Owl: Performance-Aware Scheduling for Resource-Efficient Function-as-a-Service Cloud

Huangshi Tian[1], Suyi Li[1], Ao Wang[2,3], Wei Wang[1], Tianlong Wu[3], Haoran Yang[3]

[1]*HKUST,* [2]*George Mason University,* [3]*Alibaba Cloud*

FaaS Gaining Popularity

> A new report from Datadog has found that serverless computing could be entering the **mainstream** with **over half** of all organizations using serverless ...
>
> —— TechCrunch[1], Jun. 2022

> AWS Lambda ..., and more than **a million** customers are using it today, according to AWS.
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1. Datadog finds serverless computing is going mainstream, https://tcrn.ch/3D5GhHB
2. Amazon's Werner Vogels: Enterprises are more daring than you might think, https://bit.ly/3F8Xtij

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Problem: How to serve functions efficiently?

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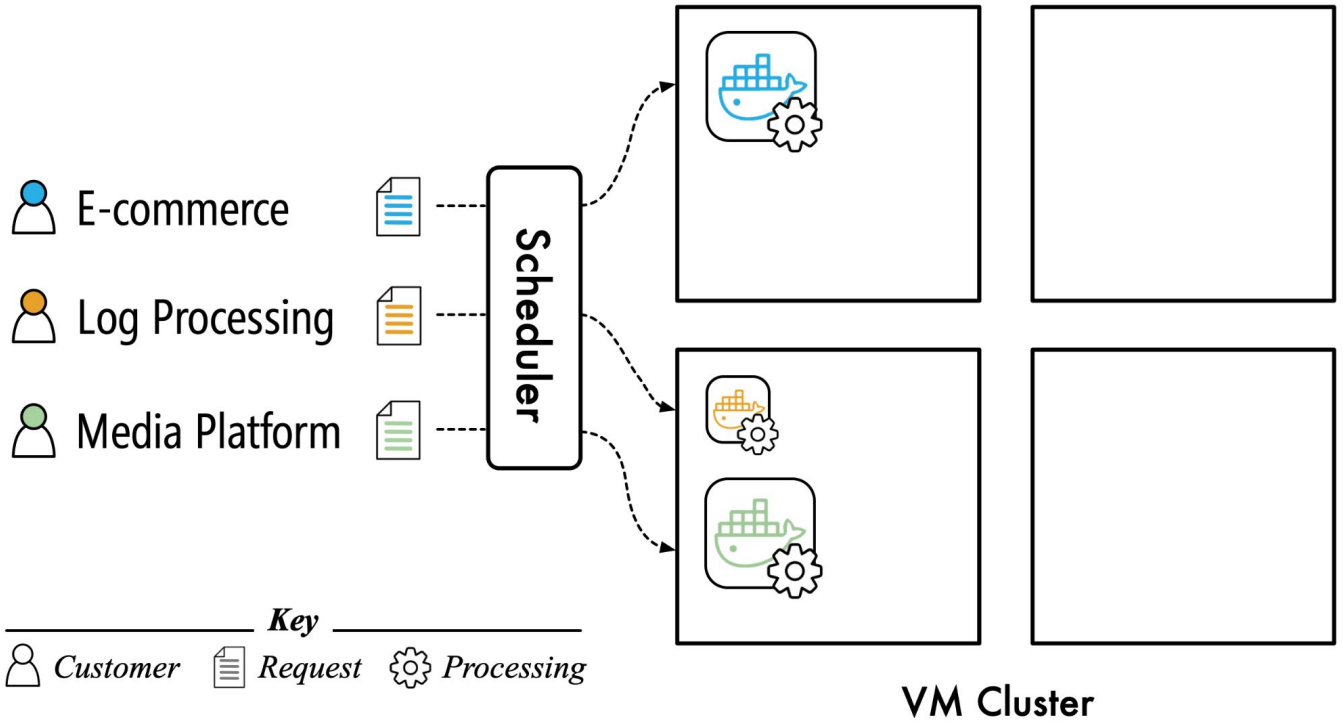
Scheduling in Public FaaS



Scheduling in Public FaaS

FaaS Scheduling

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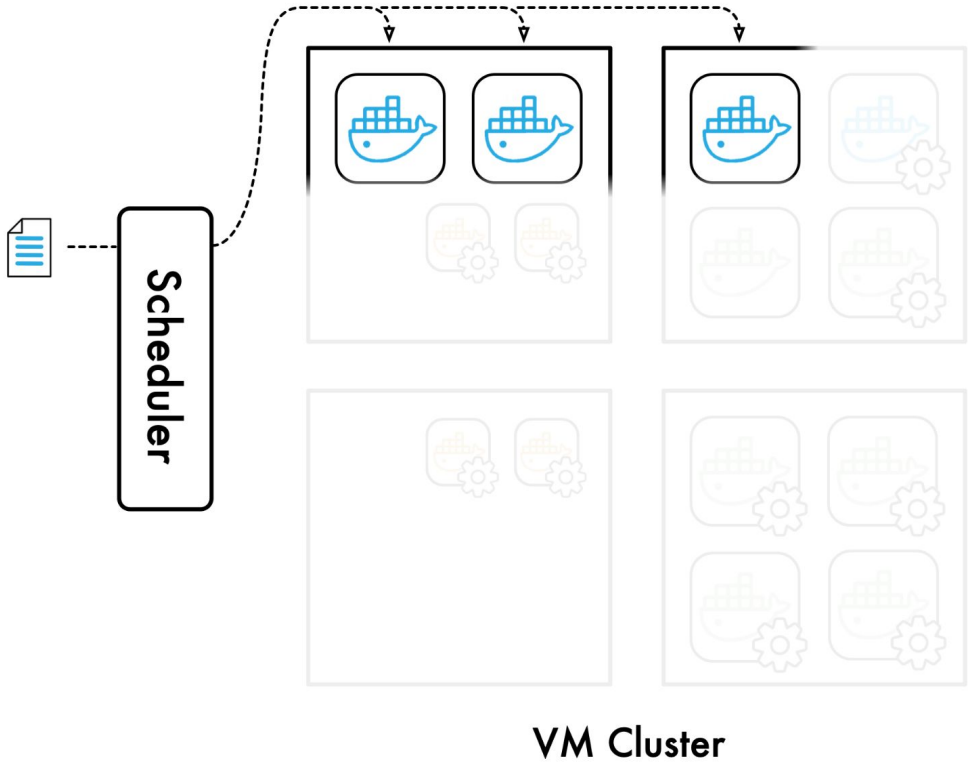
Request Routing

which sandbox to serve request?

