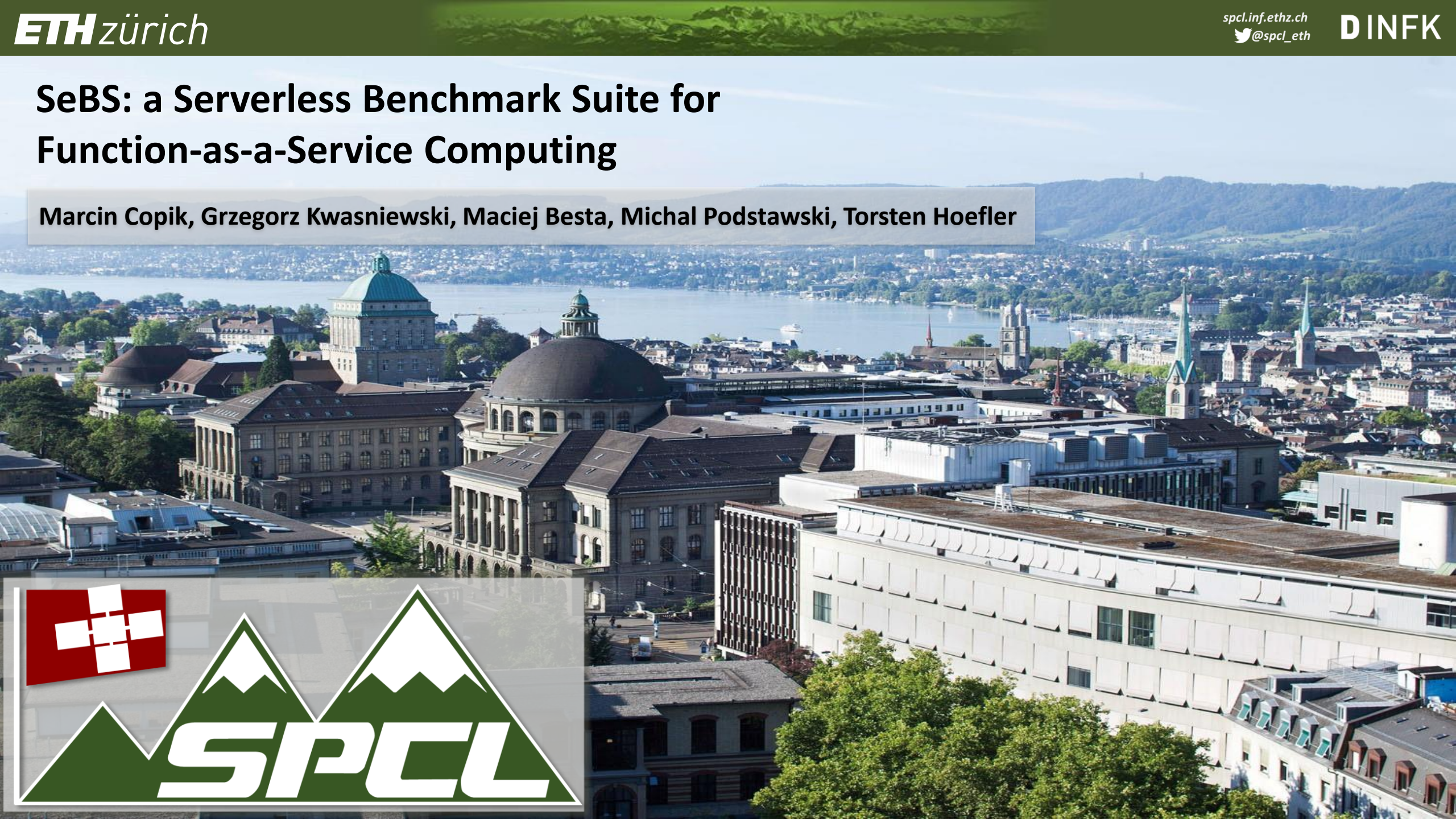
SeBS: a Serverless Benchmark Suite for Function-as-a-Service Computing

Marcin Copik, Grzegorz Kwasniewski, Maciej Besta, Michal Podstawski, Torsten Hoefler



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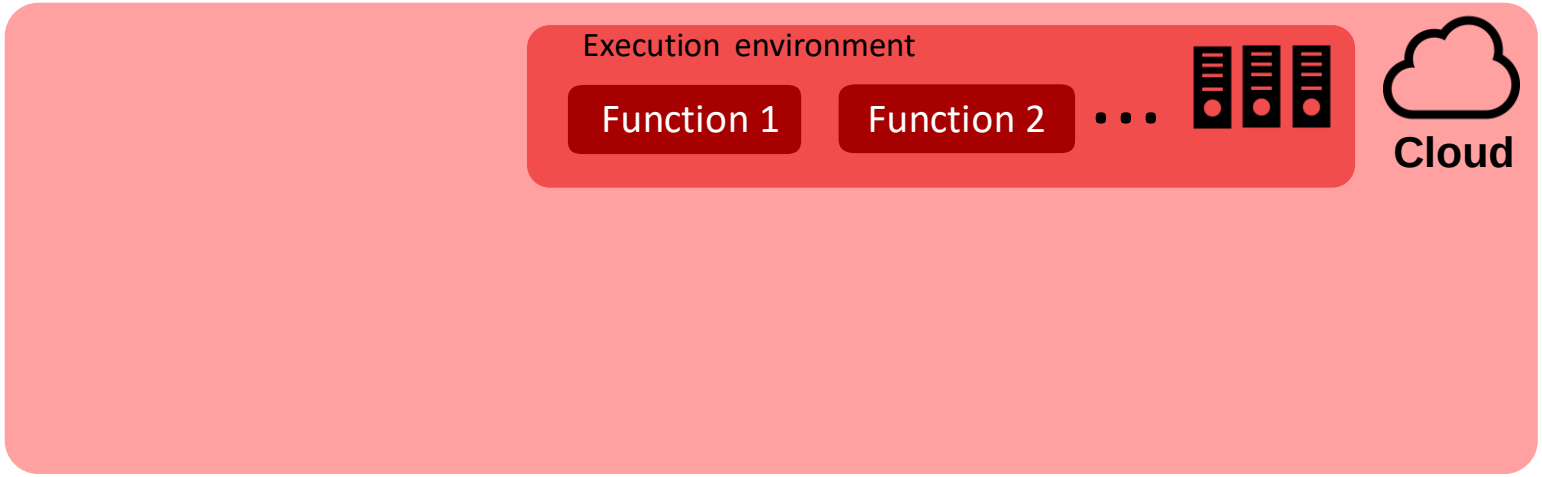

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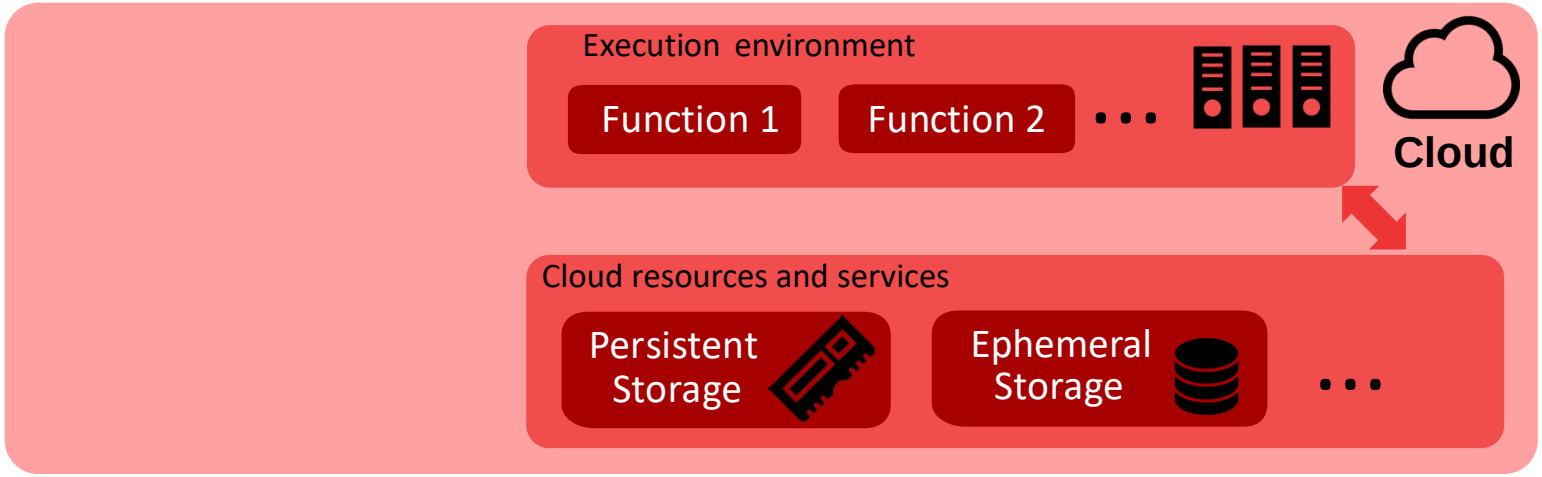

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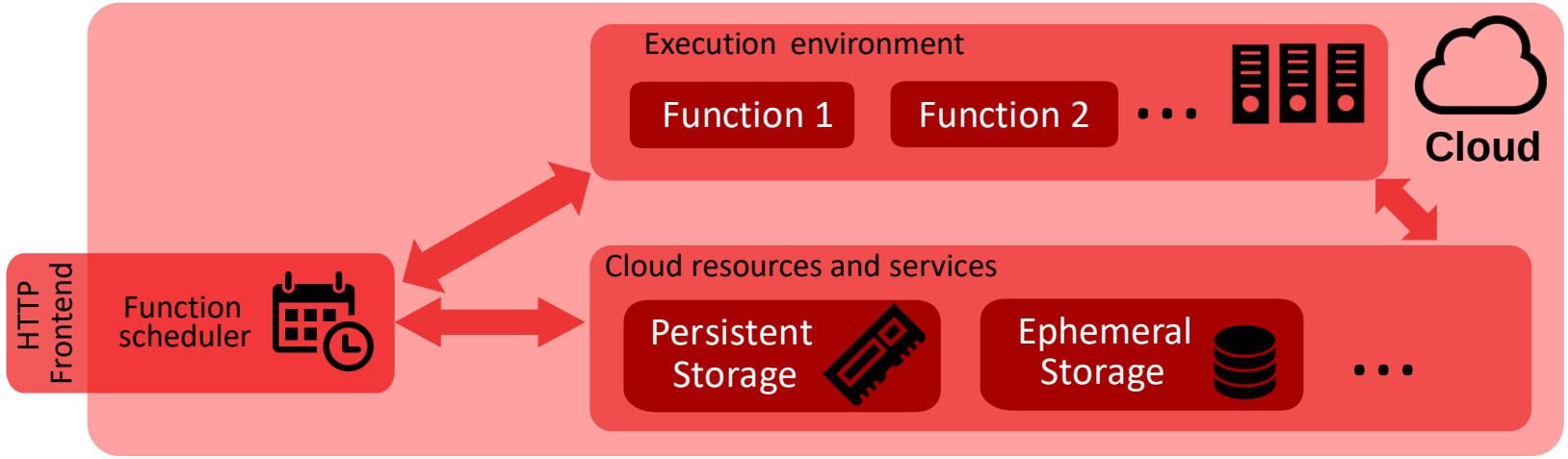

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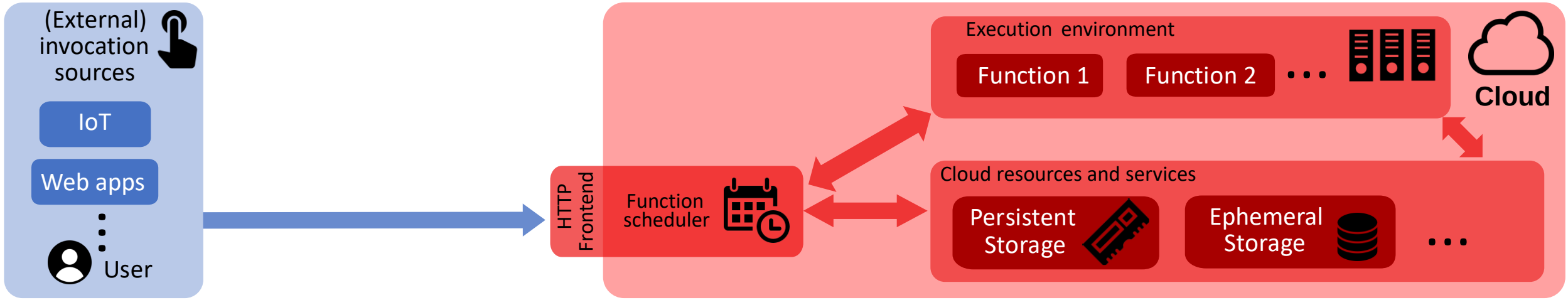

Serverless – why & why not?

User

Cloud Provider

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- Pay-as-you-go billing
- Massive parallelism
- Simplified deployment
- Architecture agnostic

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- 👎 Handling heterogeneity
- 👎 Micro-architecture effects

Commercial serverless systems

Policy	AWS Lambda	Azure Functions	Google Cloud Functions

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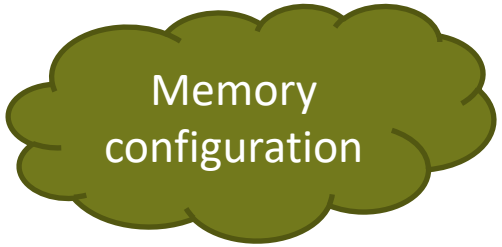

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Functions
Workers

Memory
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Billing	Duration and declared memory.	Average memory use, duration.	Duration, declared CPU and memory.
Deployment	zip package up to 250 MB.	zip package, Docker image.	zip package, up to 100 MB.
Time Limit	15 minutes	10 min / 60 min / unlimited.	9 minutes.

Function
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Allocation

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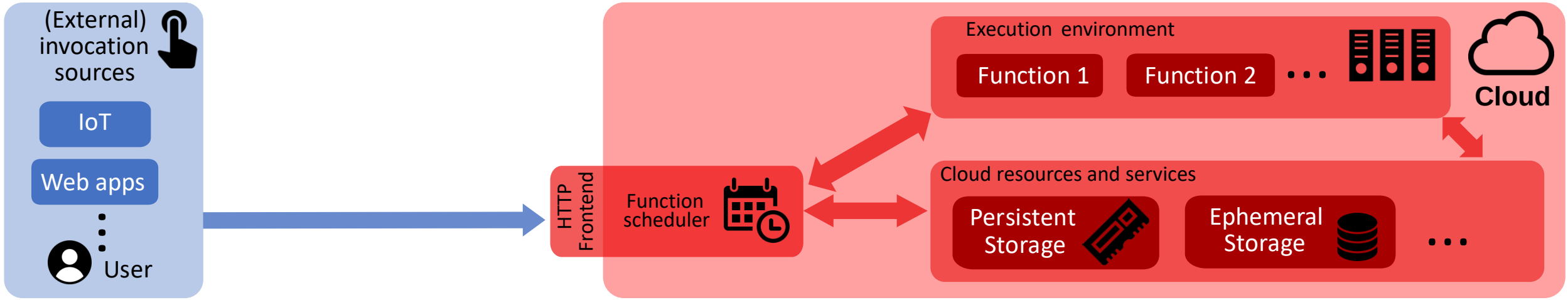

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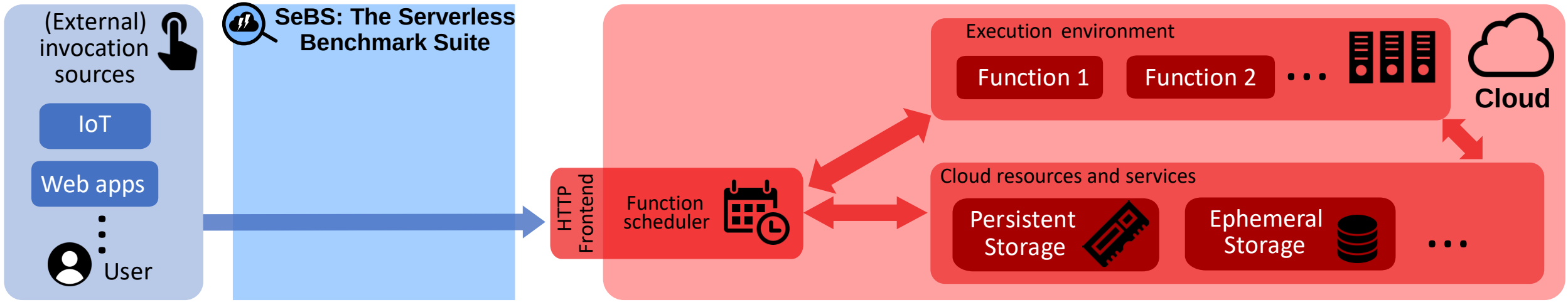

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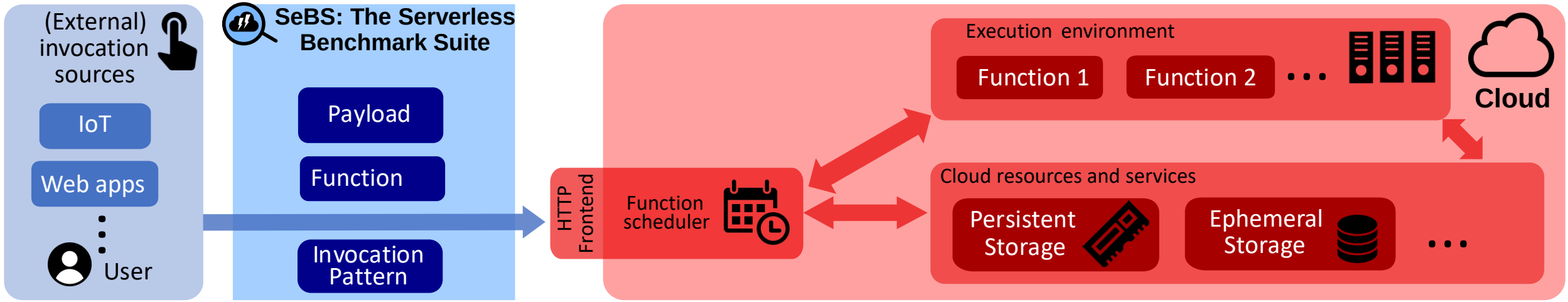

Benchmark Applications

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Results and Insights

	Results, methods, and insights

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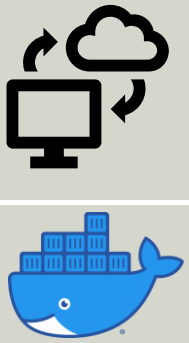
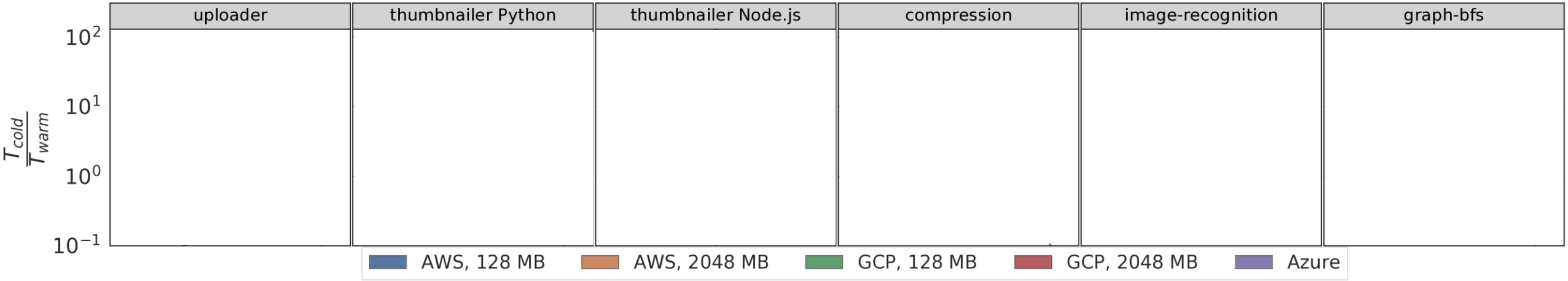
	

Performance Analysis: Cold Startups



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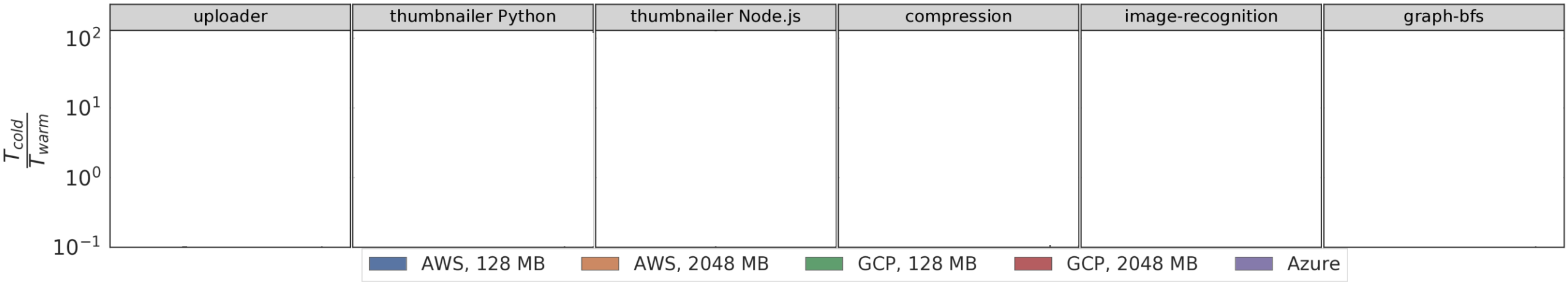

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- **Azure Functions**: mixed cold and warm executions.

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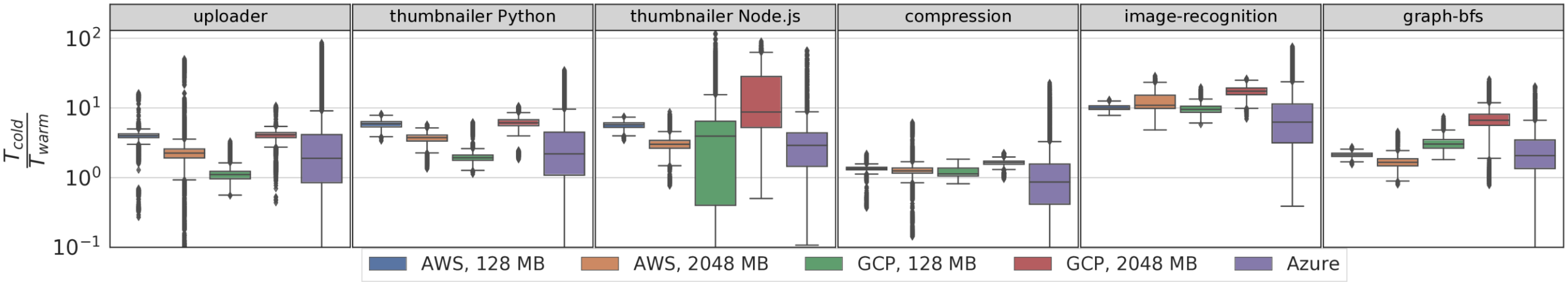

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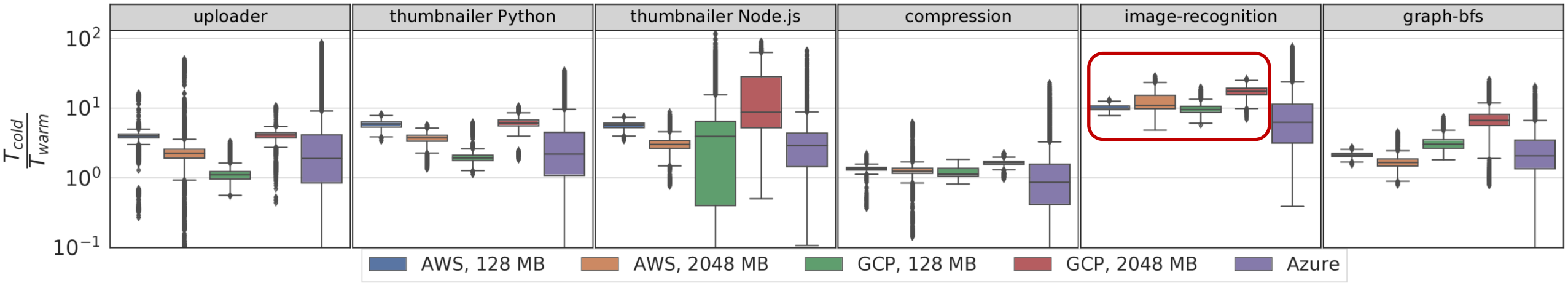

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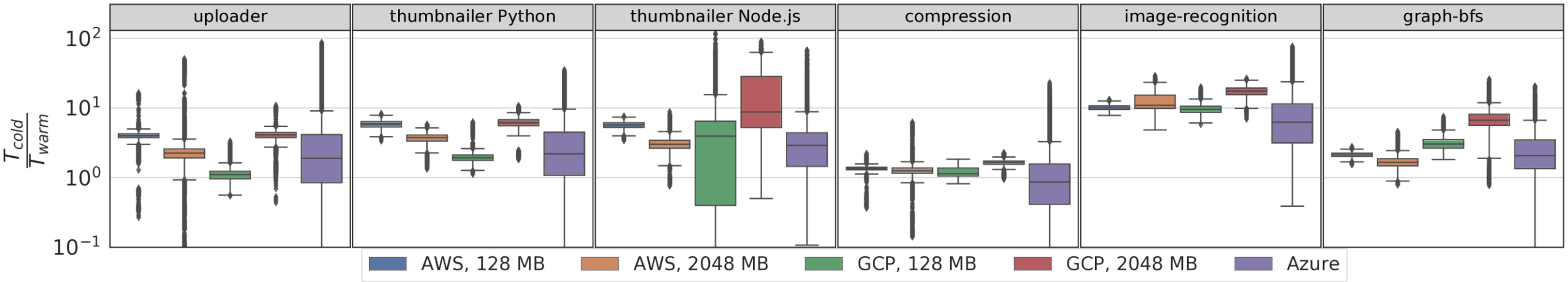

