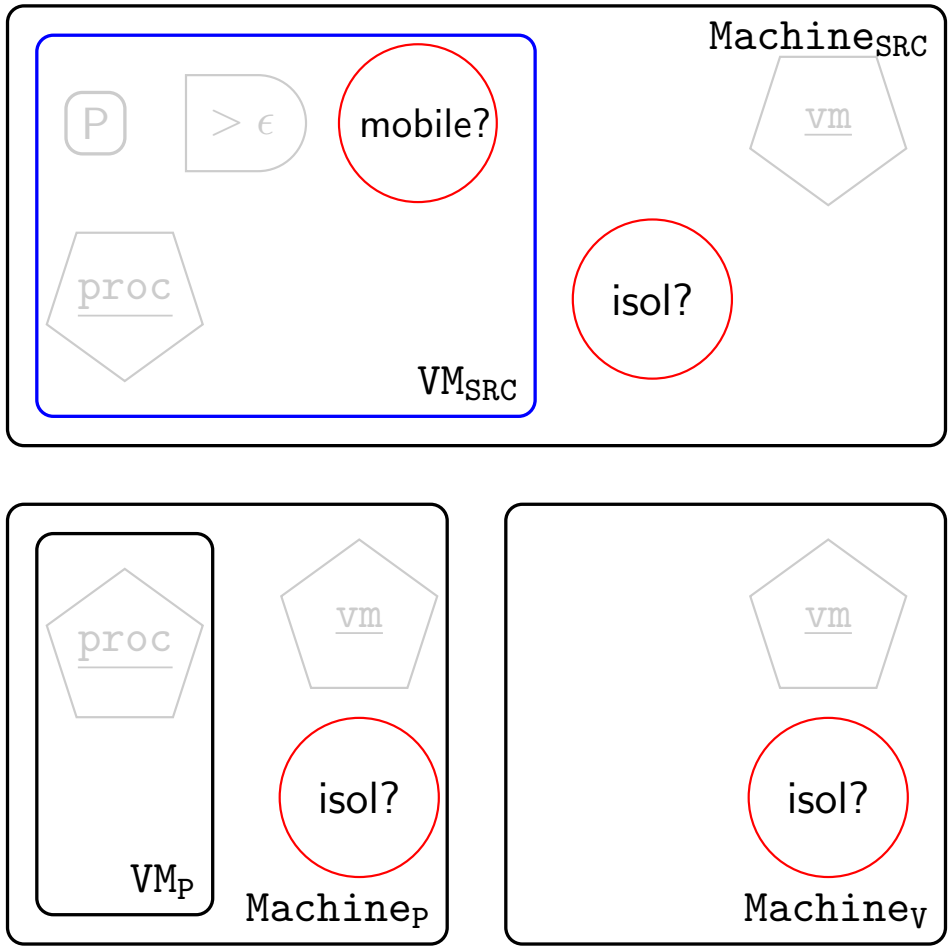

Probes/Predicates

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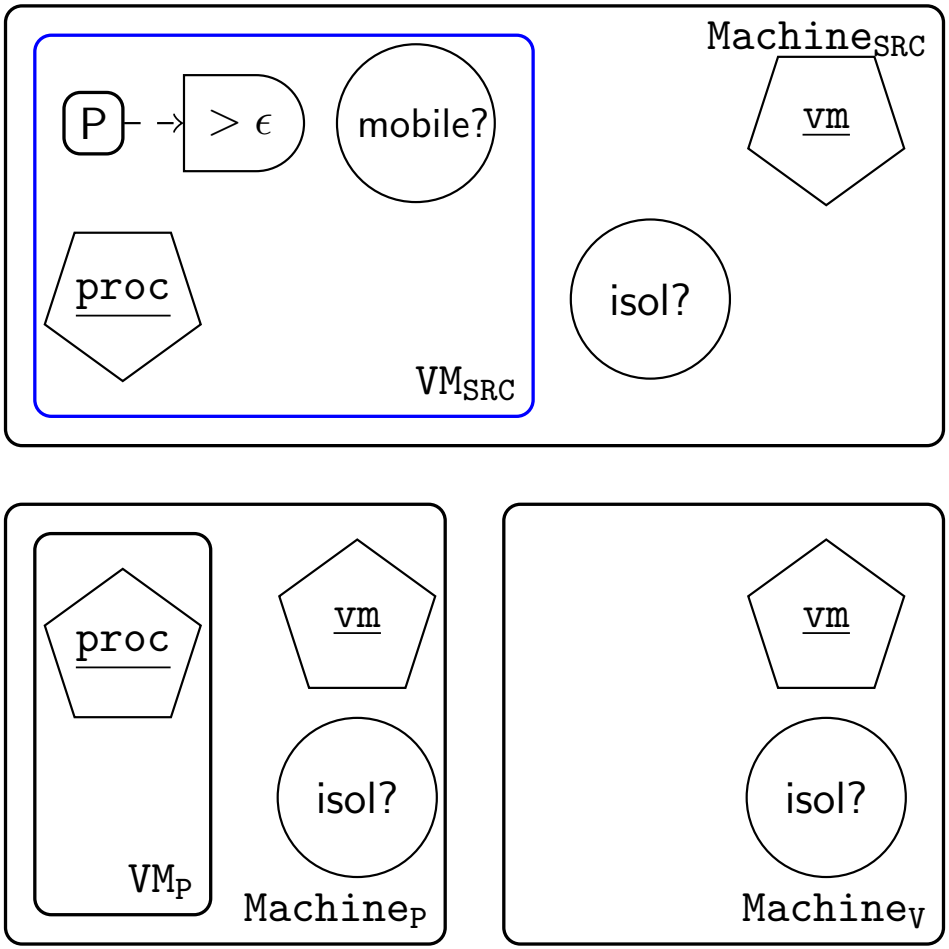

