SmartHarvest: Harvesting Idle CPUs Safely and Efficiently in the Cloud

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EuroSys 2021

CPU Underutilization in Datacenter Servers

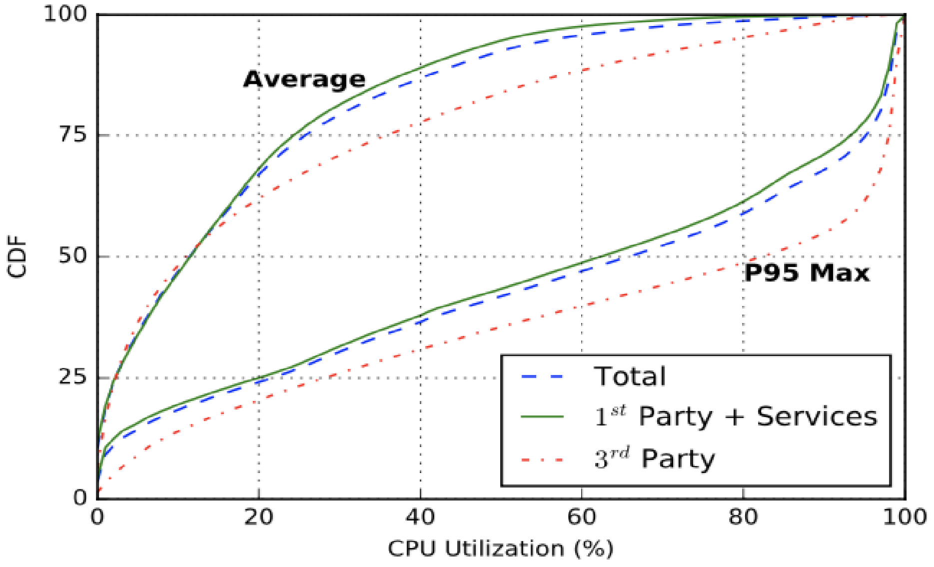

Figure 1: Average and P95 of max CPU utilizations. [1]

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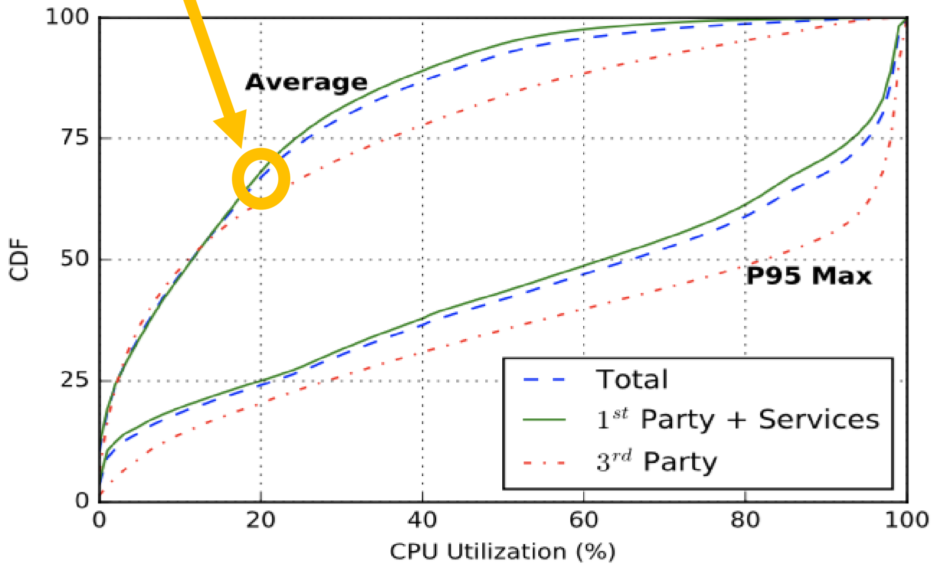
60% of the virtual machines (VMs) in Azure have an average CPU utilization < 20%



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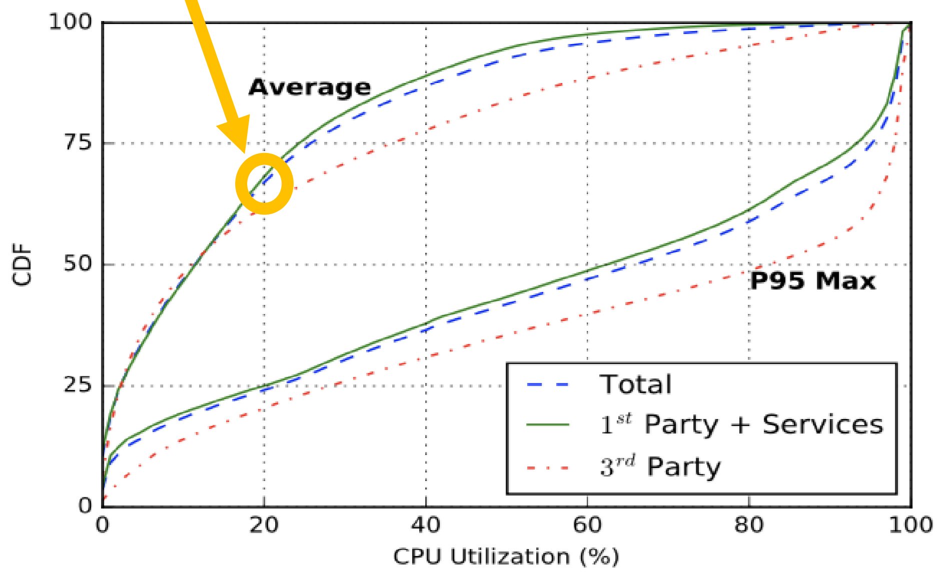

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Reason for low CPU utilization in VMs

- VMs are often oversized for peak load
- Common for user-facing workloads

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Prior approaches to increase CPU utilization

- Use spare CPU resources from latency-sensitive workloads to run batch processing tasks
  - Extensive offline workload profiling (e.g. PerfIso[2])
  - Knowledge of application characteristics (e.g. Heracles[3], Shenango[4])

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Challenge: VMs are opaque boxes in public cloud

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1. Rely only on monitoring of low-level proxies (e.g. CPU usage)
2. Assume any VM may be latency-sensitive

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- **Safely harvest idle cores** to run batch processing jobs inside ElasticVM
- Employ a **two-level safeguard** to reduce performance impact on primary VMs when learning misbehaves
- Dynamically allocate cores among VMs to
    1. **Minimize** impact on primary VMs (e.g., no more than 10%)
    2. **Maximize** harvested spare CPU resources

A new type of VM: ElasticVM

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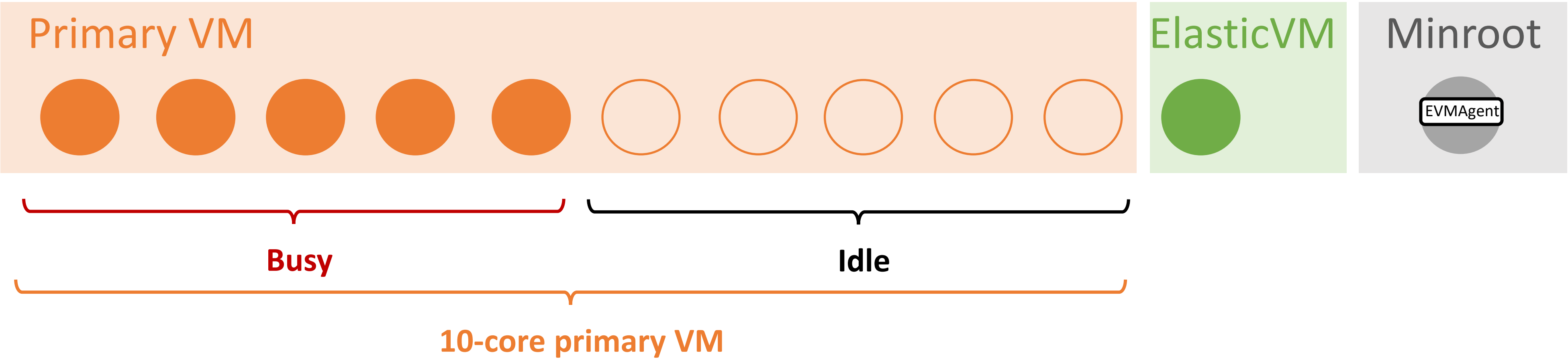
- Configured to have as many virtual cores as the total number of physical cores on the server

High-Level Design of SmartHarvest



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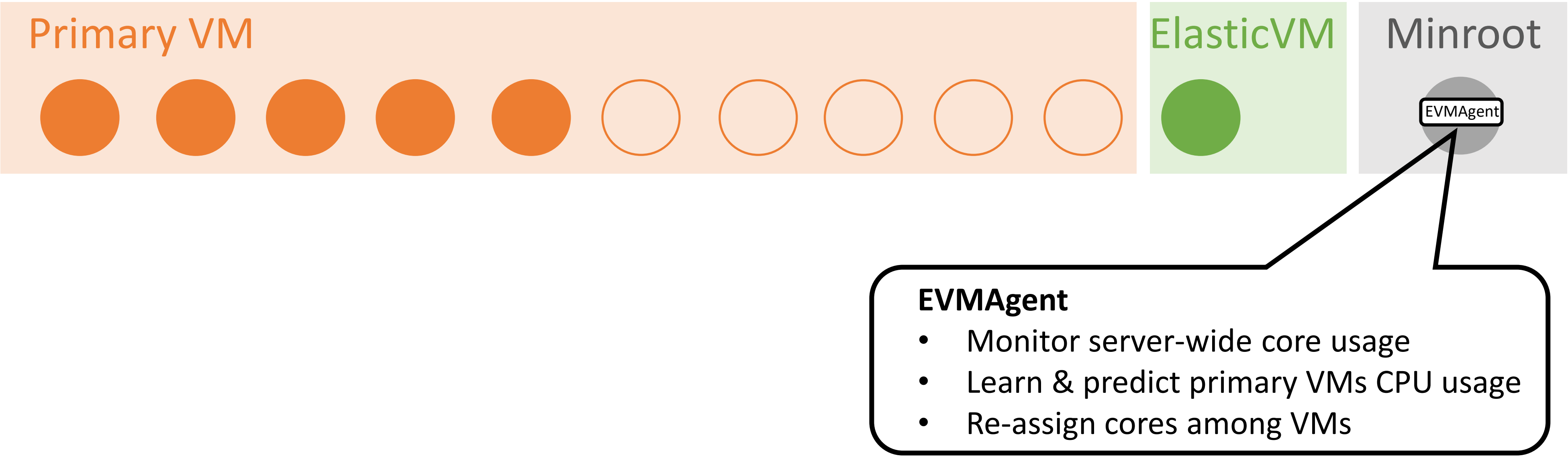