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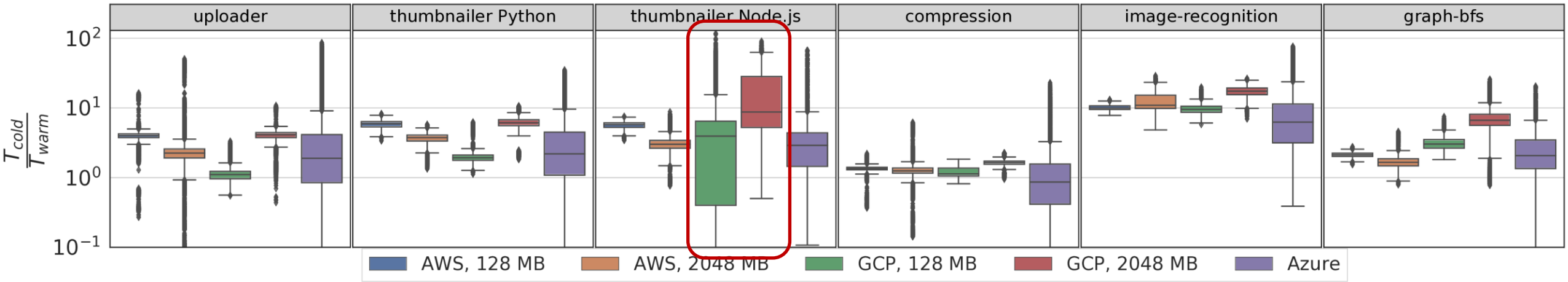

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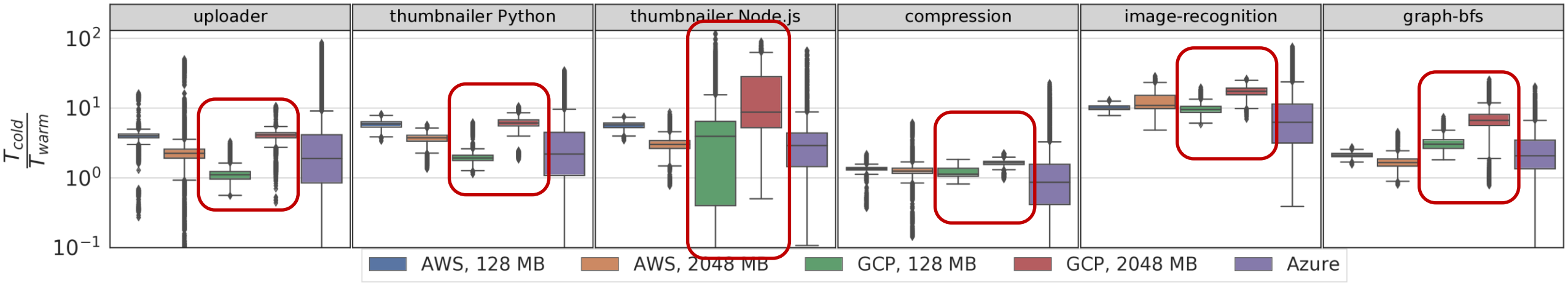

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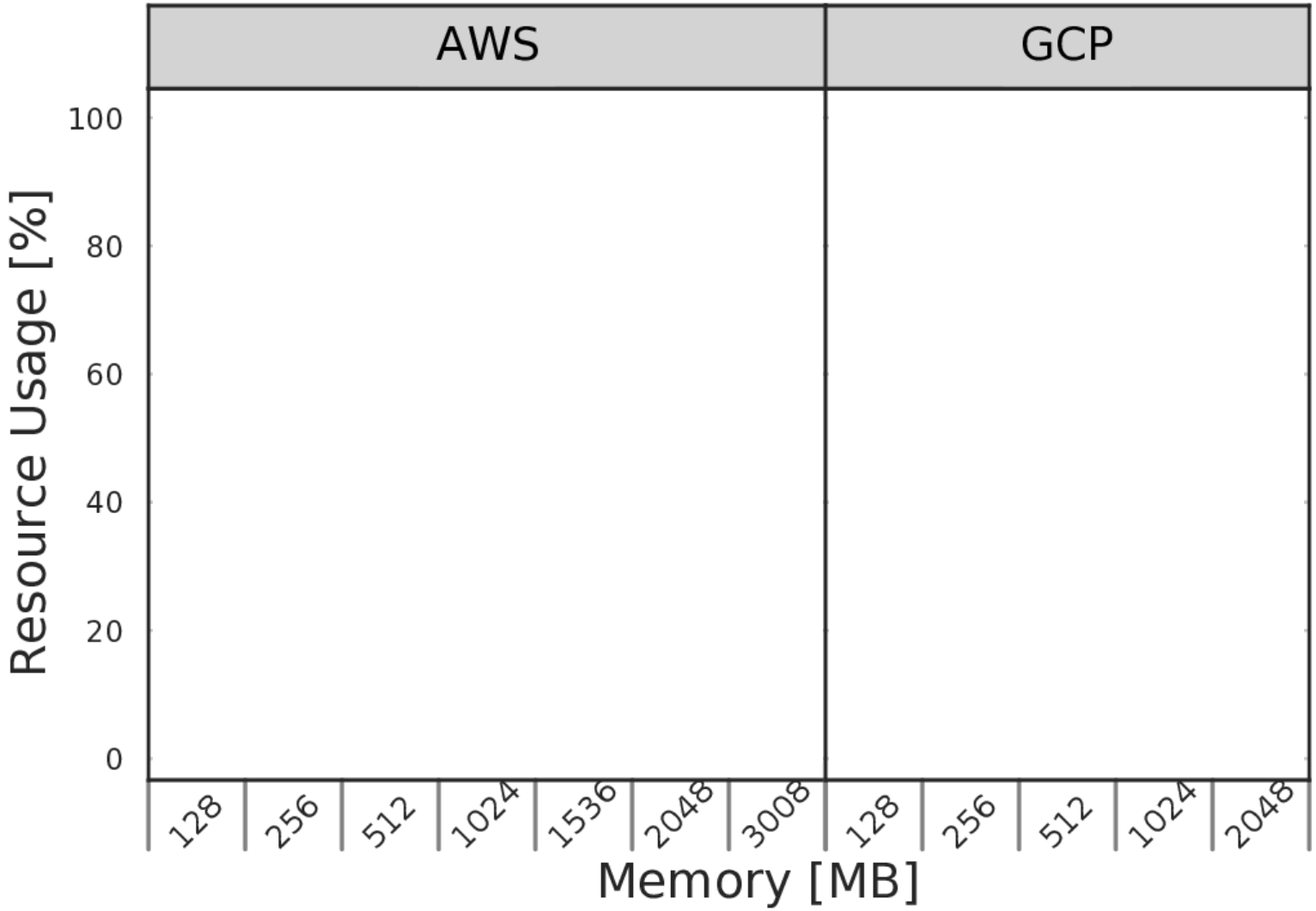

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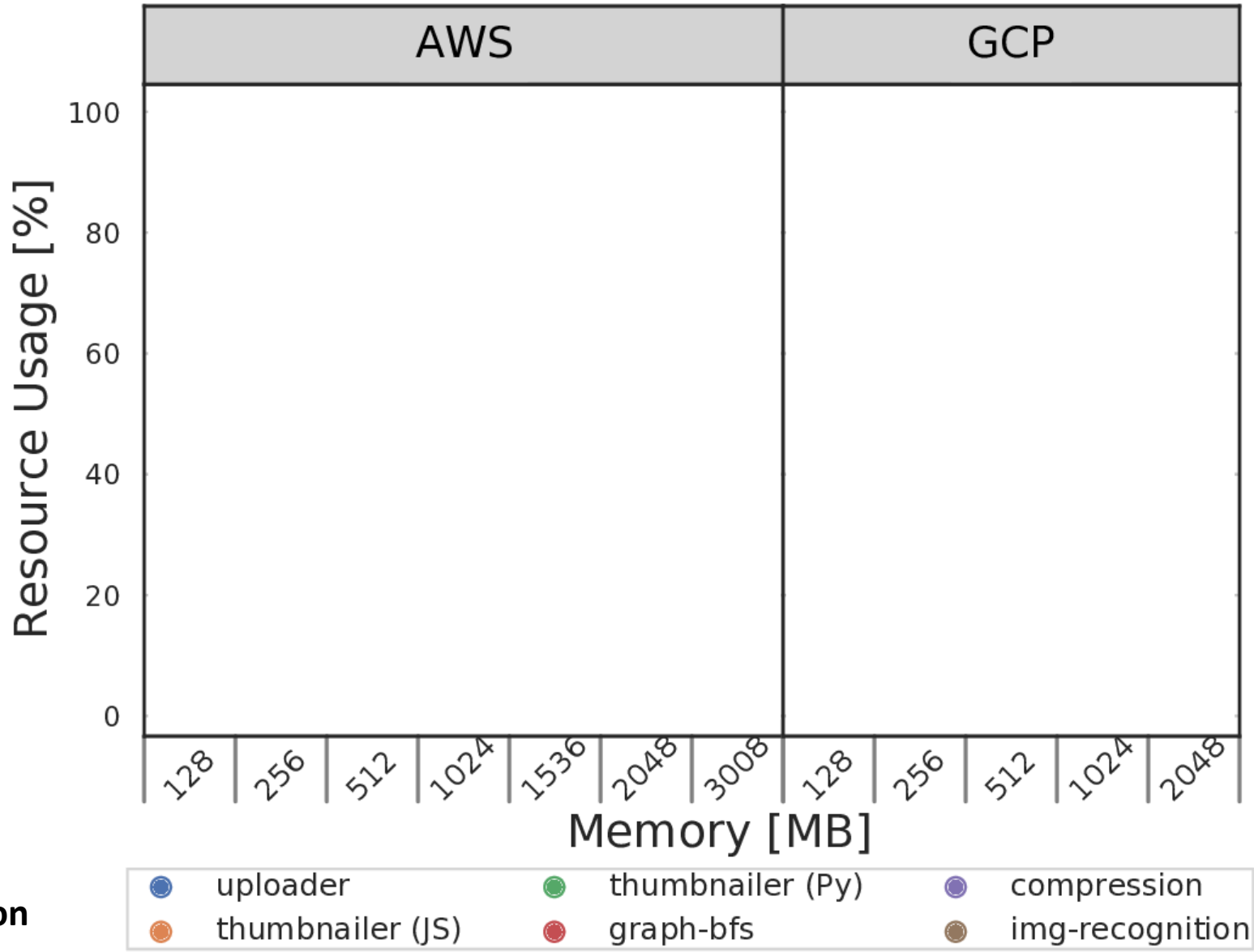

Cold Execution

Warm Execution

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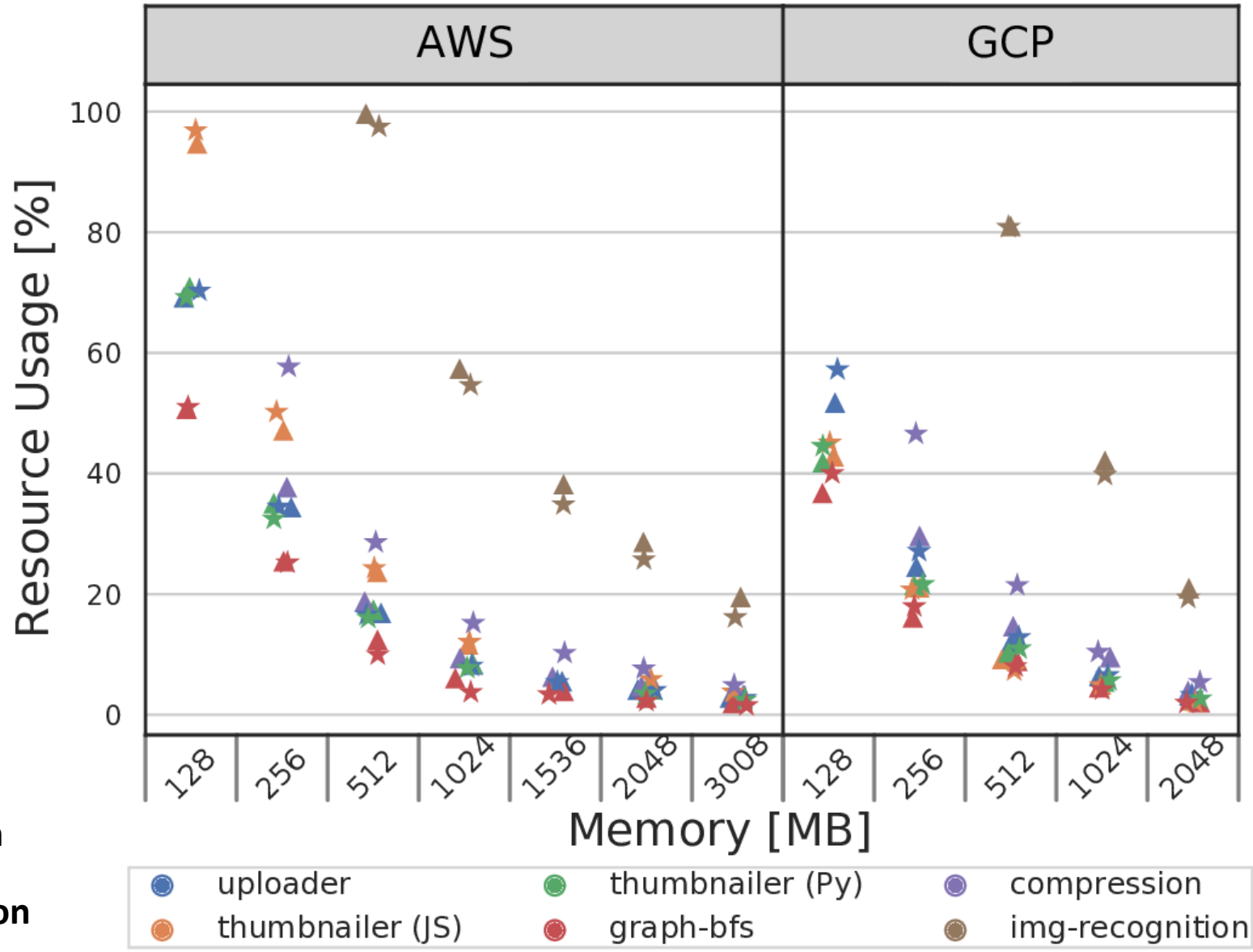

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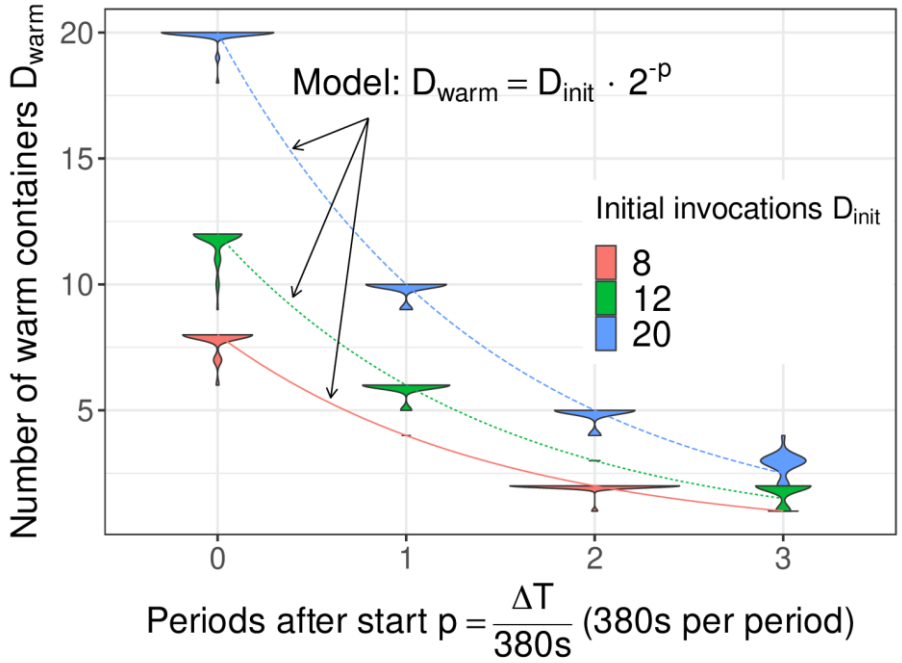

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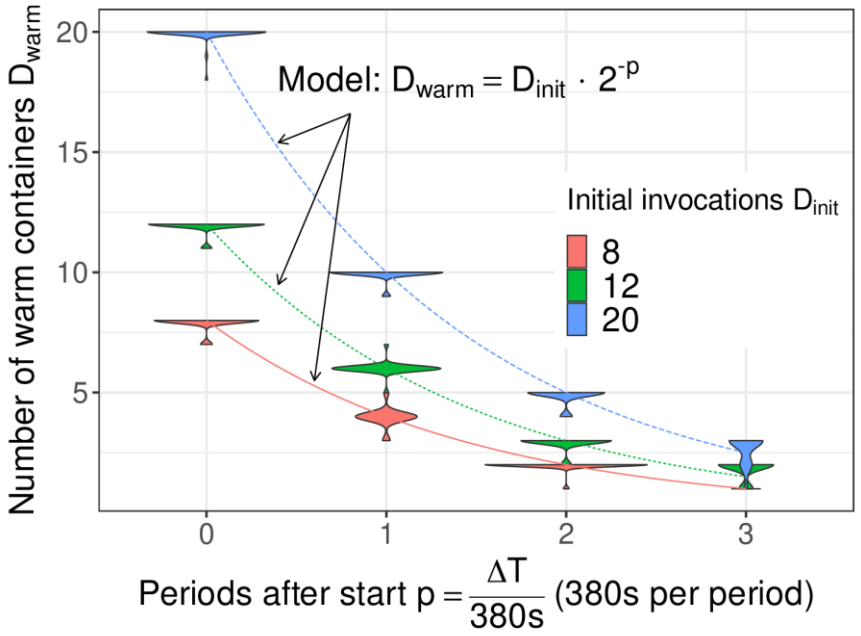

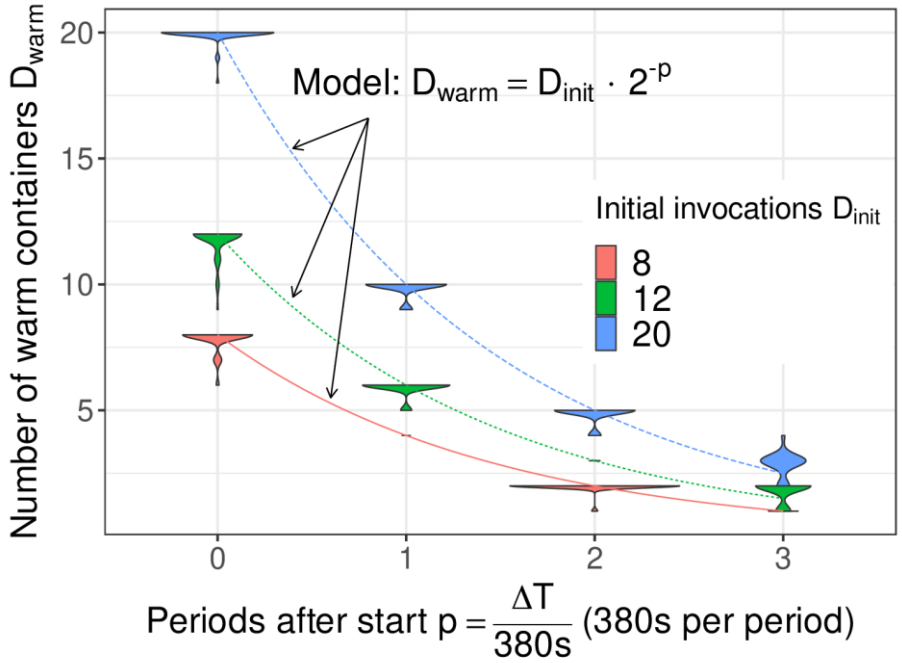

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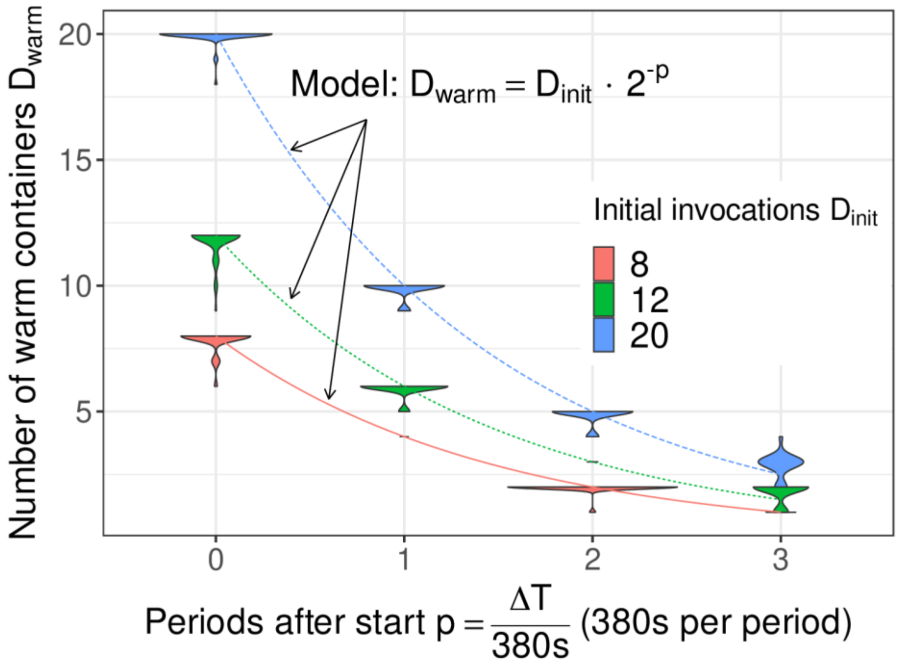

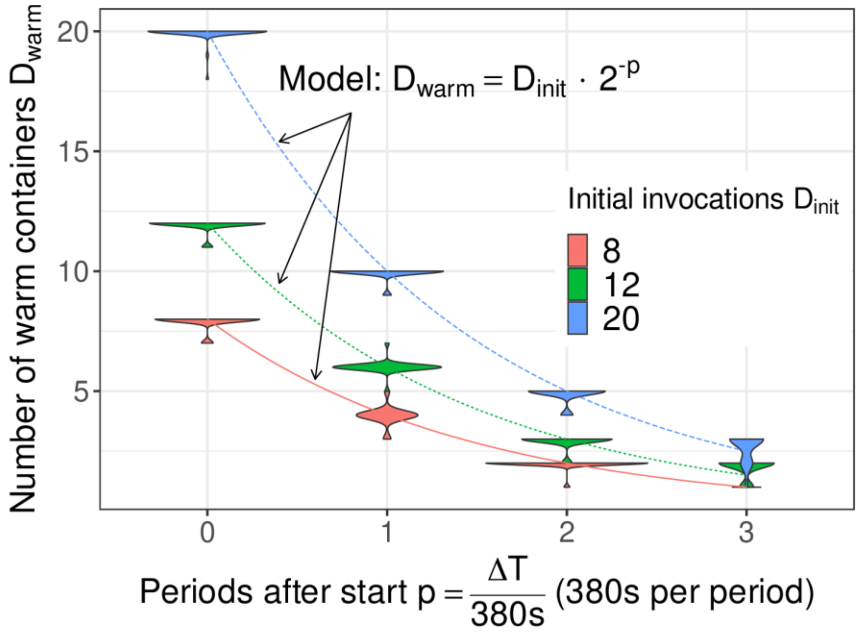

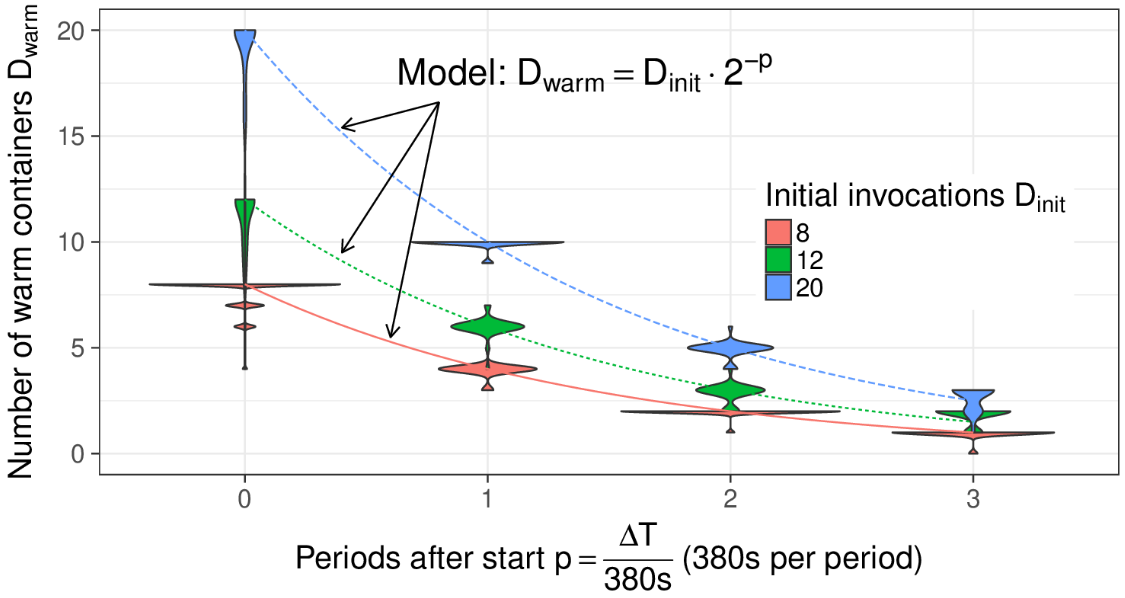

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	I/O-bound functions experience very high latency variations.
	AWS Lambda achieves the best performance on all workloads.
	Irregular performance of concurrent Azure Function executions.
	AWS Lambda performance is not competitive against VMs assuming comparable resources.
	**Resource underutilization due to high granularity of pricing models.**
	Break-even analysis for IaaS and FaaS deployment.
	High costs of Azure Functions due to unconfigurable deployment.
	The function output size can be a dominating factor in pricing.
	Accurate methodology for estimation of invocation latency.
	Warm latencies are consistent and depend linearly on payload size.
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Summary