Process emits events at rate exceeding ϵ

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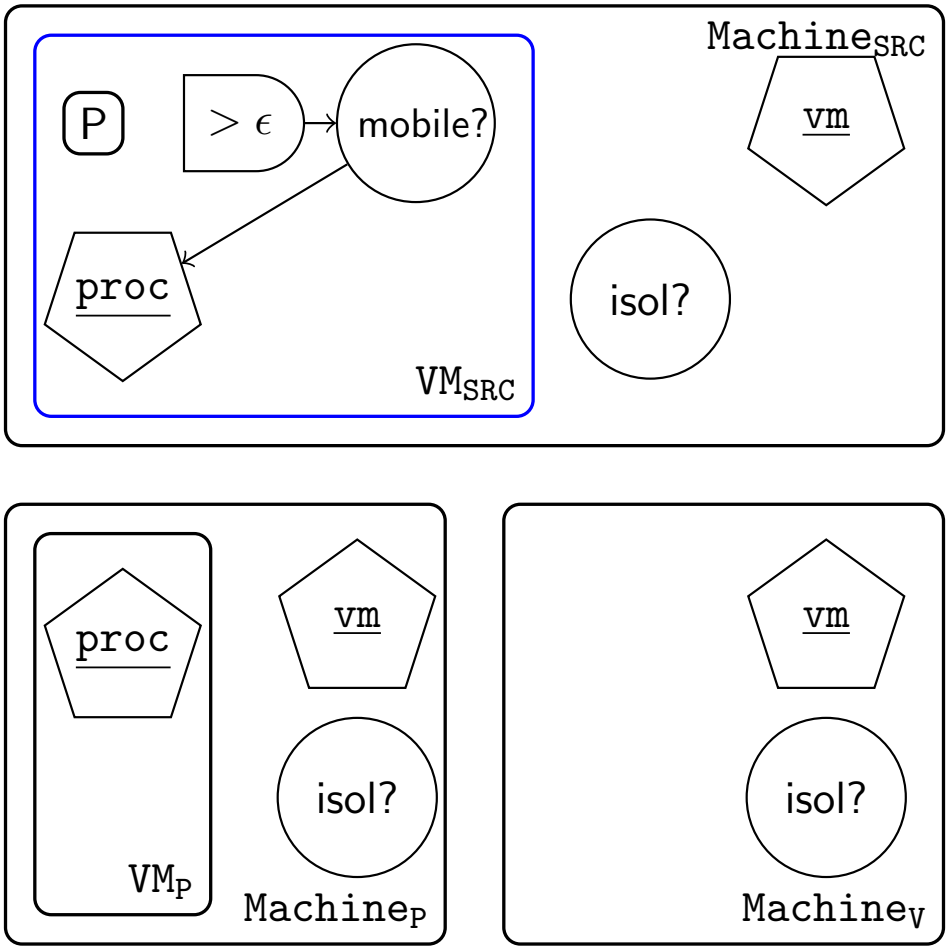

If process can be moved ...