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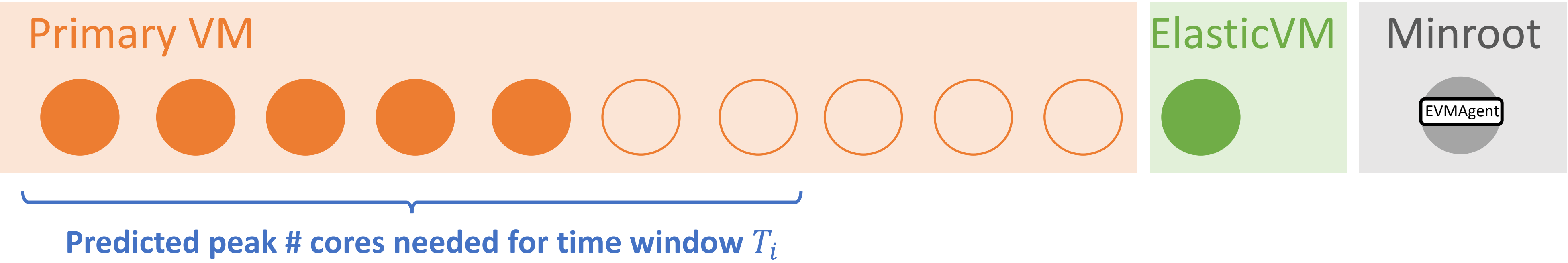

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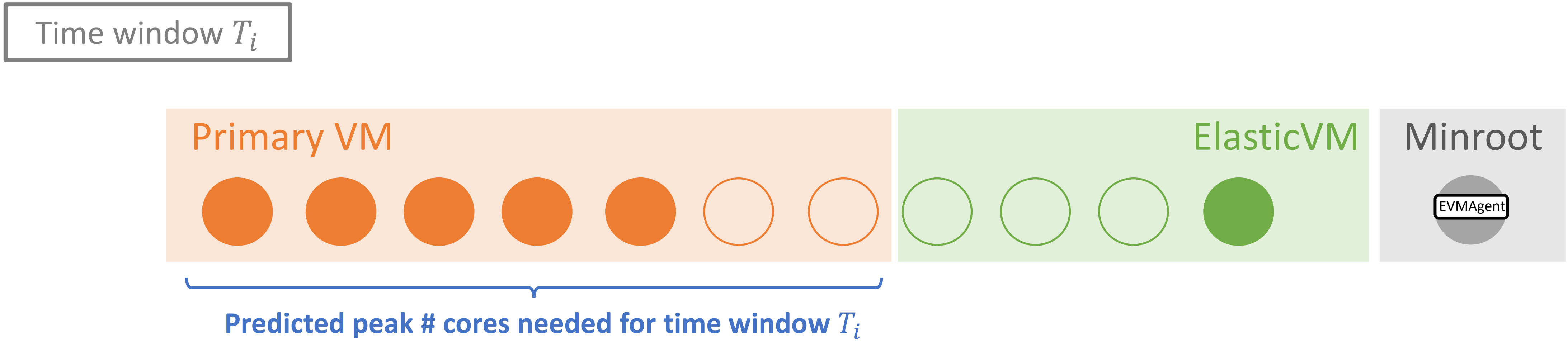

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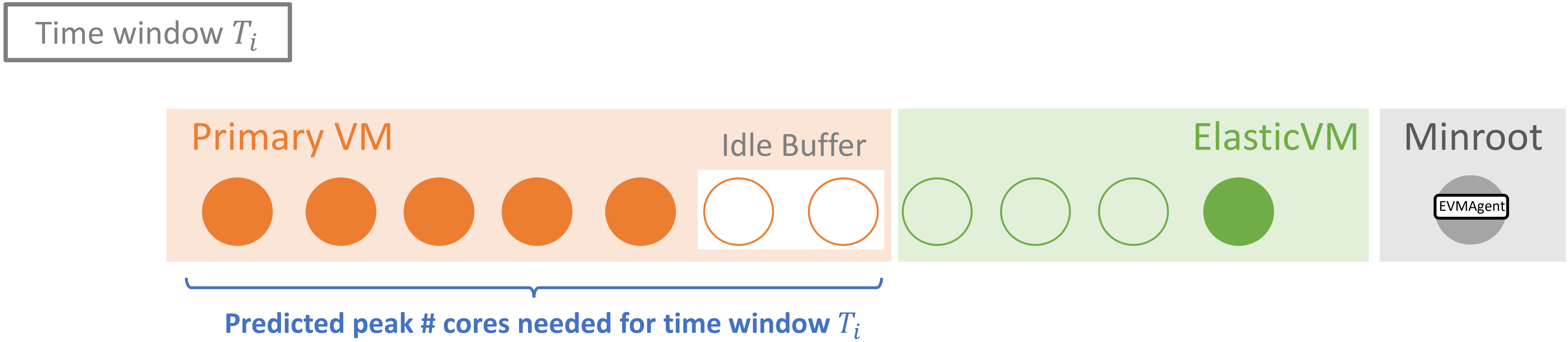

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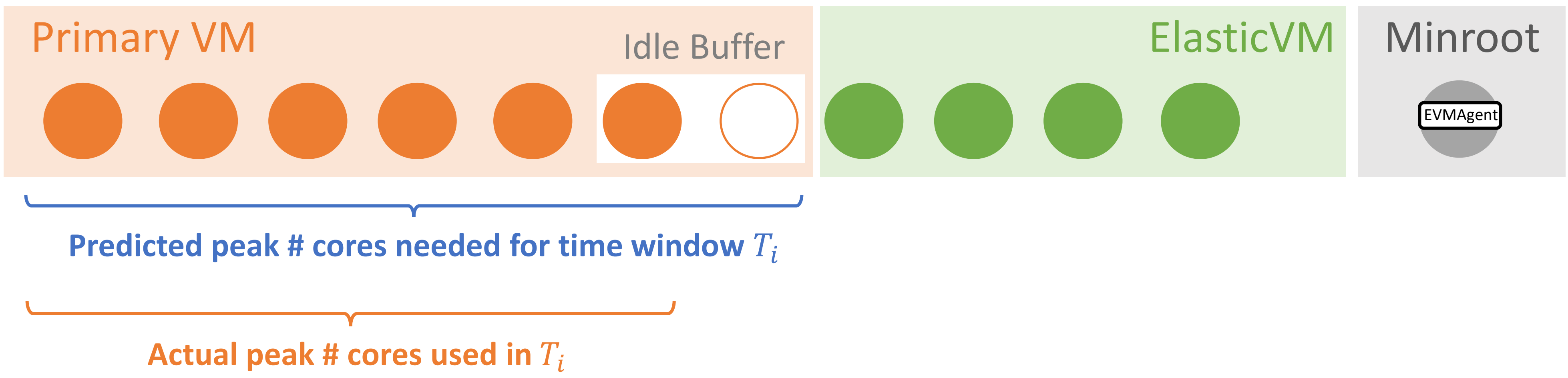
End of time window T_i



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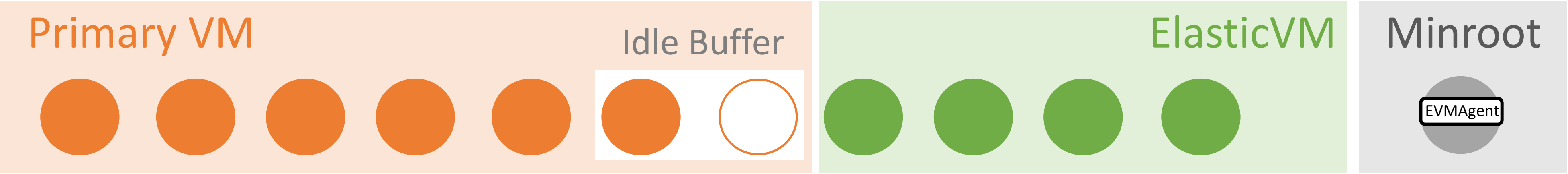