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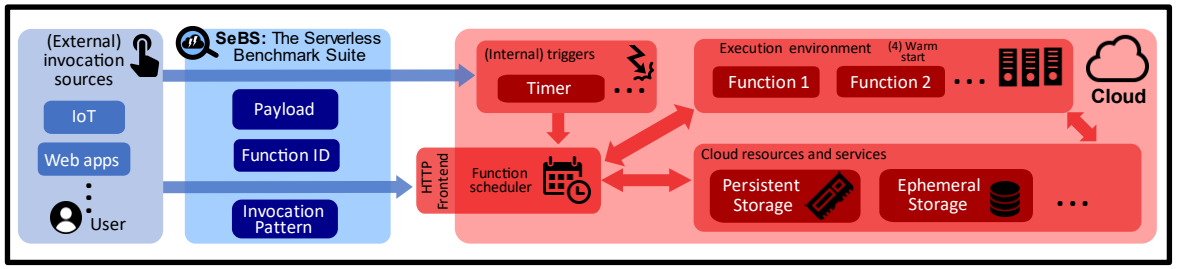
(External) invocation sources
IoT
Web apps
User
SeBS: The Serverless Benchmark Suite
Payload
Function ID
Invocation Pattern
HTTP Frontend
(Internal) triggers
Timer
Function scheduler
Execution environment
(4) Warm start
Function 1
Function 2
Cloud
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Persistent Storage
Ephemeral Storage

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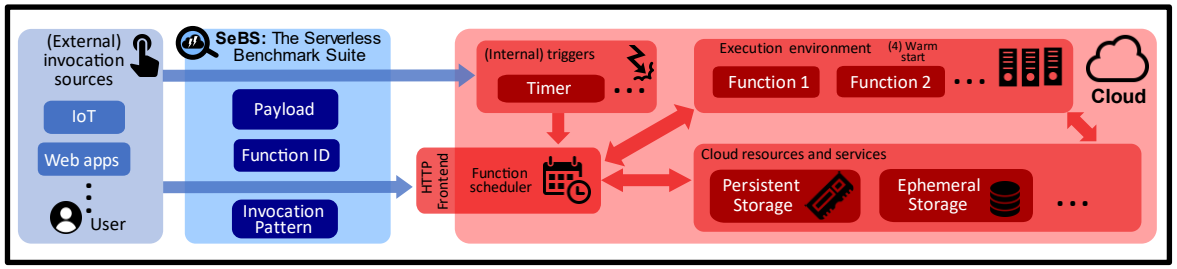

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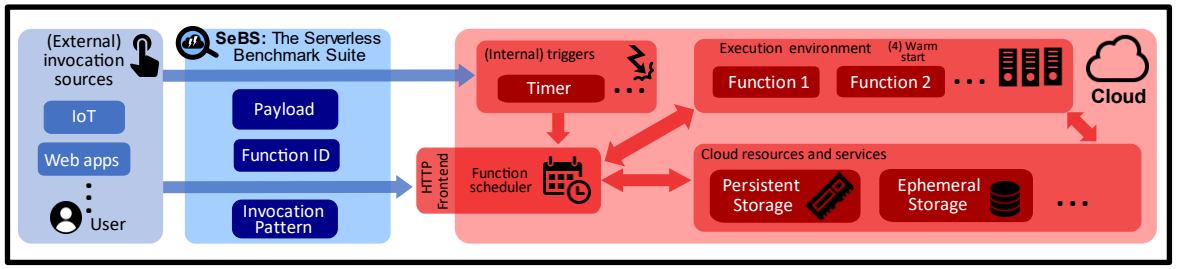

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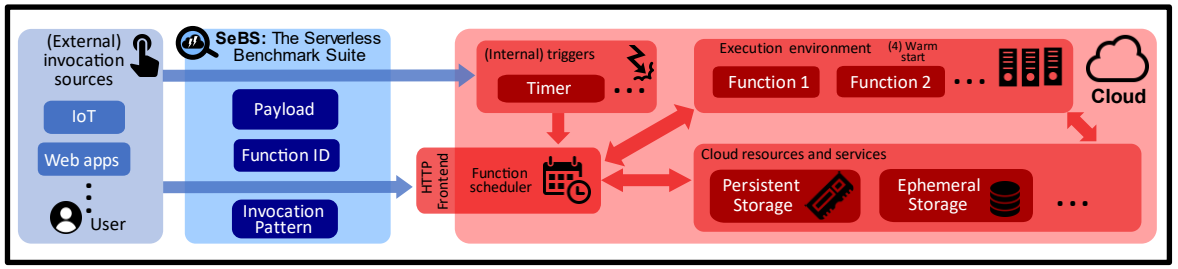

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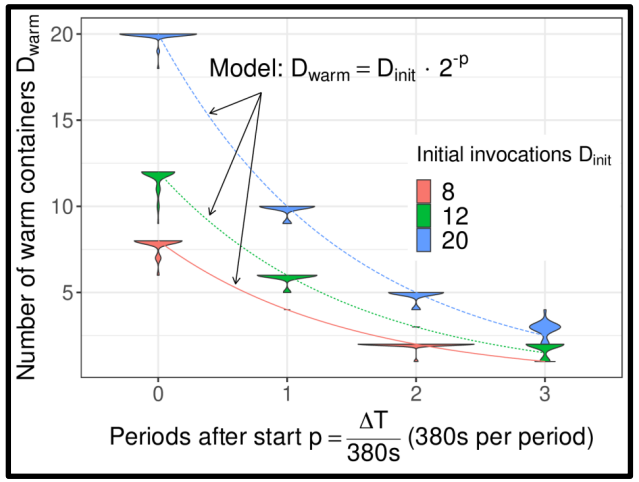
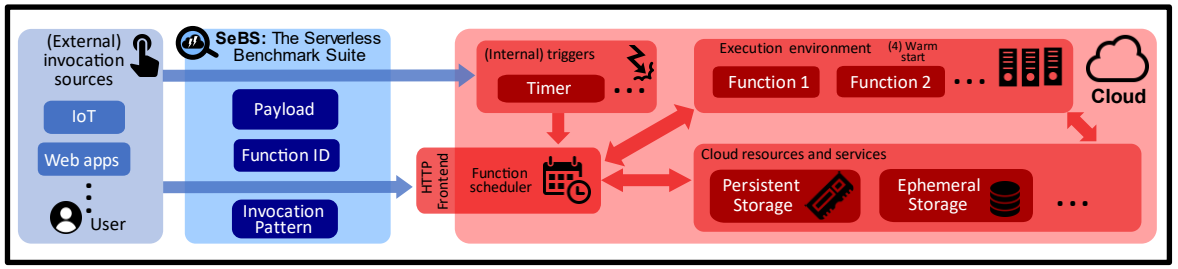


Summary



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Webapps	uploader	**Python**, Node.js
Multimedia	thumbnailer	**Python**, **Node.js**, C++
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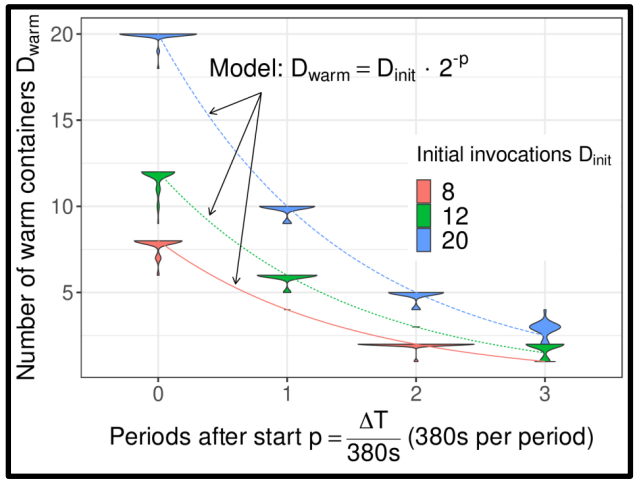
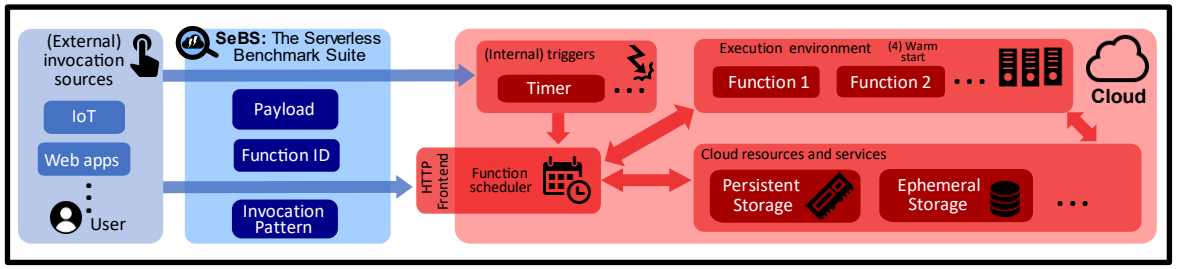


spcl/serverless-benchmarks

Summary



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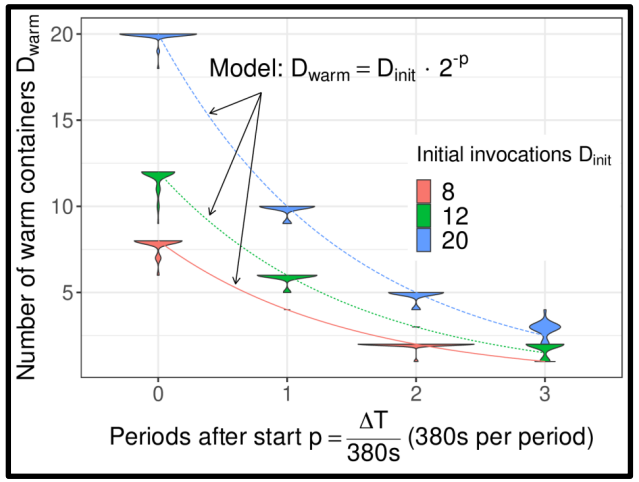

spcl/serverless-benchmarks

- OpenWhisk
- C++ Functions
- Serverless Workflows

Q&A

Future Work

Questions

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spcl/serverless-benchmarks

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spcl/serverless-benchmarks

Q&A

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Questions

- What are the requirements for a good benchmark suite?
- How can we measure function invocation latency accurately?
- How much performance do we lose when switching from IaaS to FaaS?

spcl/serverless-benchmarks

SeBS in details…

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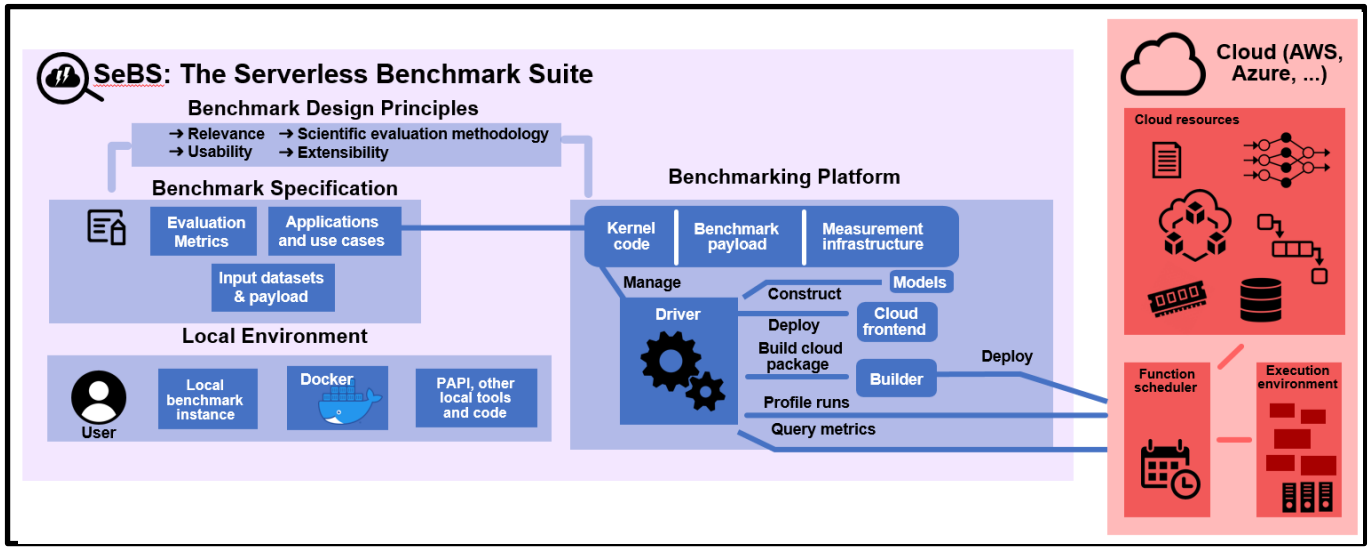

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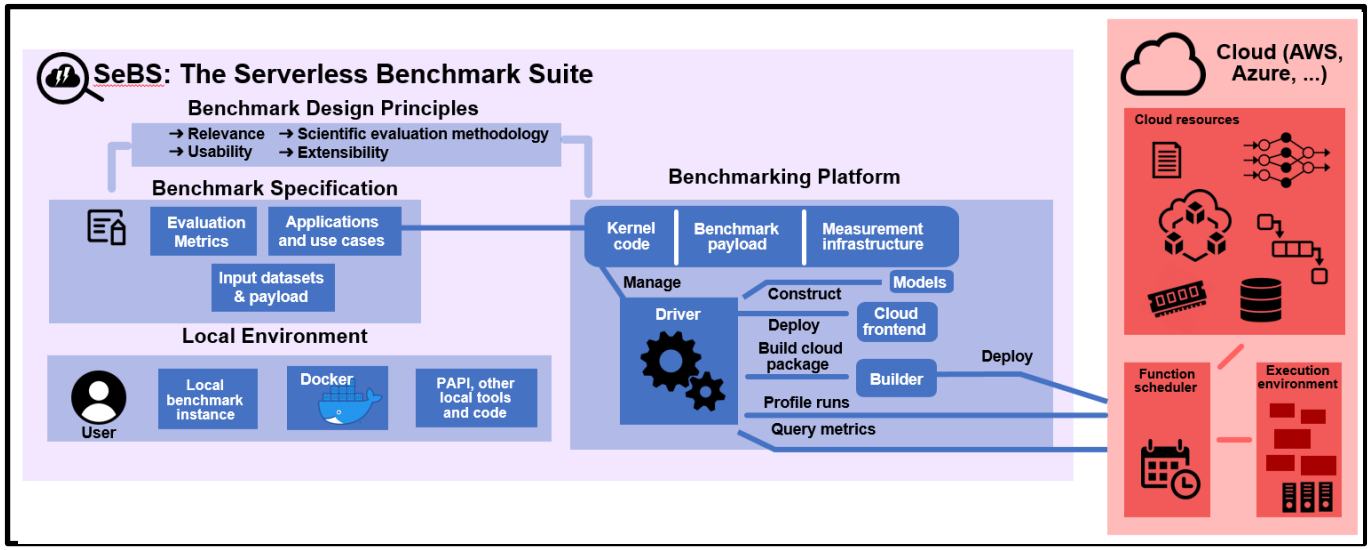

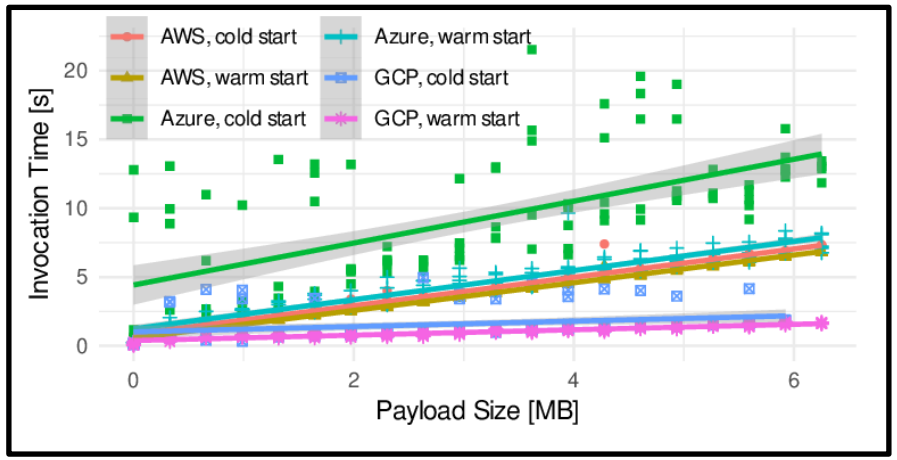

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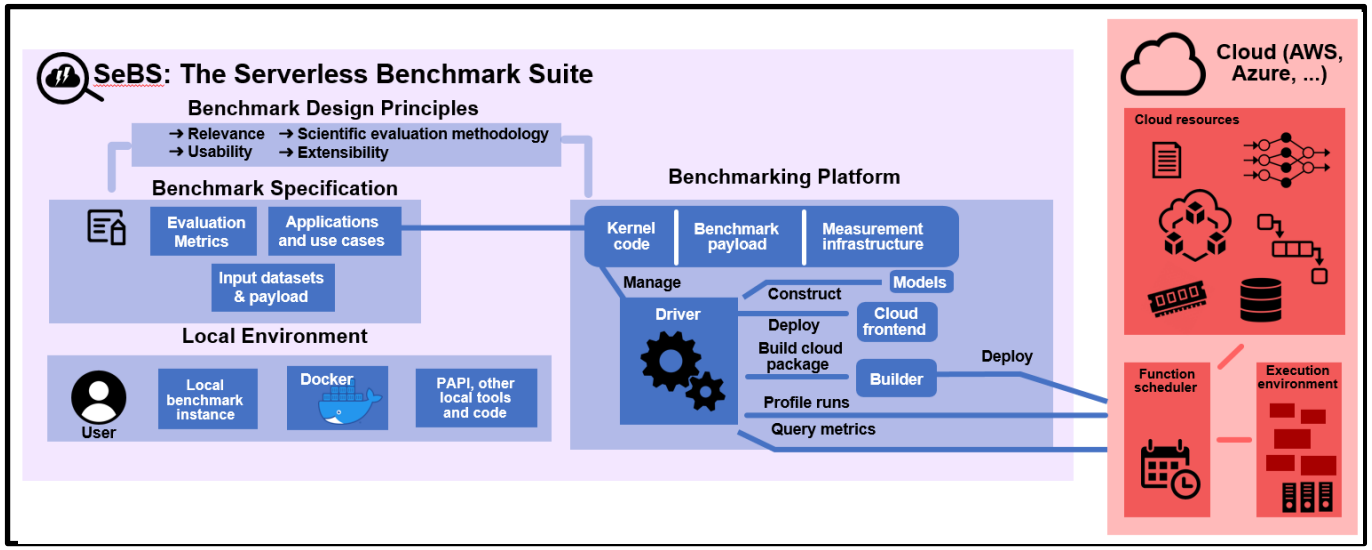

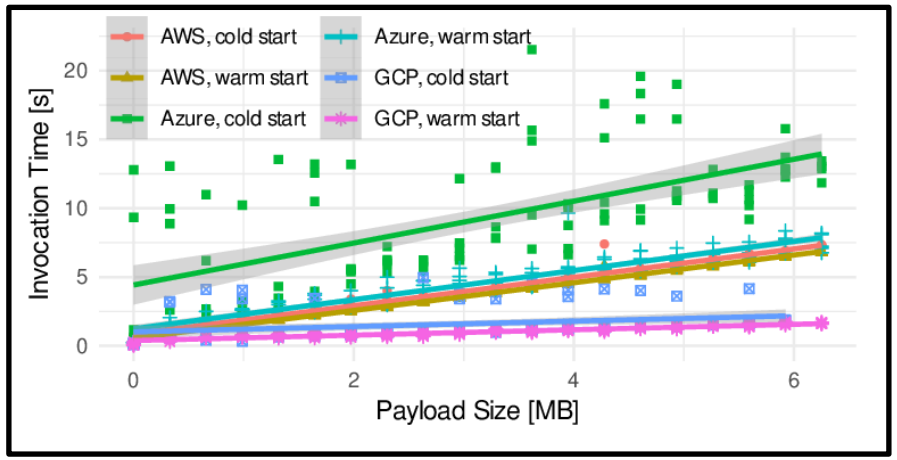

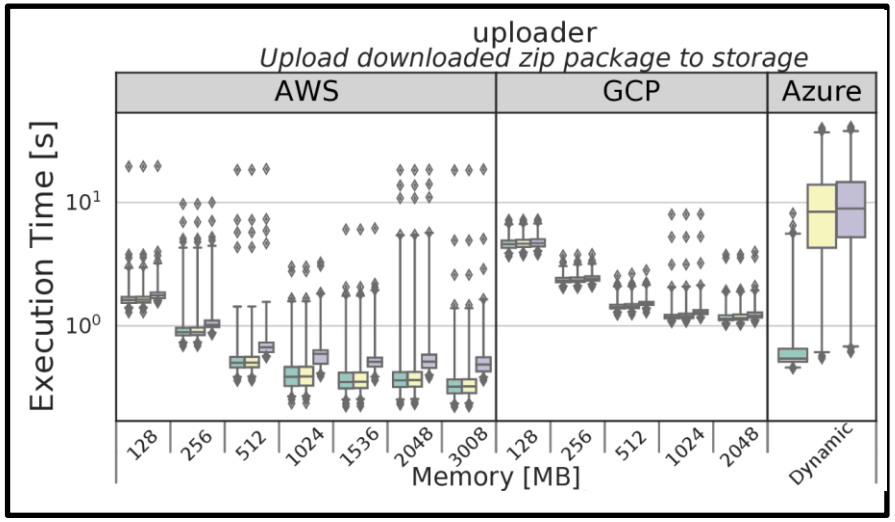

How to build a benchmark?

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Benchmarking in the Cloud: What It Should, Can, and Cannot Be

Enno Folkerts[1], Alexander Alexandrov[2], Kai Sachs[1], Alexandru Iosup[3], Volker Markl[2], and Cafer Tosun[1]

[1] SAP AG, 69190 Walldorf, Germany
firstname.lastname@sap.com
[2] TU Berlin, Germany
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[3] Delft University of Technology, The Netherlands
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Abstract. With the increasing adoption of Cloud Computing, we observe an increasing need for Cloud Benchmarks, in order to assess the performance of Cloud infrastructures and software stacks, to assist with provisioning decisions for Cloud users, and to compare Cloud offerings. We understand our paper as one of the first systematic approaches to the topic of Cloud Benchmarks. Our driving principle is that Cloud Benchmarks must consider end-to-end performance and pricing, taking into account that services are delivered over the Internet. This requirement yields new challenges for benchmarking and requires us to revisit existing benchmarking practices in order to adopt them to the Cloud.