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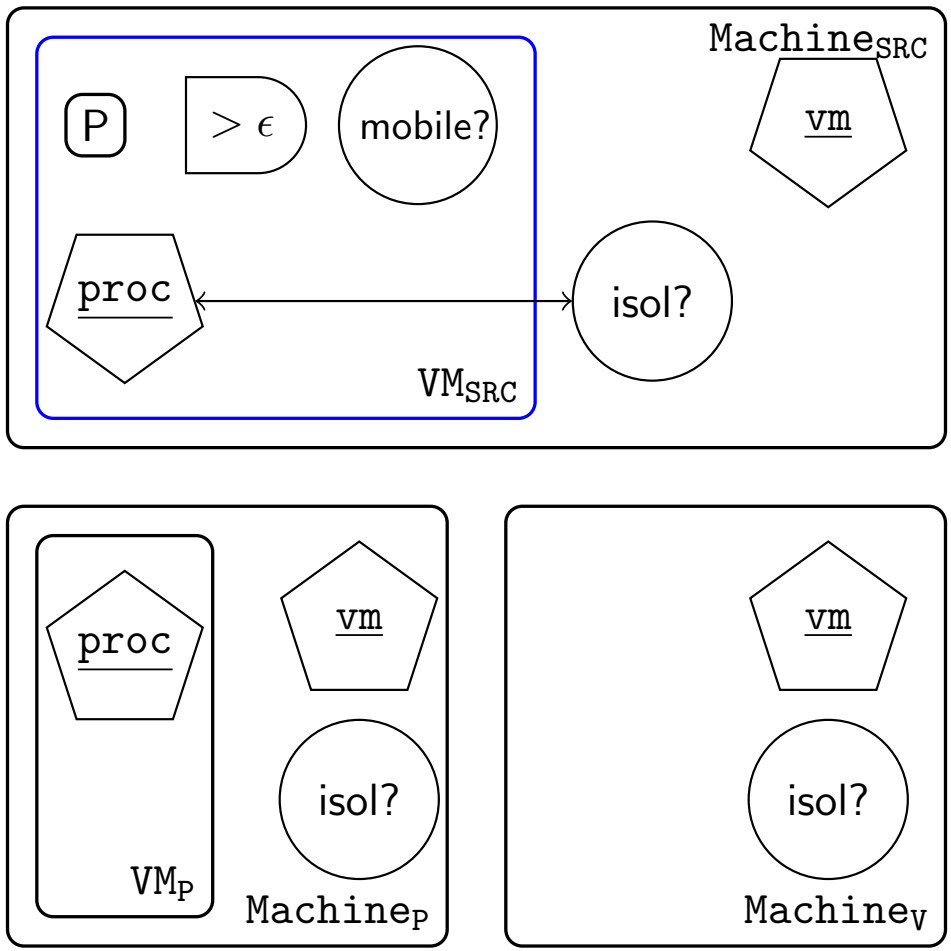

Check isolation criteria

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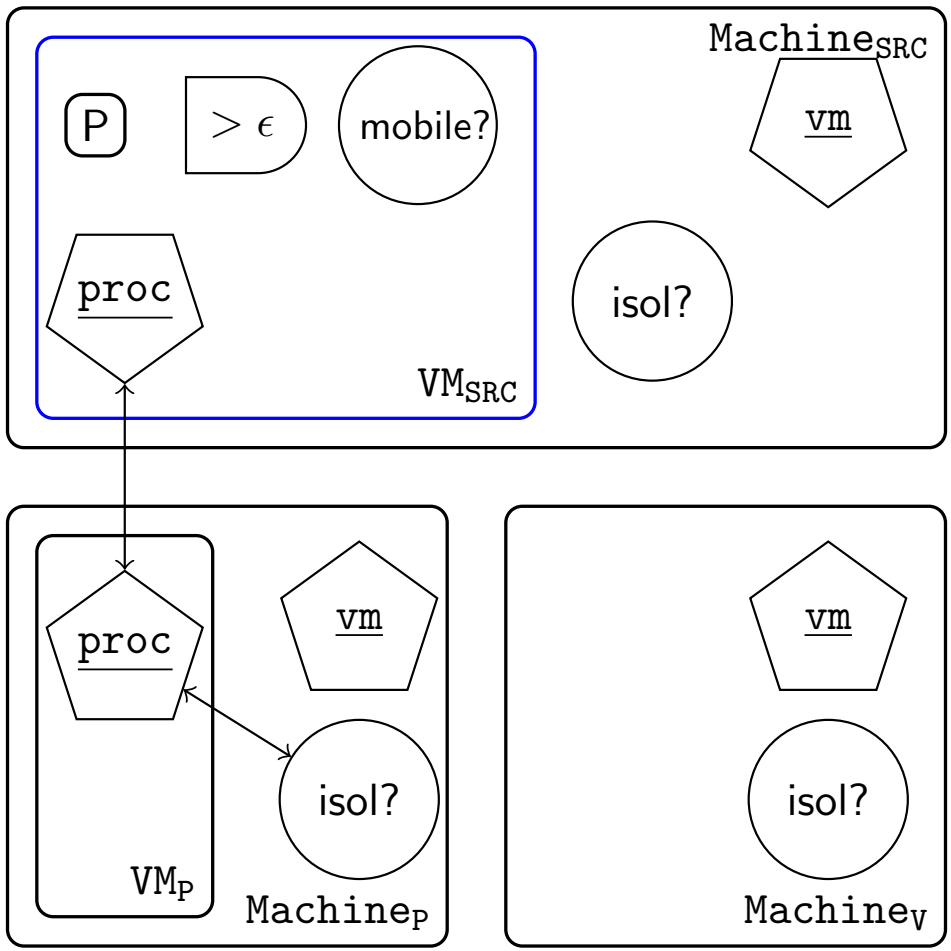

