Doppler: Understanding Serverless Query Execution

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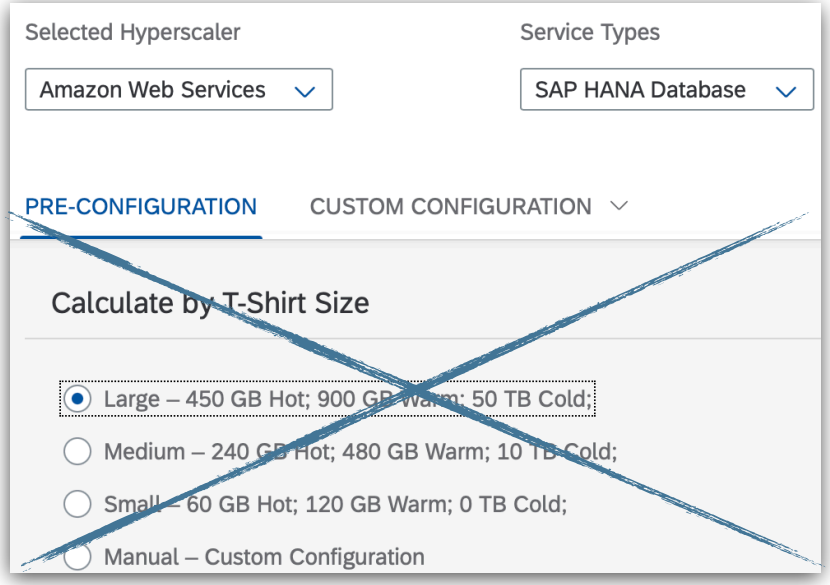
Serverless Service Paradigm

Economics

- Providers offer services with different economic model
- Customers pay for **consumption** instead of **capacity**
- Customers benefit when **resource utilization** is **low**, i.e., workload prediction and capacity planning are difficult
- Providers **charge extra** to compensate underutilization



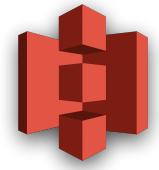
SAP HANA Cloud Capacity Unit Estimator

- Assumption: Providers are better at using resources, because of their scale

Serverless Service Paradigm
Technology

- No burden of provisioning or managing resources (like servers, thus the term *serverless*)
- No scaling, load balancing, failure tolerance, .. in distributed systems
- Infrastructure and database services moving towards consumption-based model

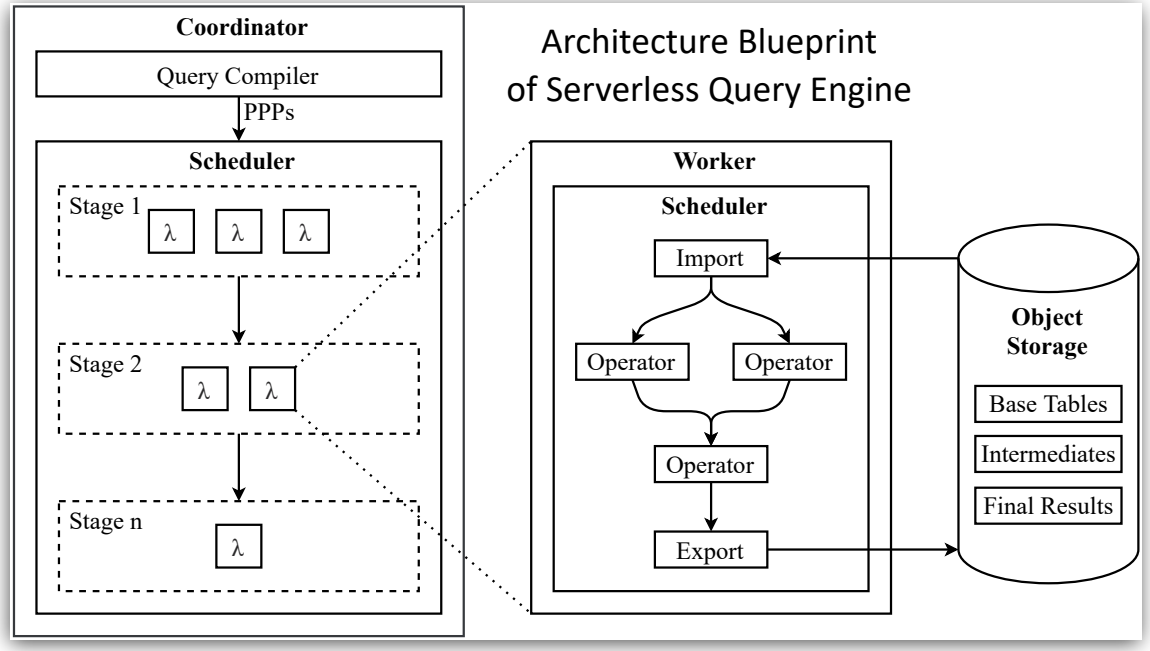
- Serverless infrastructure as an *emergent distributed environment*
  - Serverless storage (e.g., Amazon S3): Scale from bytes to EB, high-throughput, cheap
  - Serverless compute (e.g., AWS Lambda)
    - Execute pieces of code in any programming language
    - Spawn tiny, short-lived, and stateless workers in milliseconds
    - Scale to 10,000s of workers, enabling large-scale query processing


Amazon S3


AWS Lambda

Serverless Query Execution

- FaaS-based, shared-storage database architecture
  - Exploits serverless cloud infrastructure for compute and storage elasticity
  - Demonstrates cost and performance benefits for interactive queries on cold data
- Compute tier runs pipelines of query operators in cloud function workers
- Storage tier holds base tables and intermediate/final results as immutable, column-oriented, compressed objects