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How is the Weather tomorrow? Towards a Benchmark for the Cloud

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Scientific Benchmarking of Parallel Computing Systems

Twelve ways to tell the masses when reporting performance results

Torsten Hoefler
Dept. of Computer Science
ETH Zurich
Zurich, Switzerland
htor@inf.ethz.ch

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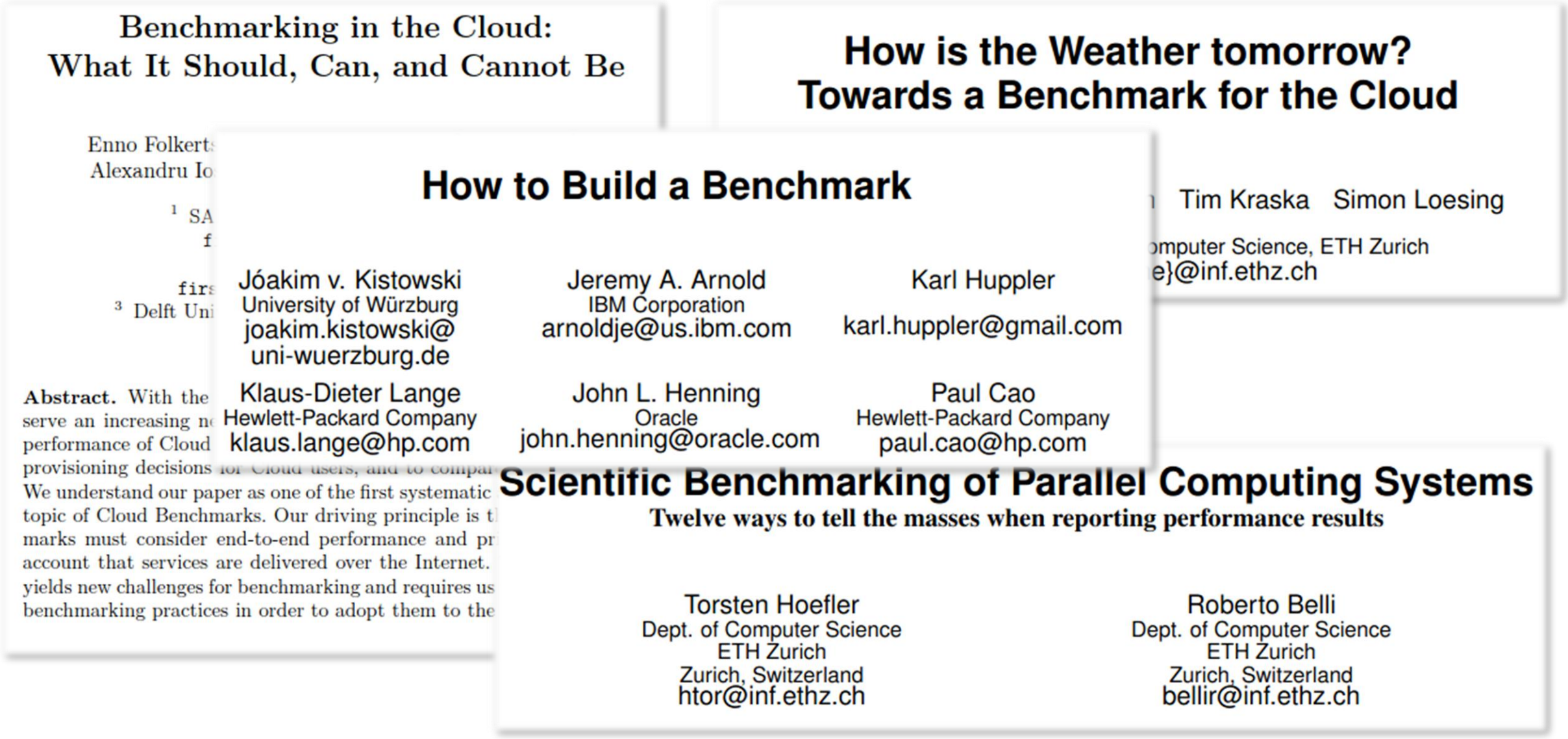

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How to Build a Benchmark

Jóakim v. Kistowski
University of Würzburg
joakim.kistowski@
uni-wuerzburg.de

Jeremy A. Arnold
IBM Corporation
arnoldje@us.ibm.com

Karl Huppler
karl.huppler@gmail.com

Klaus-Dieter Lange
Hewlett-Packard Company
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John L. Henning
Oracle
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Benchmarking Goals

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Principles

- ✓ Usability
- ✓ Portability
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Experiments

- ✓ Performance and cost
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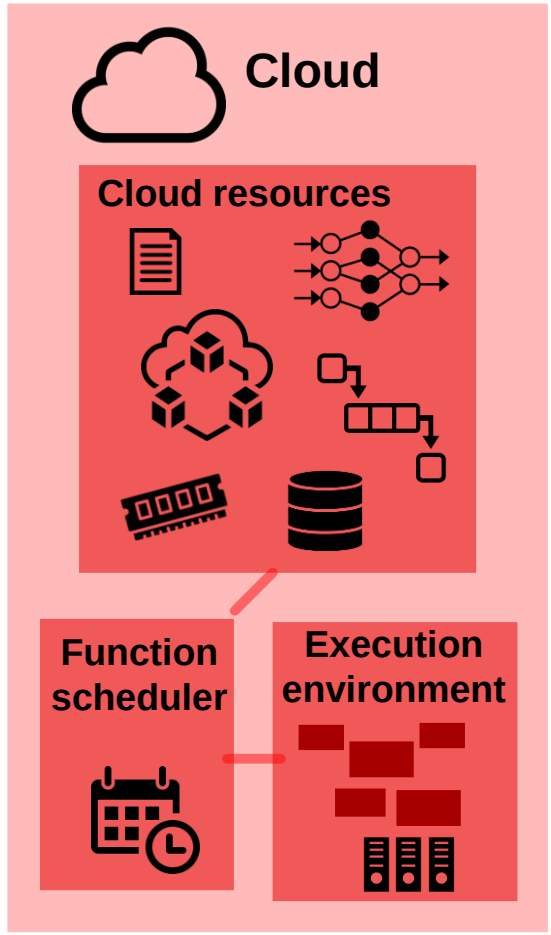

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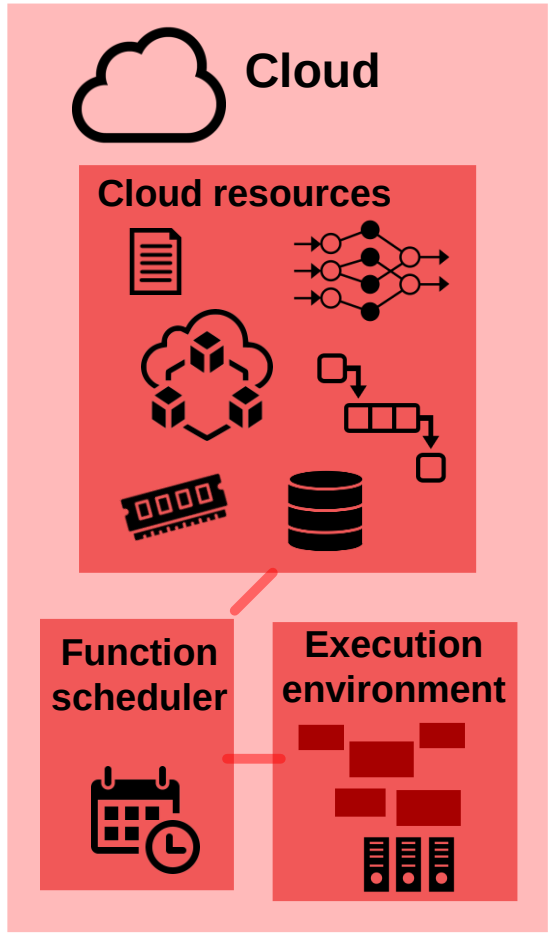
SeBS: The Serverless Benchmark Suite



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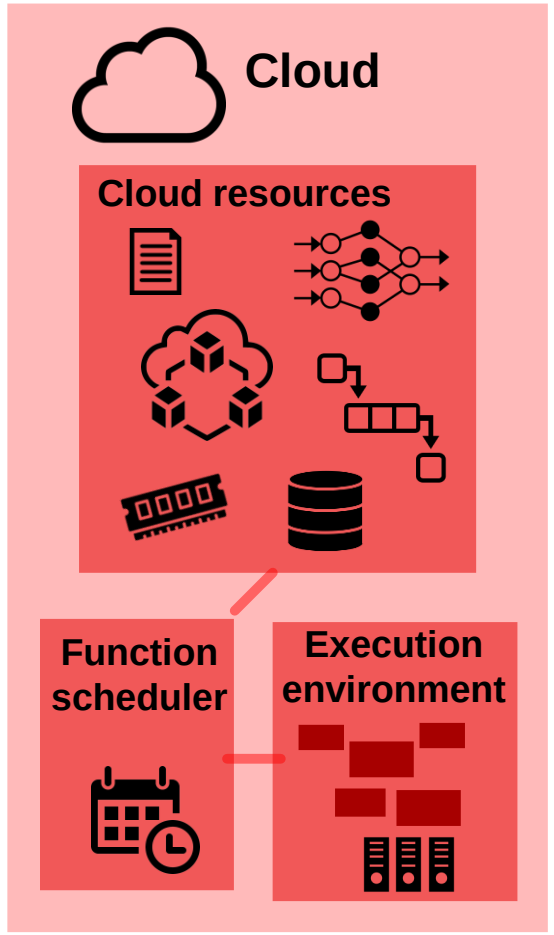
Benchmark Design Principles

→ Relevance → Scientific evaluation methodology
→ Usability → Extensibility



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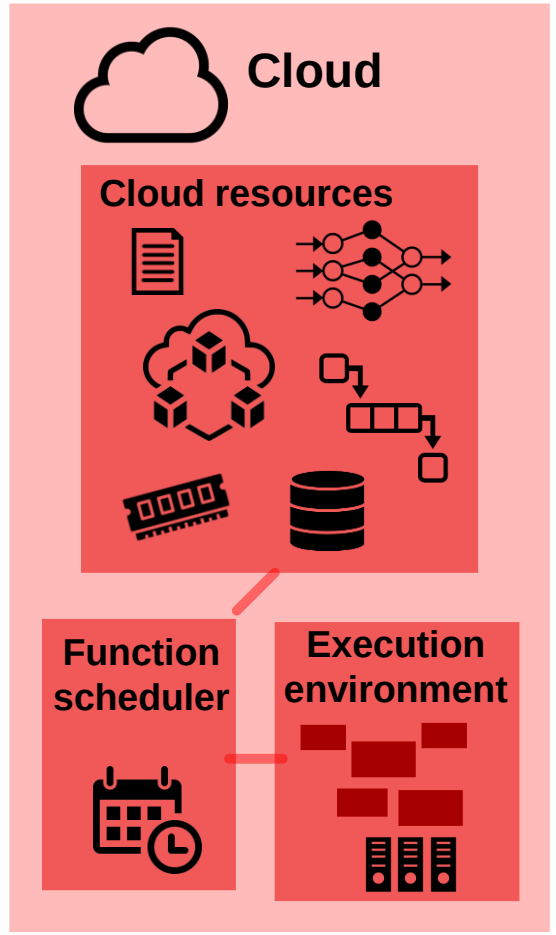
Input datasets



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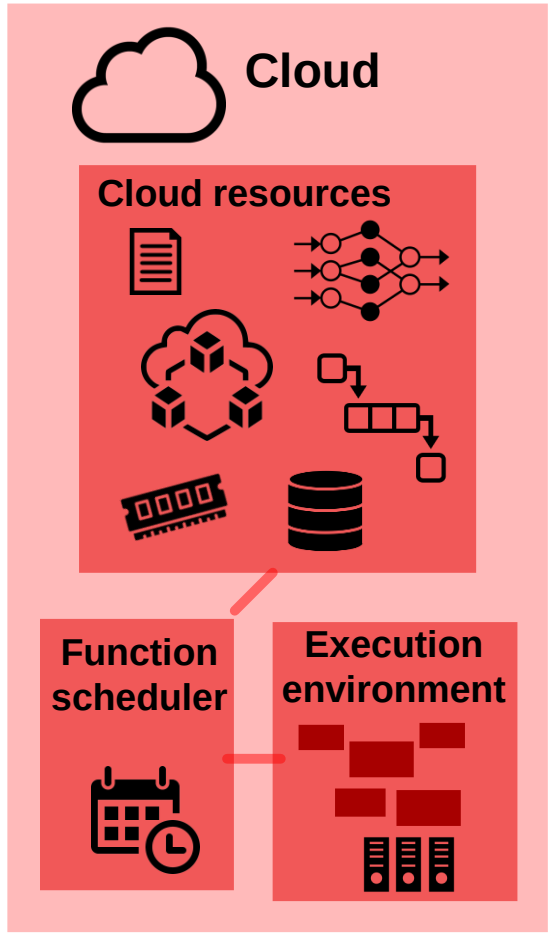

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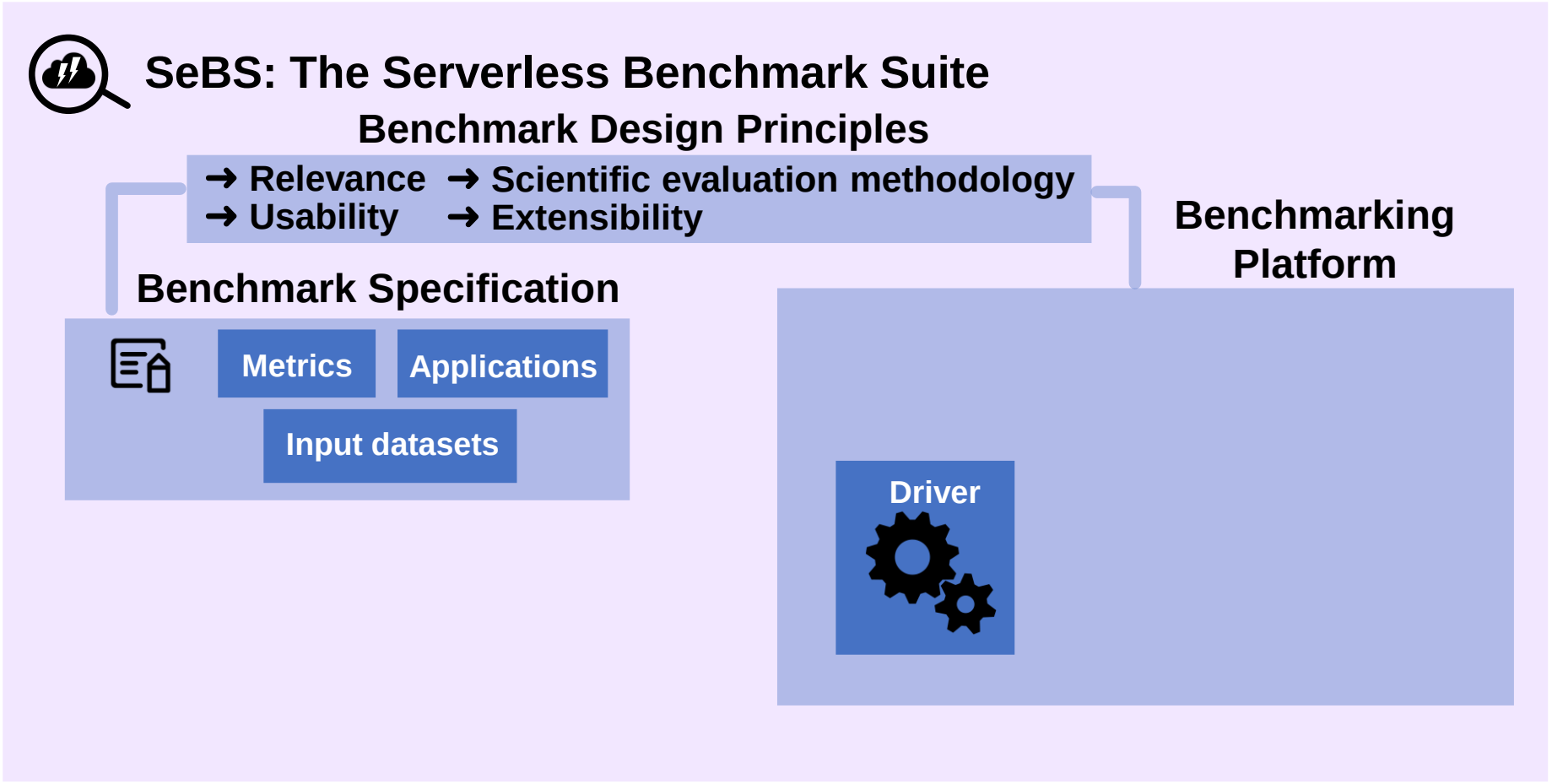

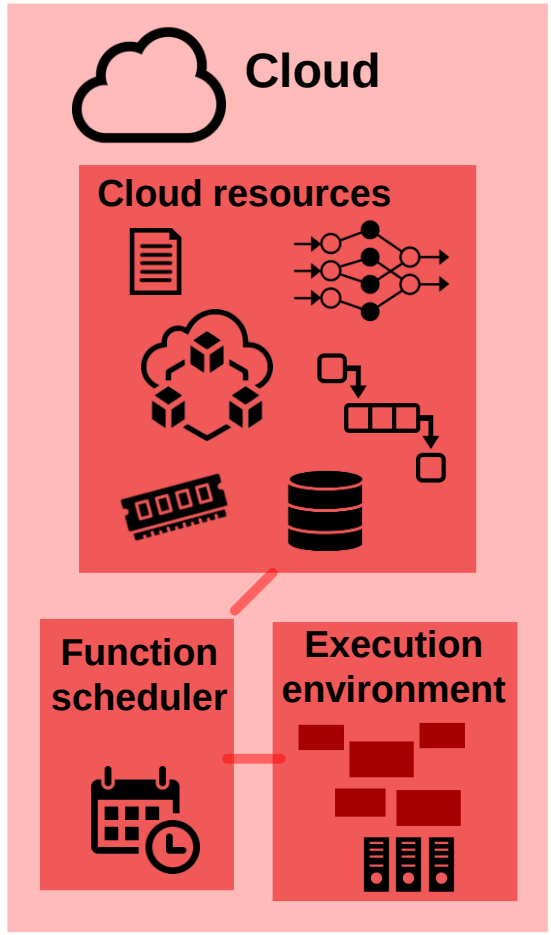

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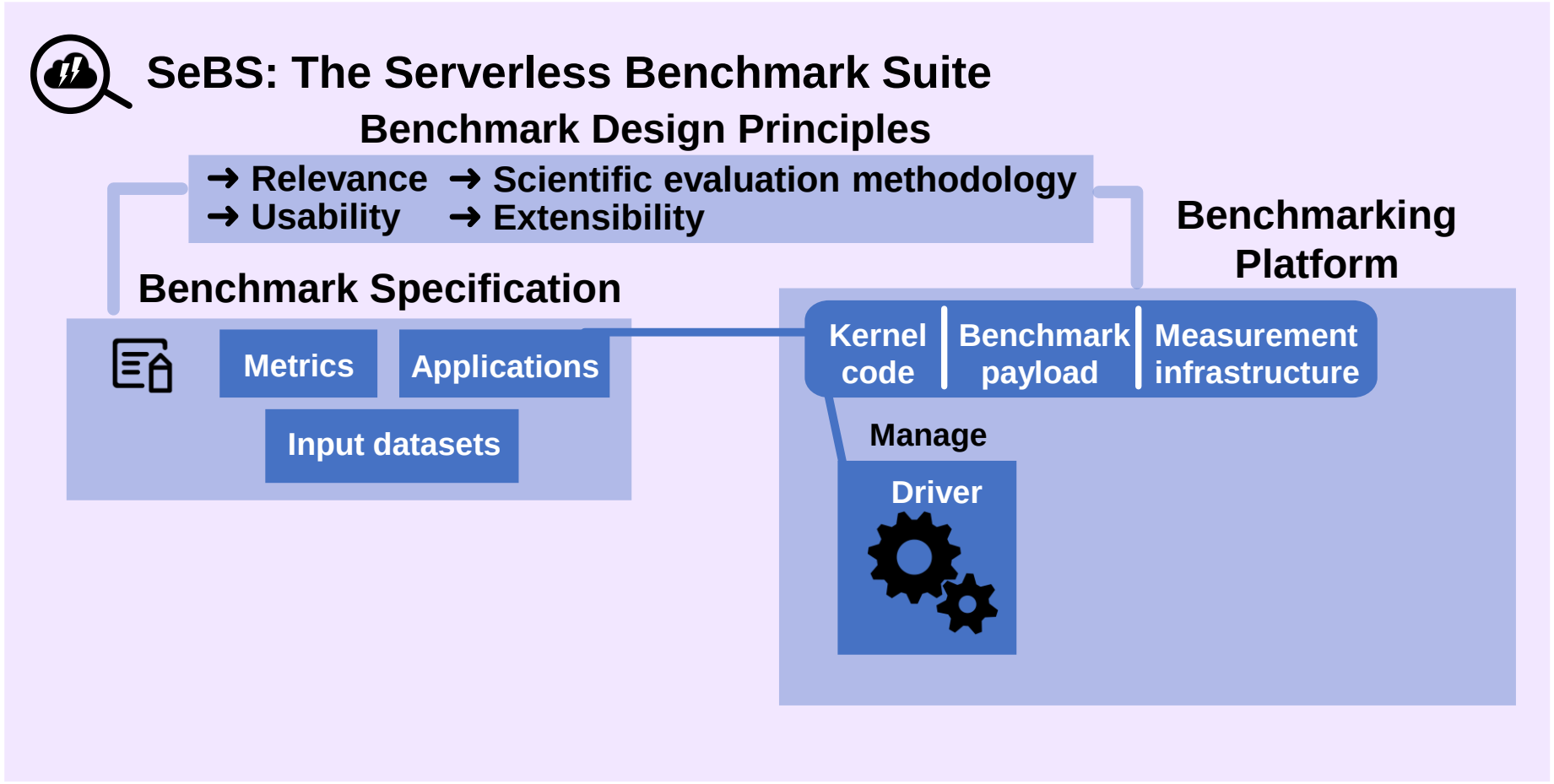

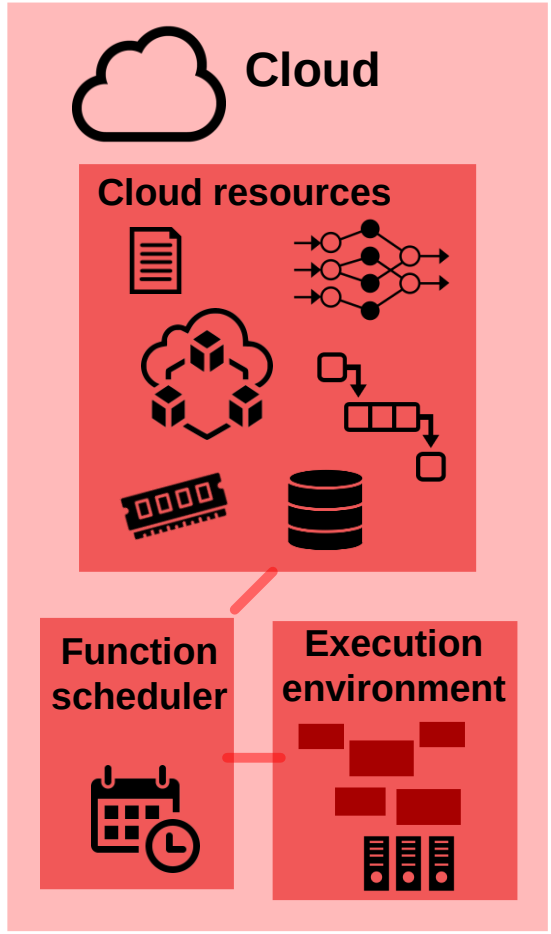

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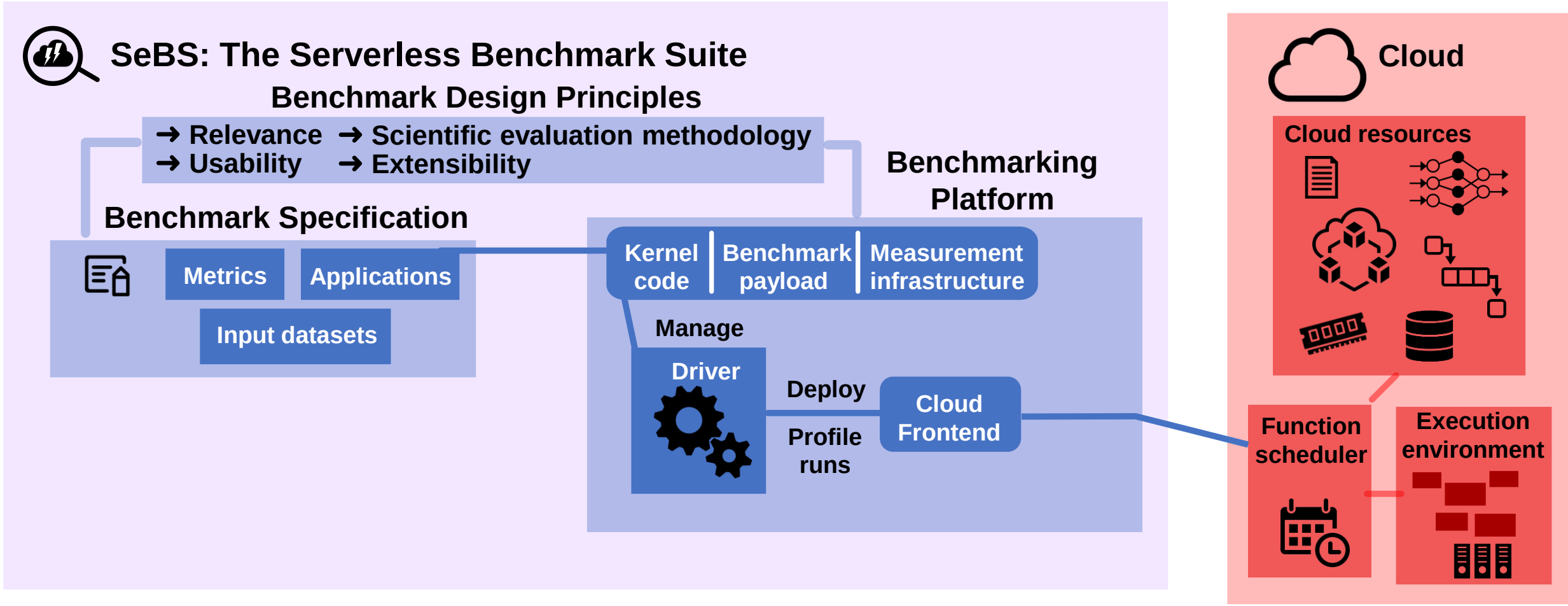

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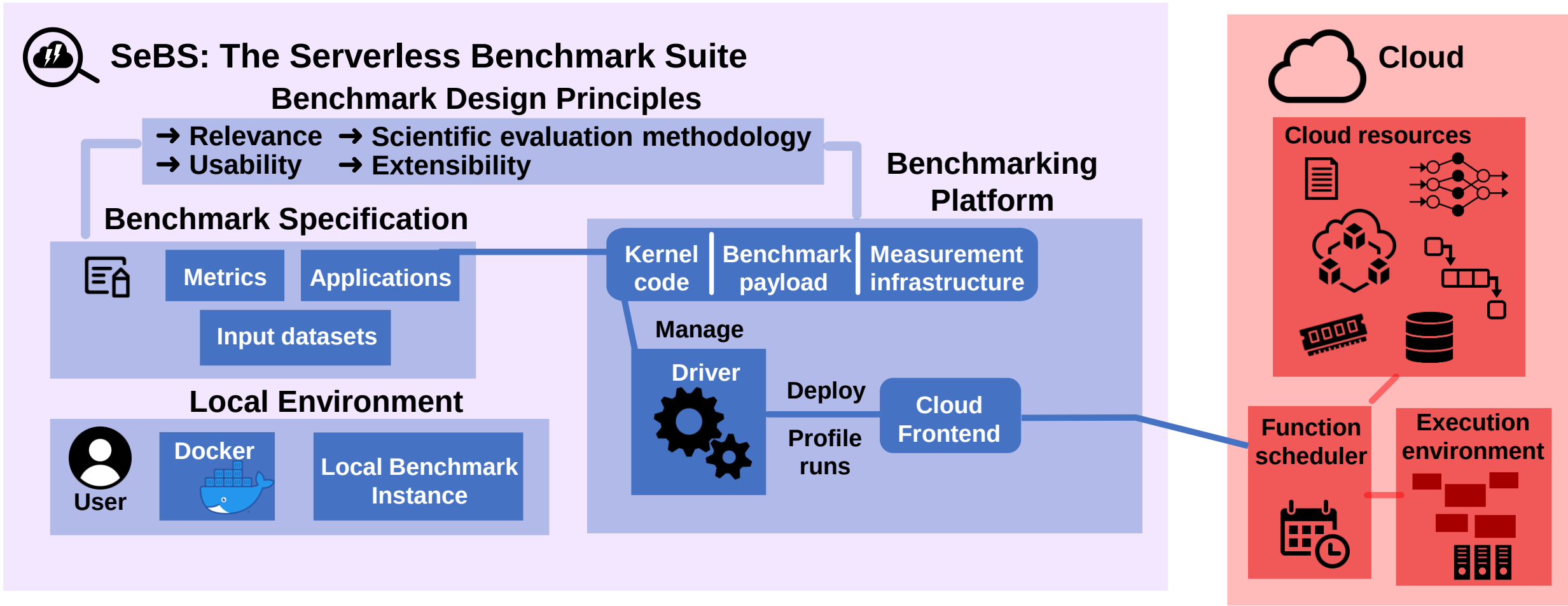