Find target system matching criteria

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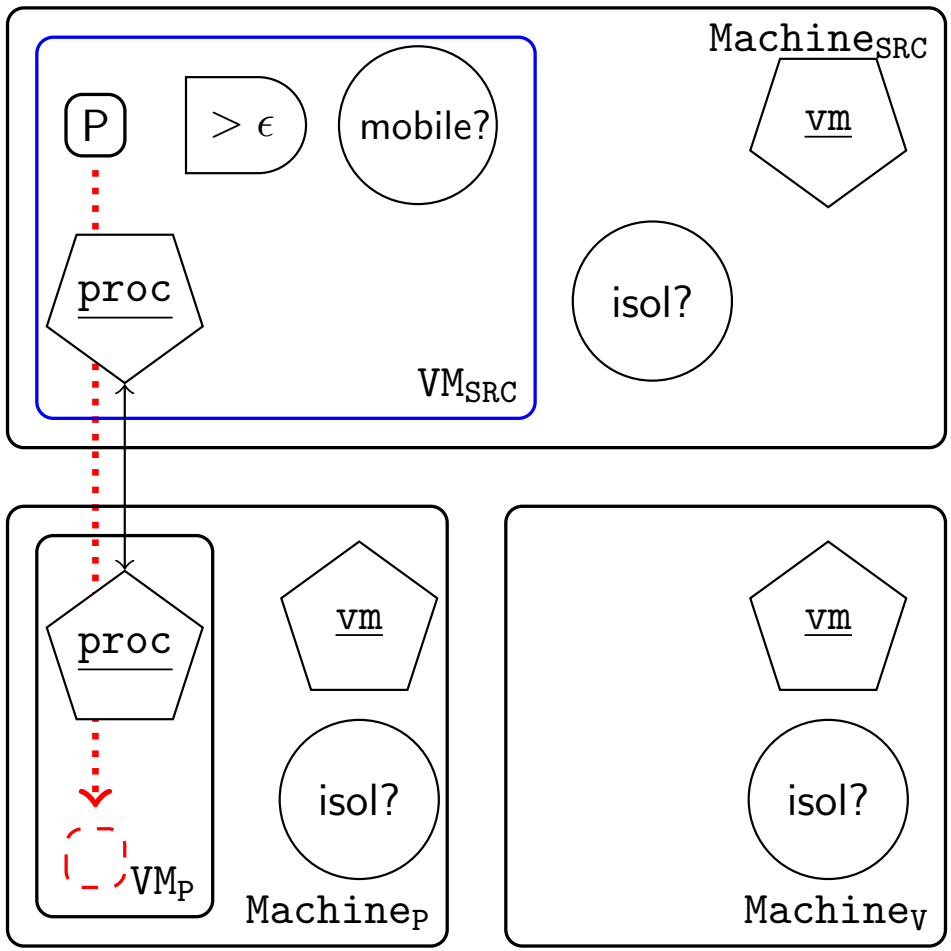

Migrate process

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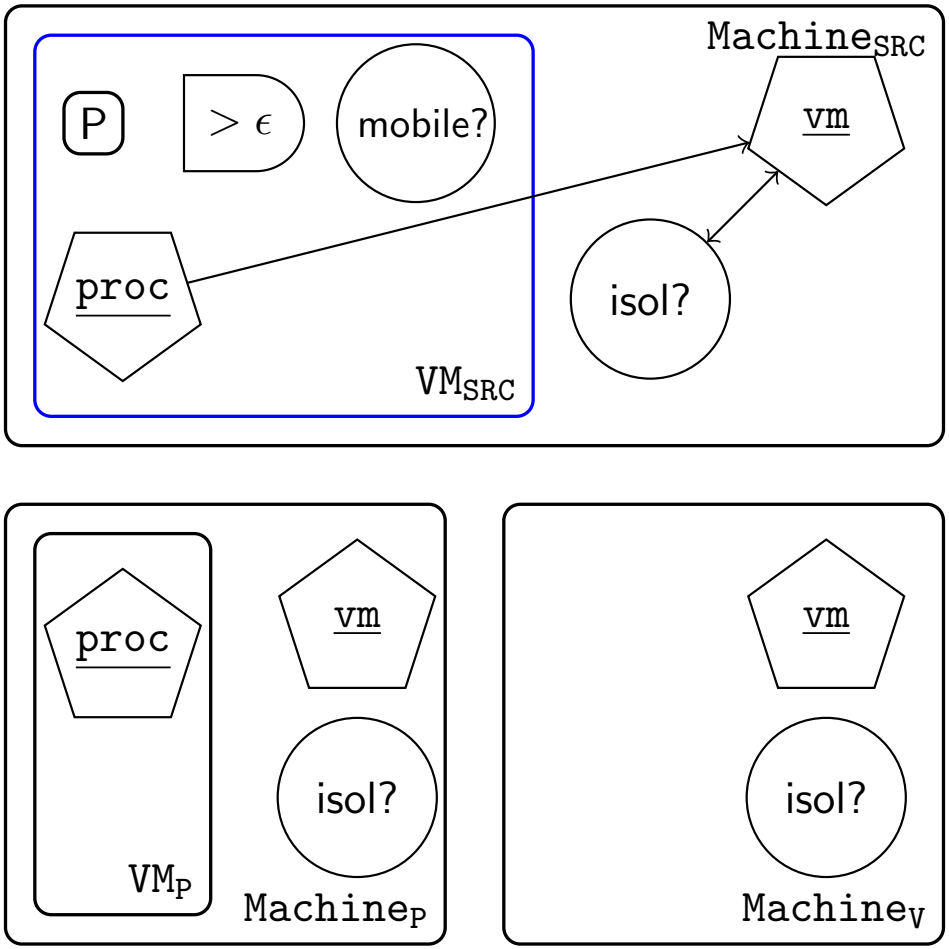