+

Sandbox Placement

which VM to place sandbox?



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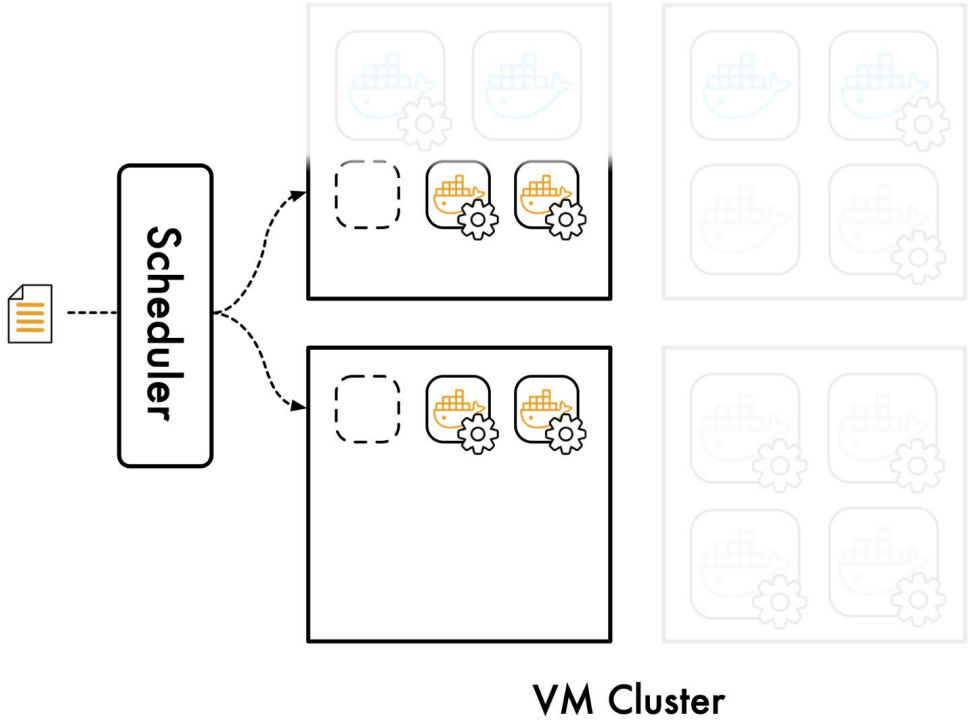

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Model*

1. Each **VM** has a memory capacity.
2. Each **sandbox** has a memory size.

Goal

Pack sandboxes onto VMs.

*** similar as bin-packing**

Status Quo

FaaS Scheduling

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State of the Practice

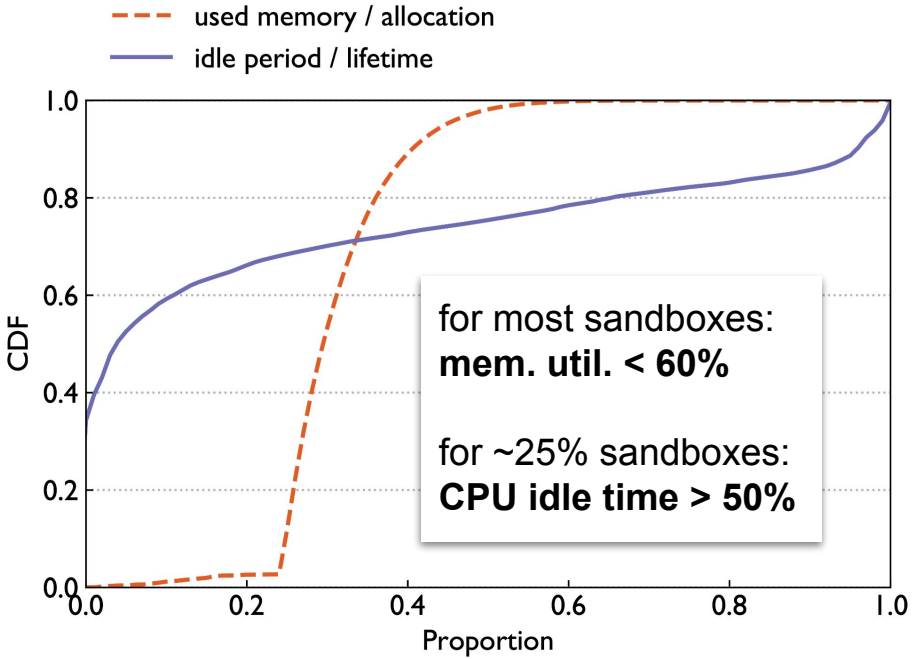
=

Most-Recently Used
for keeping more sandboxes idle

+

First Fit
for quick decision

Resource Inefficiency



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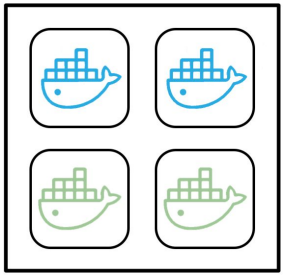
* data collected from an one-day production trace

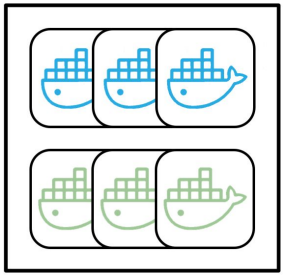
Naive Overcommitment



Normal VM

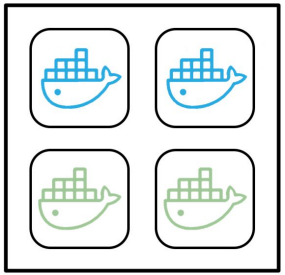
—Sandbox Overcommitment→

usage-based heuristic:
allocate what sandbox utilizes



Ovct.'ed VM

Naive Overcommitment Falls Short



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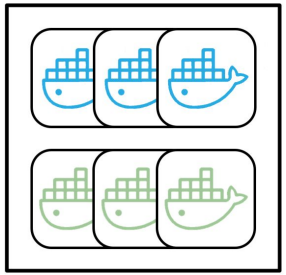