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	Results, methods, and insights
	
	
	
	

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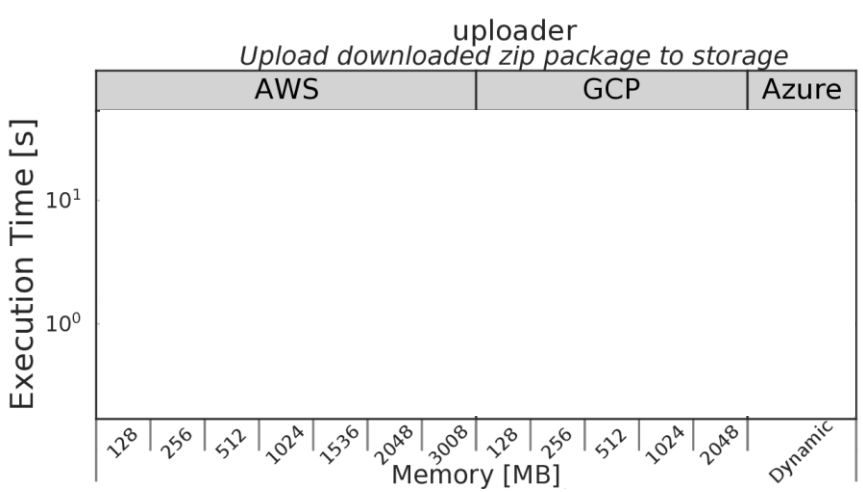

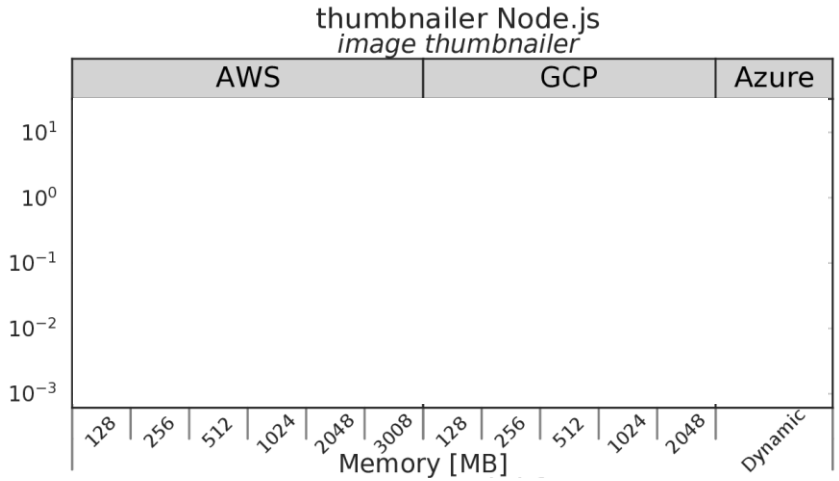

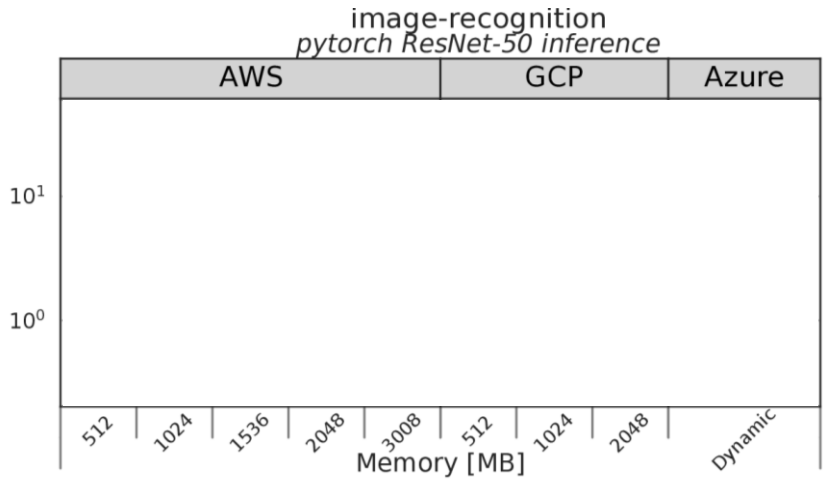

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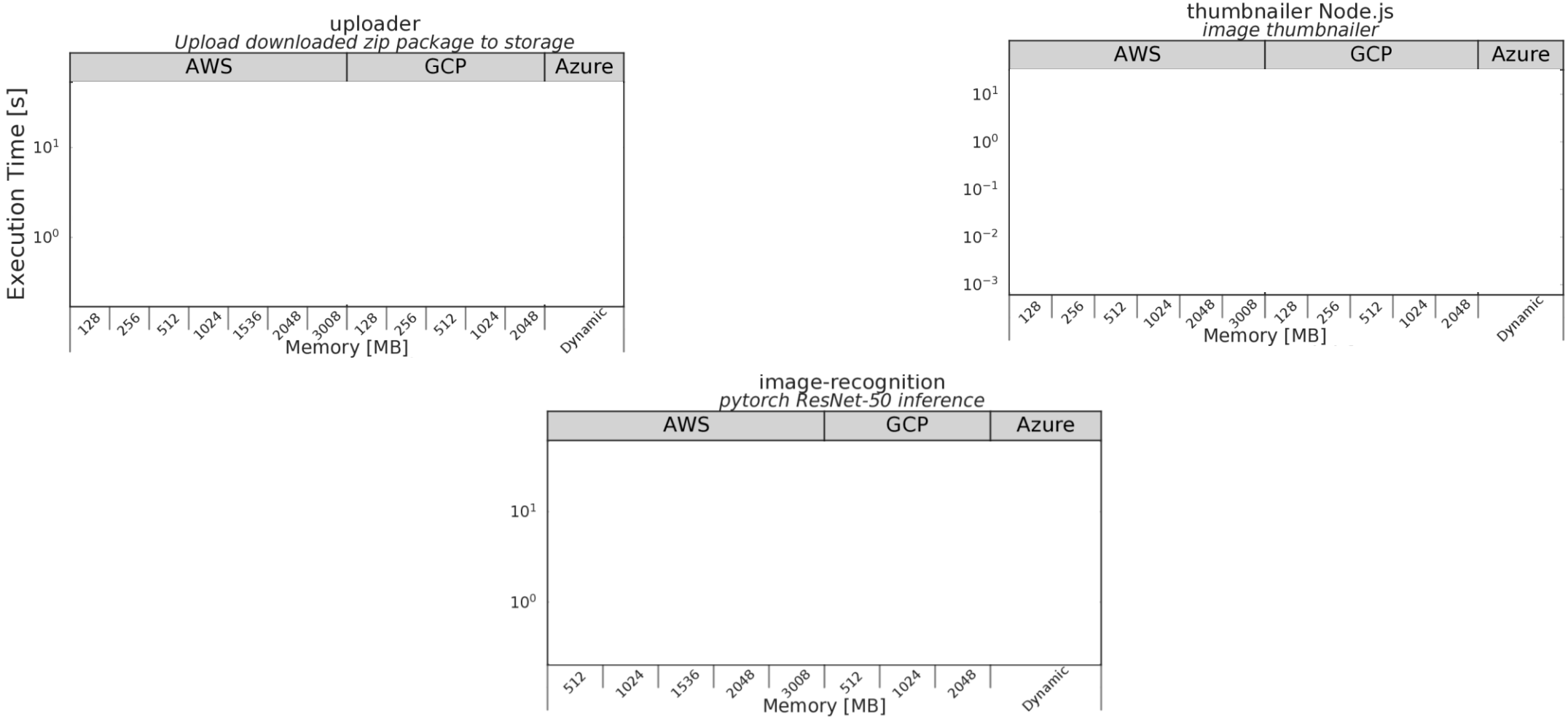

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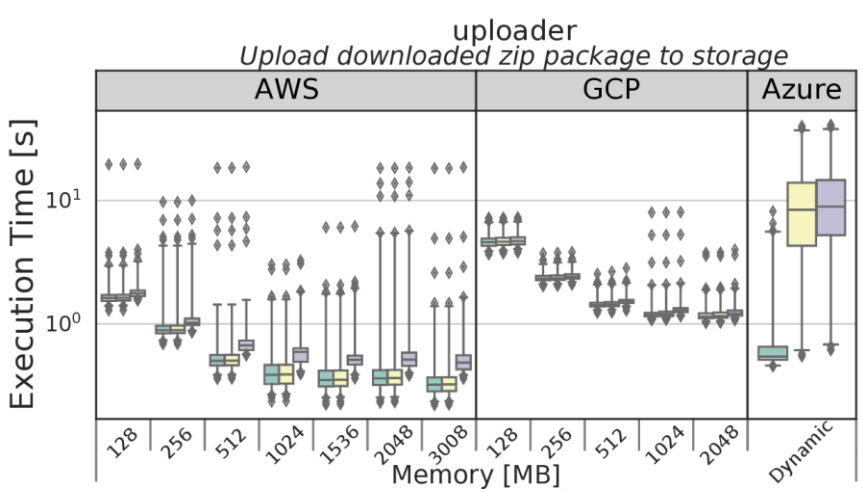

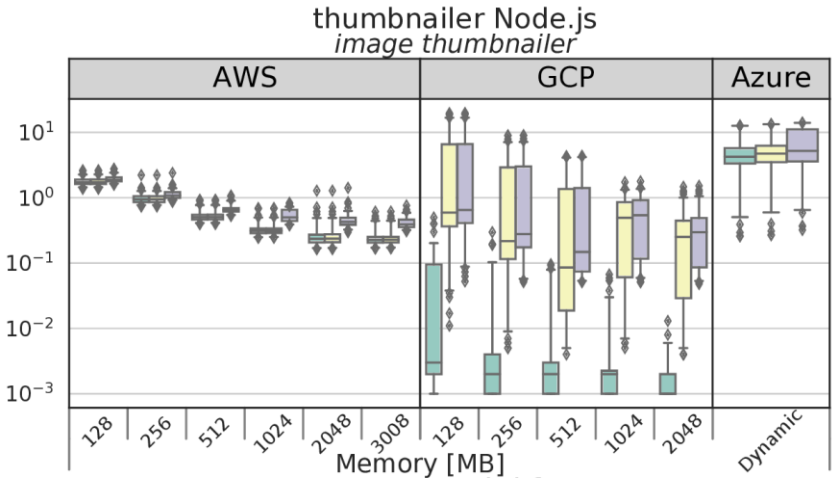

Benchmark Time Provider Time Client Time

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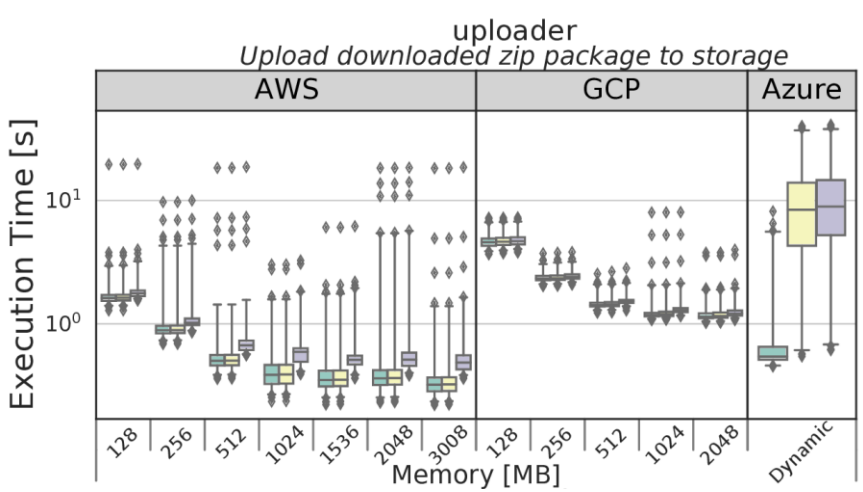

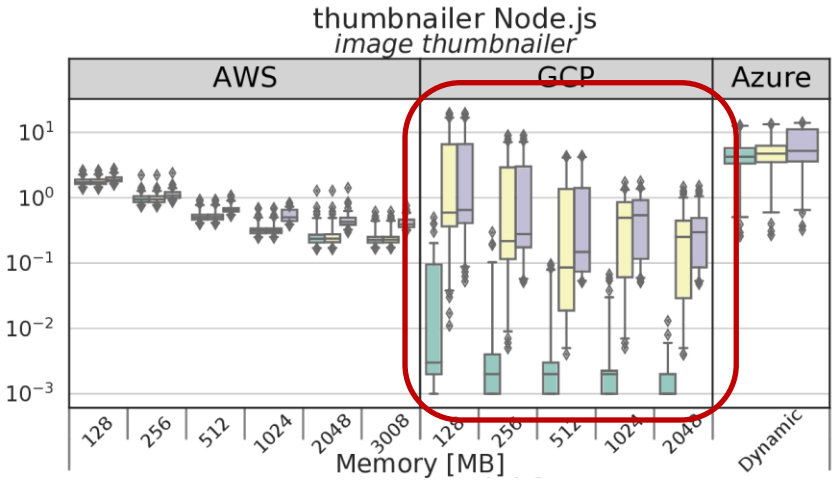

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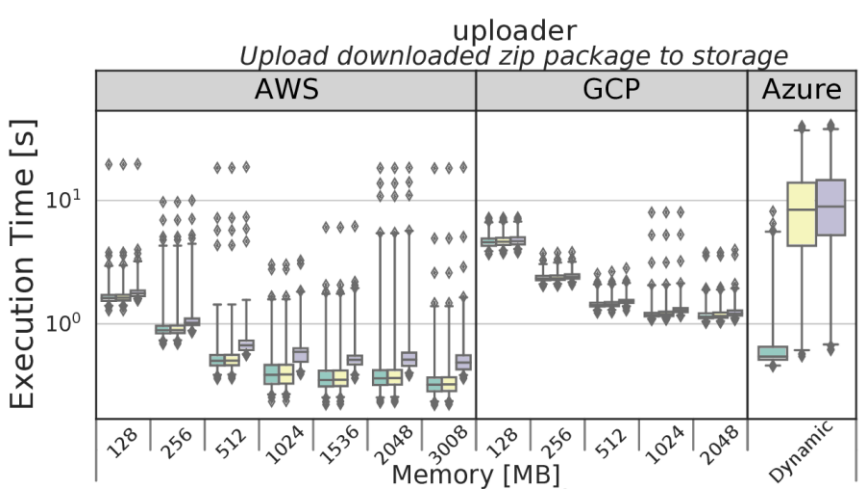
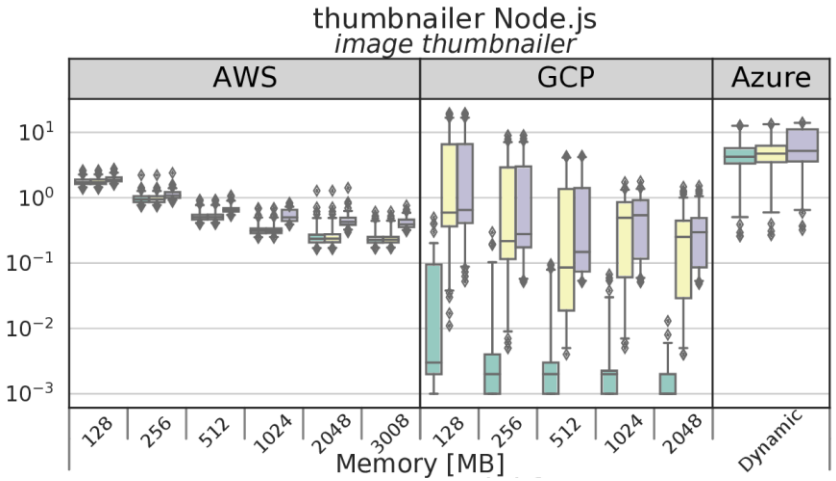
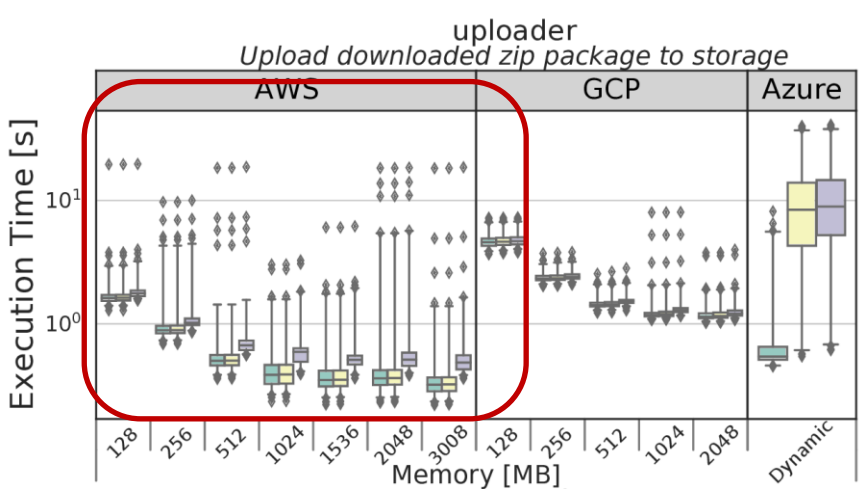
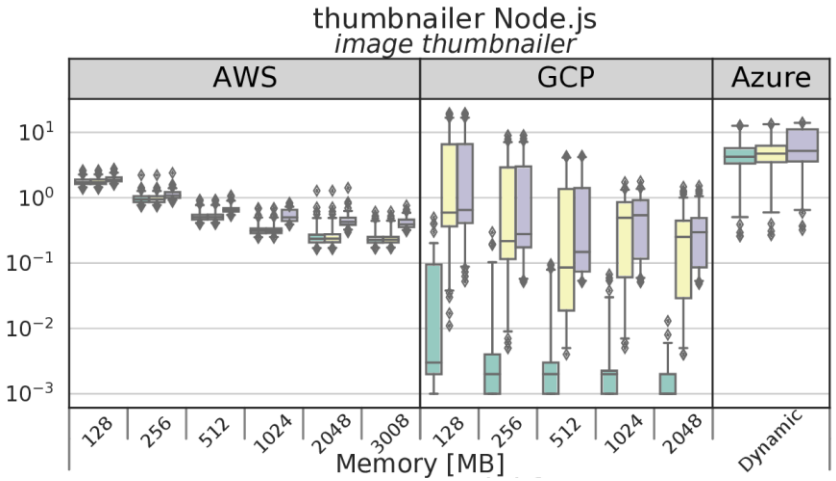




Benchmark Time Provider Time Client Time

Performance Analysis: Warm Startups





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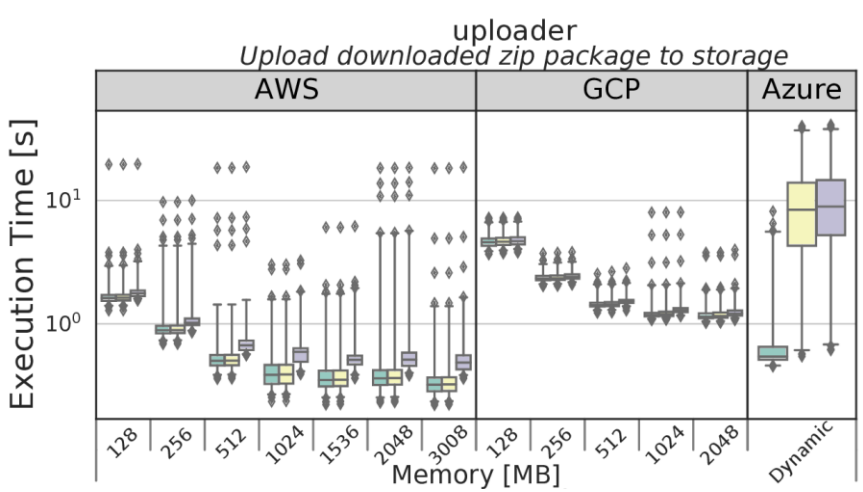

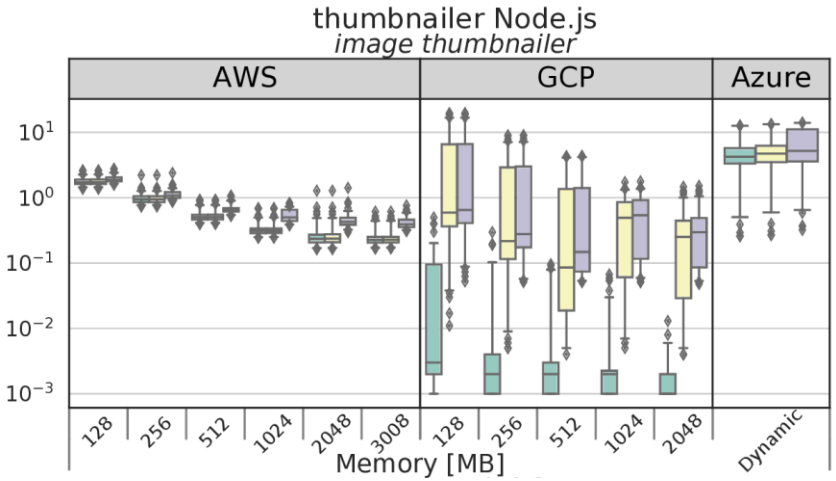

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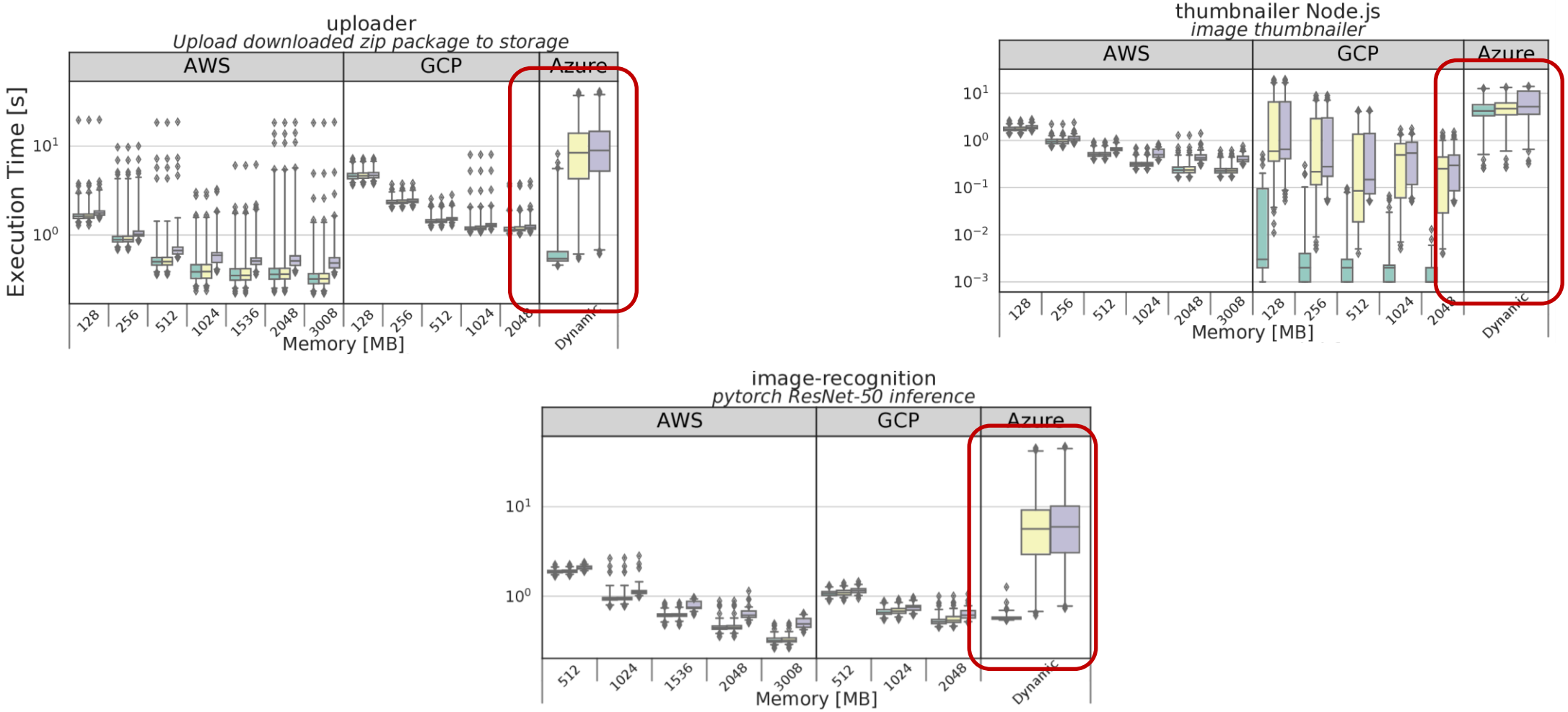

Results and Insights

	Results, methods, and insights
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Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search

Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS [s]						
FaaS [s]						
Overhead						
Memory [MB]						

Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.
- **Measurements:** 200 warm executions.

Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS [s]	0.316	0.13	0.191	2.803	0.235	0.03
FaaS [s]	0.389	0.188	0.253	2.949	0.321	0.075
Overhead	1.23x	1.43x	1.24x	1.05x	1.37x	2.4x
Memory [MB]	1024	1024	2048	1024	3008	1536

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	Break-even analysis for IaaS and FaaS deployment.
	