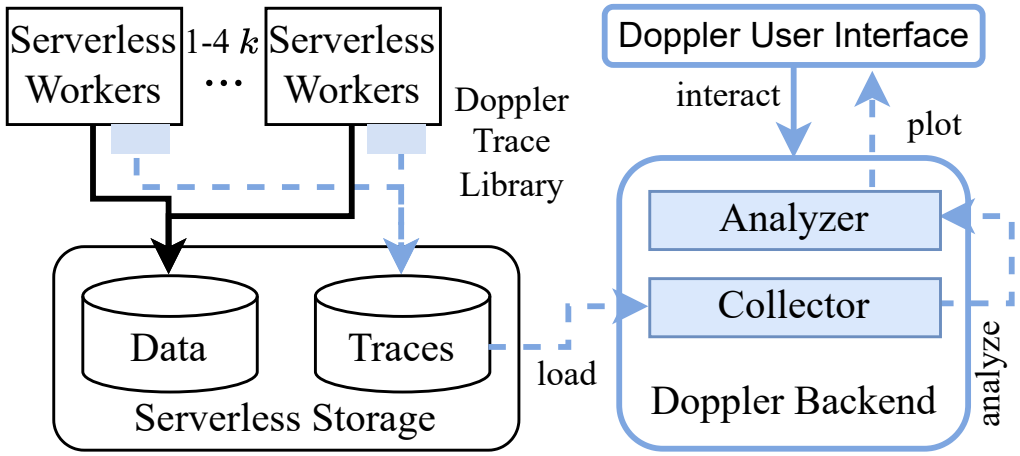
[1] Perron et al. Starling: A Scalable Query Engine on Cloud Function Services. In SIGMOD 2020.
[2] Müller et al. Lambada: Interactive Data Analytics on Cold Data Using Serverless Cloud Infrastructure. In SIGMOD 2020.
[3] Cai et al. Integrated Querying of SQL database data and S3 data in Amazon Redshift. In IEEE Data Engineering Bulletin 2018.

Challenges in Understanding Serverless Query Execution

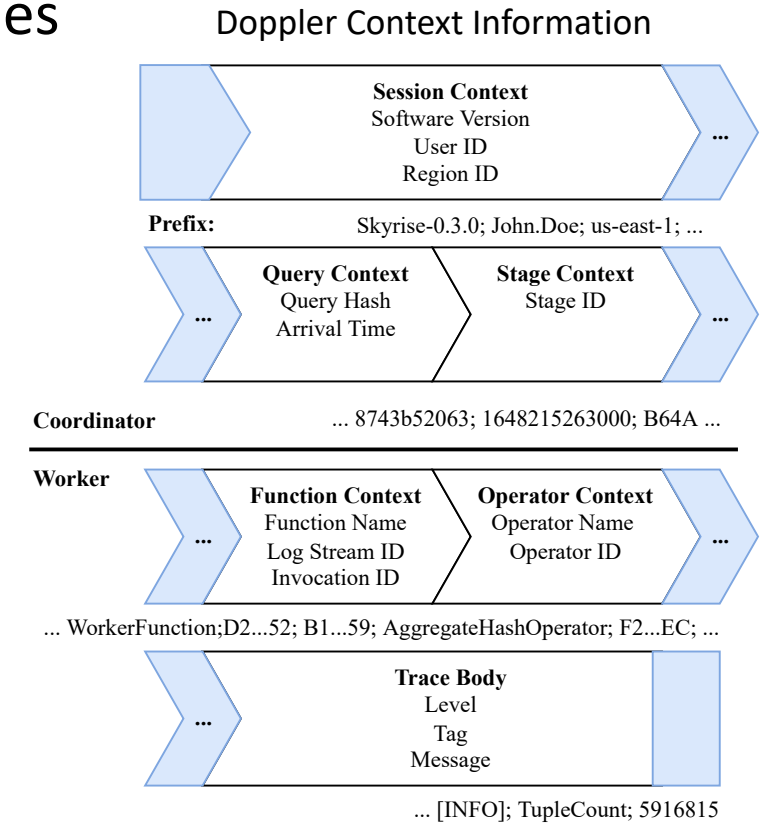
- Analyzing query execution dynamics in cloud-based distributed databases is difficult
- Serverless query execution is more challenging!
  - Impedes understanding, maturity, and adoption of technology
- Observing large ephemeral clusters of stateless workers
- Contextualizing, integrating and analyzing distributed query traces
- Timely and with little cost and performance overhead

Doppler: Debugging and Performance Profiling for Serverless Query Execution

- Toolkit for post-mortem analysis of serverless queries
- Puts query context into traces to relate traces back to semantic parts of a query
- Collects traces from cloud functions via library that wraps most basic persistent log service
- Integrates and analyzes distributed traces