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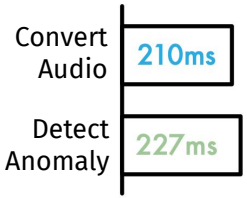

P95 Lat.[1]

Performance Degrades

unacceptable in production

Ovct.'ed P95 Lat.[1]

1. The latency is measured from a benchmark workload. (See §7.1 in the paper).

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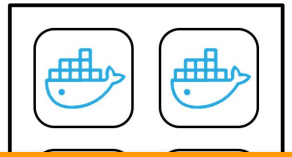

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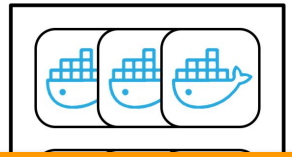
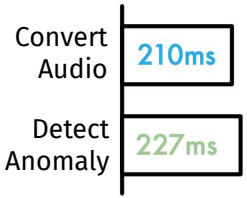


Objective:
Resource-Efficient and Performance-Aware FaaS Scheduling

Normal VM

Ovct.ed VM



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Outline

1. Background and Motivation

2. Collocation Profiling

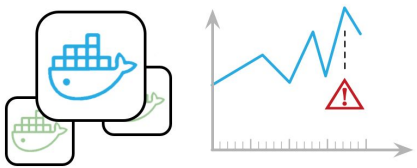
3. Profile-Guided Overcommitment

4. Performance-Monitored Overcommitment

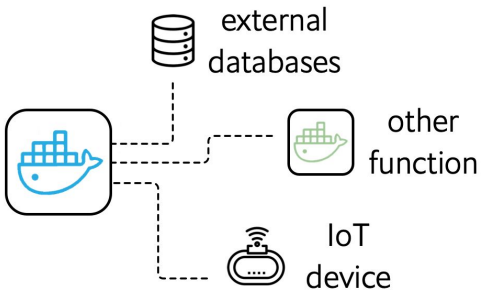
5. Owl and its Evaluation

Restrictions for Profiling

No latency **degradation**.



No **offline** invocation (b/c of side-effect).



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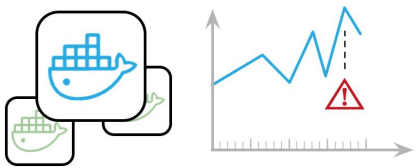

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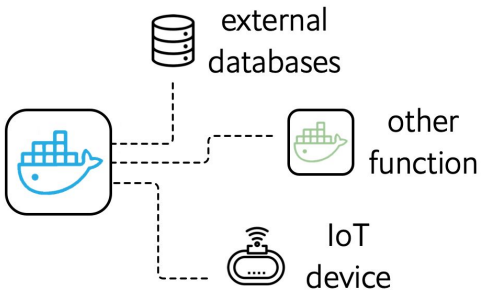

Ideal profiling:

- ☐ **in-production**
- ☐ **performance-protected**

New Technique: Collocation Profiling

Key Question

How many sandboxes can a VM host?

☐ **in-production** ☐ **performance-protected**

Collocation Profiling

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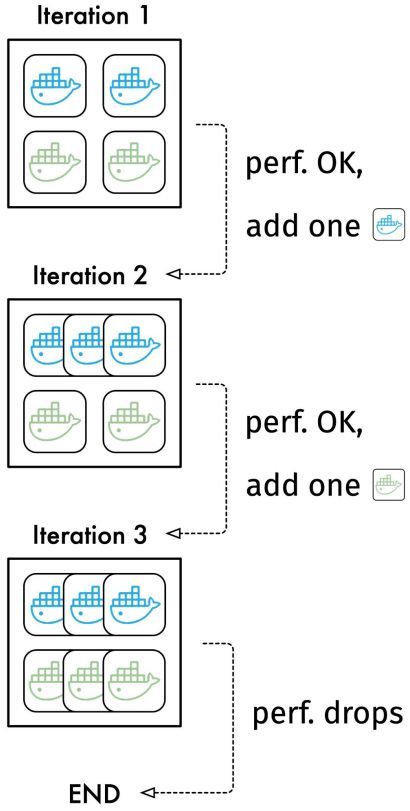
How many sandboxes can a VM host?

Procedure

1. **Saturate** sandboxes with requests.
2. Iteratively add more sandboxes …
3. … until perf. starts dropping.



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Collocation Profiling

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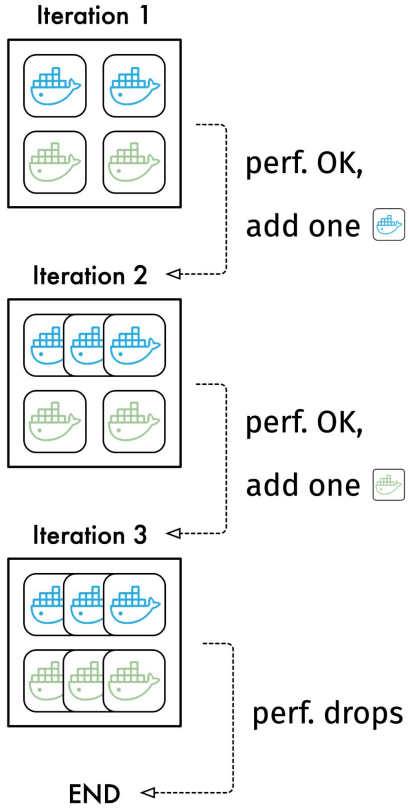