Process cannot move; resolve at VM level

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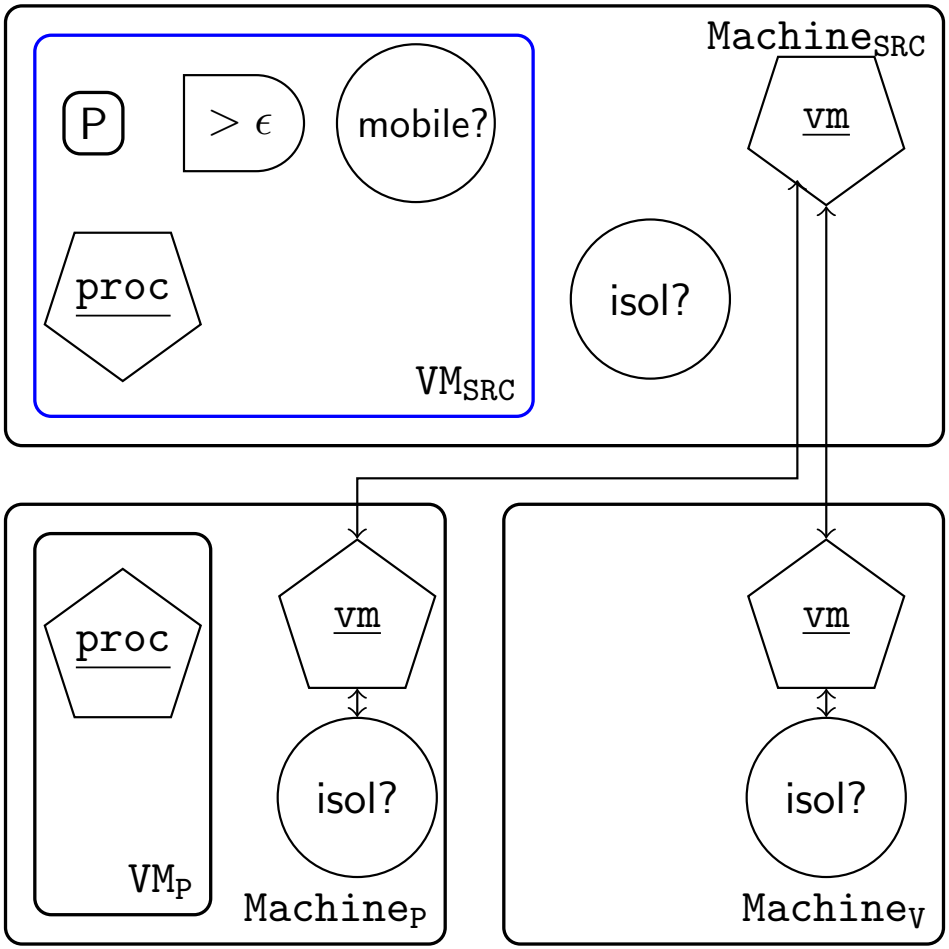