Doppler Architecture



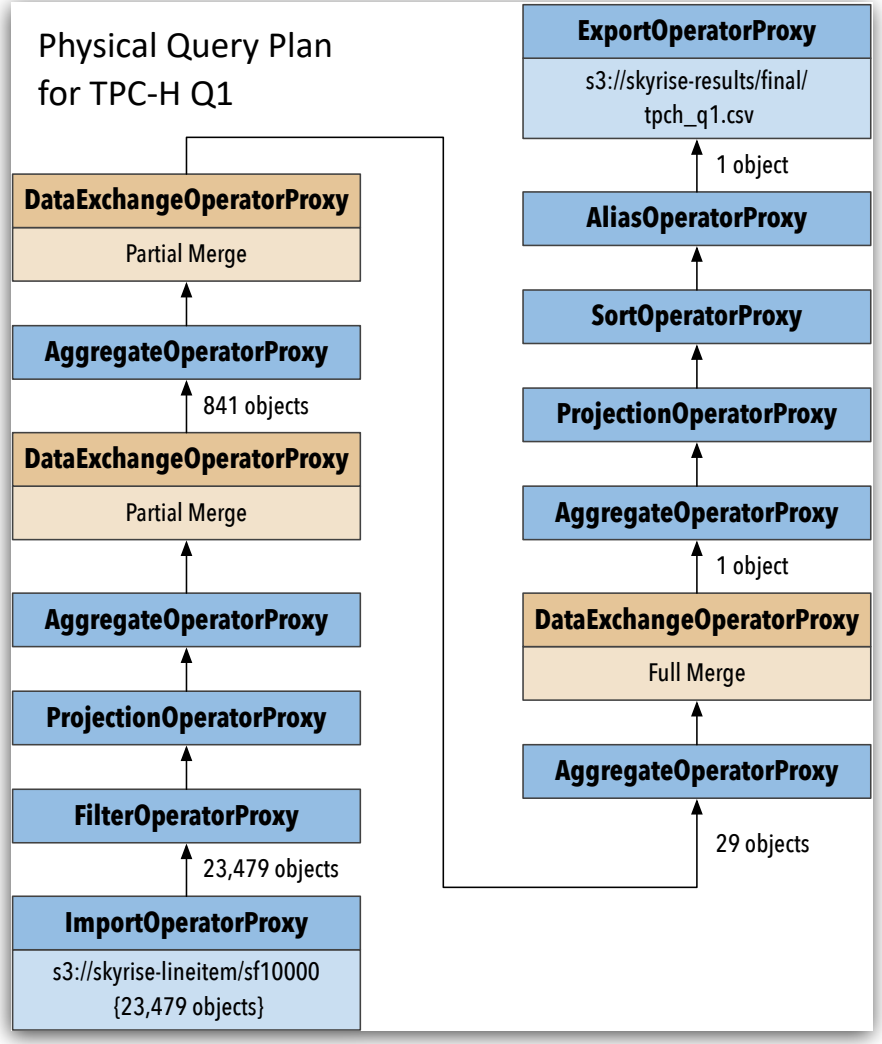
Demonstration of Doppler
Scenarios

- Straggling query workers
  - Stragglers taking much longer than other workers severely impact performance
  - Can occur due to a variety of reasons across hardware/software stack, data skew, ..
  - We induce at random 5s delays into query operators
- Serverless function concurrency limit
  - Cloud functions are subject to provider-side cluster size limits
  - We restrict our worker functions to run at low concurrency
- Local node errors
  - A distributed system is still subject to all local error types
  - We inject at random non-fatal errors into query operators

Demonstration of Doppler

Setup

- We integrate Doppler with the Skyrise query processor
- Standard TPC-H benchmark query #1
- On datasets of scale factors 1 to 10,000 (10 TB)
  - Stored in columnar, compressed ORC files
- In AWS region US-East-1
  - No “serverful” resources running
  - Max. Lambda concurrency 20,000 instances
  - Coordinator instance at 10 GB, workers at 4 GB



[1] Bodner. Elastic Query Processing on Function as a Service Platforms. In VLDB PhD Workshop 2020.

Demonstration of Doppler

Outline

1. Local CLI invokes serverless coordinator with SQL query string

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skyrise> Run q=1 sf=1000;
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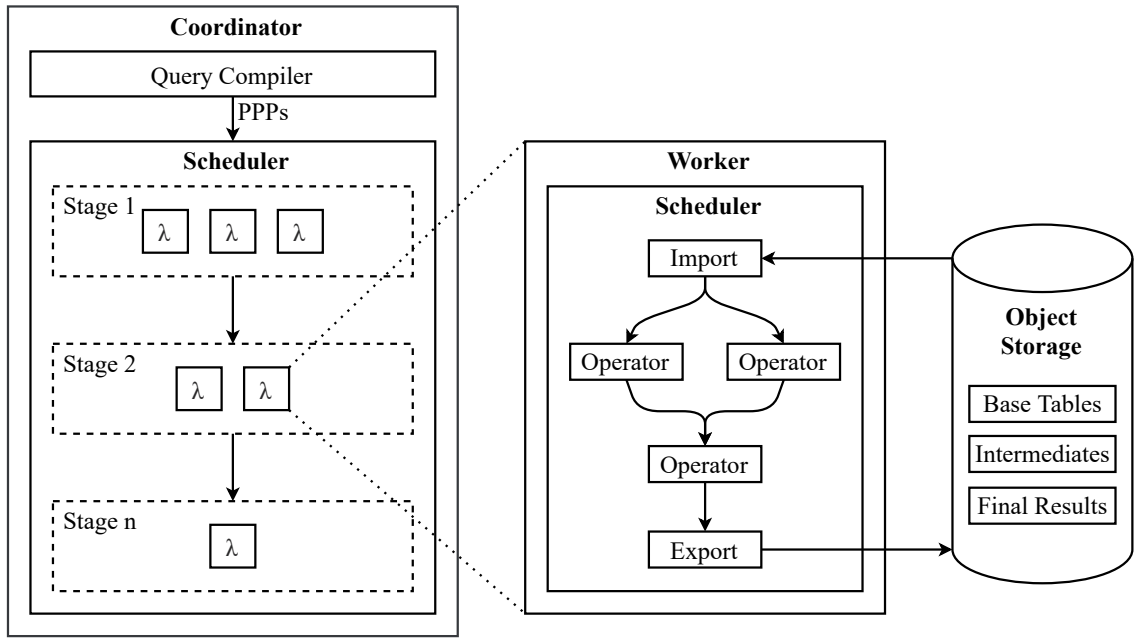