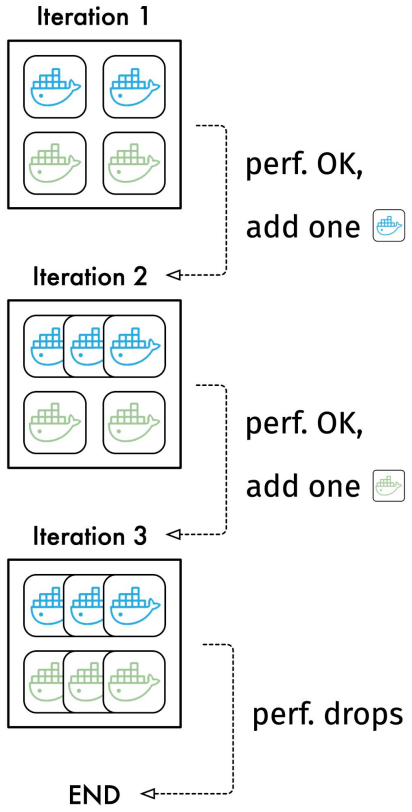
☑ **in-production**
cf. Step 1, 2

☑ **performance-protected**
cf. Step 3

☑ **resource-overcommitted**
cf. Step 2

Collocation Profiling

Collocation[2]	Util.[1]
×3 ×3	1.48
×3 ×5	1.42
×3 ×3	1.26
×5	1.22
×5	1.24
×7	1.20



1. Util. = Allocated Memory / Total VM Memory
   (> 1 means *overcommitment*)

2. Limited to two functions b/c of complexity.

Profile-Guided Overcommitment

Collocation	Util.
×3 ×3	1.48
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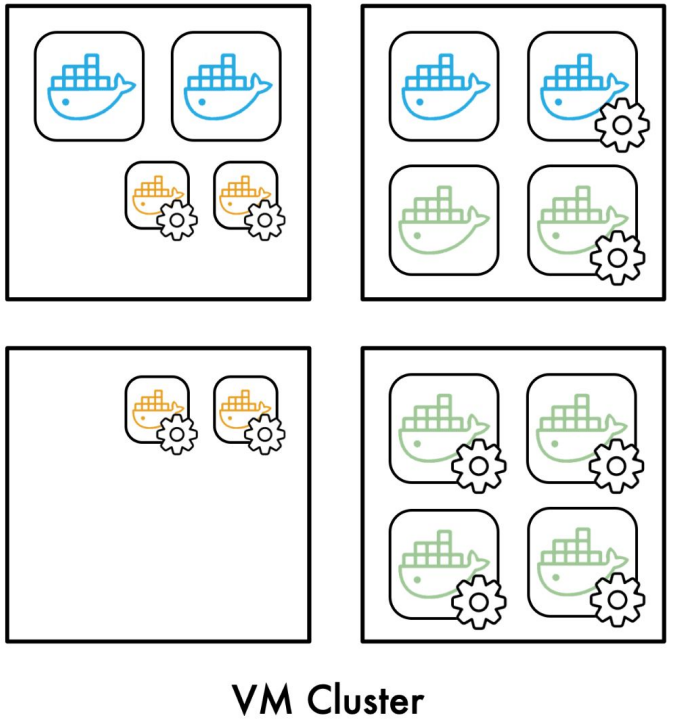
Key Question

How to place sandboxes using profiles?



VM Cluster

Profile-Guided Overcommitment

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Greedy Algorithm

Collocating sandboxes with highest util.

VM Cluster

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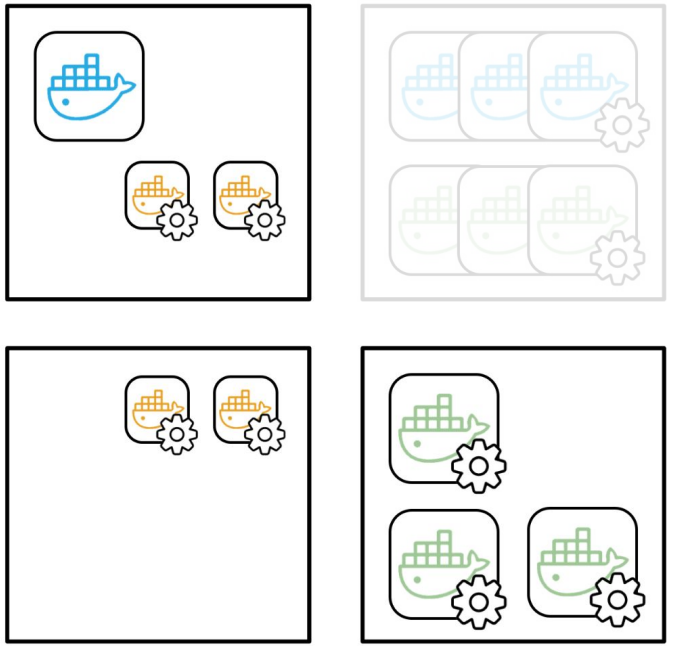

VM Cluster

Profile-Guided Overcommitment

Offline

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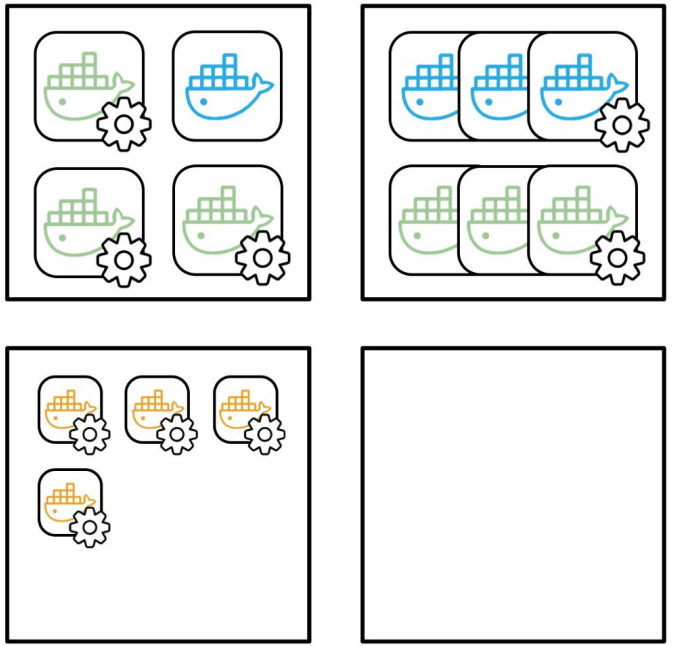