Consult VM-level agents to identify isolated target

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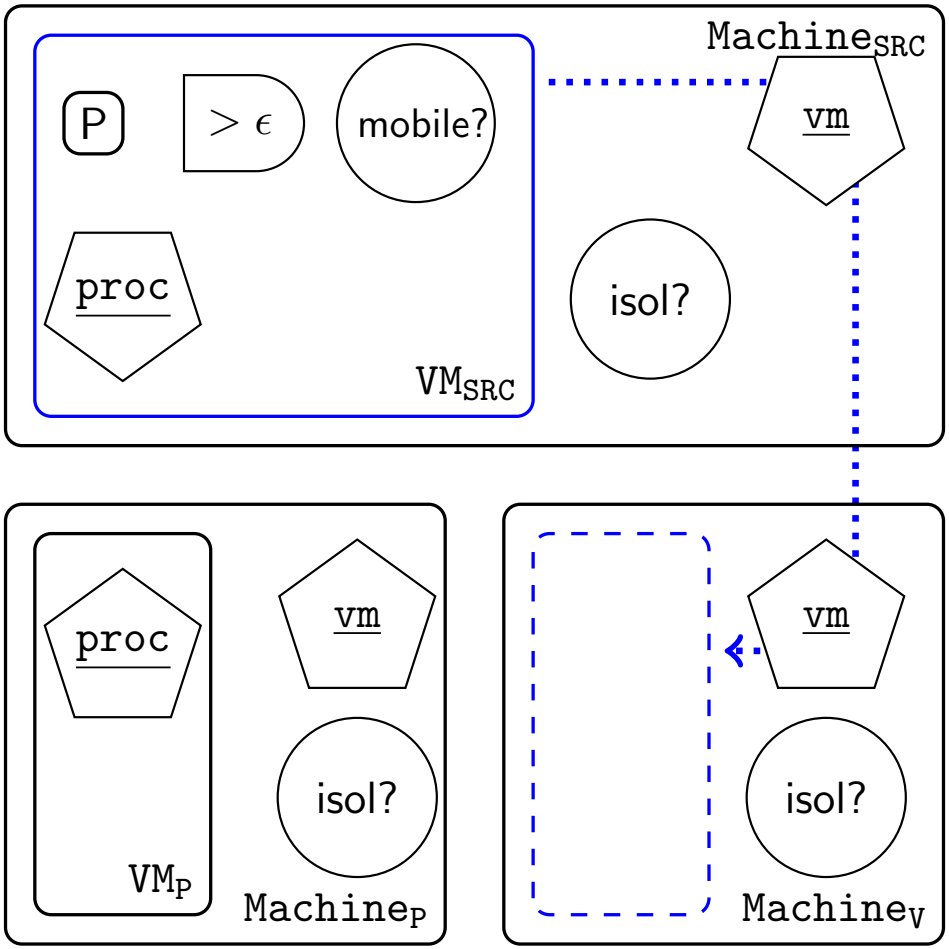

Perform VM migration

Evaluation: Detector

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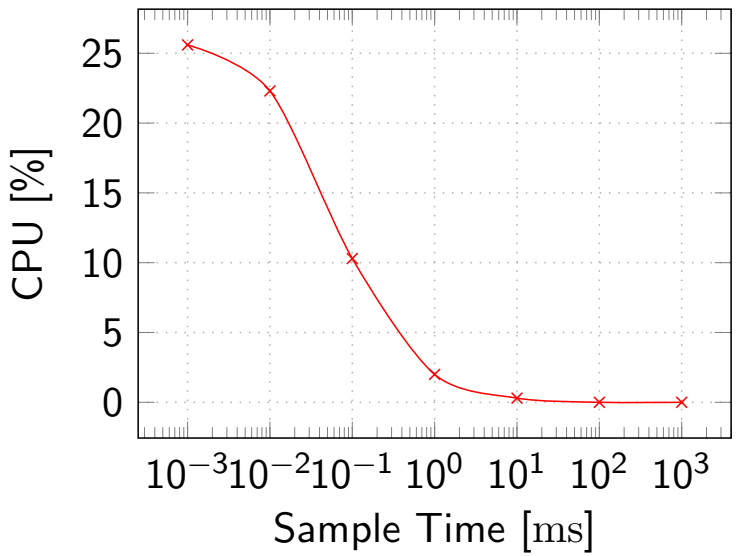
Observe frequency of misaligned atomic memory operations using hardware counters.

$$\text{Sample Time} = \frac{\text{Period}}{\#\ \text{Processes}}$$

- Fixed period (1000, 2500ms)
- 120-200 processes, low duty cycle
- Detects vast majority in first pass



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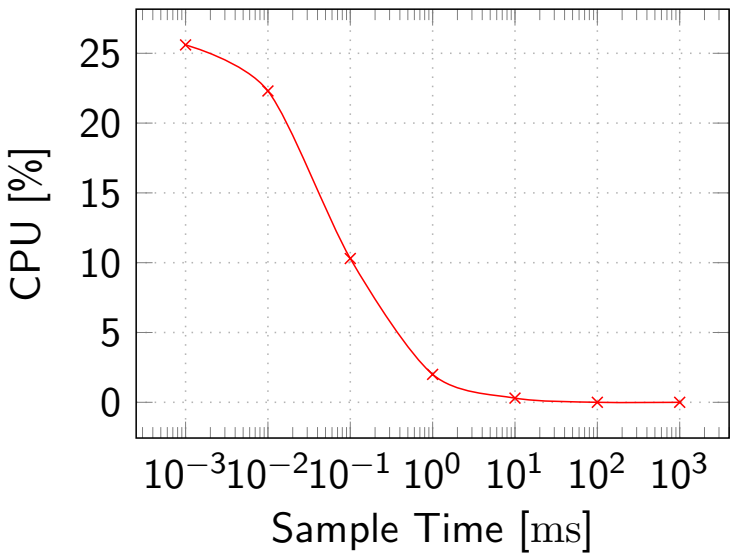

*can be even faster/more accurate!