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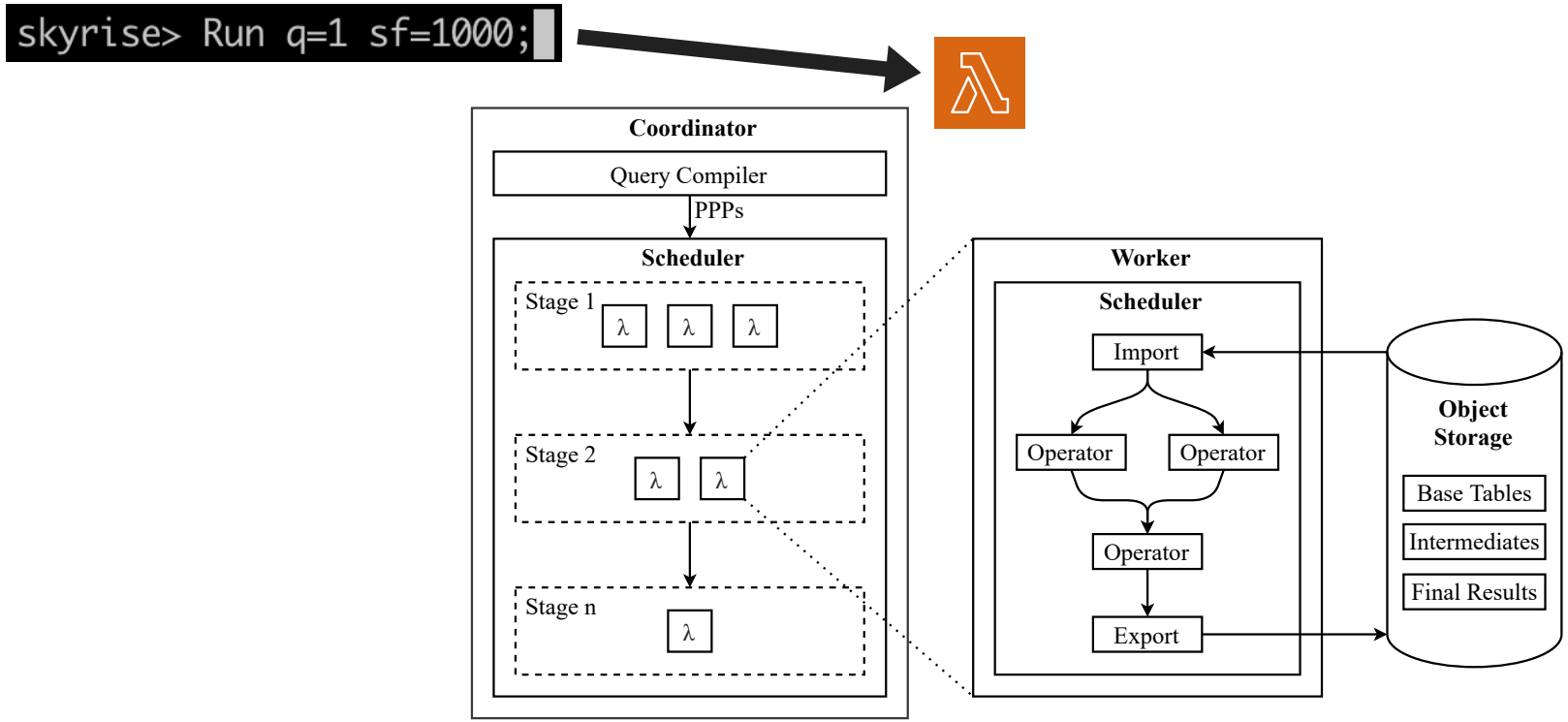

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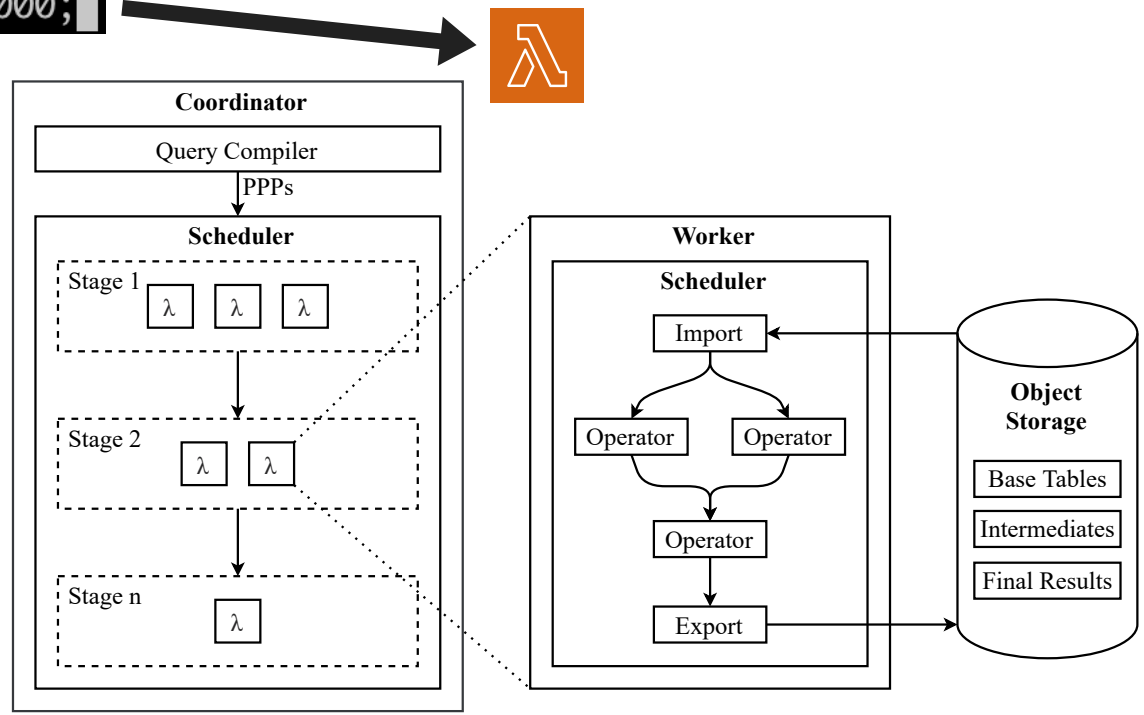