Profile-Guided Overcommitment

Offline

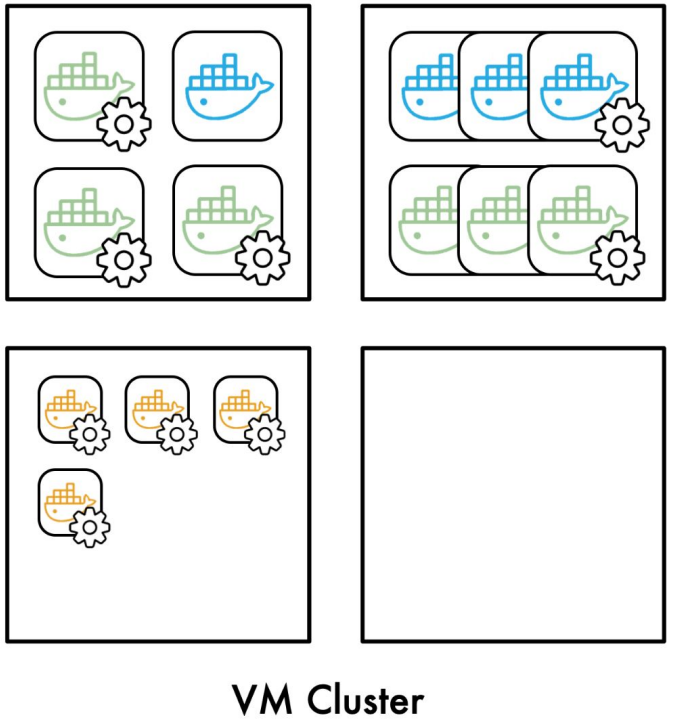
Collocating sandboxes with highest util.

Online

1. Periodically update placement.

2. Only include VMs with **sandbox change**.

[more details and optimizations in paper]



