Accelerate Performance at Scale: Best Practices for Trino with Amazon S3

Dai Ozaki

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Cloud Support Engineer, AWS Support Engineering, Amazon Web Services

- Responsible for solving the most complex technical issues related to AWS big data services such as Amazon Athena, AWS Glue, and Amazon EMR
- Athena subject matter expert

SUPPORT ENGINEERING
aws
Athena
SUBJECT MATTER EXPERT

Agenda

- Why Amazon S3 with Trino?
- Common challenges in scaling Trino workload
- Best practices to scale workload with Amazon S3

Why Amazon S3 with Trino?

Amazon S3

Amazon S3

- Durable
- Highly available
- Scalable
- Cost effective
- Secure

Use Case of Amazon S3 with Trino

- Trino is a powerful tool to query data from data lakes

- Amazon S3 is the best place to build a data lake

Cost effective to store data

Unmatched **durability,availability,** and **scalability**

Best **security, compliance,**and **audit** capabilities

Common challenges in scaling Trino workload

Common challenges in scaling Trino workload

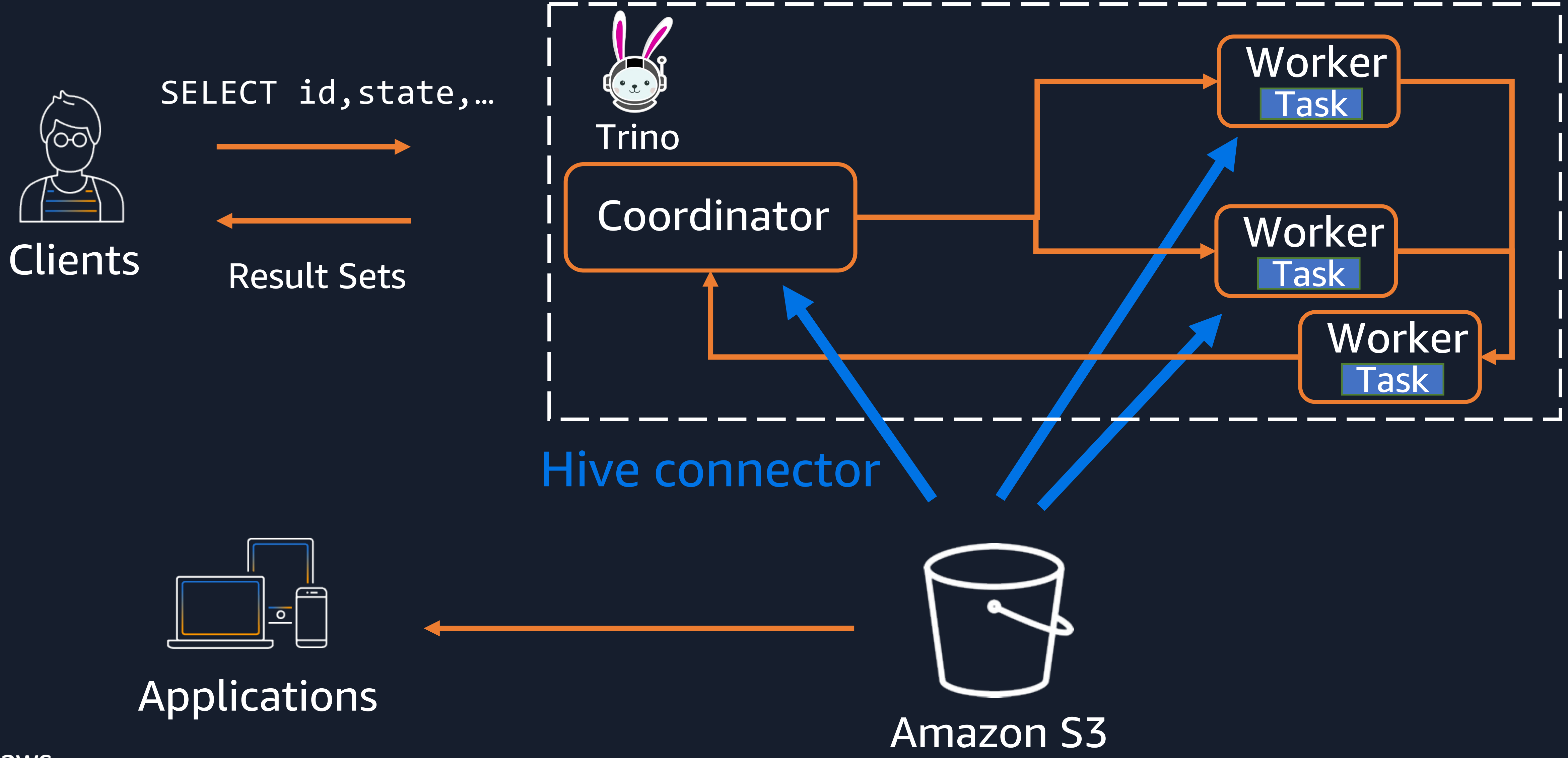
Huge data scan

HTTP Slow Down error

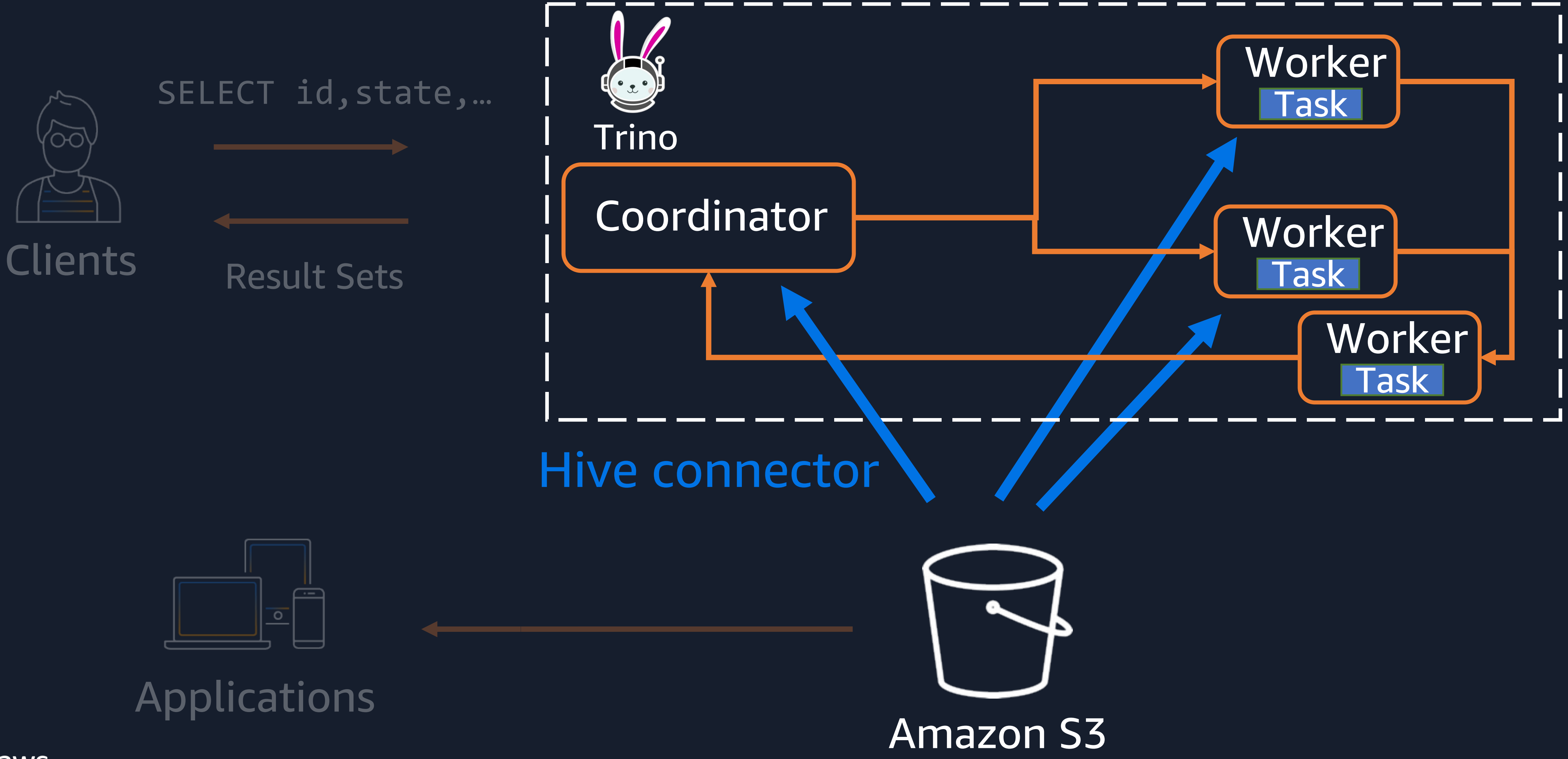
Many small files issue

Unneeded data is stored

Common Architecture



Challenge 1: Huge data scan