Predicted peak # cores needed for time window T_i

Actual peak # cores used in T_i

True CPU peak in T_i is known

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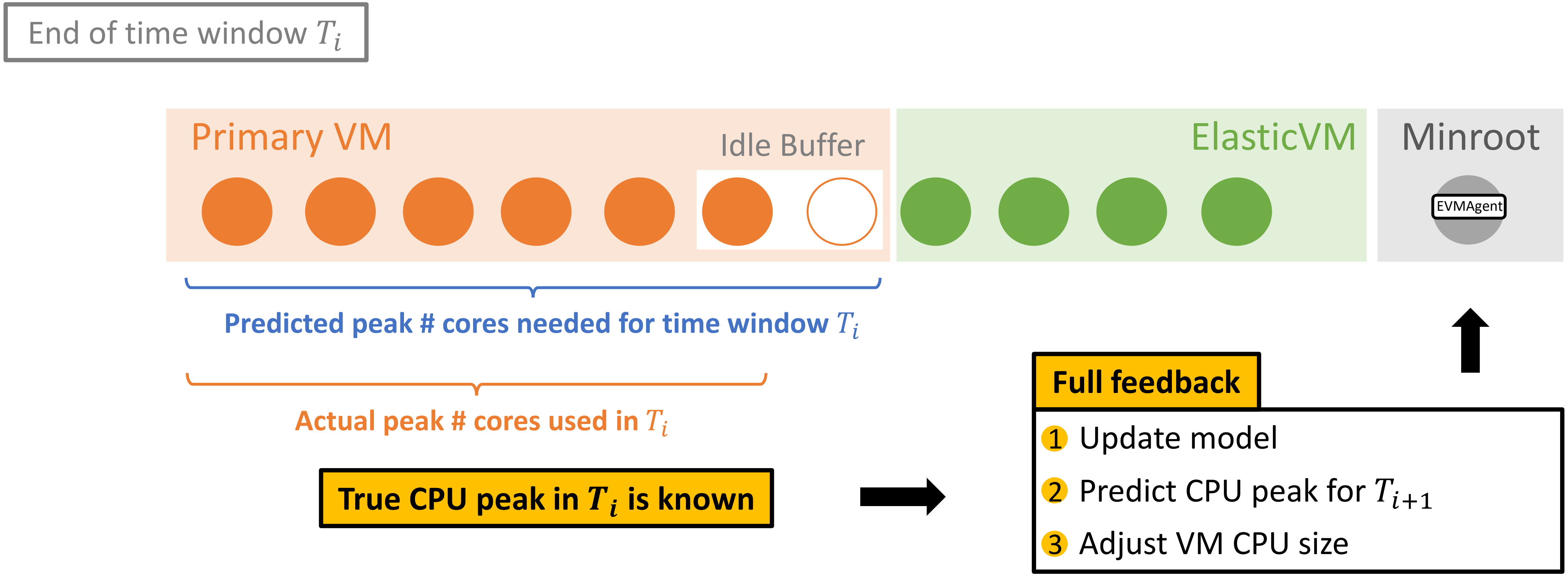

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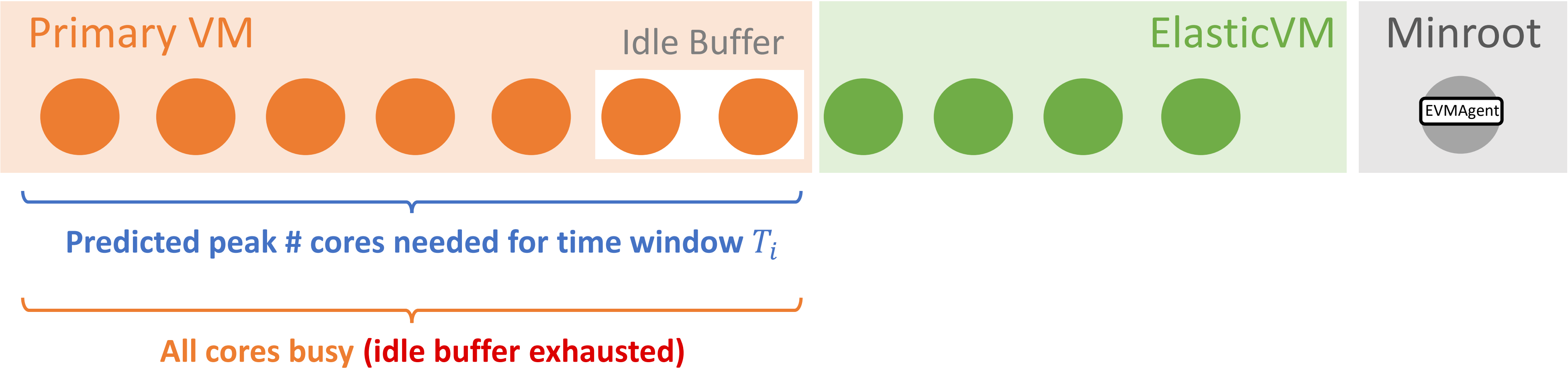

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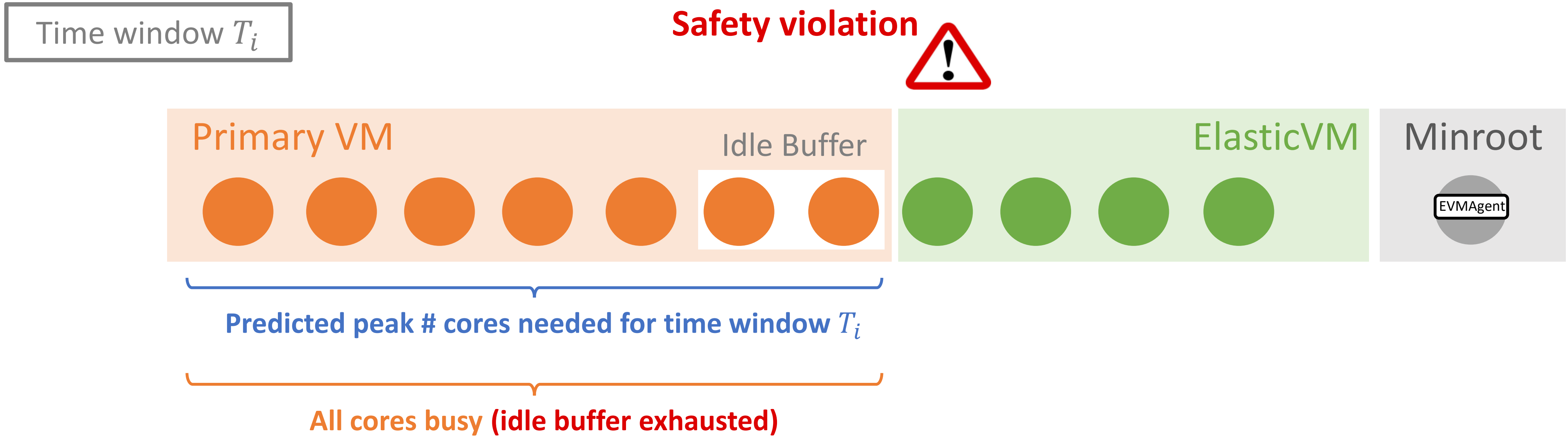

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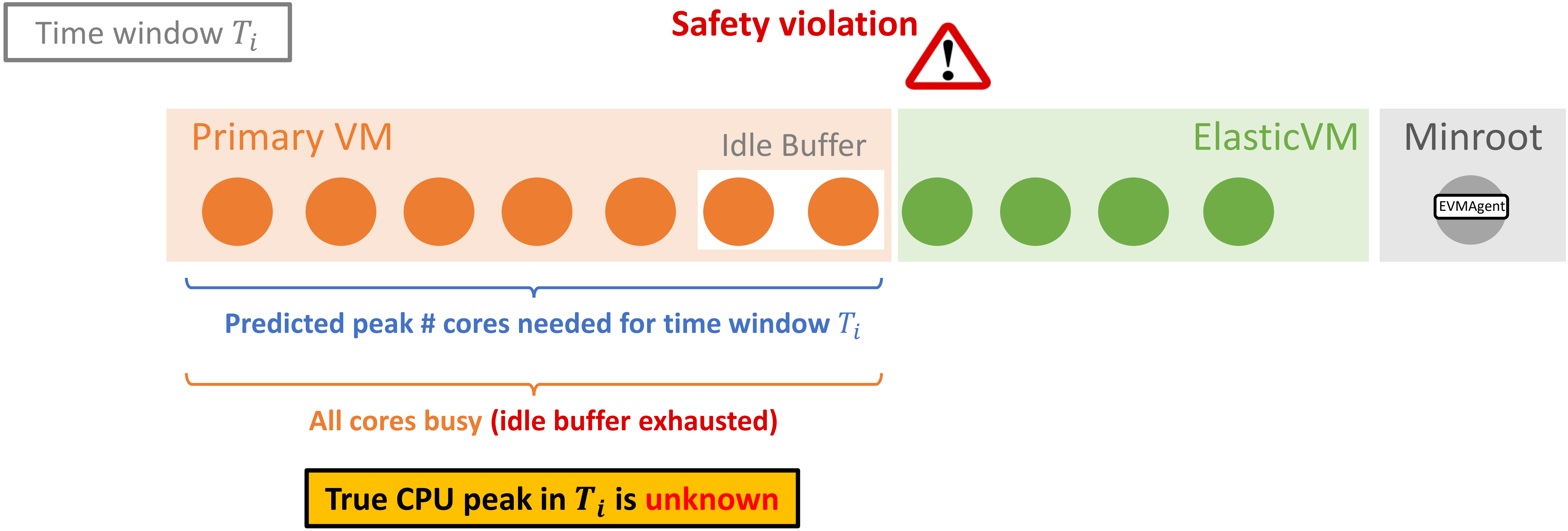

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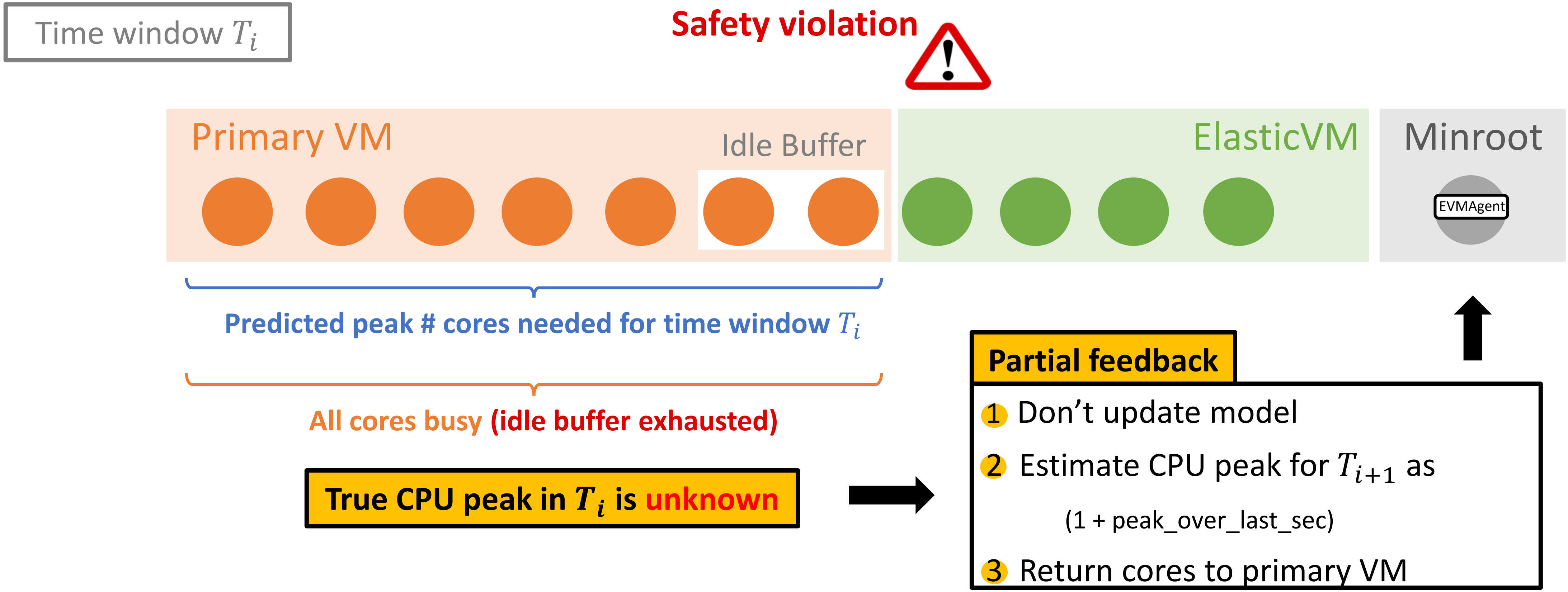