	

Cost Analysis: FaaS vs IaaS

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IaaS							
FaaS							

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Cost Analysis: FaaS vs IaaS

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	Eco Break-Even	3275	5062	3093	362	733	5568
	Perf 1M [$]	6.67	3.34	10	50	19.58	2.5
	Perf Break-Even	1740	3480	1160	232	592	4640

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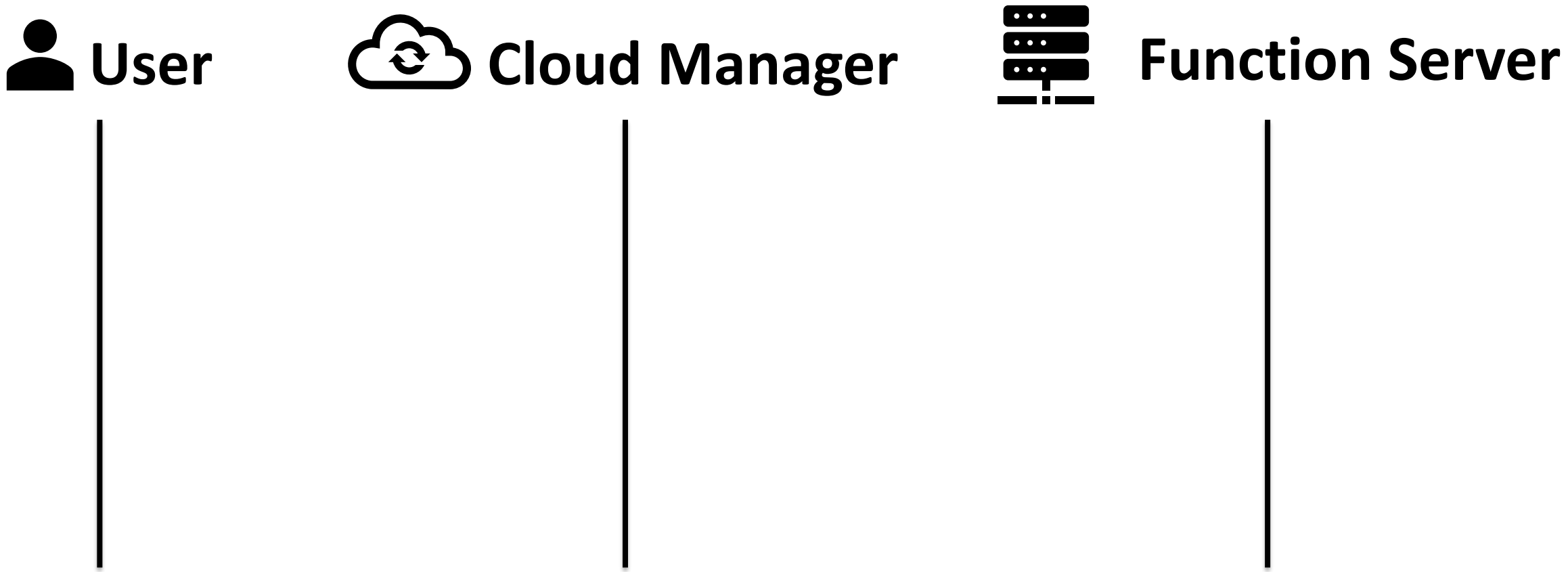
	Break-even analysis for IaaS and FaaS deployment.
	Accurate methodology for estimation of invocation latency.
	Warm latencies are consistent and depend linearly on payload size.
	Highly variable and unpredictable cold latencies on Azure and GCP.
	

FaaS Analysis: Invocation Overhead



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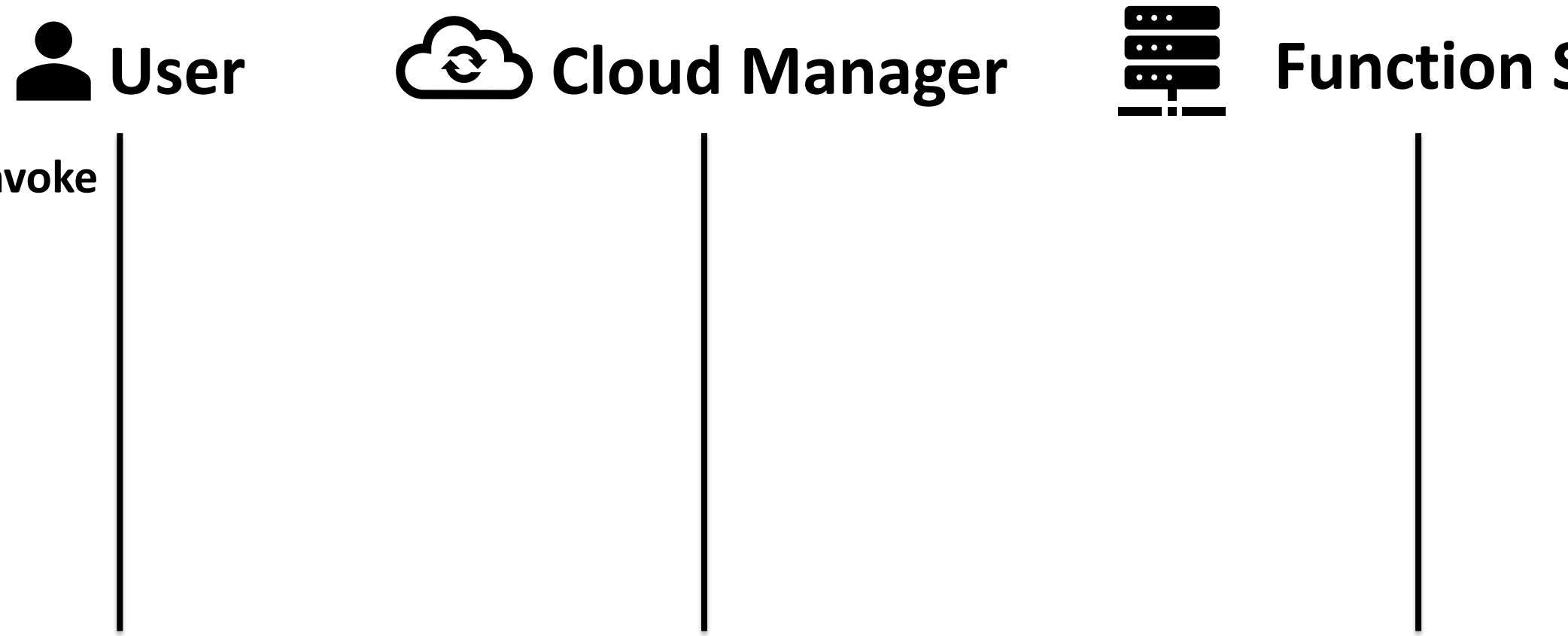

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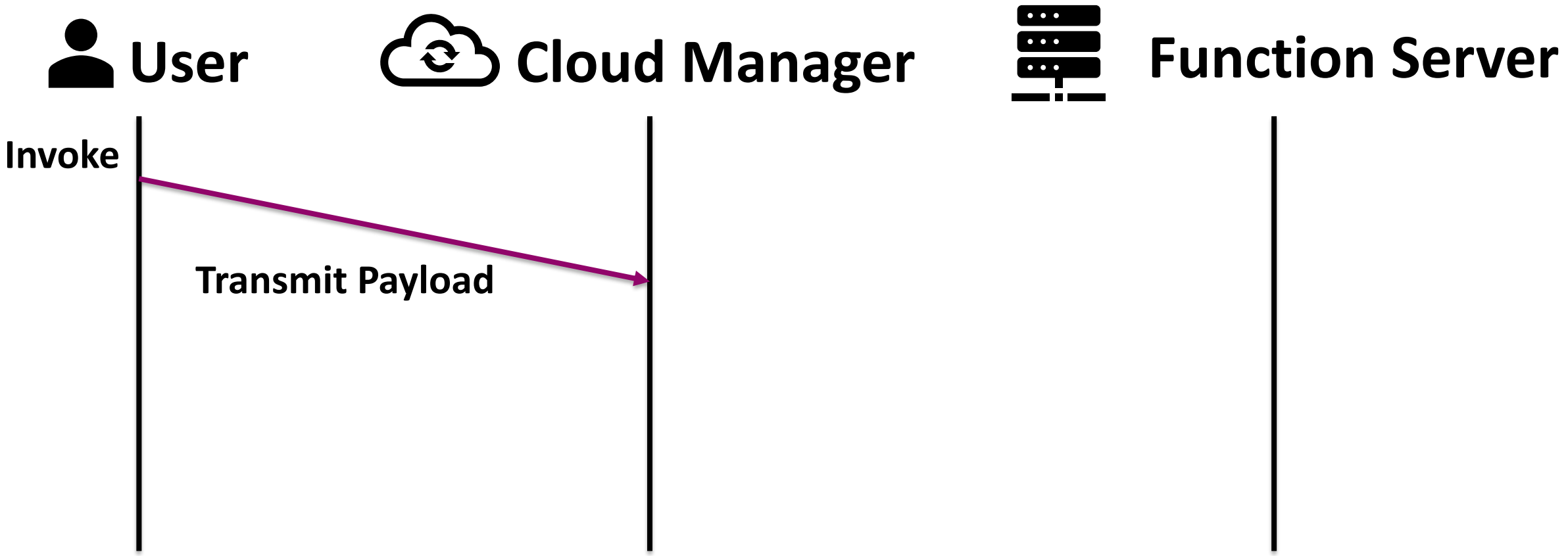

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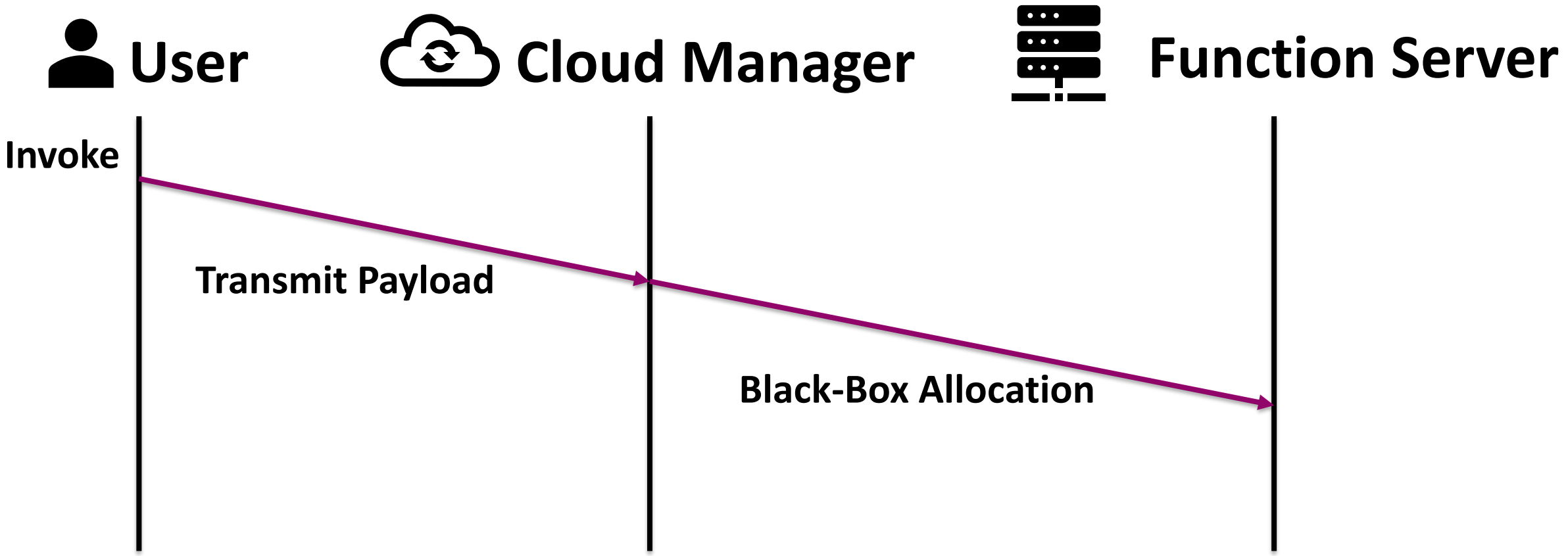

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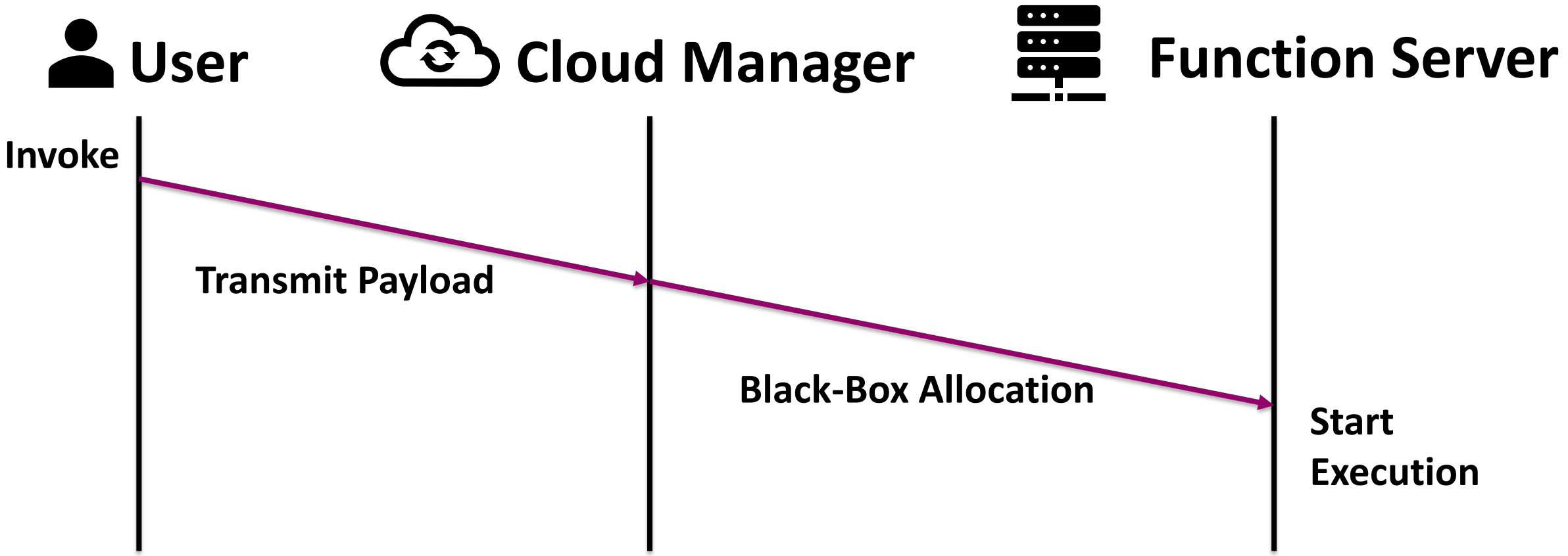

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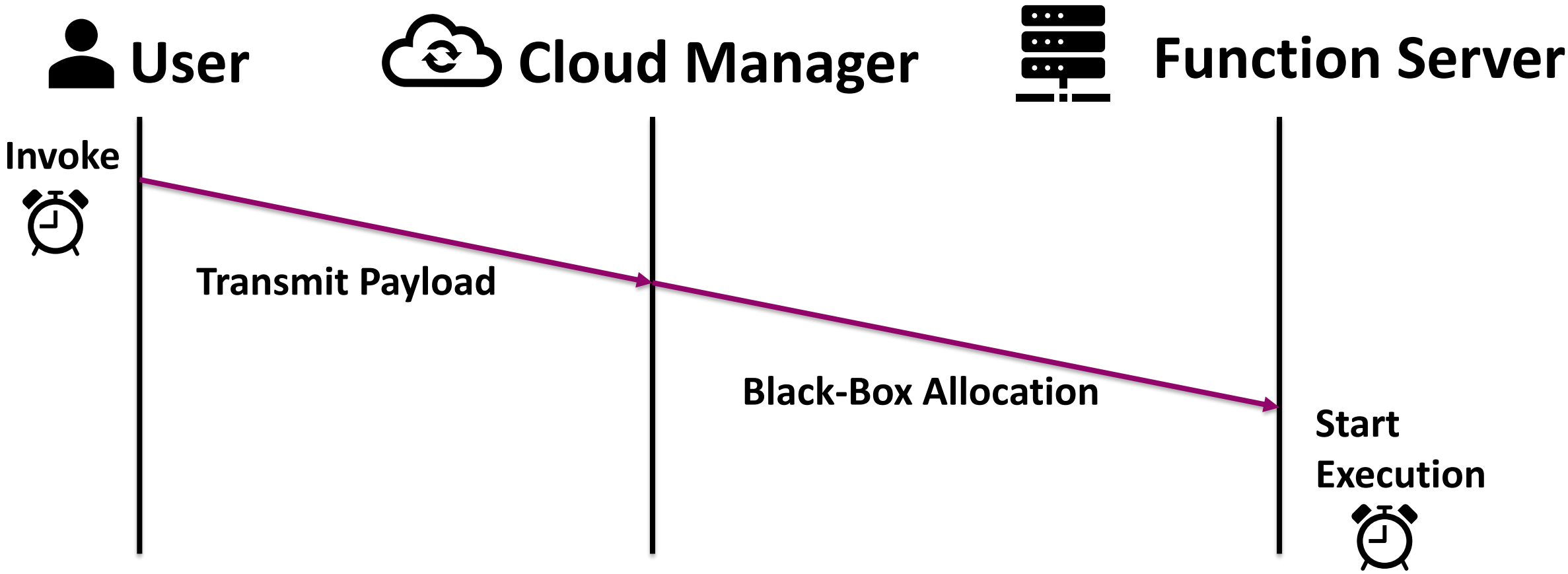

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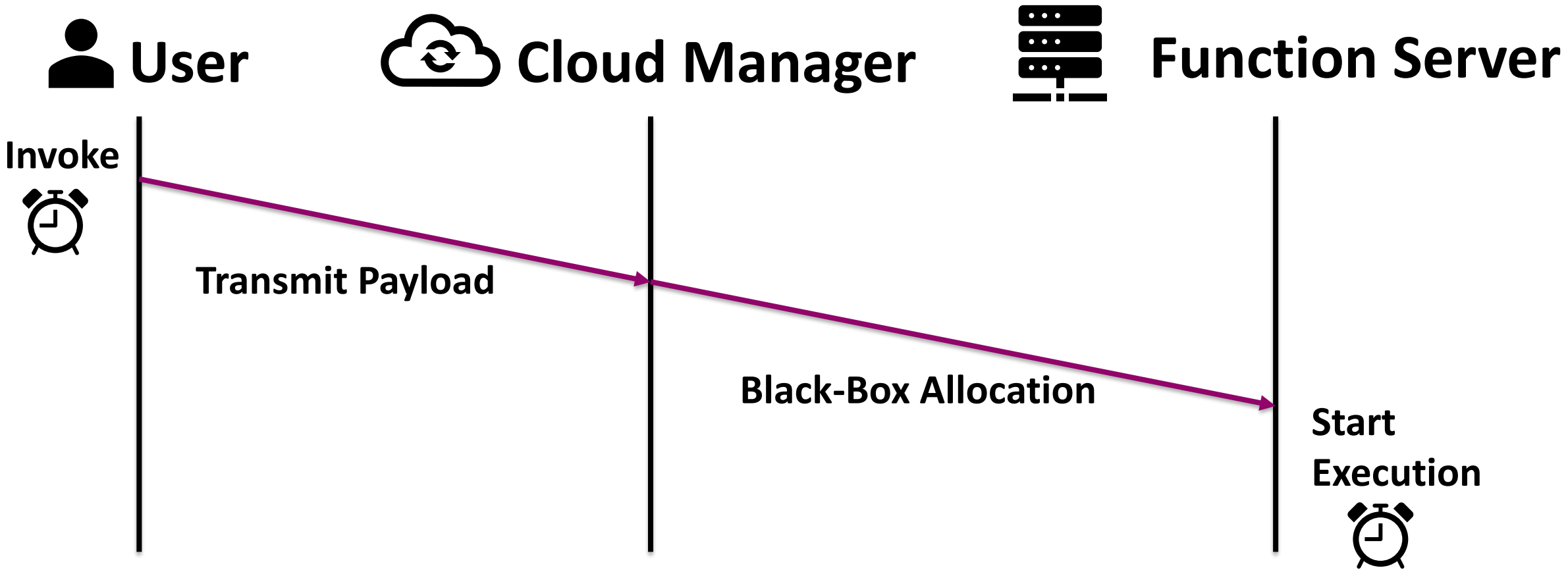

Solution: apply clock-drift estimation protocols!

FaaS Analysis: Invocation Overhead

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Configuration:

- Compare timestamps on client and function side.
- Clock drift estimation protocol.
- Payload: 1 kB – 5.9 MB

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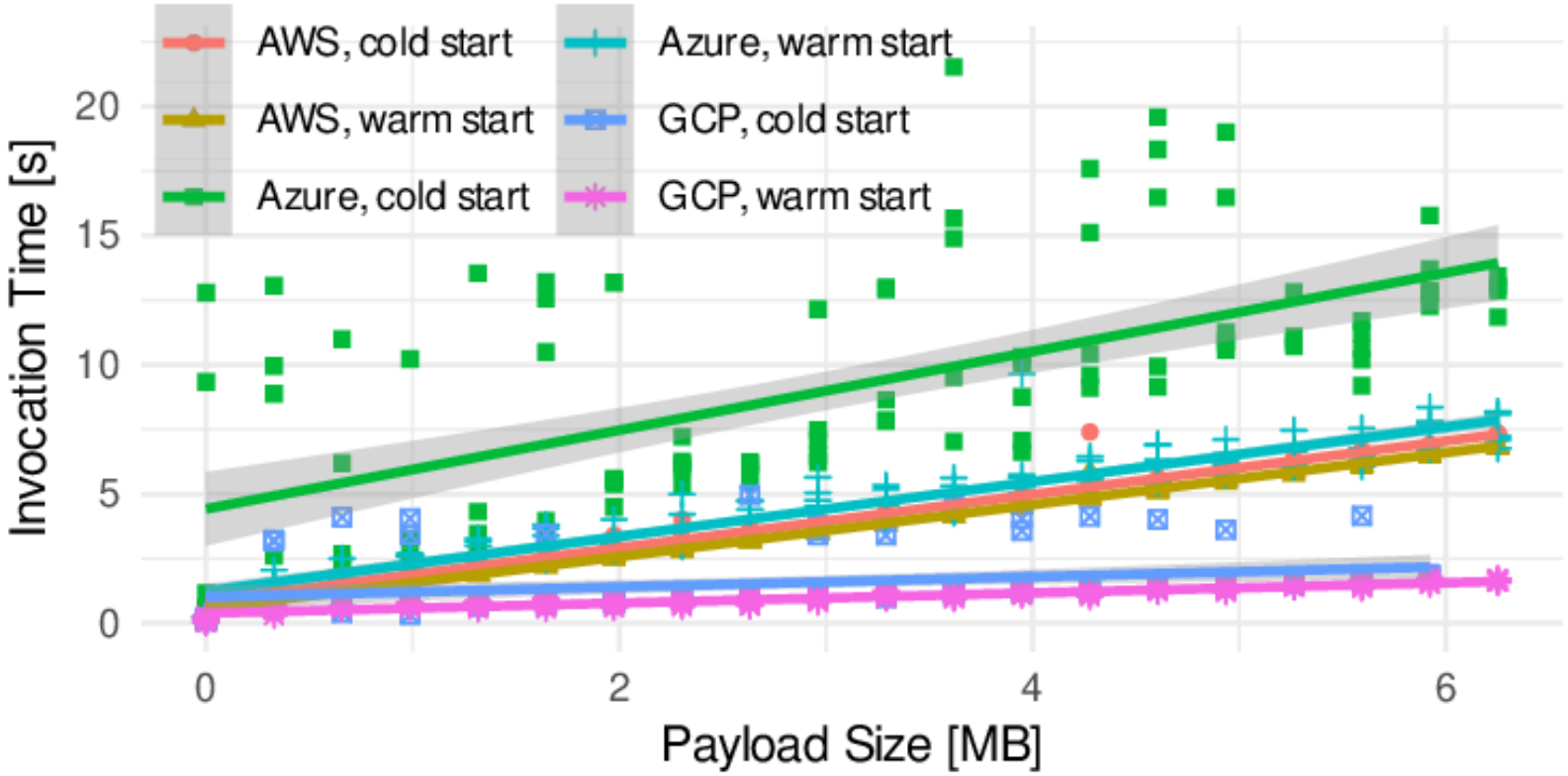

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Summary

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spcl/serverless-benchmarks

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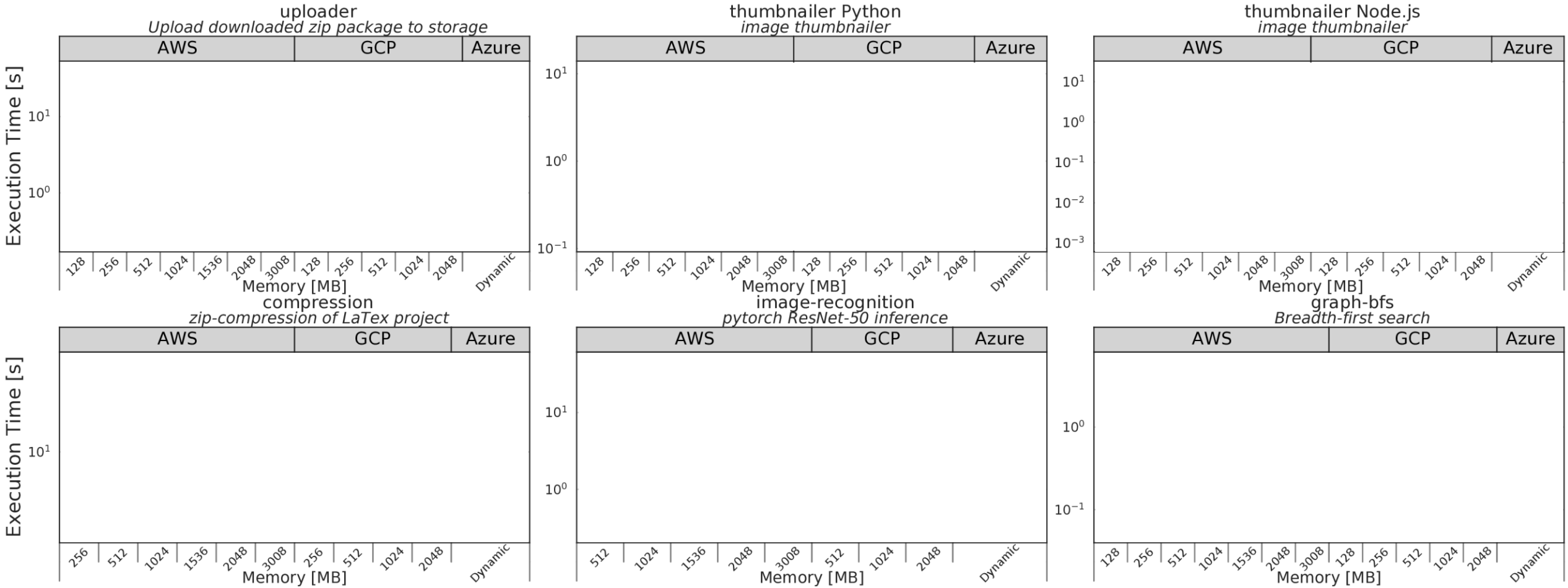