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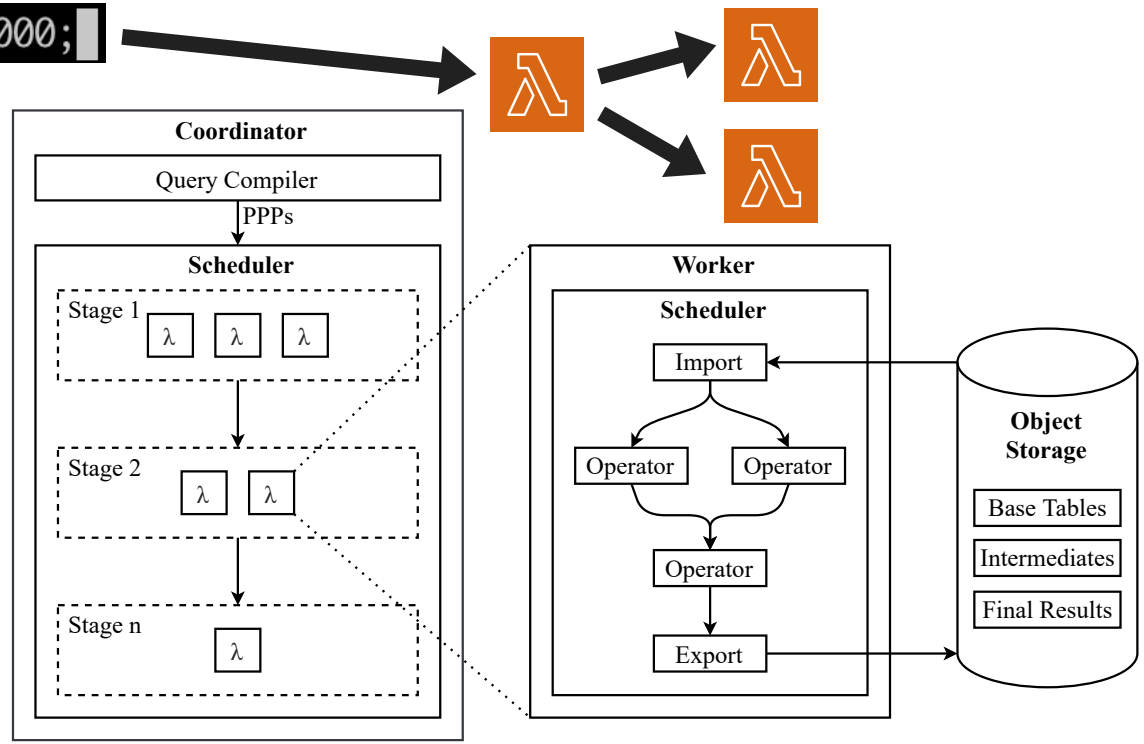

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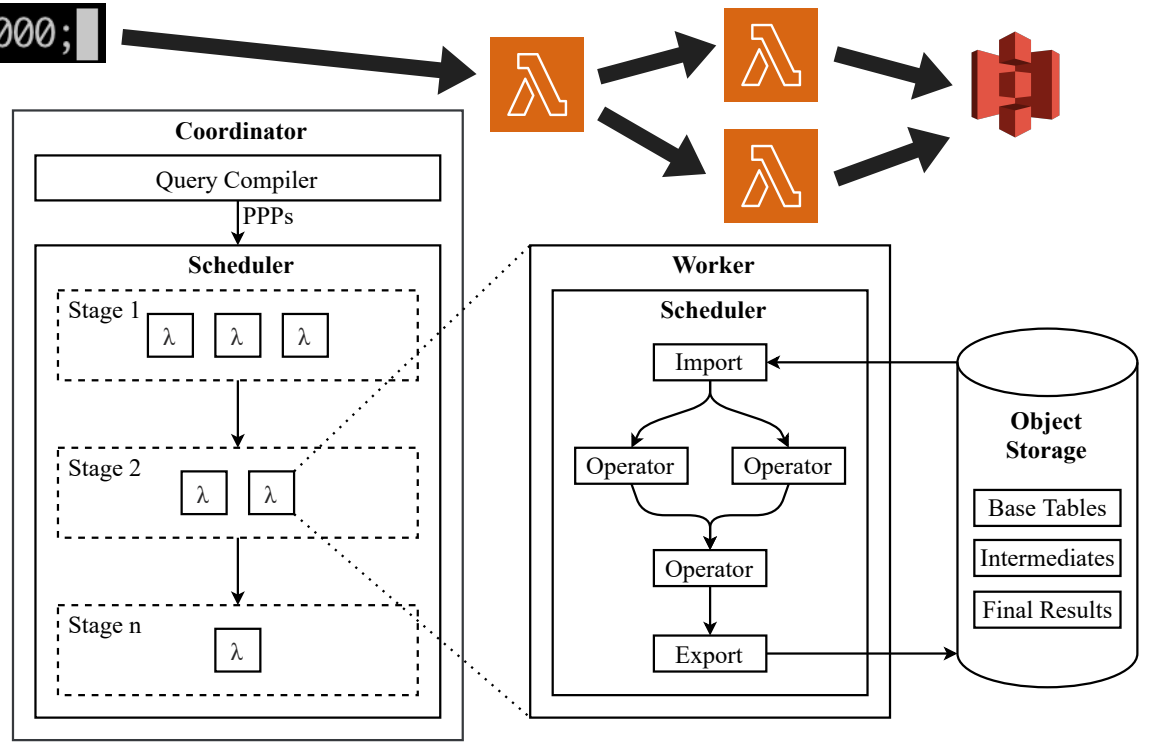