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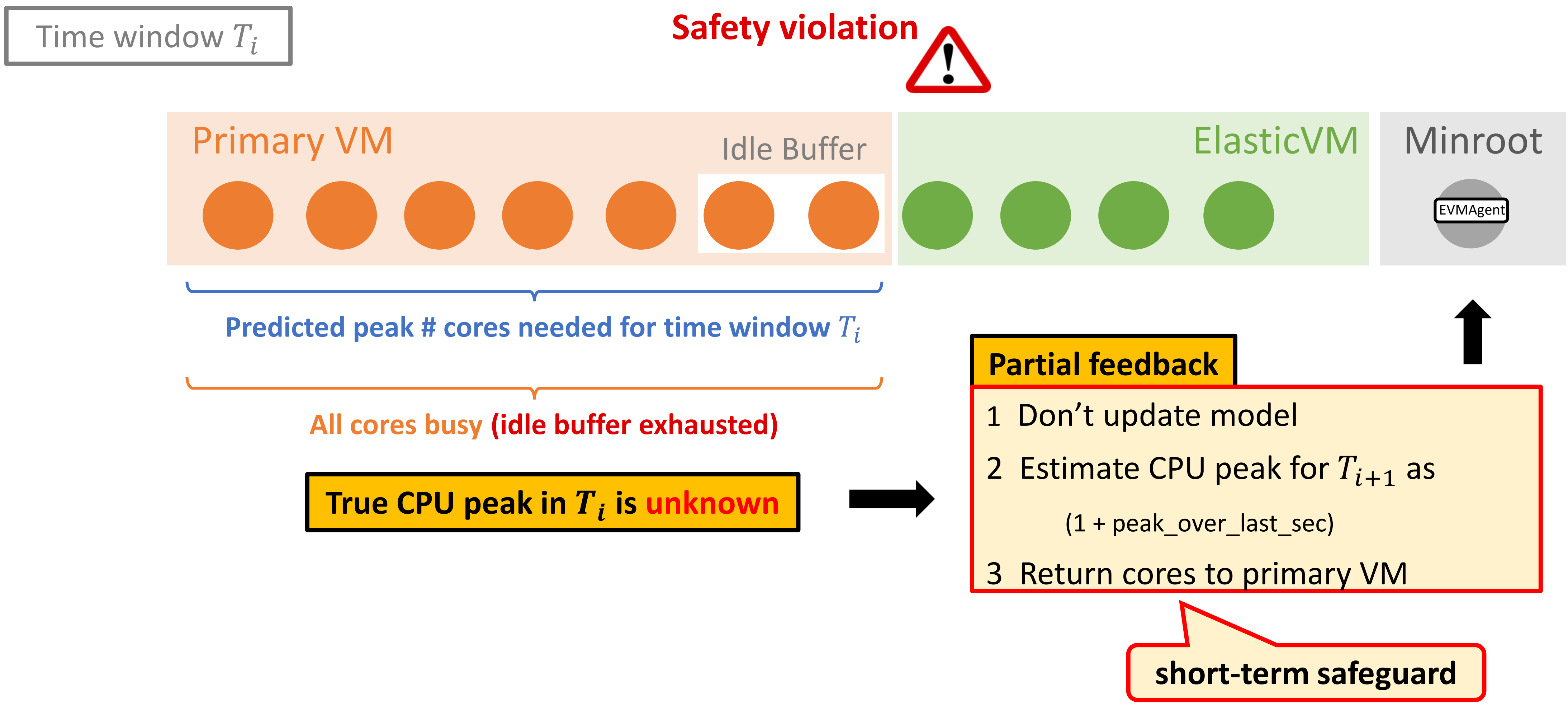

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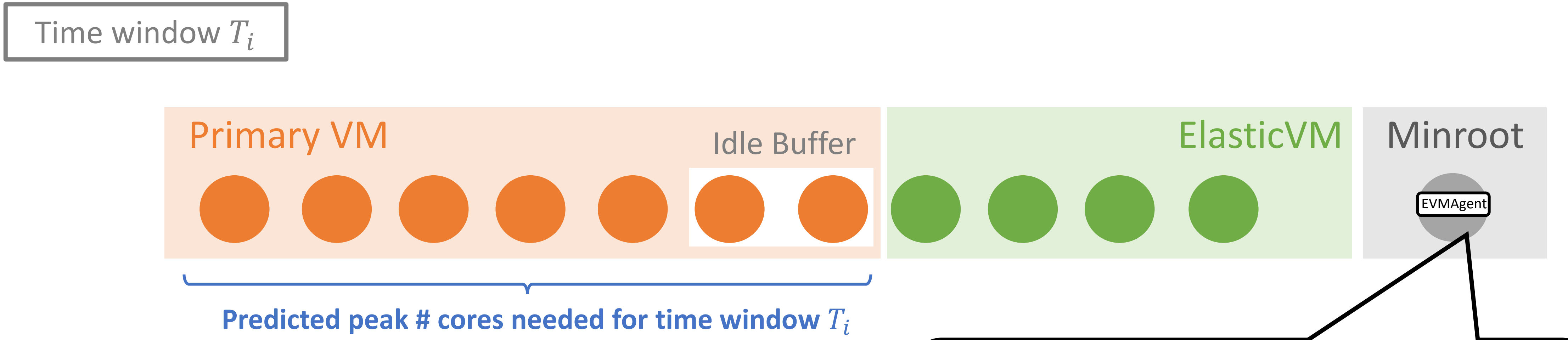

EVMAgent

- Disable harvesting when primary VM experiences long vCPU wait time → proxy for VM performance
  - e.g., more than 1% of vCPU wait times > 50 μs

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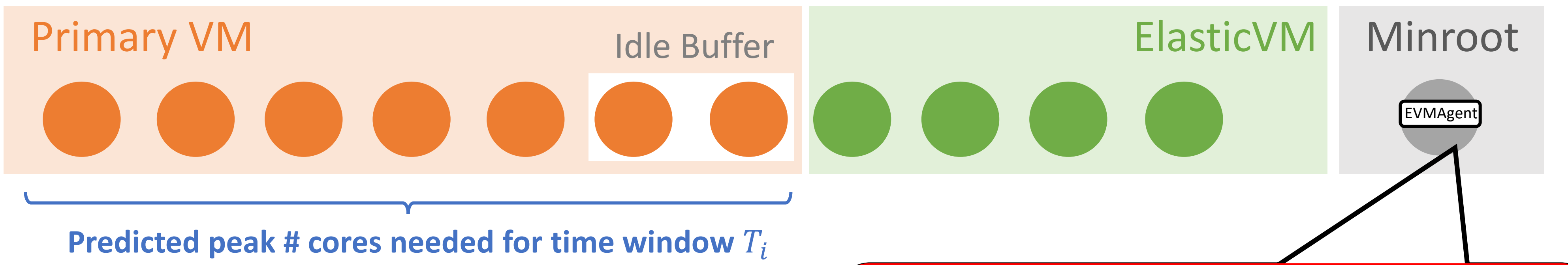

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Long-term safeguard

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Most useful set of features

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☆ Offers fast prediction and update times (e.g. <15μs)