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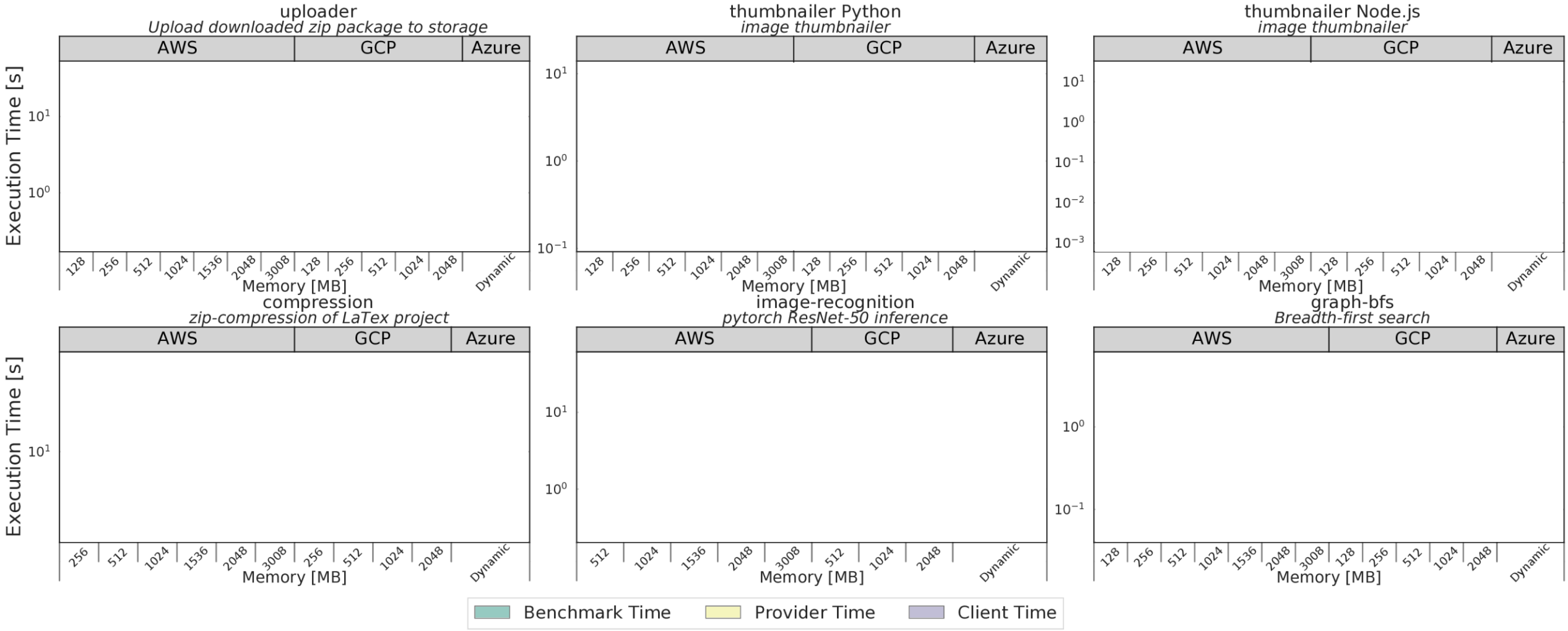

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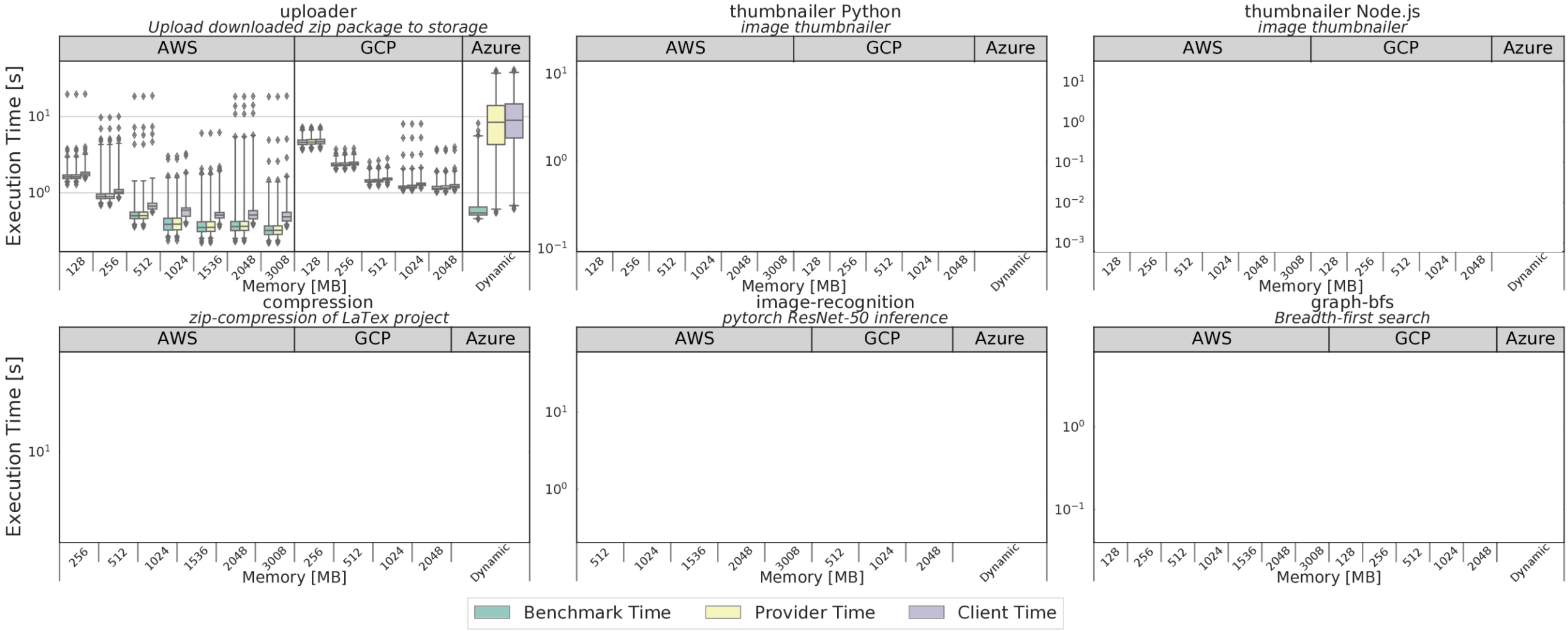

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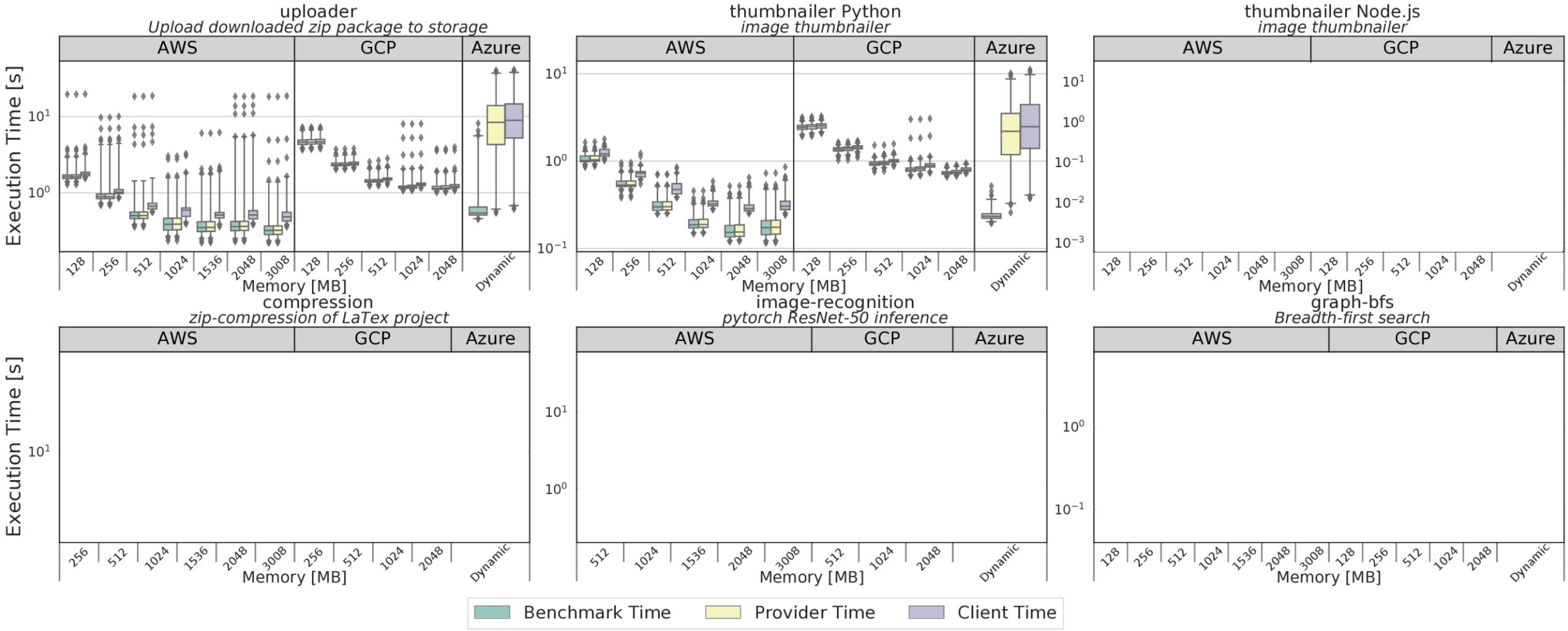

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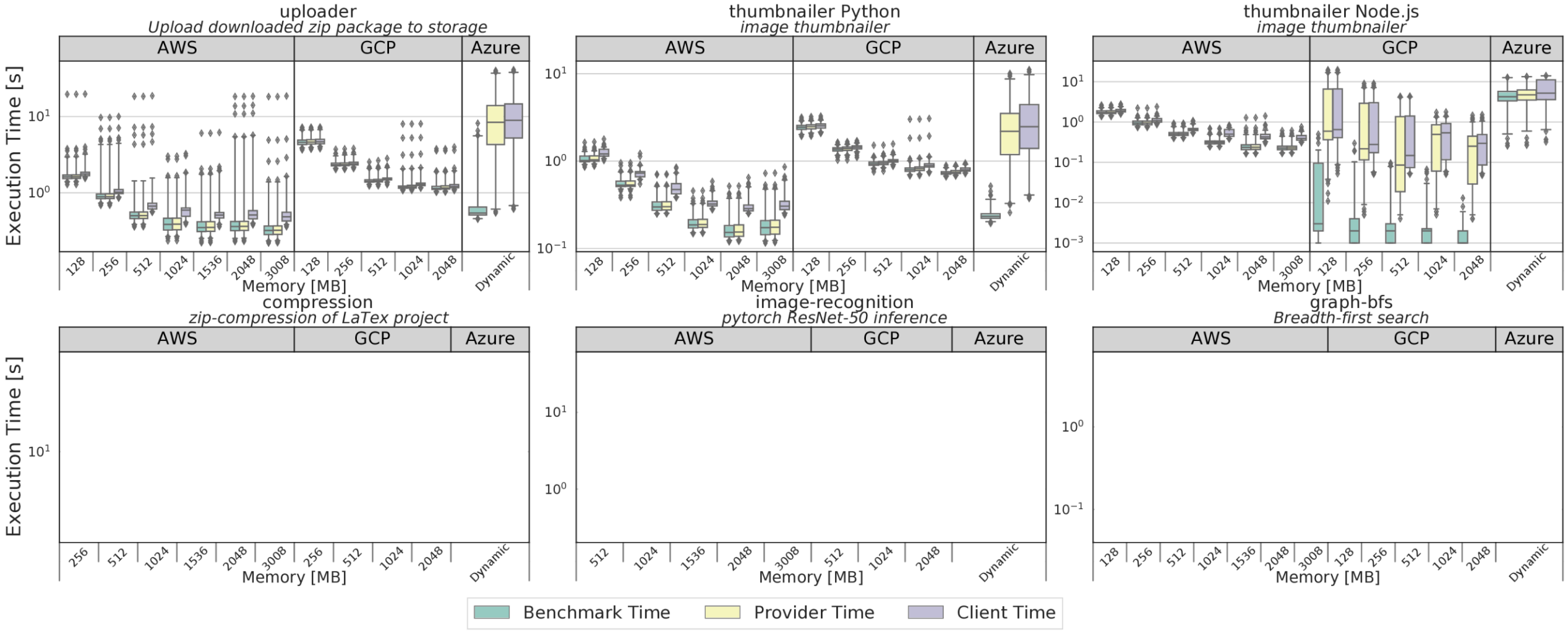

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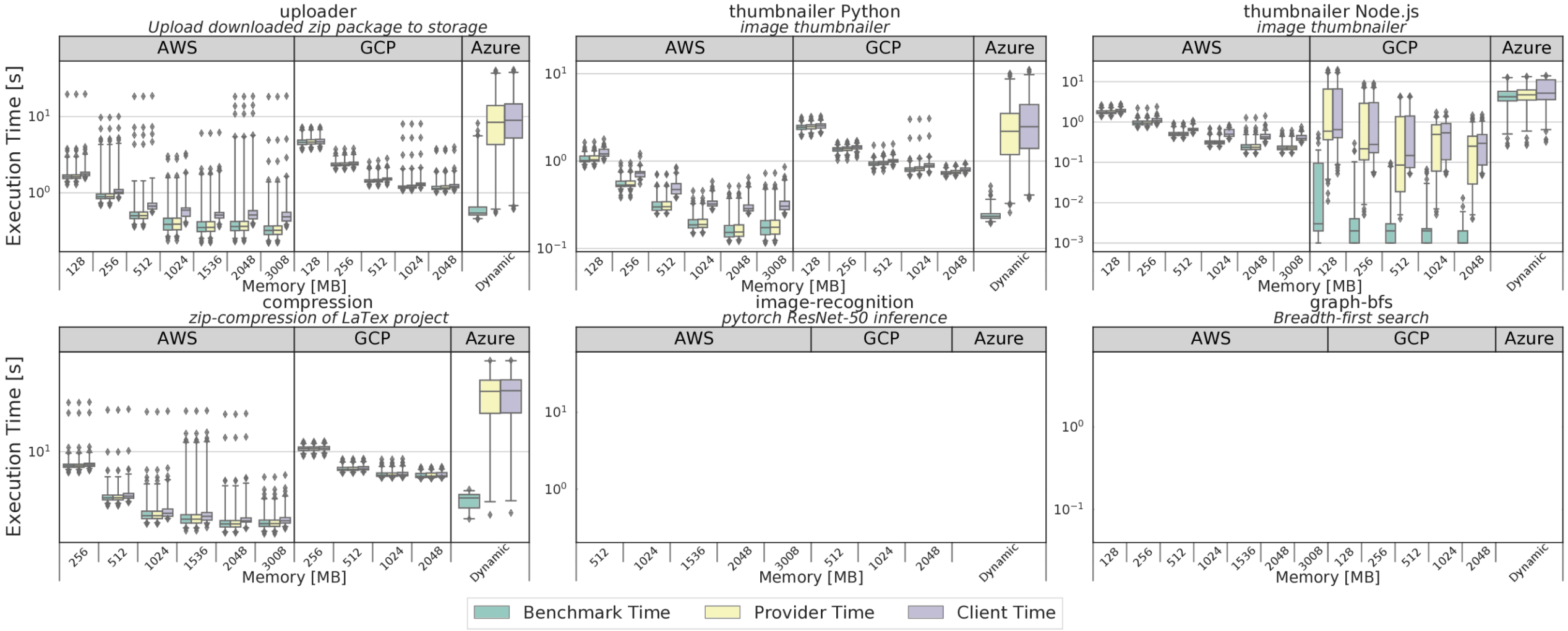

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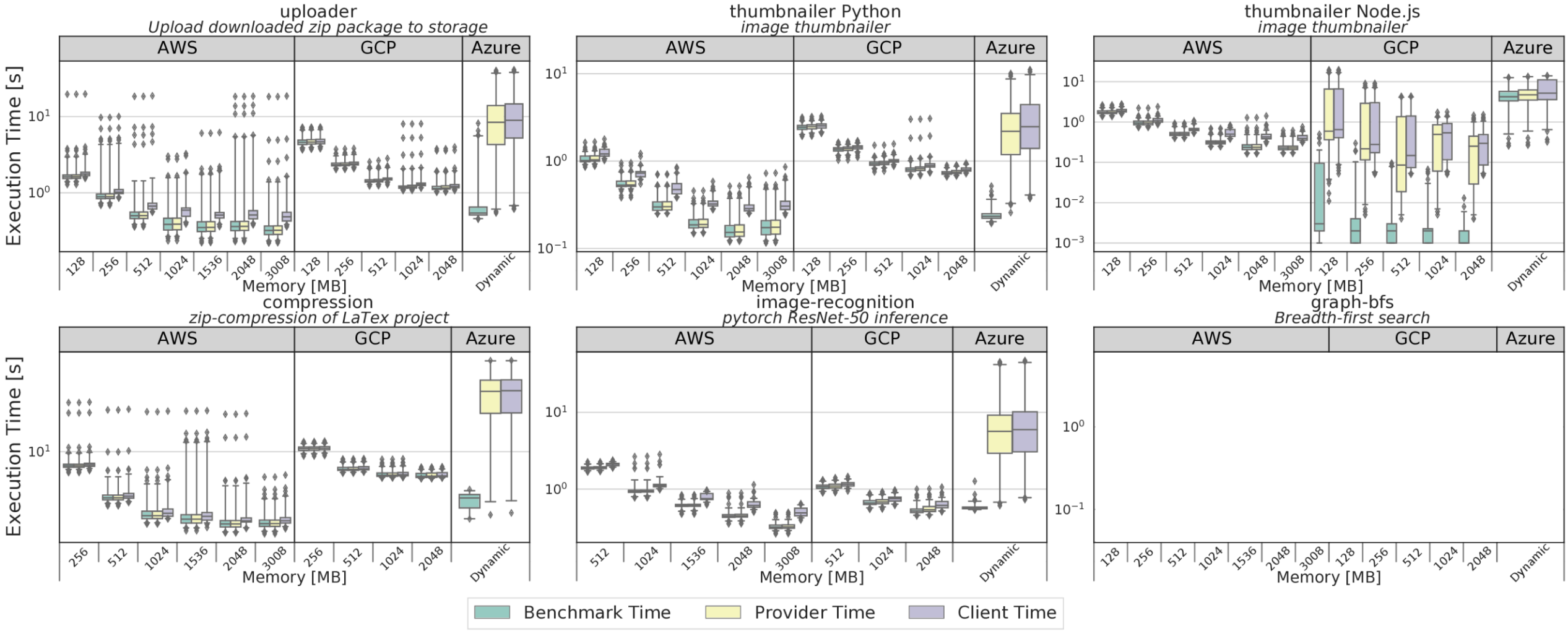

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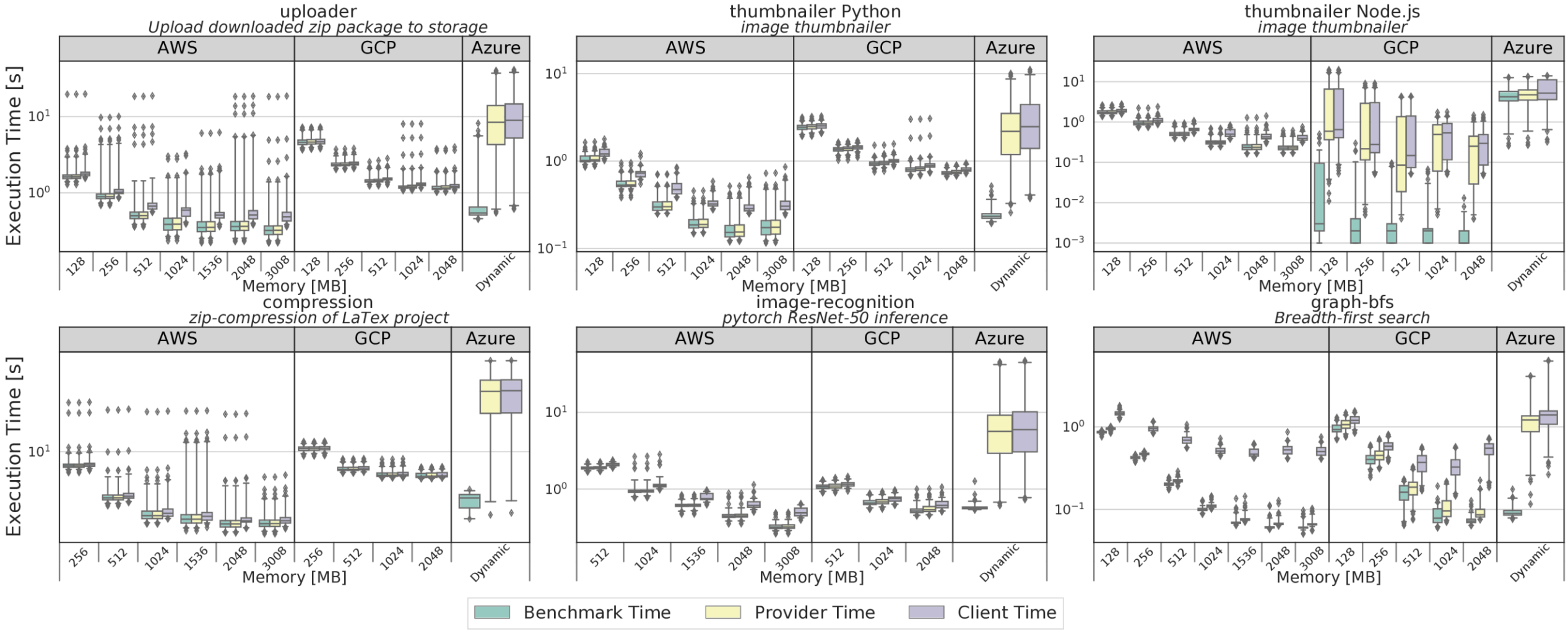

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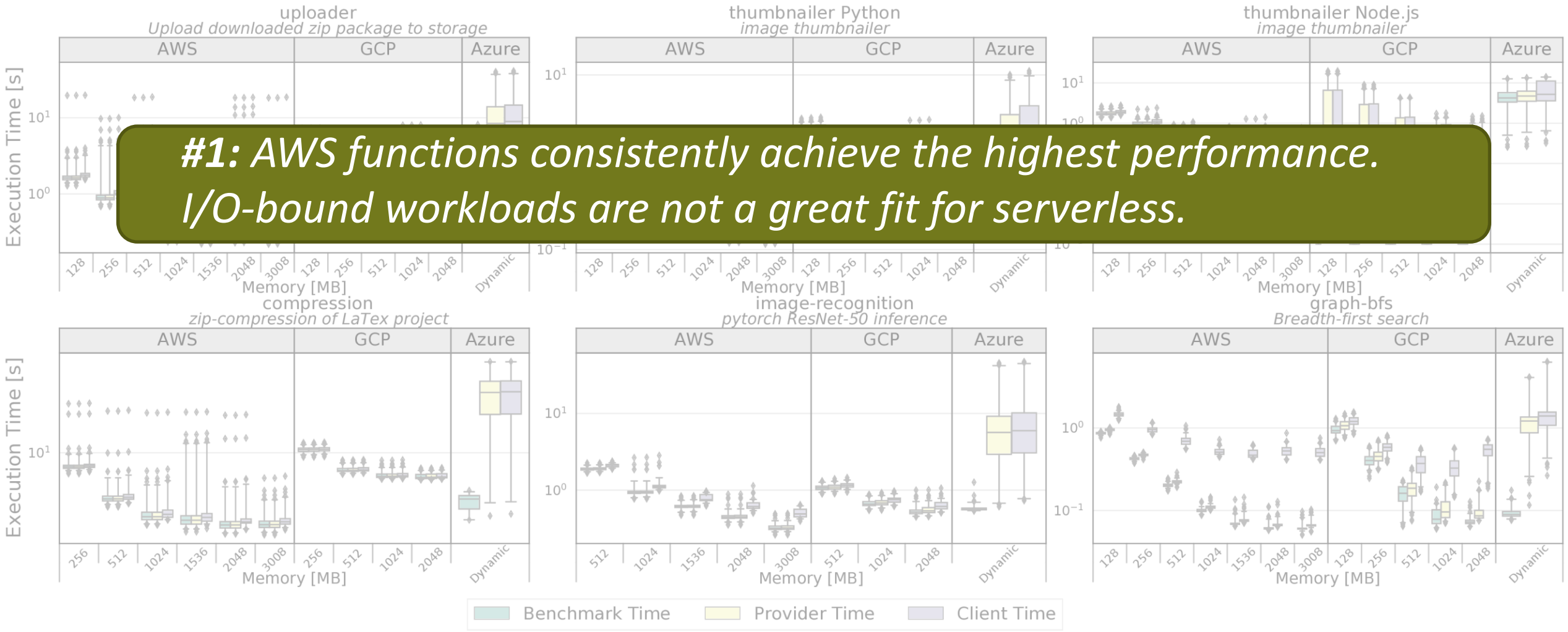