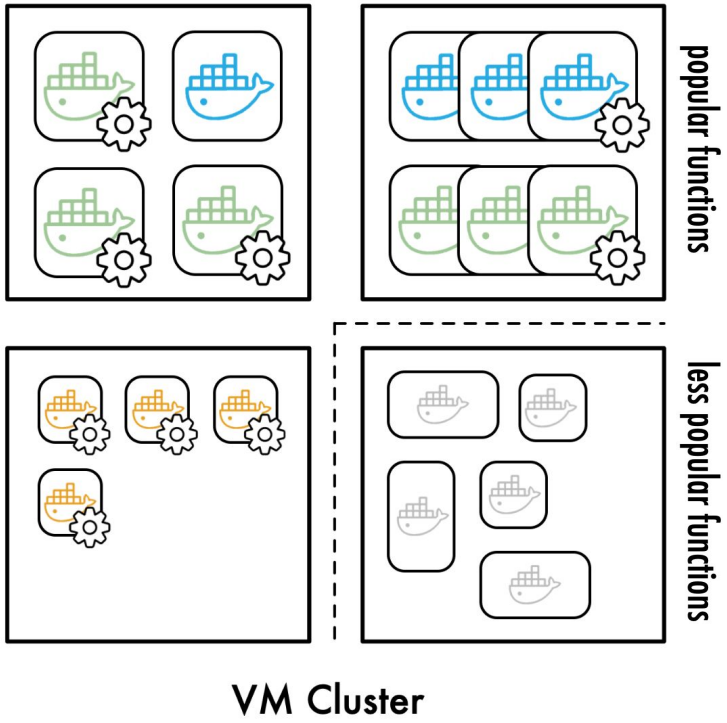
VM Cluster

Profile-Guided Overcommitment

Problem

profiling requires continuous requests

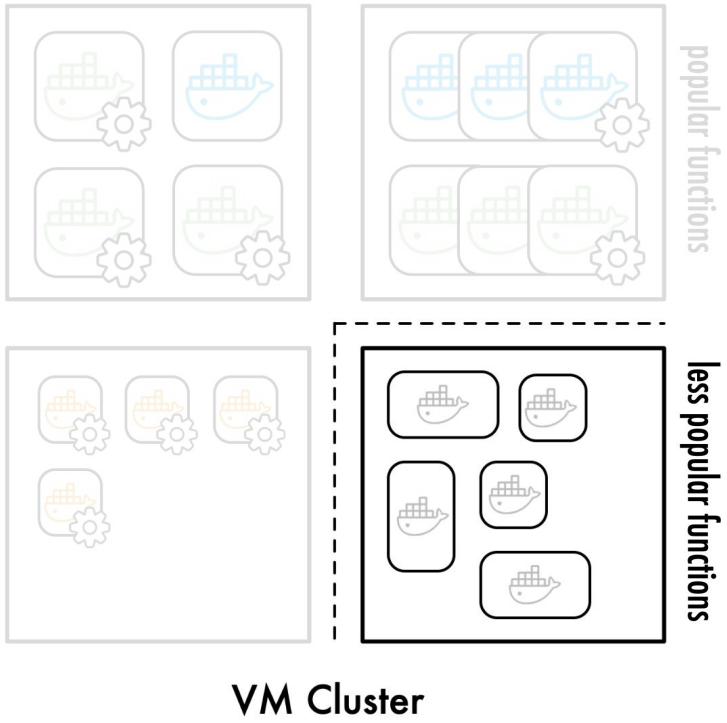
⇒ only applies to popular functions



Performance-Monitored Overcommitment

Solution

1. Usage-based overcommitment.
2. Keep **monitoring** performance.
3. **Remedy** degradation (e.g., sandbox migration).



Problem: External Degradation

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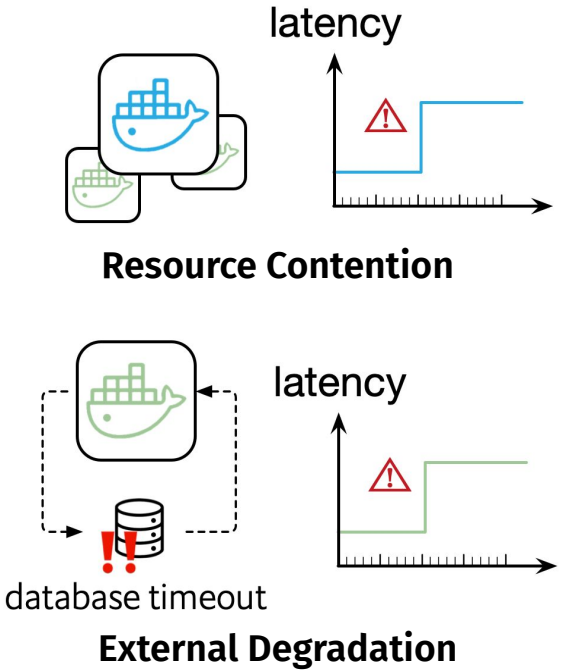
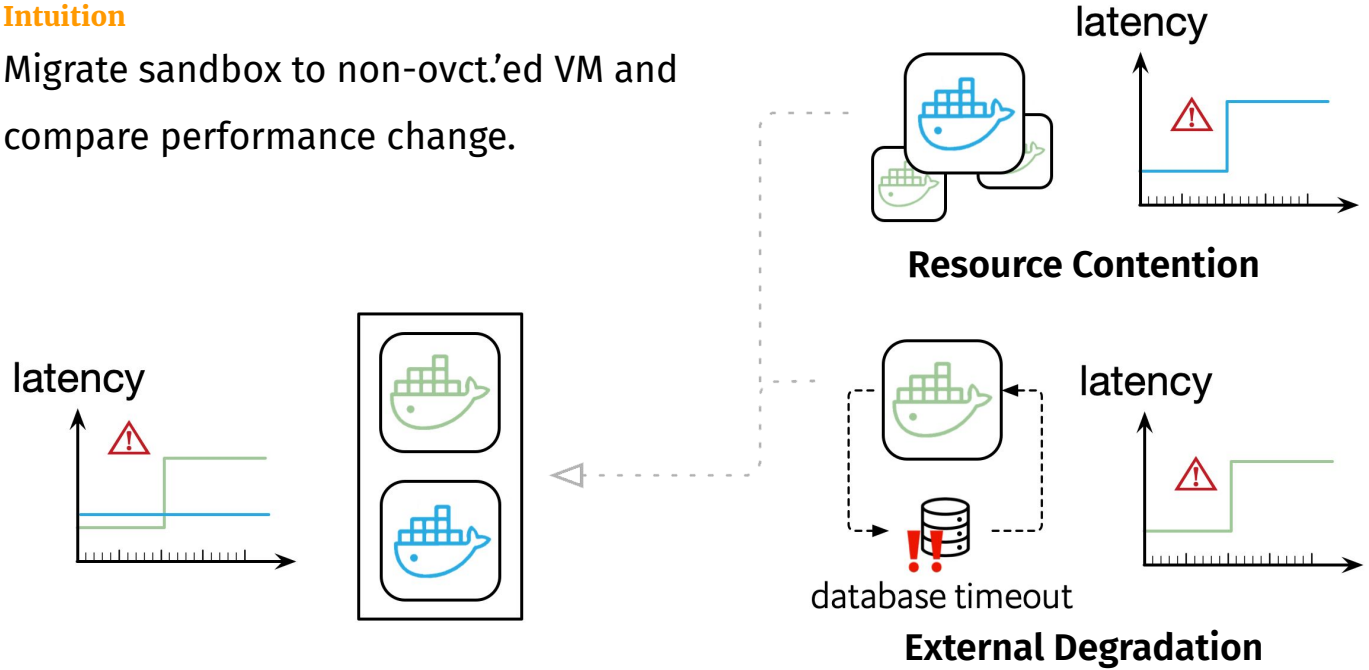


New Technique: Comparative Validation

Intuition

Migrate sandbox to non-ovct.'ed VM and compare performance change.



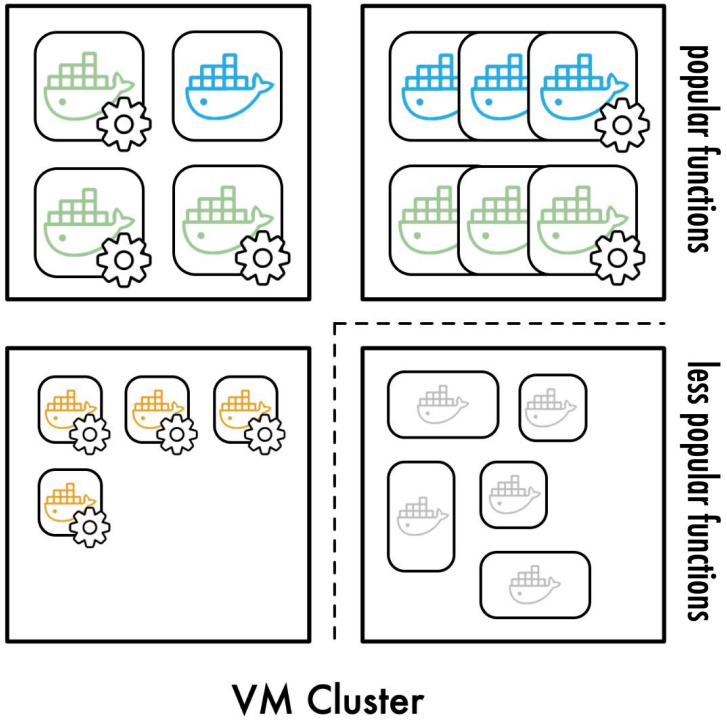
Putting it all Together

Popular Functions

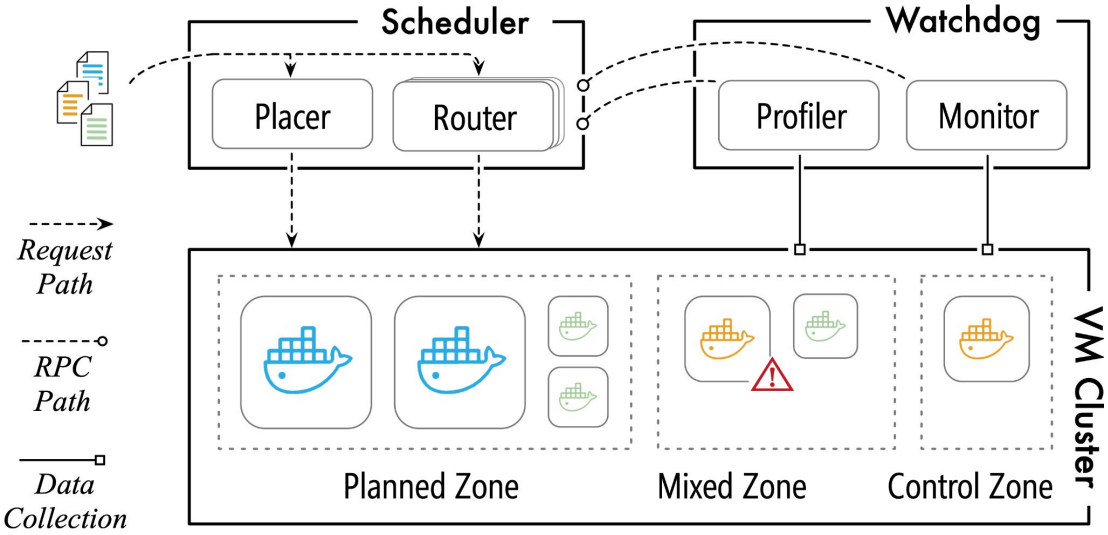
1. Profile Collocations
2. Collocate Sandboxes
3. Consolidate Idle Ones