Full-feedback model update

```
if pred_peak > observed_peak:
        true_peak = observed_peak
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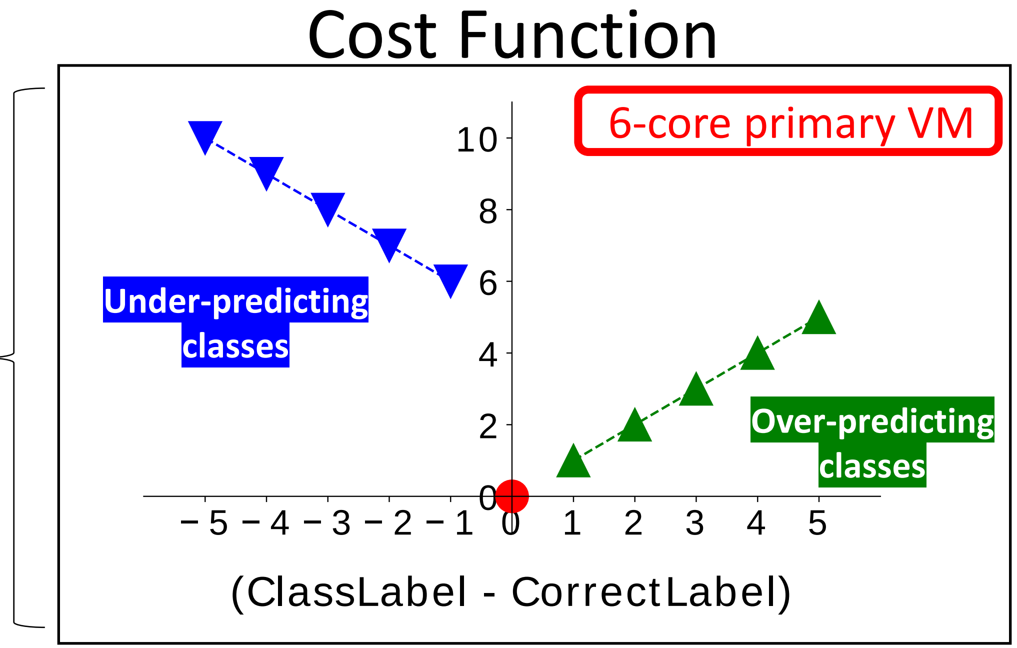
Update model with a cost for each class



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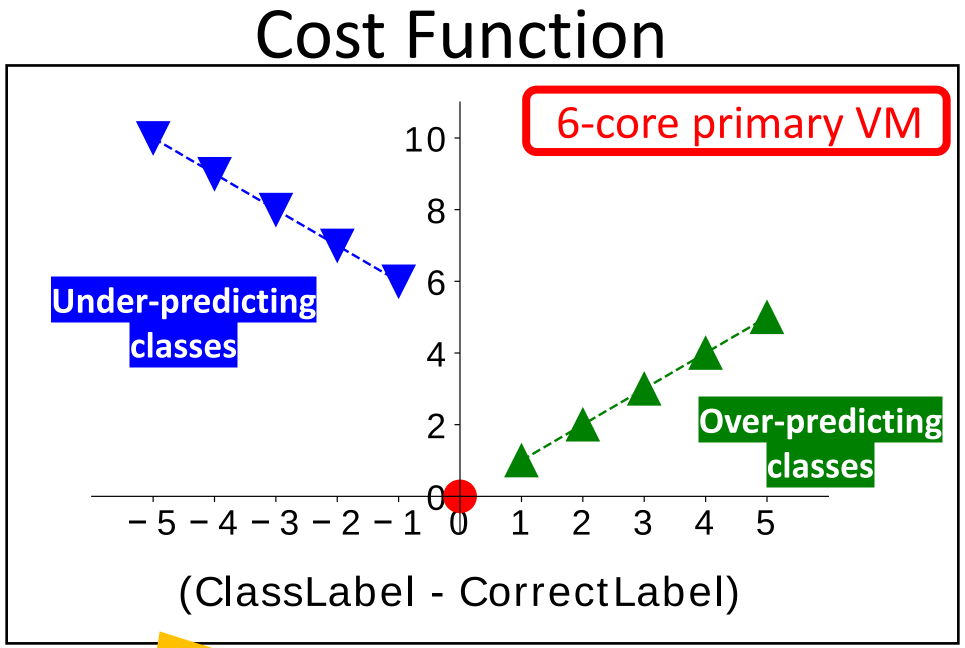

Penalize under-predicting classes more to skew away from aggressive harvesting

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Cost Function

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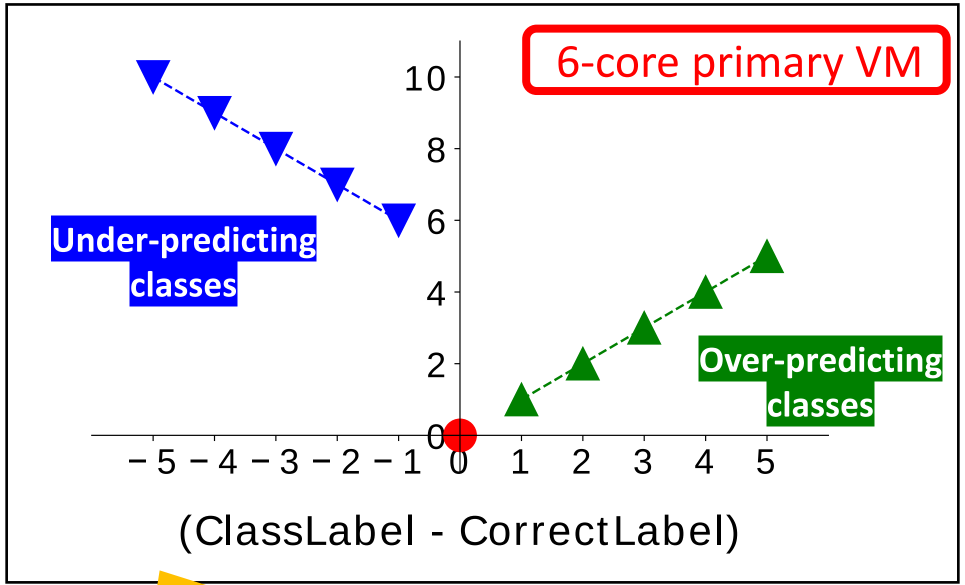

Penalize under-predicting classes more to skew away from aggressive harvesting

E.g. **true_peak = 3 (correct class label)**

- Class 1: cost = |1-3|+5=7
- Class 2: cost = |2-3|+5=6

Classes that were under-predicting