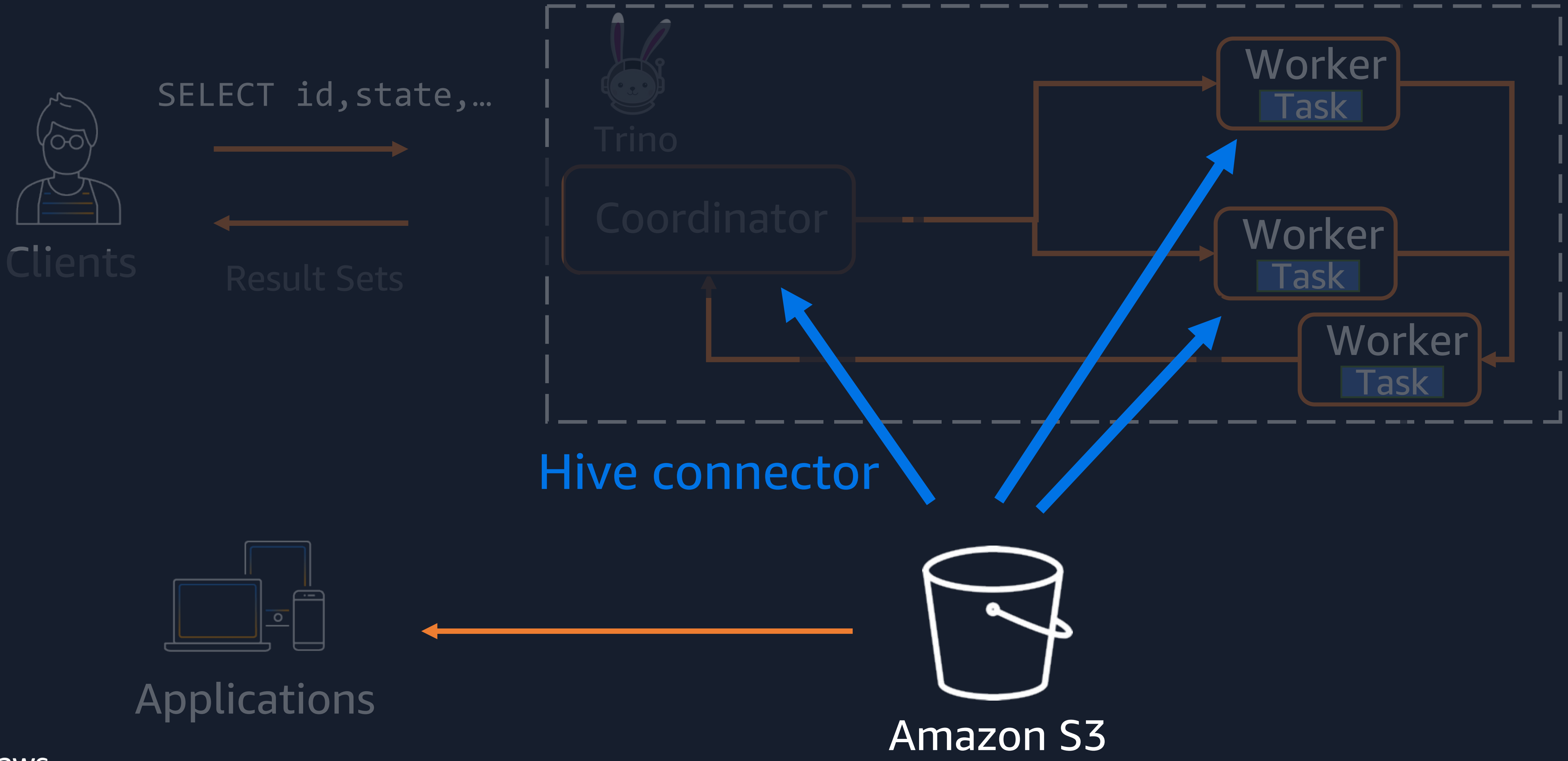
Challenge 1: Huge data scan

Slower query

Worker OOM

High cost

Challenge 2: HTTP Slow Down error



Challenge 2: HTTP Slow Down error

- Amazon S3 performance is defined per **prefix**

s3://bucket/daily-uploads/20240613/drive-data.csv

Prefix

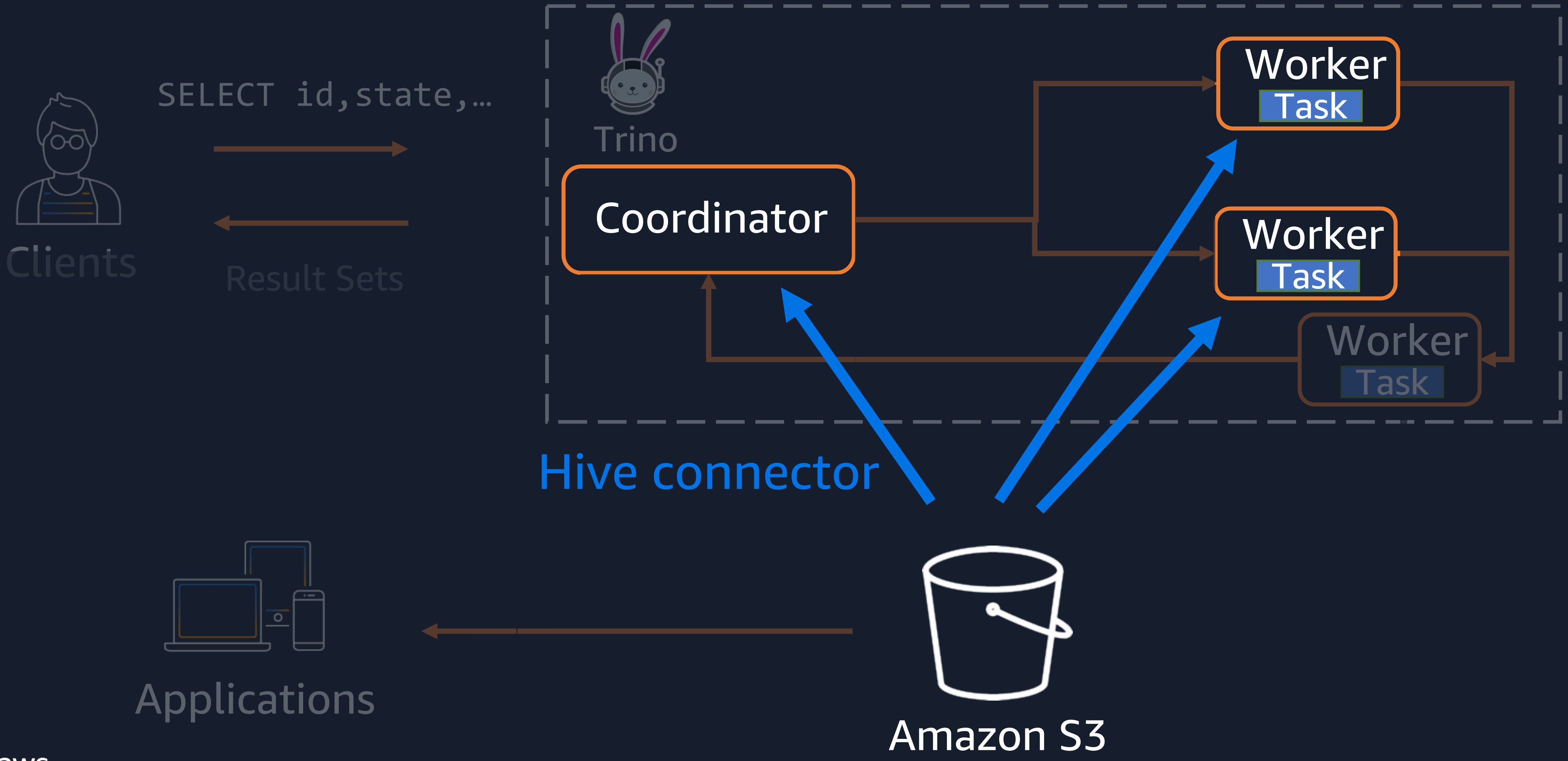
- You can achieve 3,500 PUT/COPY/POST/DELETE requests or 5,500 GET/HEAD requests per second per prefix in a bucket