Evaluation: VM Migration Modes

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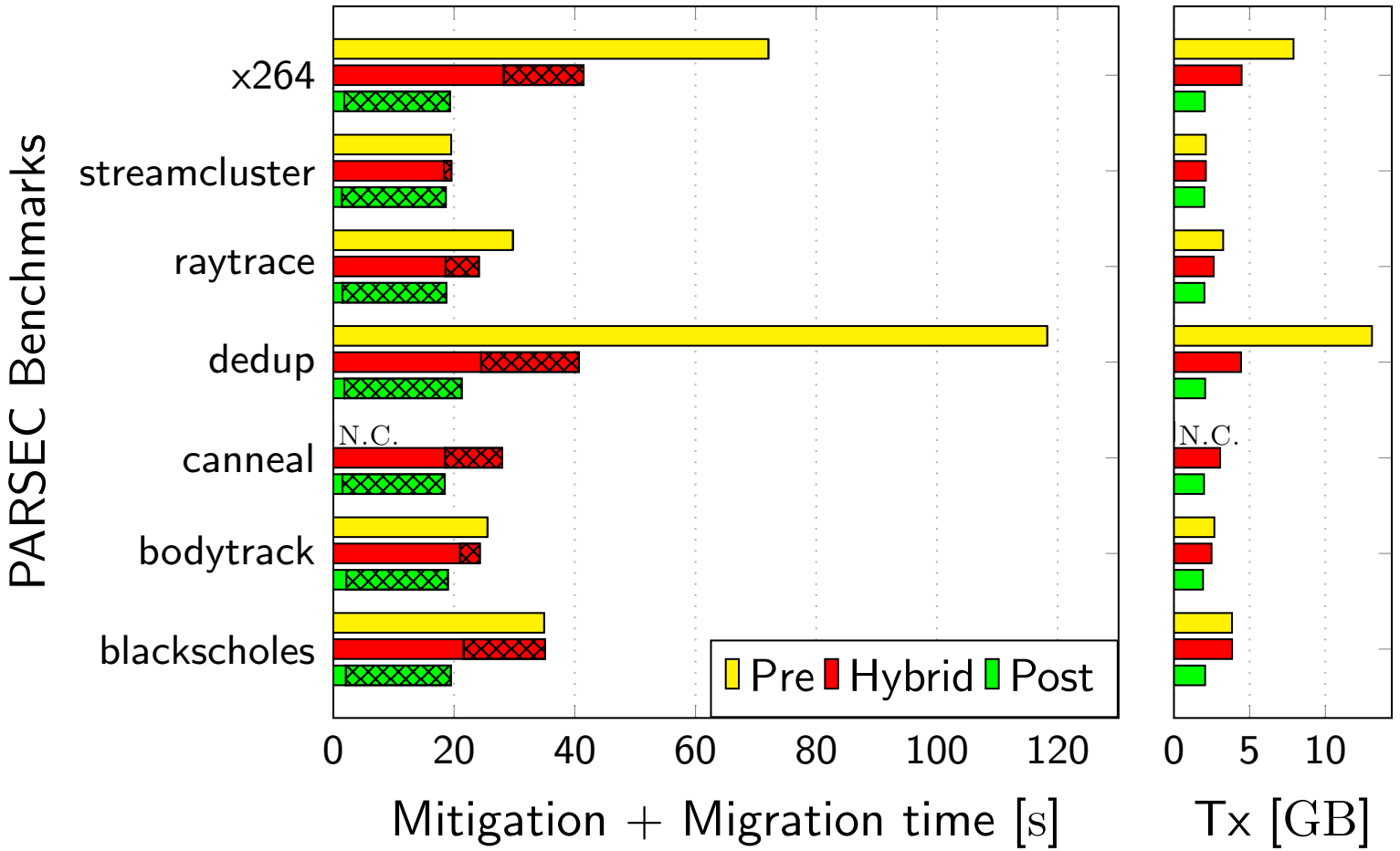