- Class 3: cost = |3-3|=0 → Correct class
- Class 4: cost = |4-3|=1
- Class 5: cost = |5-3|=2
- Class 6: cost = |6-3|=3

Classes that were over-predicting

Evaluation

- **Primary VM workloads**
  - Microsoft Bing IndexServe
  - Memcached: in-memory key-value store
  - moses: machine translation application
  - img-dnn: image recognition application

P99 Latency

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  } P99 Latency
- **ElasitcVM workloads**
  - CPUBully (synthetic CPU-bound workload) } Avg. # of cores harvested

Evaluation (cont’d)

- **Alternative policies**
  - **FixedBuffer policy**
    - Adjusts primary CPU size to maintain a fixed buffer of idle cores
  - **PrevPeak policy**
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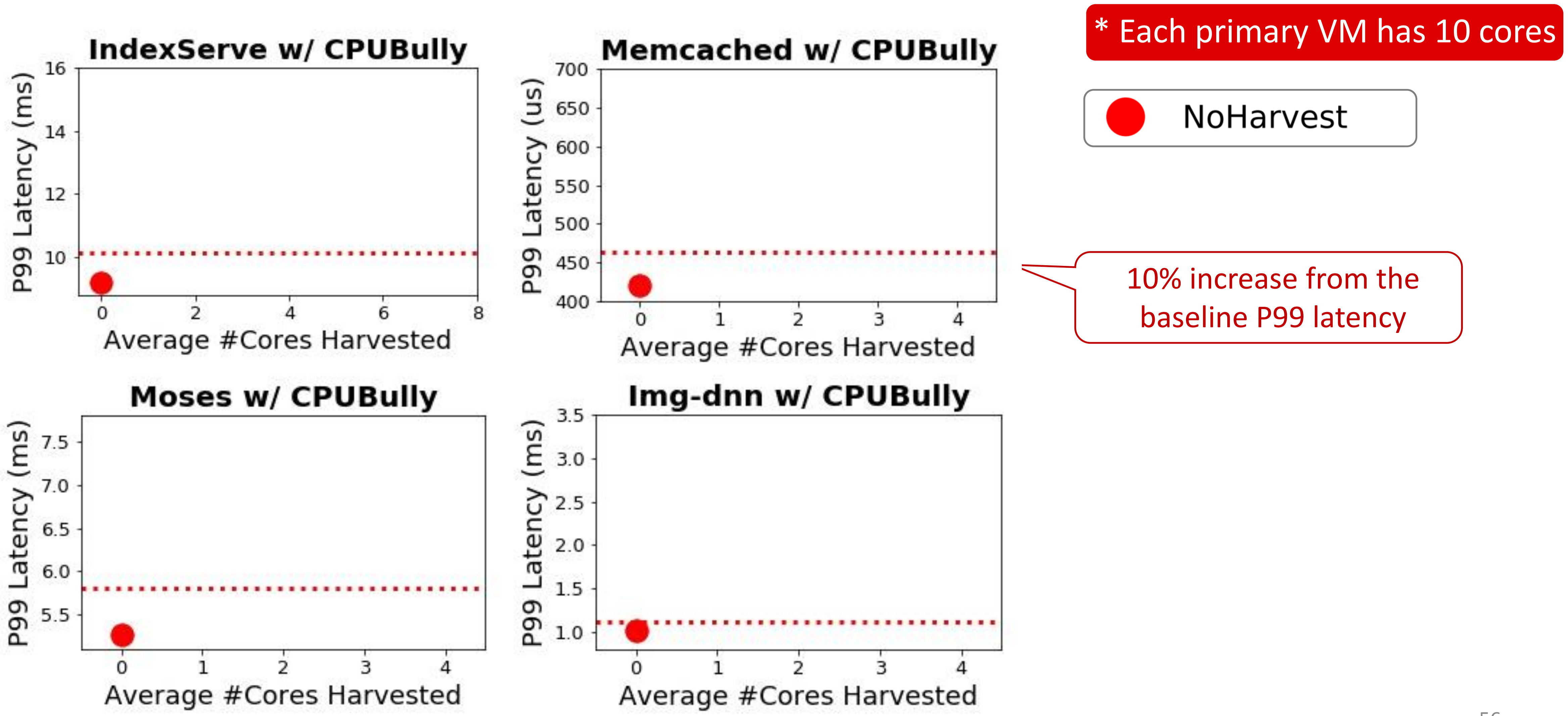