Less Popular Functions

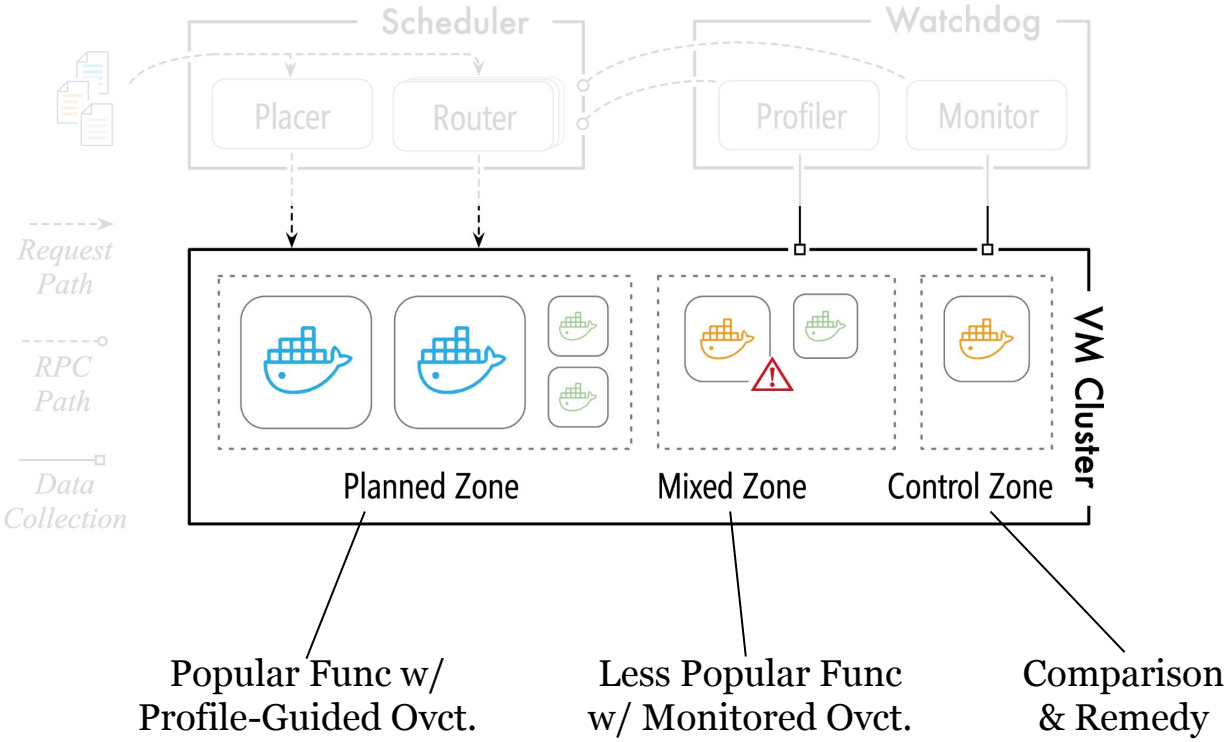
1. Monitor Performance
2. Remedy Degradation
3. Validate Cause