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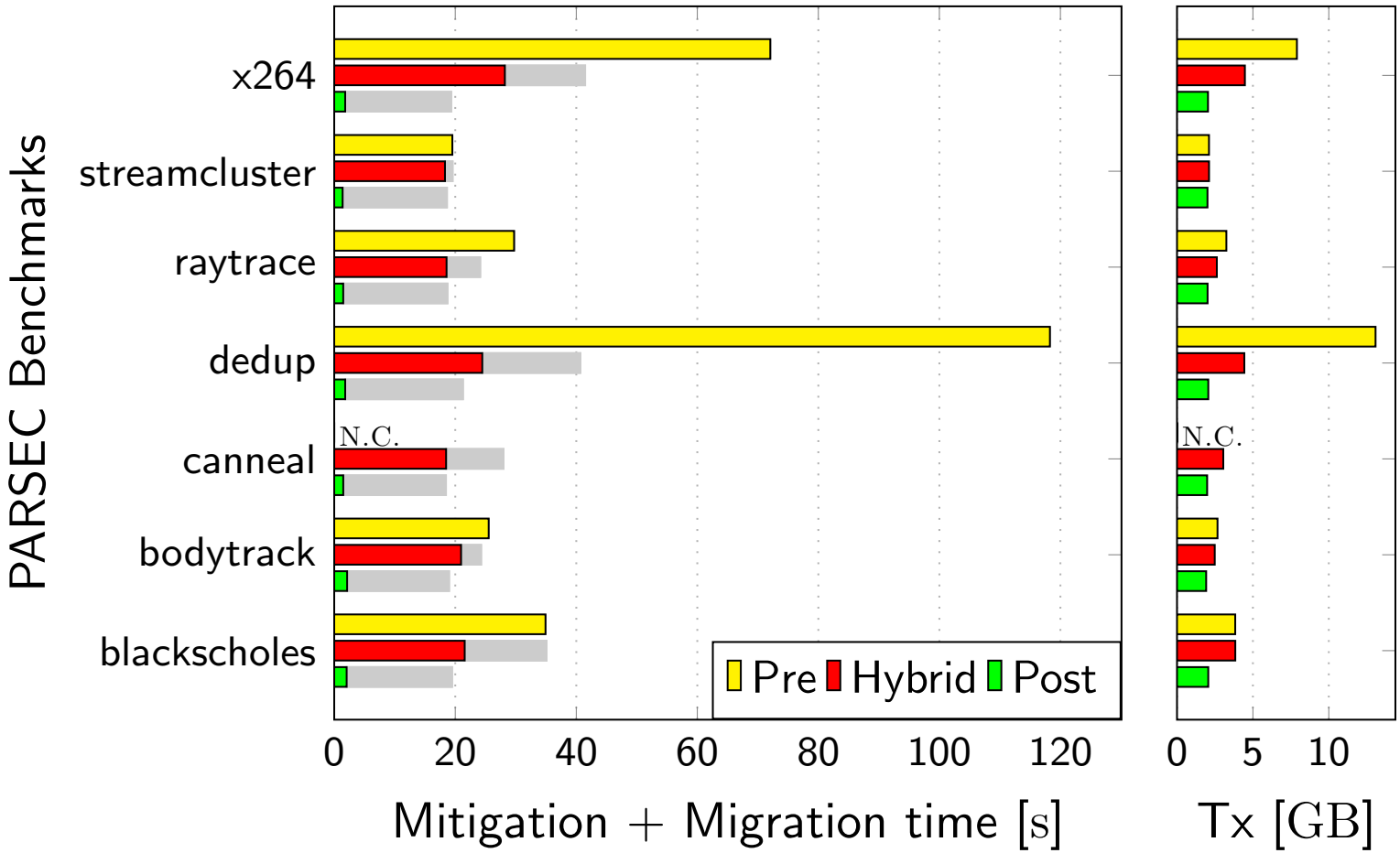

Evaluation: Combining Detector and Post-copy

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		Min	Max	Geo. Mean	Arith. Mean
Detection, period = 1s		0.015	3.16	0.54	0.72
Post-copy migration	+	1.281	2.13	1.47	1.48
Total (seconds)	=	**1.296**	**5.29**	**2.01**	**2.20**

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Evaluation: Summary

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Condensed results:

- Migrating processes to cores/vCPUs takes $\approx$ 25ms
- Container checkpoint and restore times are workload-dependent – order of seconds
  - Checkpoint: $\approx$ 4s - 24s, mean $\approx$ 10s
  - Restore: $\approx$ 1s - 8s, mean $\approx$ 2s
  - Memory pressure largest C/R performance factor
  - `rsync` incurred massive performance penalty ($\approx 40s$)
- Post-copy VM migration times are very consistent
  - $\approx$ 20s total transfer for a 2GB VM
  - Migrating every 30s halved performance; 60s $\approx$ 30% overhead

Conclusion

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Conclusions

1. Conjunction of mechanisms makes the approach viable. Other factors include total system capacity and economic concerns.
2. Post-copy makes it possible to mitigate attacks at the coarsest level of granularity in a timely manner.
3. Process migration is theoretically the most general mitigation, but it is not yet sufficiently robust.

Future work

- Automatic property generation
- Finding intermediate levels of granularity

Conclusion

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Thank you!