- **Testbed**
  - Two-socket Intel server with Xeon Platinum 8160 processor
  - 2.10GHz, 24 cores per socket, 255GB DRAM
  - Running the Hyper-V hypervisor

Single primary VM co-located with CPUBully



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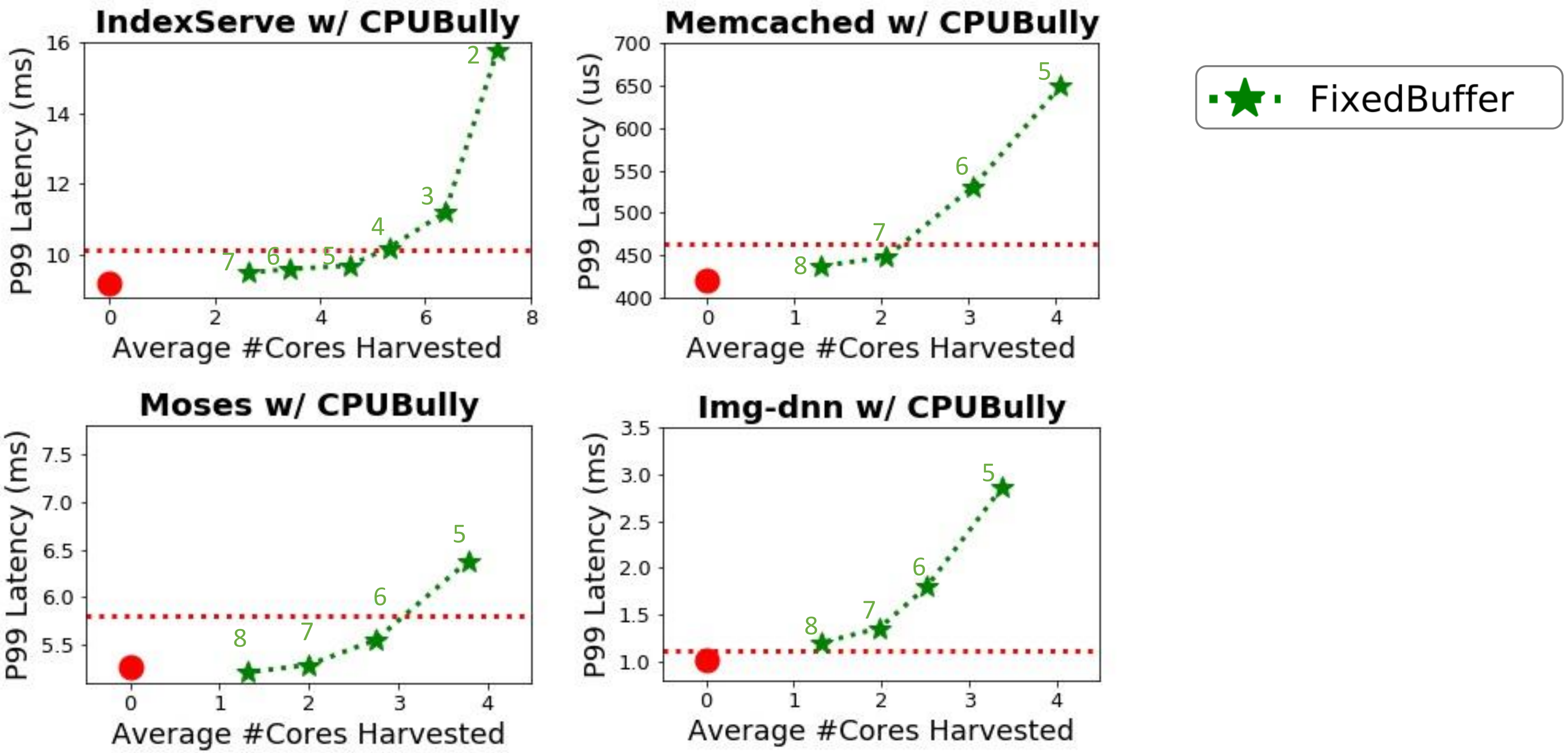

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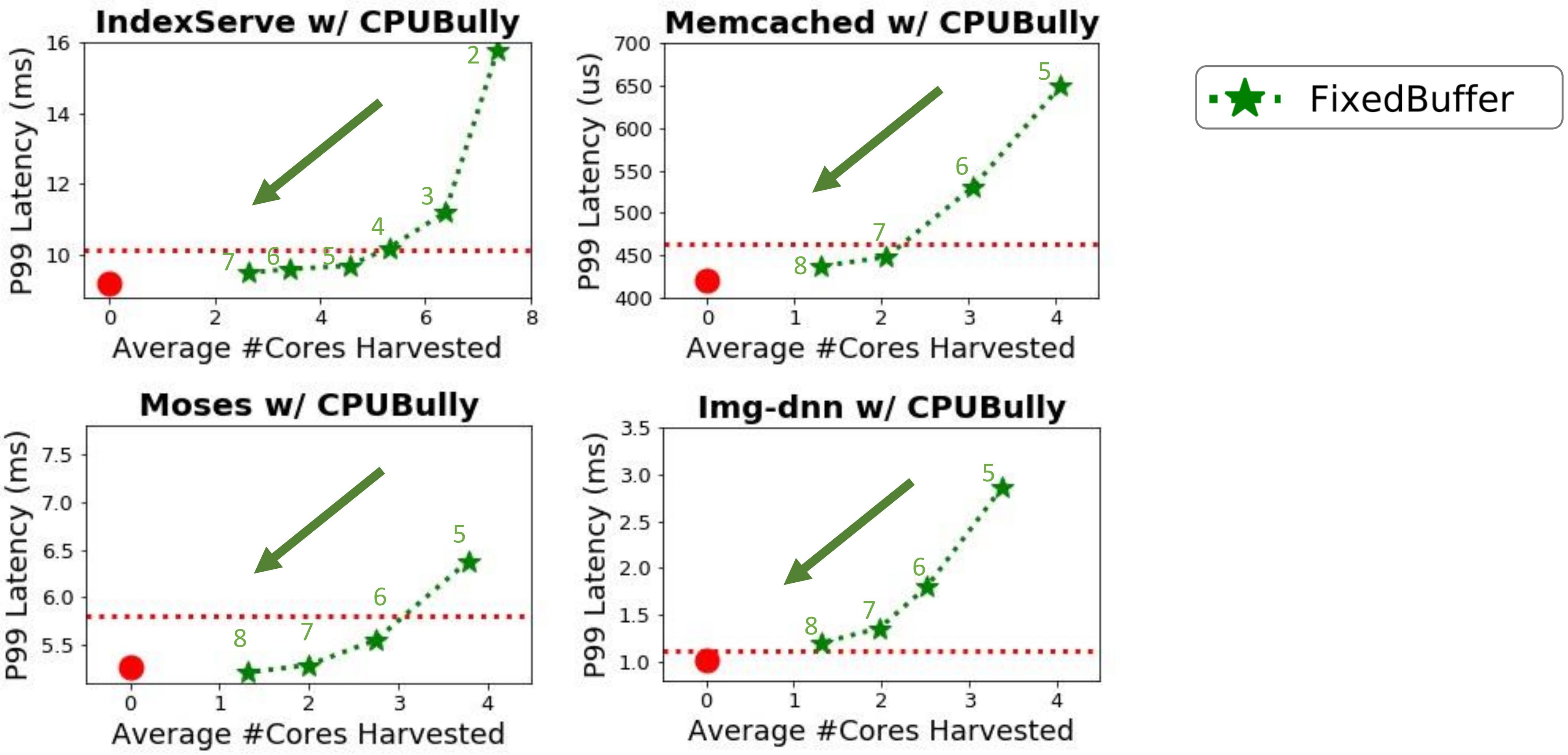

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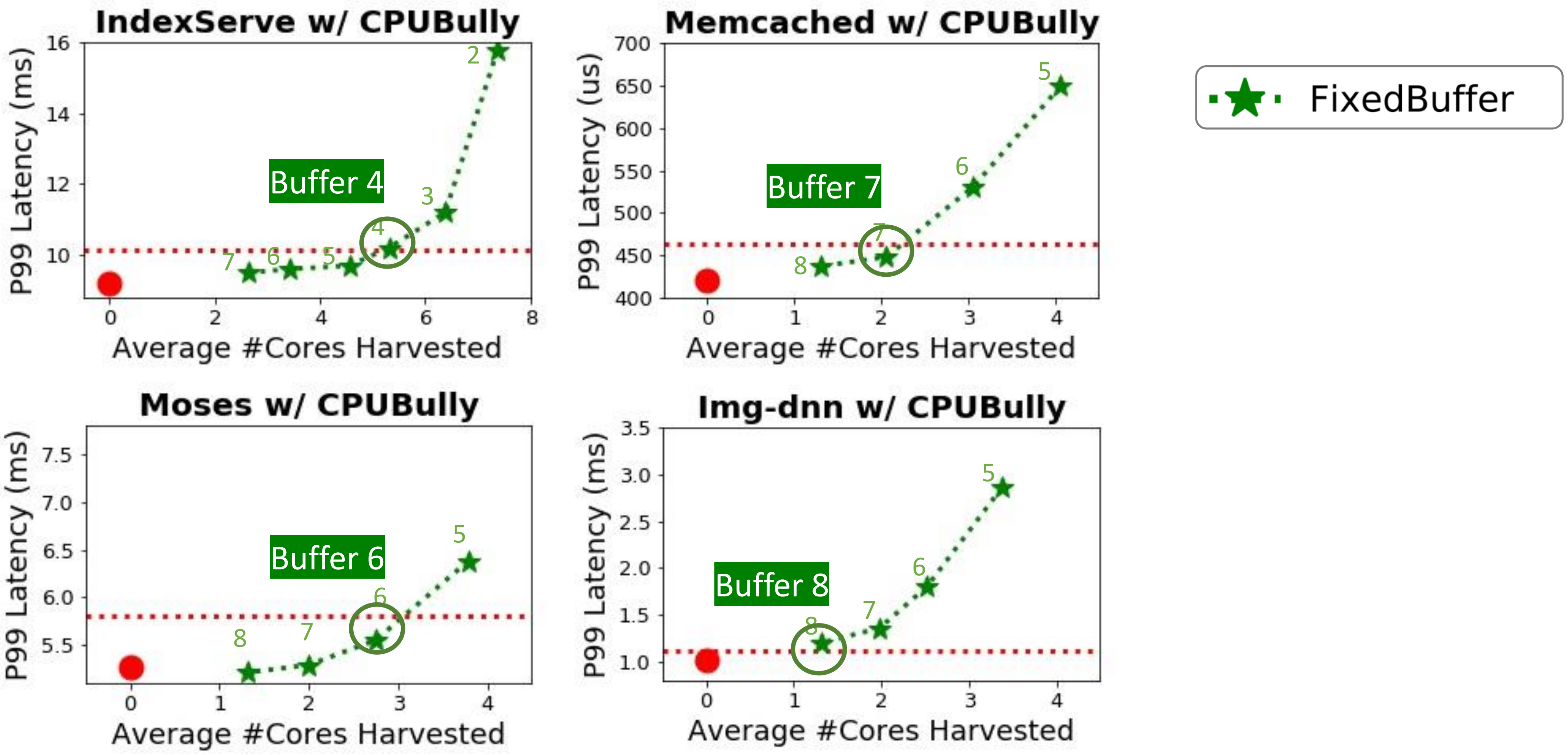

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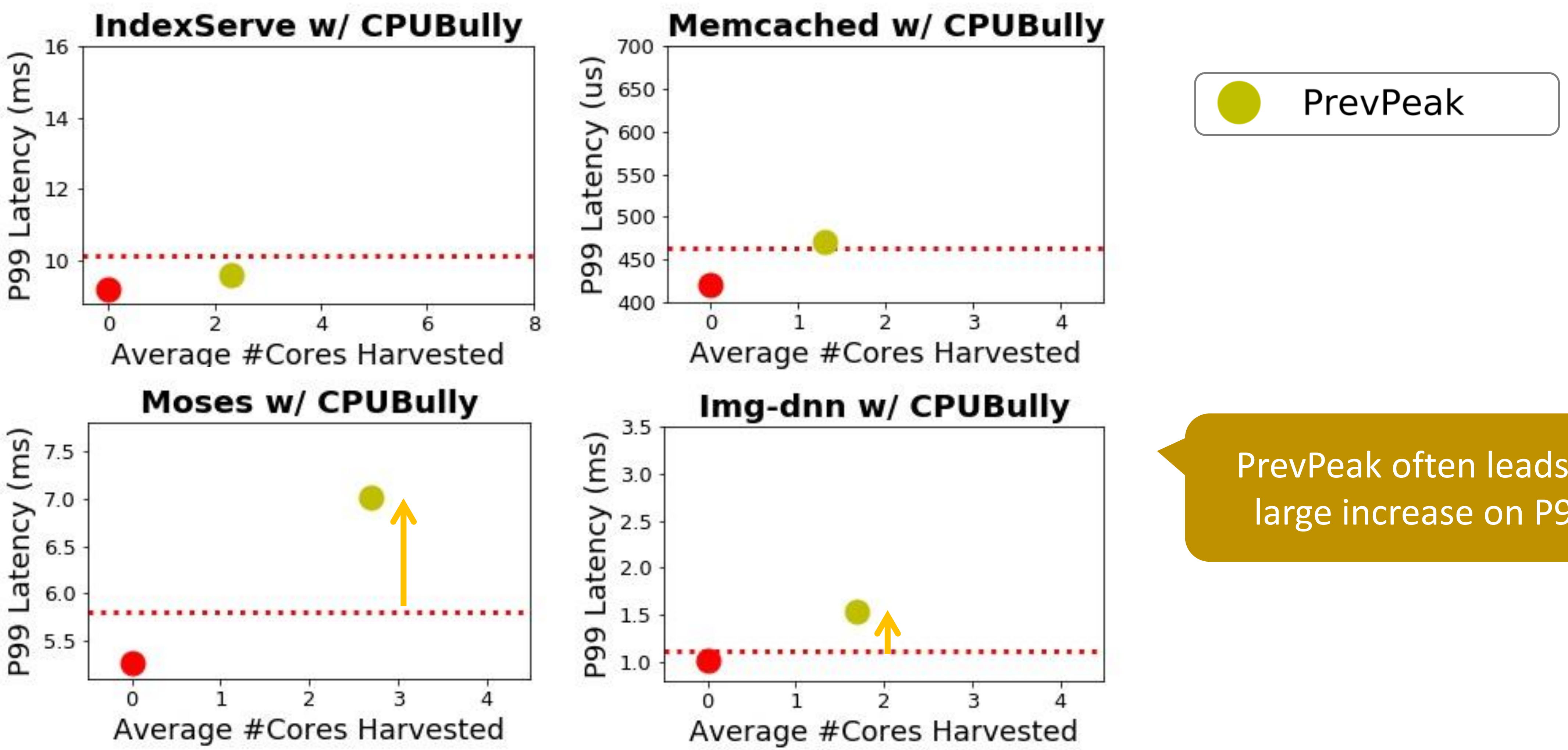

PrevPeak often leads to large increase on P99

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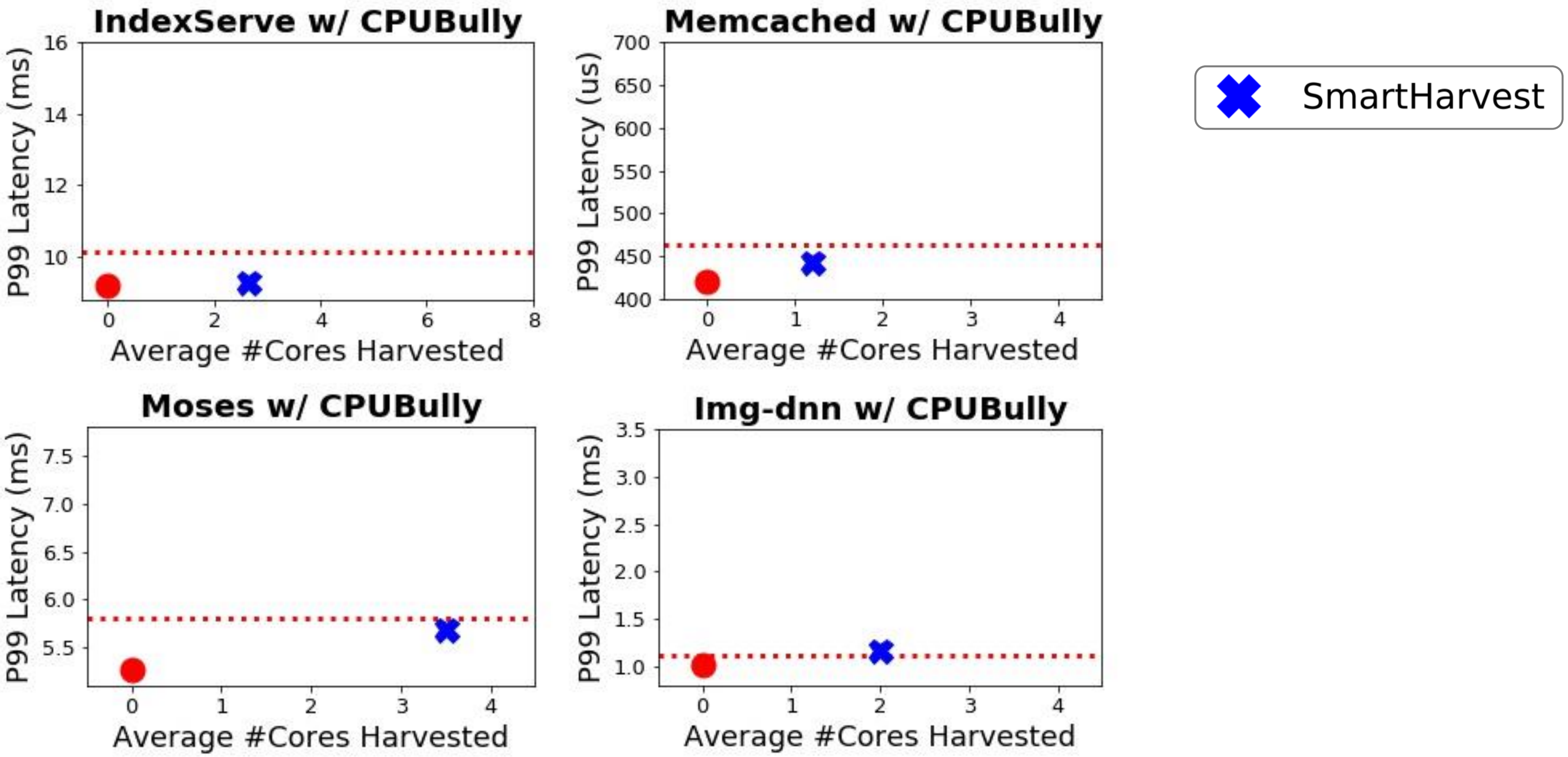