Challenge 2: HTTP Slow Down error

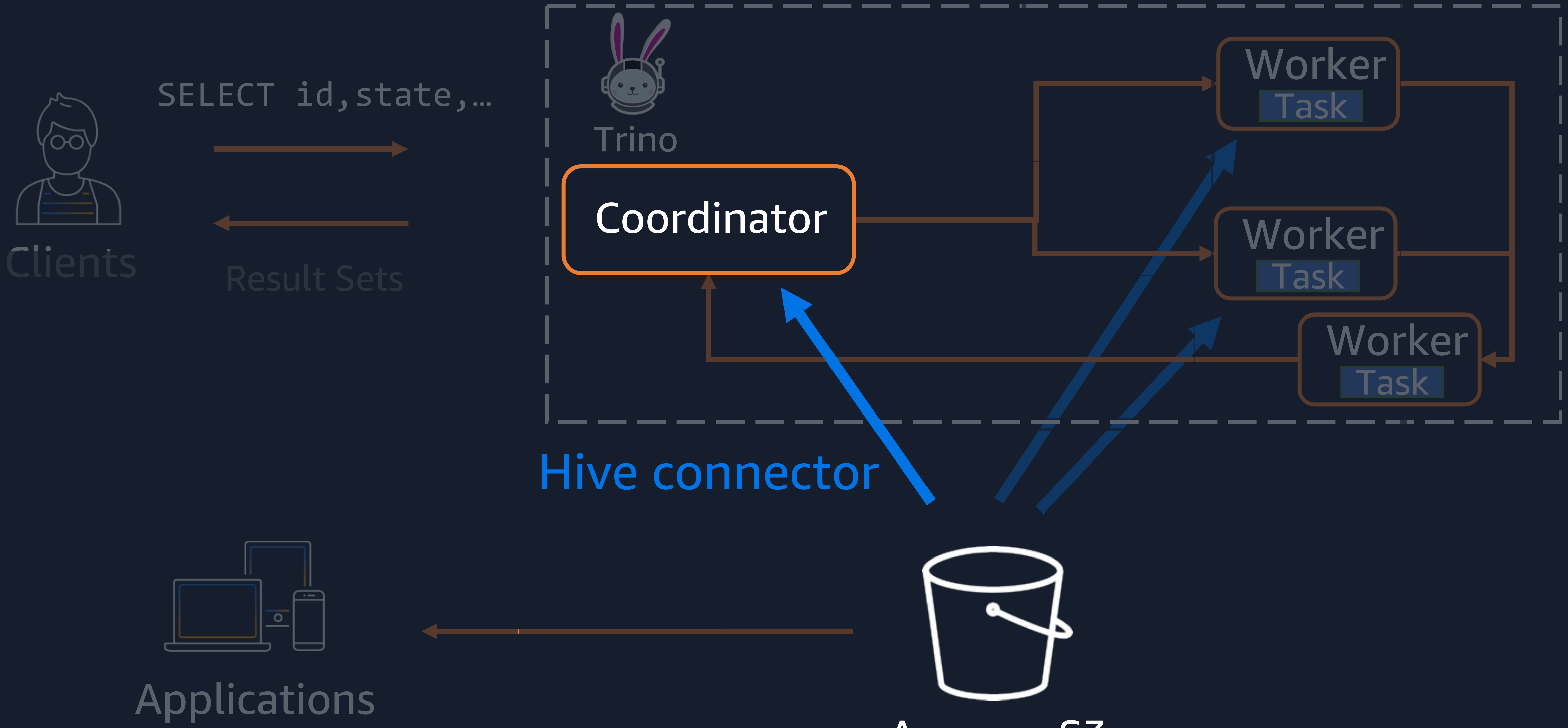
- If your requests exceed threshold, you will face HTTP 503 Slow Down error

```
AmazonS3Exception: Please reduce your request
rate. (Service: Amazon S3; Status Code: 503;
Error Code: SlowDown)
```