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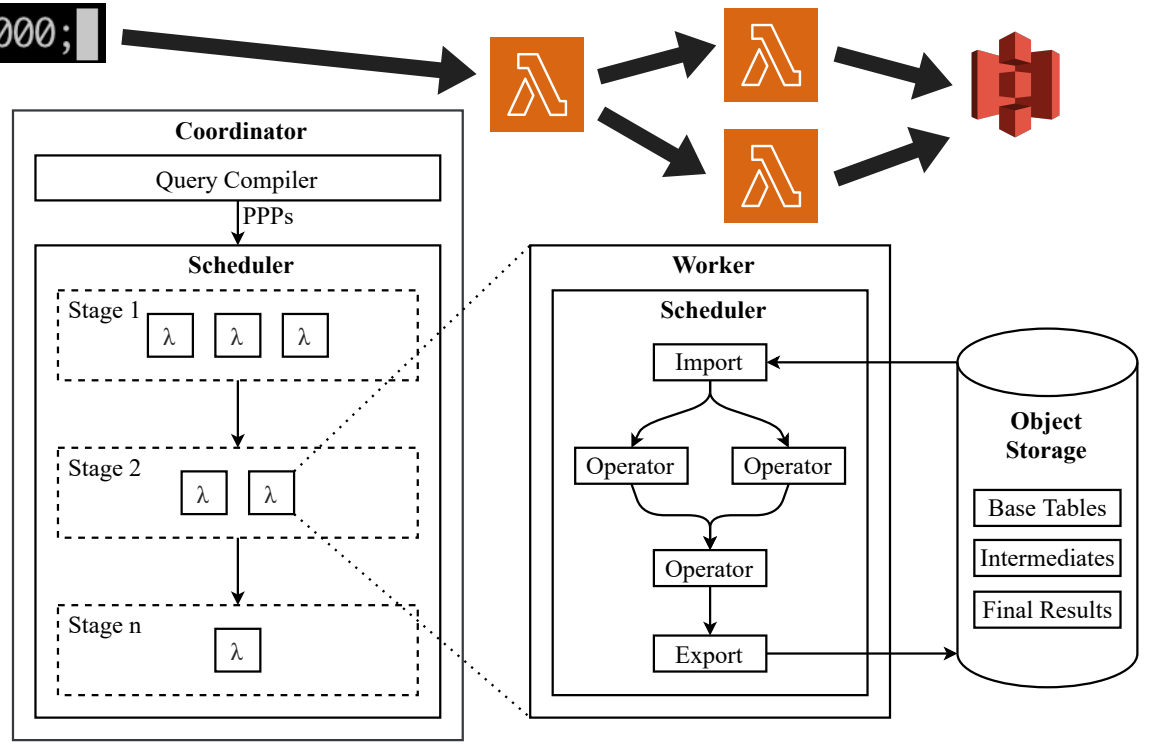