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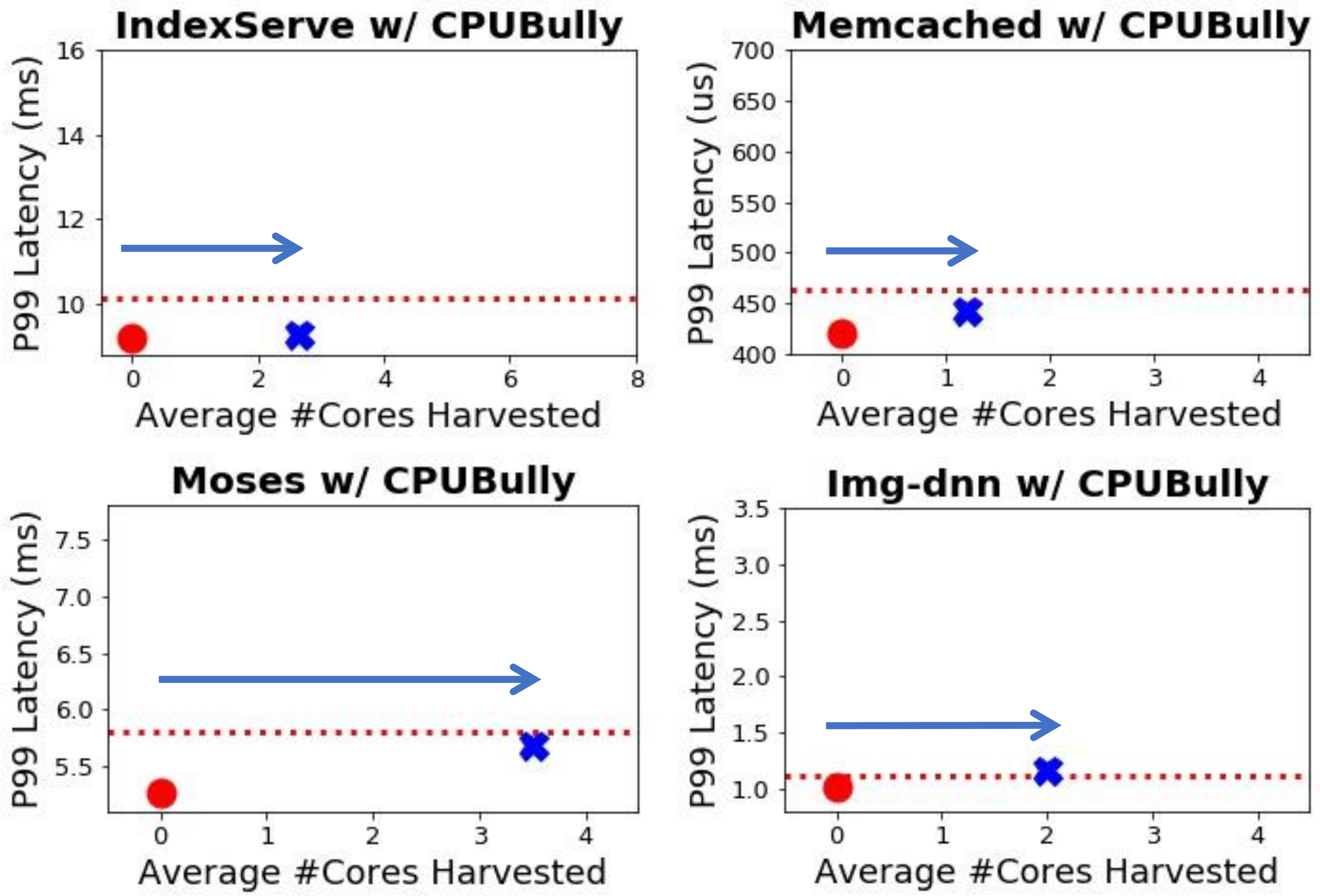

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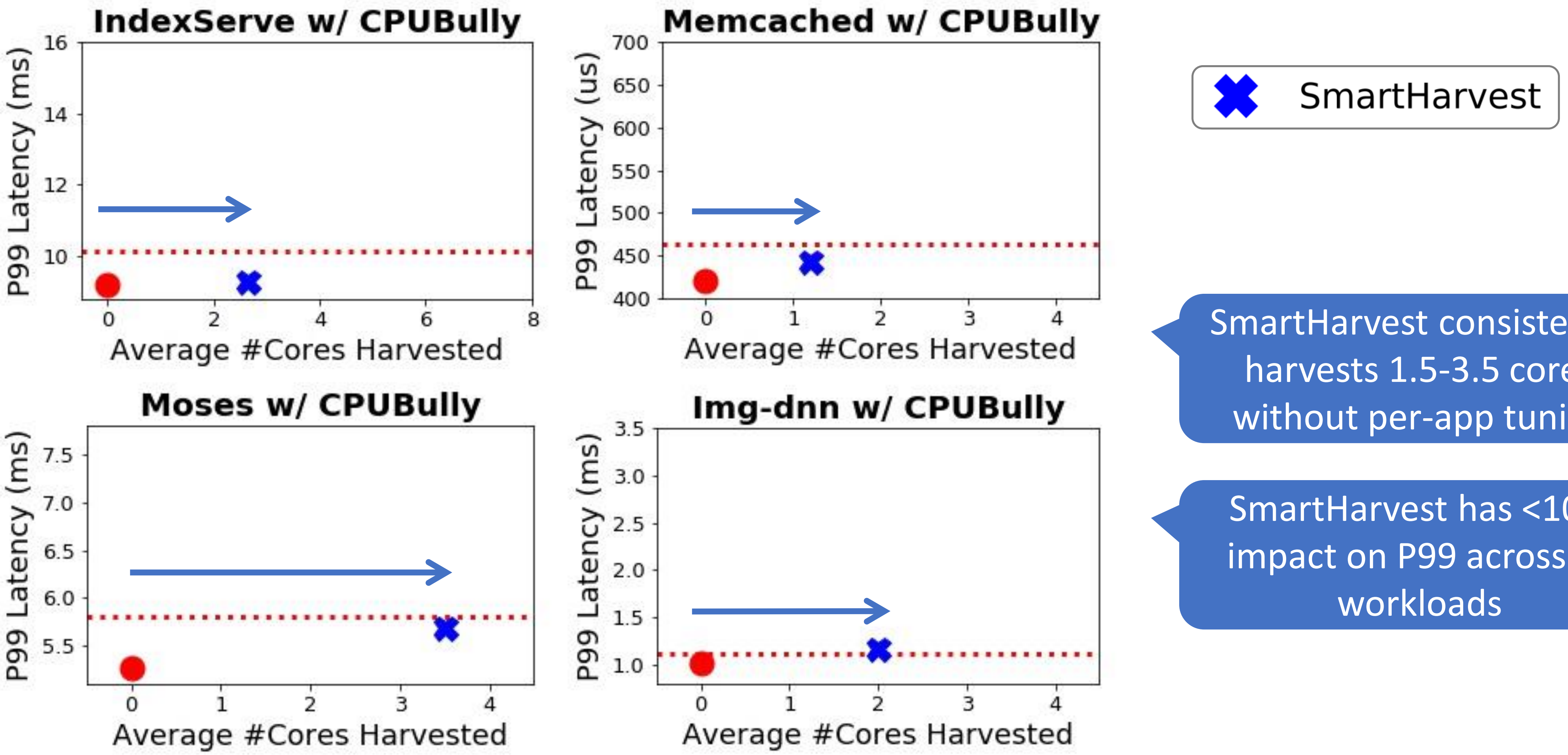

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SmartHarvest has <10% impact on P99 across all workloads

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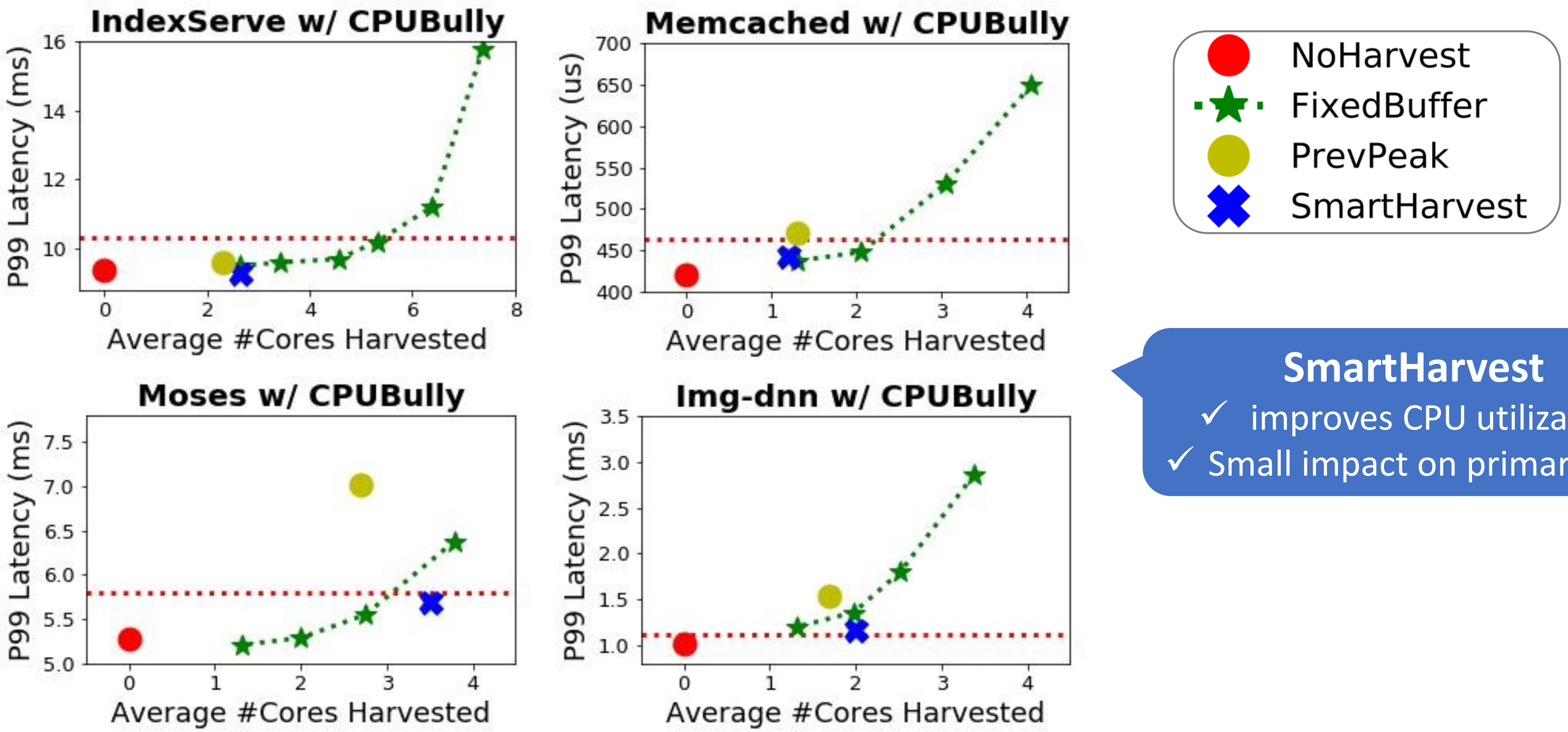

SmartHarvest

✓ improves CPU utilization

✓ Small impact on primary VM

More evaluation results in the paper

- Running realistic batch workloads in ElasticVM
- Harvesting from multiple primary VMs
- Learning window selection
- Cost function comparison
- Effectiveness of safeguards
- System responsiveness vs benefit of learning

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Thank you!

Contact: yawenw@stanford.edu