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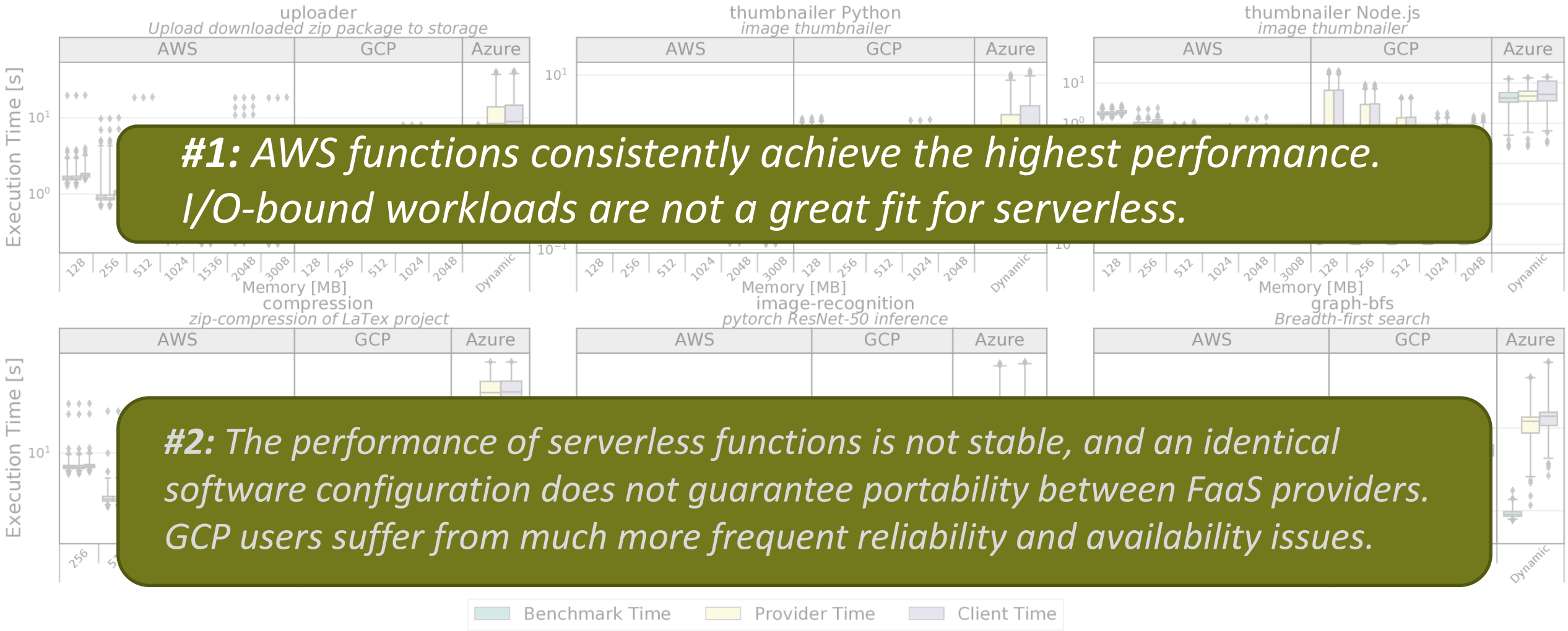

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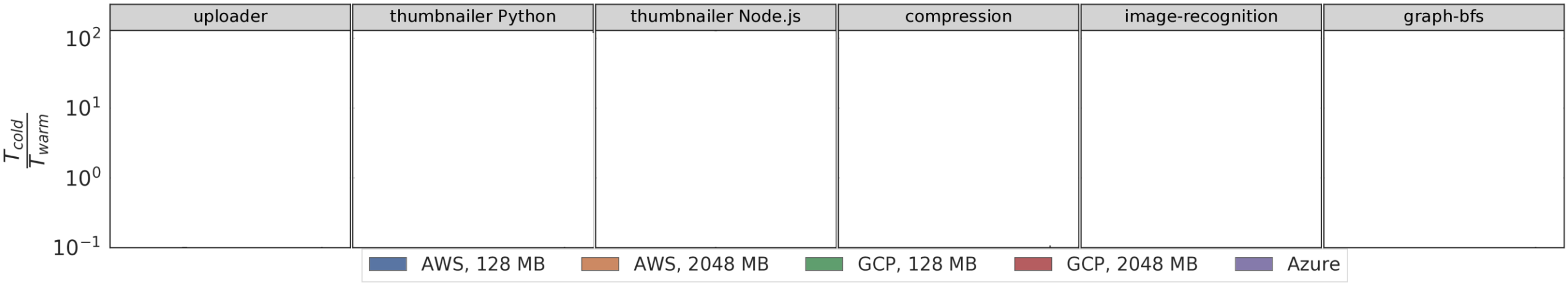
***#2:** The performance of serverless functions is not stable, and an identical software configuration does not guarantee portability between FaaS providers. GCP users suffer from much more frequent reliability and availability issues.*

Performance Analysis: Cold Startups



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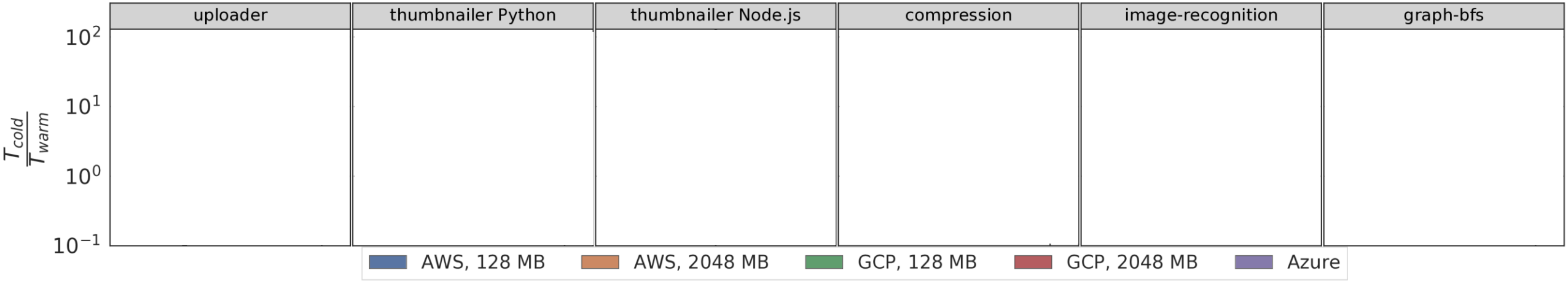

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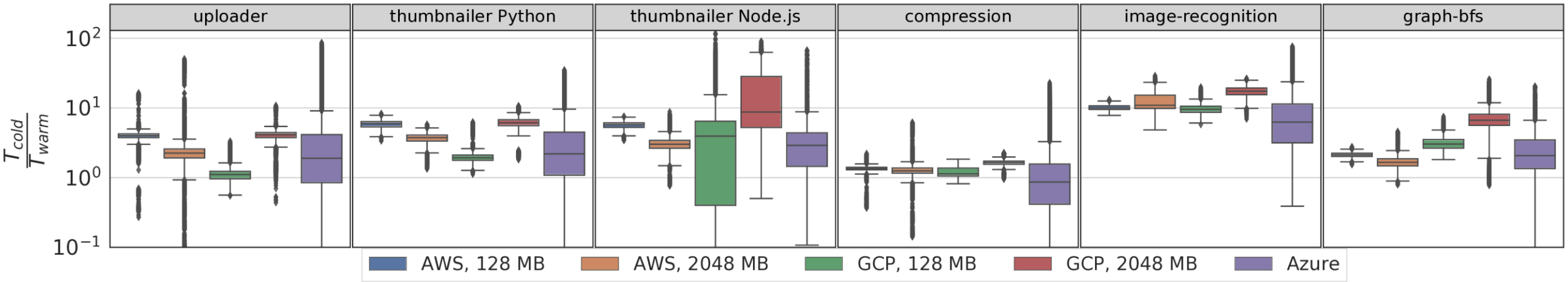

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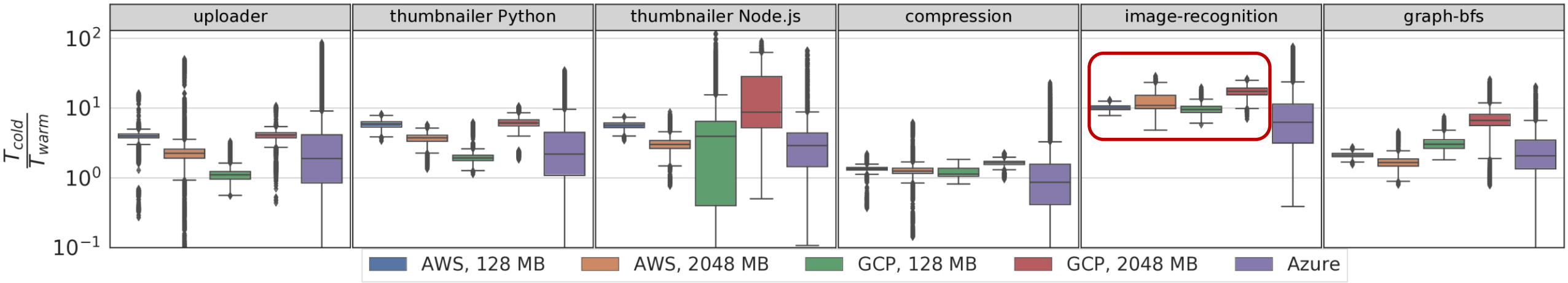

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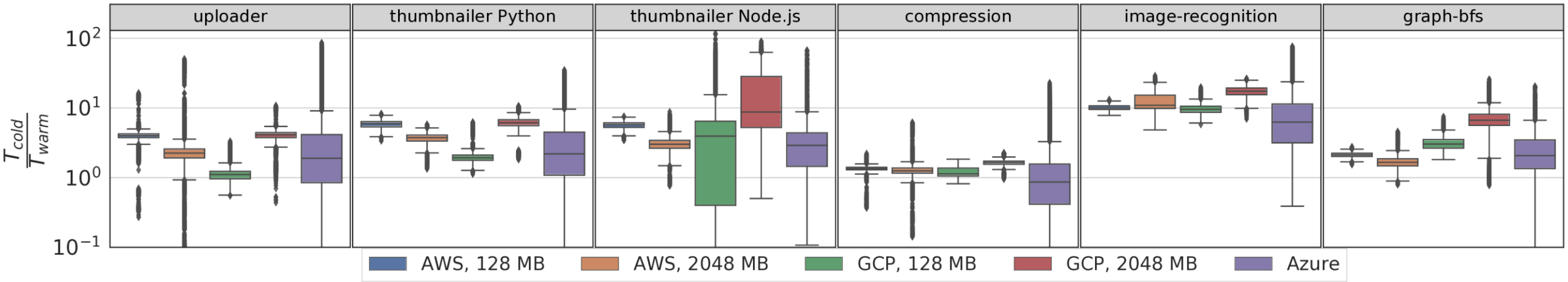

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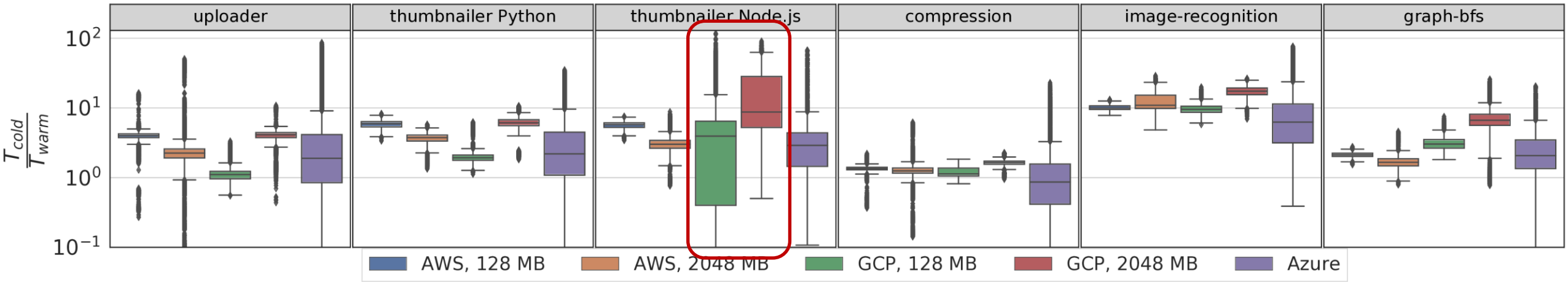
- **Azure Functions**: mixed cold and warm executions.

Performance Analysis: Cold Startups



Configuration:

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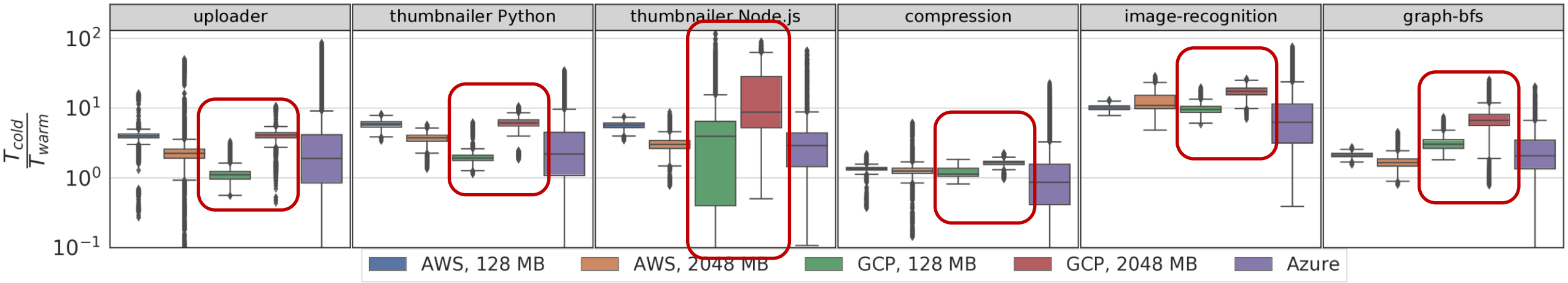
Performance Analysis: Cold Startups



Configuration:

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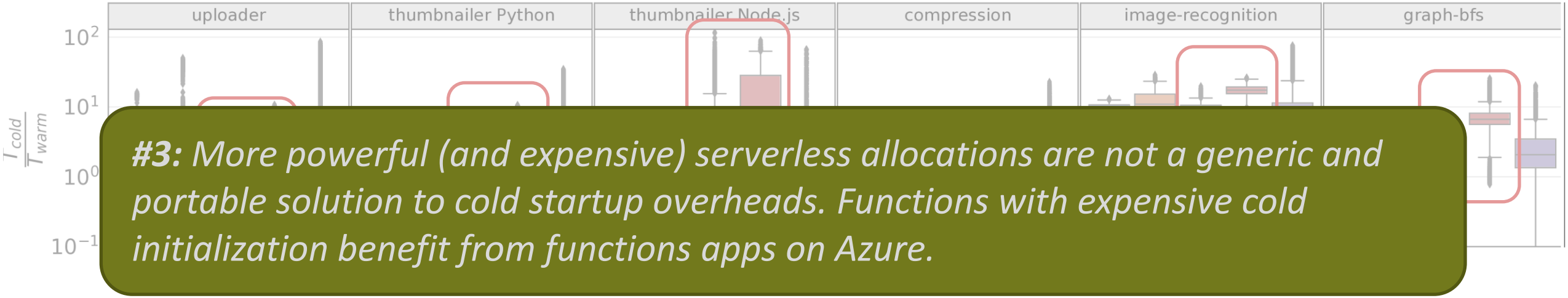
Performance Analysis: Cold Startups



***#3:** More powerful (and expensive) serverless allocations are not a generic and portable solution to cold startup overheads. Functions with expensive cold initialization benefit from functions apps on Azure.*

Configuration:

- **Measurements:** 200 warm and 200 cold executions.
- **Estimation:** all N^2 combinations of N warm and N cold executions.
- **Azure Functions**: mixed cold and warm executions.

Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search

Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS, Local Storage [s]						
IaaS, S3 [s]						
FaaS [s]						
Overhead, Local Storage						
Overhead, S3						
Memory [MB]						

Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS, Local Storage [s]						
IaaS, S3 [s]						
FaaS [s]						
Overhead, Local Storage						
Overhead, S3						
Memory [MB]						

Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.
- **Measurements:** 200 warm executions.

Performance Analysis: IaaS vs FaaS

	Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS, Local Storage [s]	0.216	0.045	0.166	0.808	0.203	0.03
IaaS, S3 [s]	0.316	0.13	0.191	2.803	0.235	0.03
FaaS [s]	0.389	0.188	0.253	2.949	0.321	0.075
Overhead, Local Storage	1.79x	4.14x	1.43x	3.65x	1.58x	2.49x
Overhead, S3	1.23x	1.43x	1.24x	1.05x	1.37x	2.4x
Memory [MB]	1024	1024	2048	1024	3008	1536

Configuration:

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- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.
- **Measurements:** 200 warm executions.

Performance Analysis: IaaS vs FaaS

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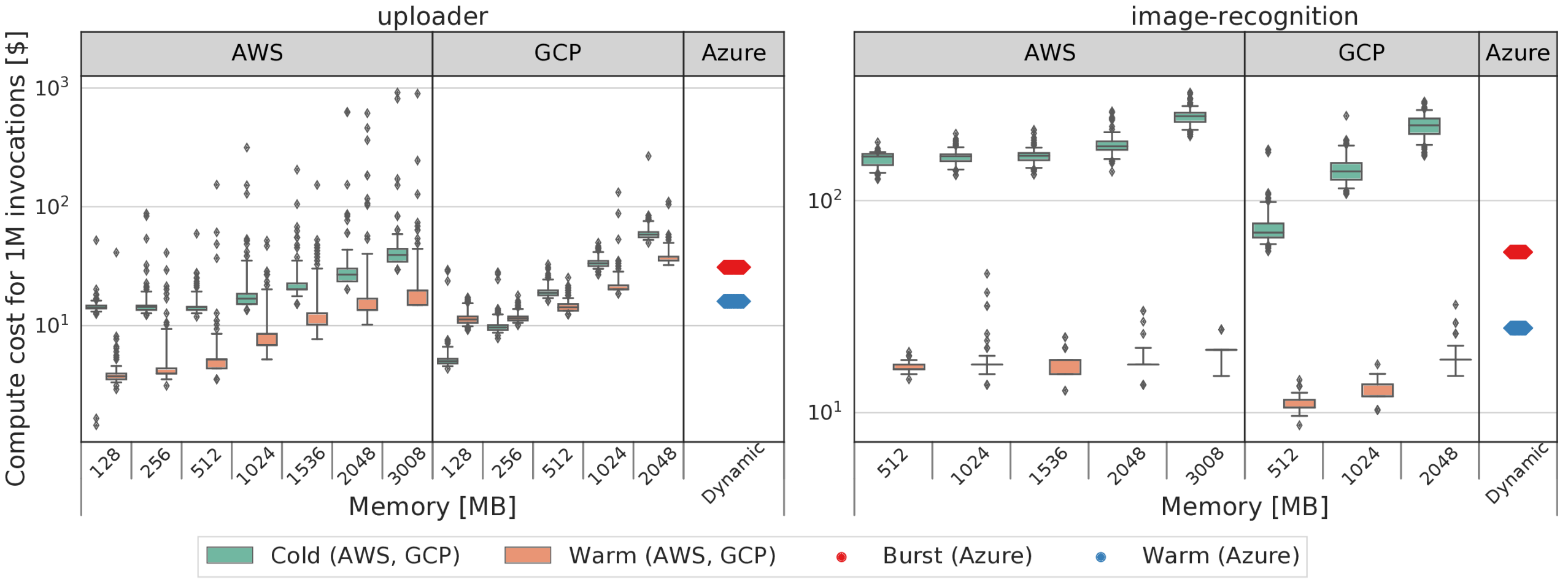
IaaS, S3 [s]	0.316	0.13	0.191	2.803	0.235	0.03
Faa						
Ove						
Ove						
Memory [MB]	1024	1024	2048	1024	3008	1536

***#4:** Performance overheads of FaaS executions are not uniformly distributed across application classes. The transition from a VM-based deployment to serverless architecture is currently accompanied by significant performance losses.*

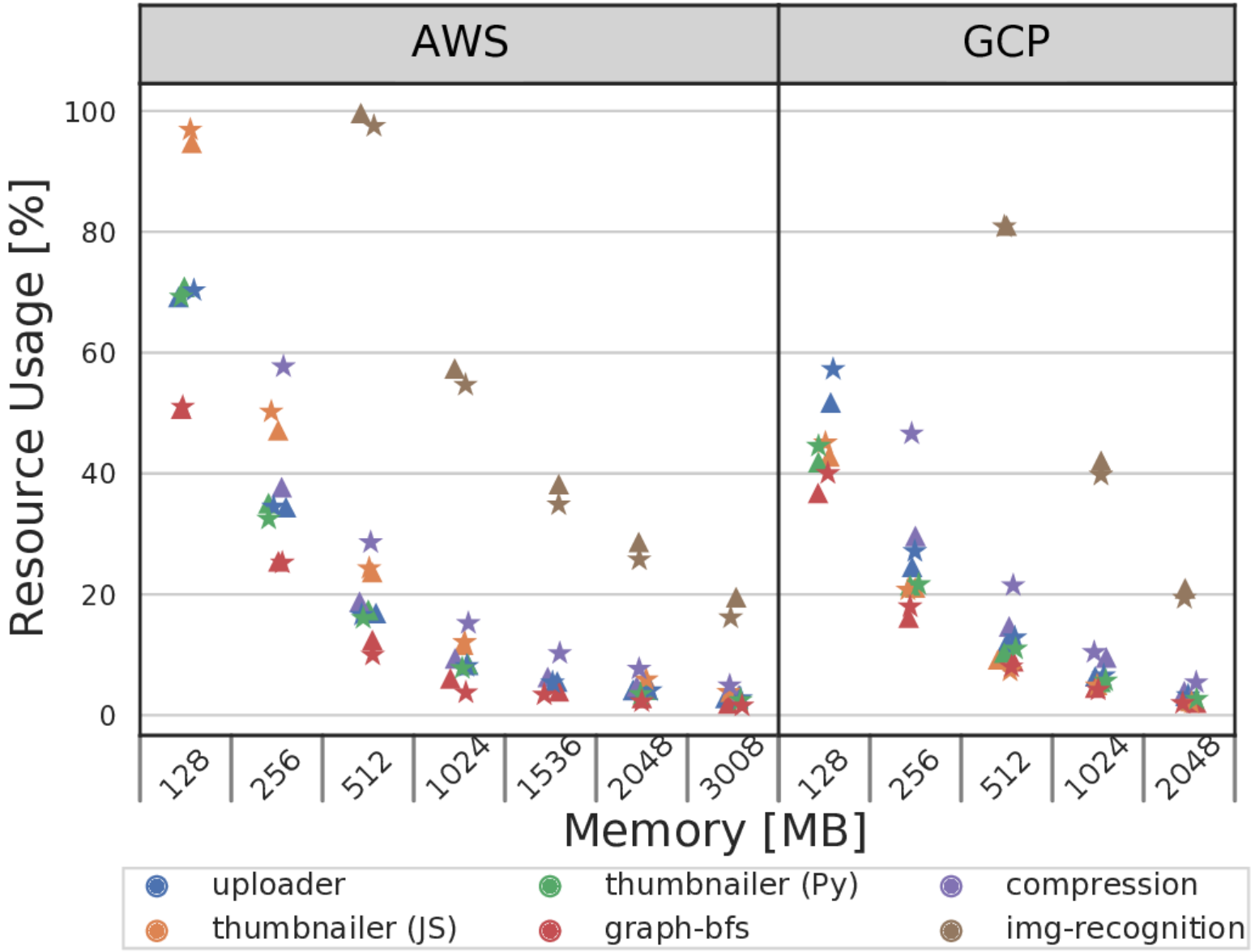
Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.
- **Measurements:** 200 warm executions.

Cost Analysis: Eviction Modeling



Cost Analysis: Eviction Modeling



Cost Analysis: FaaS vs IaaS

		Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS							
FaaS							

Cost Analysis: FaaS vs IaaS

		Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS							
FaaS							

Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM, 100% utilization, $0.011 6/h.
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.

Cost Analysis: FaaS vs IaaS

		Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS	Local Storage [req/h]						
	Cloud Storage [req/h]						
FaaS	Eco 1M [$]						
	Eco Break-Even						
	Perf 1M [$]						
	Perf Break-Even						

Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM, 100% utilization, $0.011 6/h.
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.

Cost Analysis: FaaS vs IaaS

		Uploader	Thumbnailer Python	Thumbnailer Node.js	Compression	Image Recognition	Breadth-First Search
IaaS	Local Storage [req/h]	16627	79282	21697	4452	17658	119272
	Cloud Storage [req/h]	11371	27503	18819	1284	15312	117153
FaaS	Eco 1M [$]	3.54	2.29	3.75	32.1	15.8	2.08
	Eco Break-Even	3275	5062	3093	362	733	117153
	Perf 1M [$]	6.67	3.34	10	50	19.58	2.5
	Perf Break-Even	1740	3480	1160	232	592	4640

Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM, 100% utilization, $0.011 6/h.
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.

Cost Analysis: FaaS vs IaaS

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	Perf Break-Even	1740	3480	1160	232	592	4640

Configuration:

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FaaS	Perf Break-Even	1740	3480	1160	232	592	4640

***#7:** The IaaS solution delivers better performance at a lower price, but only in systems where high utilization is achieved.*

Configuration:

- **IaaS:** AWS t2.micro instance with 1 vCPU and 1 GB RAM, 100% utilization, $0.011 6/h.
- **FaaS**: AWS Lambda.
- **Local storage**: Minio as Docker container.