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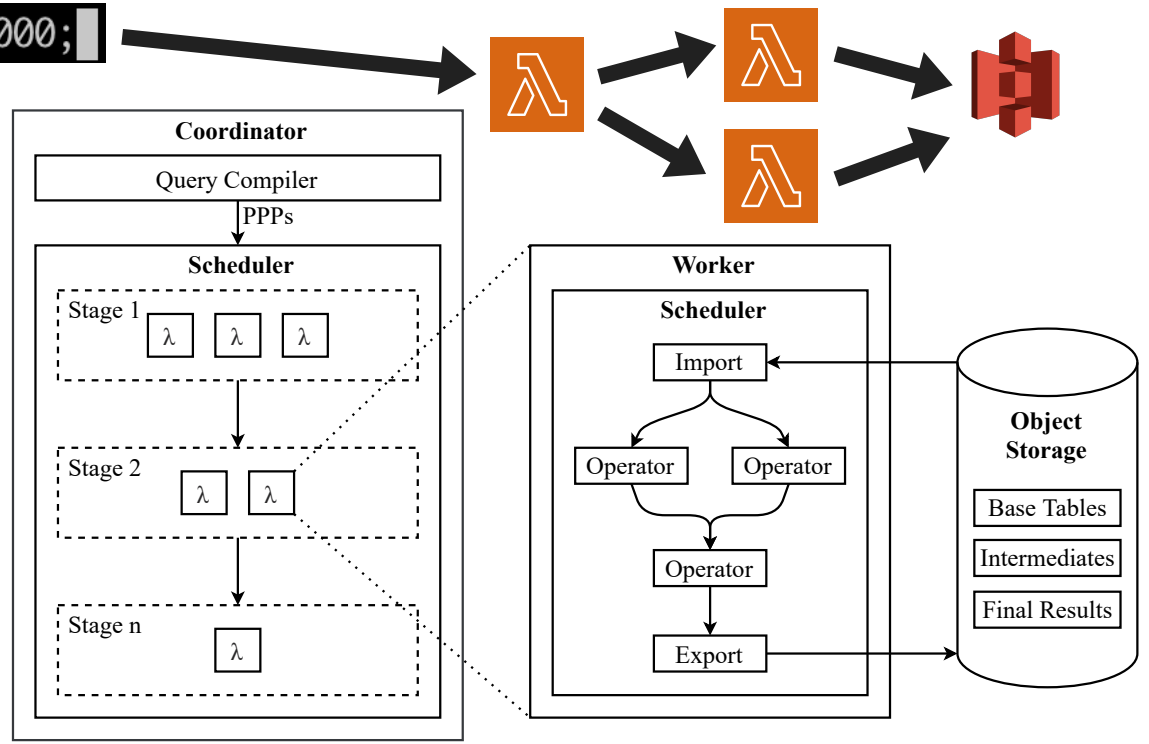
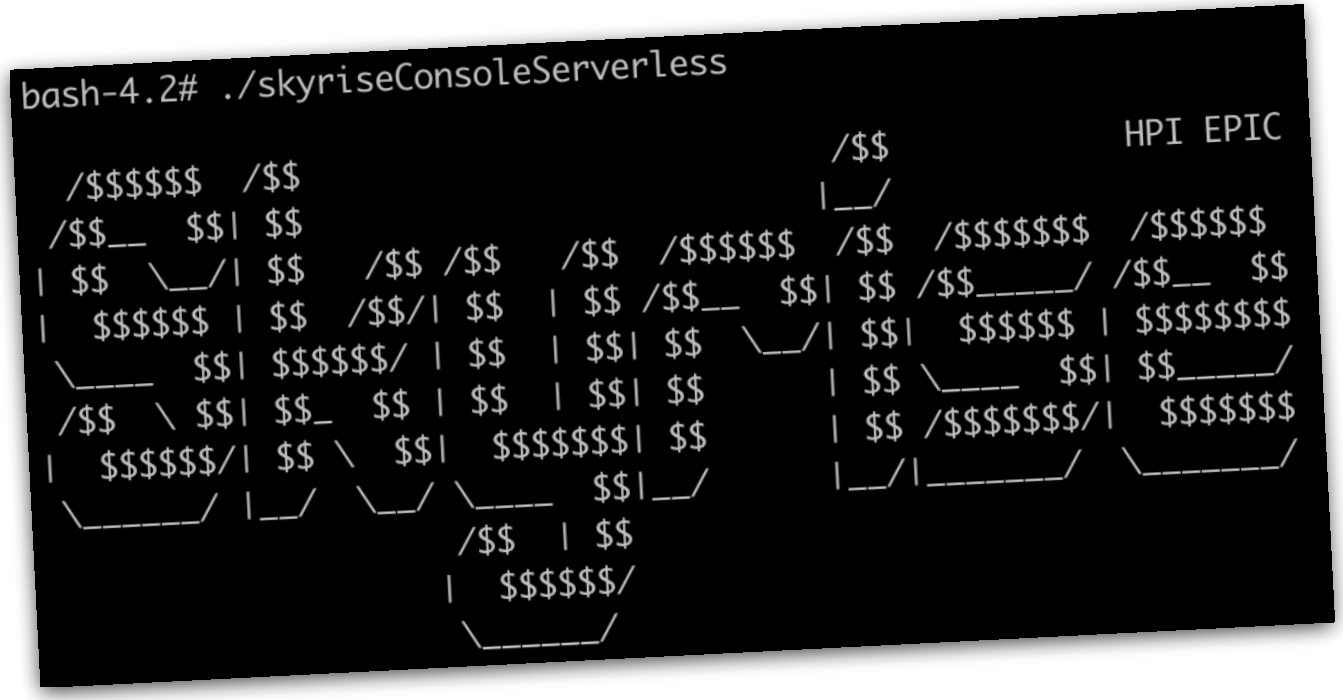