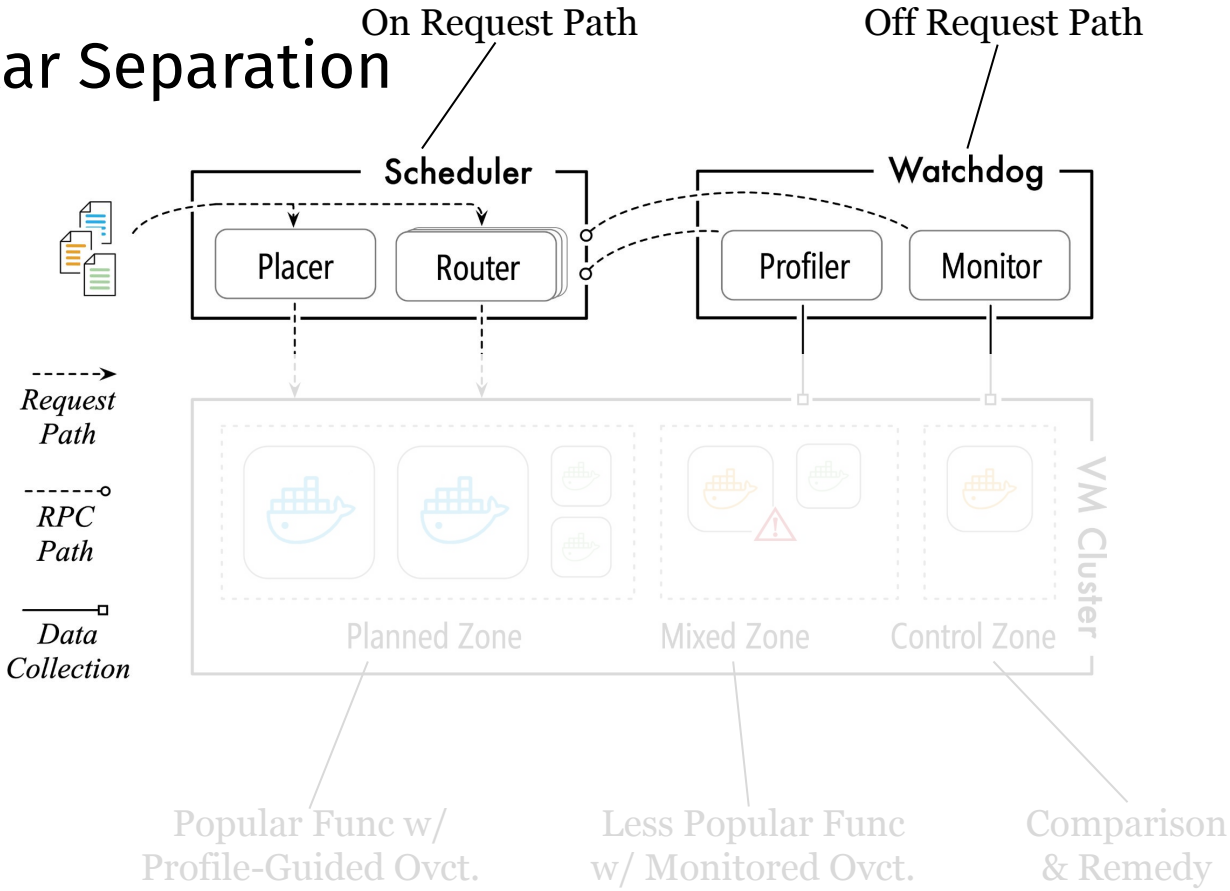
Implementation



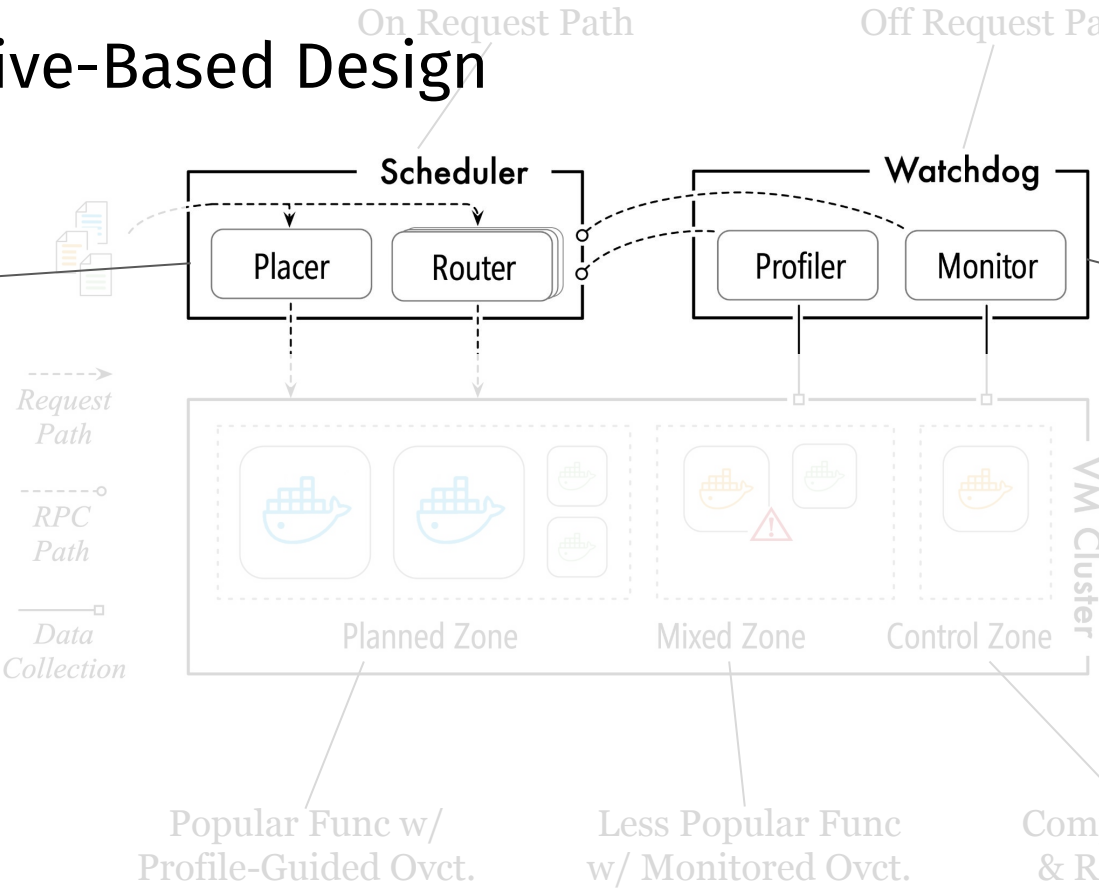
Cluster Zoning



Modular Separation



Primitive-Based Design



Evaluation Highlight

More results in the paper.
(1) scheduling latency
(2) microbenchmarking
(3) large-scale validation

Setting

- three 20-minute production workloads
- four variant schedulers with different techniques enabled

Results	VM Cost	Function Performance
① Baseline	-	not degraded
② Naive Overcommitment	decrease by 44.26% from ①	degraded
③ … /w Profile Guidance	increase by 9.24% from ②	not degraded
④ … /w Consolidation	decrease by 8.53% from ③	not degraded
Overall	decrease by 43.8% from ①	not degraded

Open-Source Benchmark

Abbreviation	Function	Memory Size	Actual Usage	Lanaguage	Dependencies
QV	Query Vacancy	256 MiB	~70MiB	JavaScript	Key-Value Store
RS	Reserve Spot	256 MiB	~70MiB	JavaScript	Key-Value Store, Message Queue
AL	Anonymize Log	1024 MiB	~20MiB	Rust	Message Queue
FL	Filter Log	1024 MiB	~20MiB	Rust	Message Queue
DO	Detect Object	3072 MiB	~1700MiB	Python	Model Serving Framework
CI	Classify Image	2560 MiB	~500MiB	Python	Model Serving Framework
GMM	Get Media Meta	128 MiB	~20MiB	Python	Object Store
CA	Convert Audio	256 MiB	~100MiB	Python	Object Store
ID	Ingest Data	768 MiB	~10MiB	C++	SQL Database
DA	Detect Anomaly	768 MiB	~10MiB	C++	SQL Database

https://github.com/All-less/faas-scheduling-benchmark

Conclusion

Performance-Aware and Resource-Efficient Scheduling in Public FaaS

1. Profile-Guided Overcommitment

2. Performance-Monitored Overcommitment