6. Local Doppler backend collects traces based on query handle and analyzes traces

Demonstration of Doppler Debugging and Performance Profiling Toolkit



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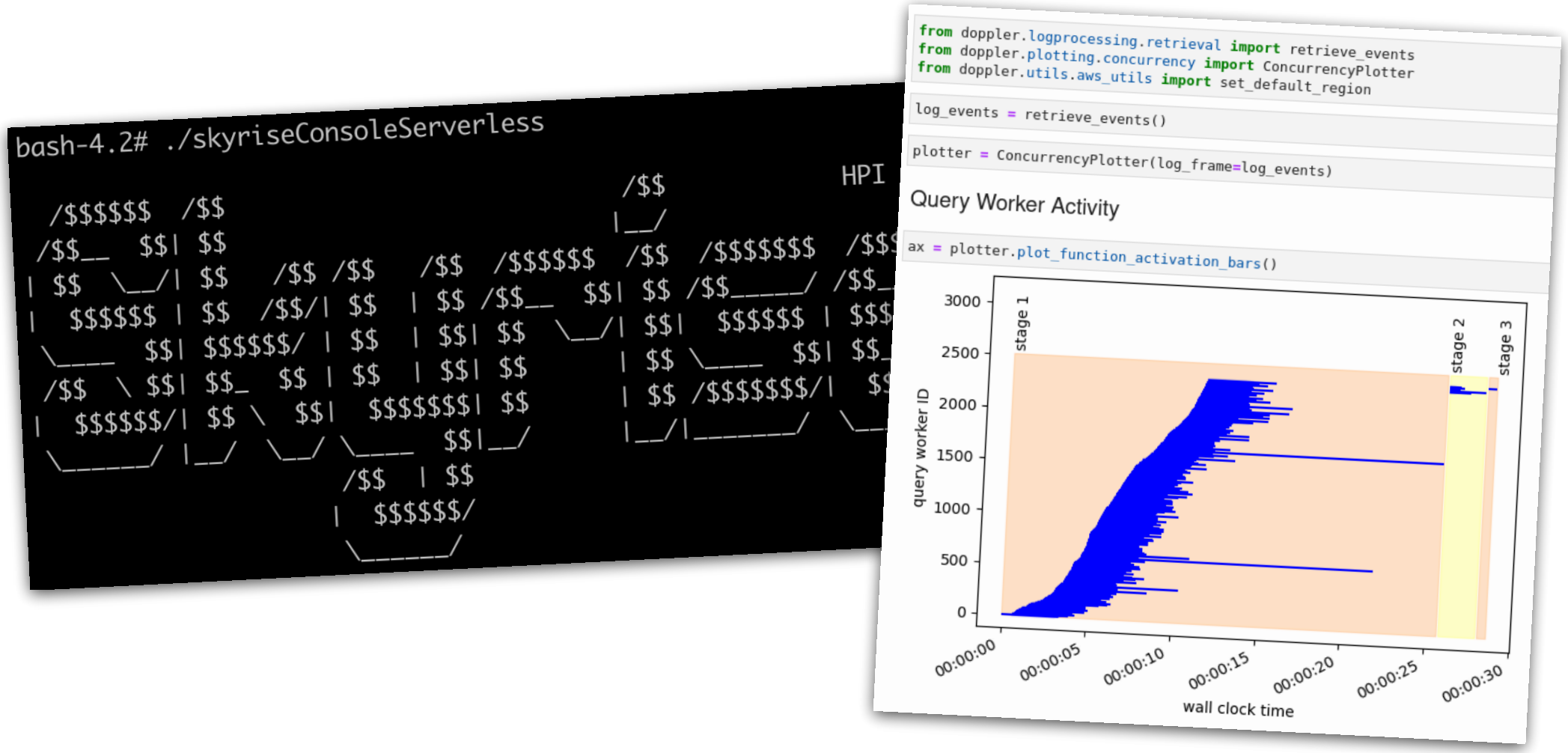


Thank you!
Questions?

Backup Slides

Serverless Infrastructure

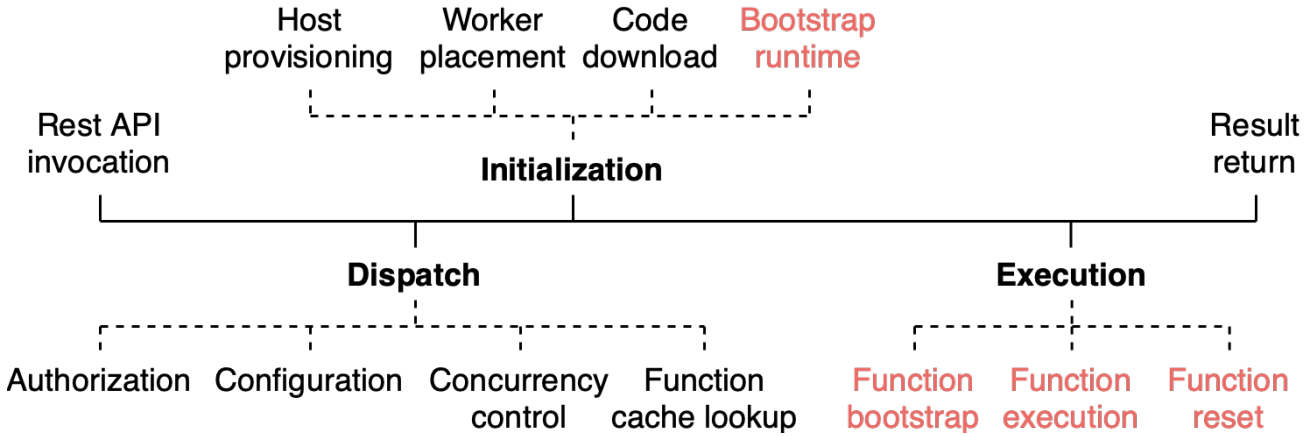
AWS Lambda under the Hood

HPI Hasso Plattner Institut

Lambda Node

- Database Code
- Guest Kernel
- Firecracker Hypervisor
- Host Kernel + KVM
- Nitro ASICs for Acceleration
- Regular C5/C6g EC2 Instance

Lambda Control Plane



Serverless Infrastructure
Lambda Limits and Performance Characteristics

- Service limits
  - Concurrent executions: Up to 10,000s
  - CPU: Up to 6 vCPUs
  - RAM: 128 to 10,240 MB in 1 MB increments
  - Disk: 512 to 10,240 MB in 1 MB increments
  - Network bandwith: 50-300 MB/s
  - Timeout: 15 min

- Performance
  - Hypervisor starts >150 VMs/s/host at <125ms with 5 MB overhead
  - Accumulated network bandwidth: 100s of GB/s, matches memory bandwidth of x86 machines
  - Accumulated compute: TFLOPS for 1,000s of functions, surpasses large x86 machines

Serverless Infrastructure
Current Challenges for Query Processing

- Launch overheads (potentially 10s of seconds)
- Tight resource limits (6 vCPUs, 10 GB RAM/Disk and 15 min runtime)
- Observability of blackbox cloud function services
- Indirect communication due to disabled inbound network connections
- Fault tolerance via transparent re-execution

- All of the above can be dealt with today

- Expectation for them to go away as compute variants converge
- Or to stay as part of the new programming model