Challenge 2: HTTP Slow Down error



Challenge 2: HTTP Slow Down error



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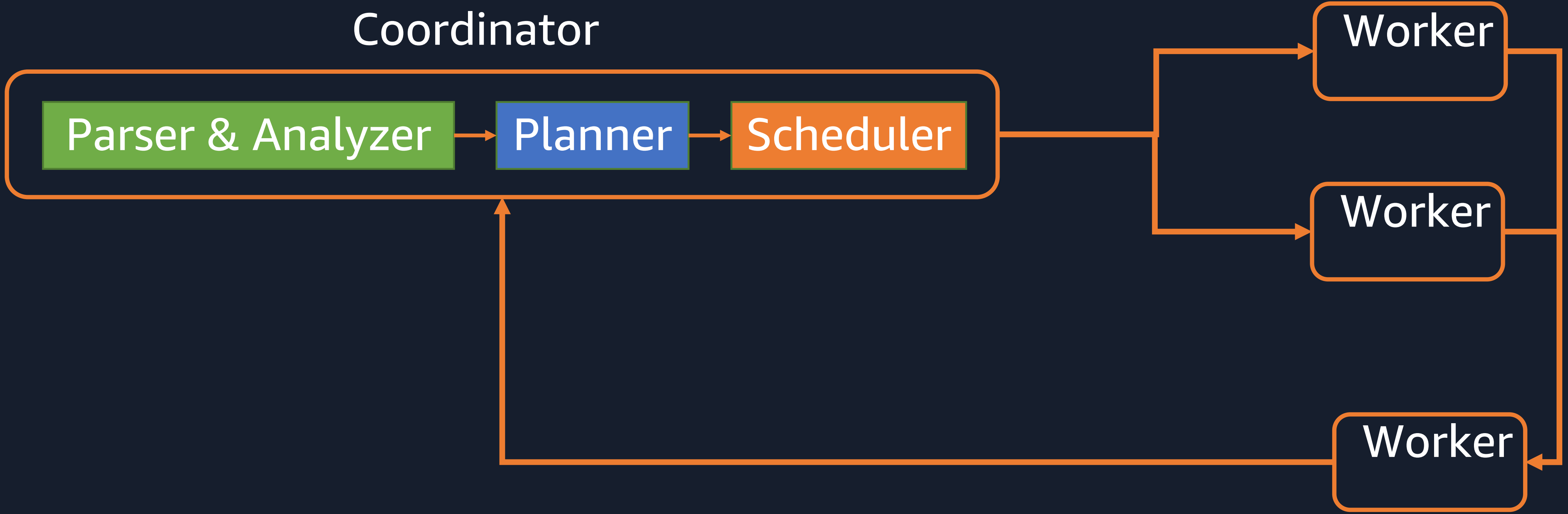

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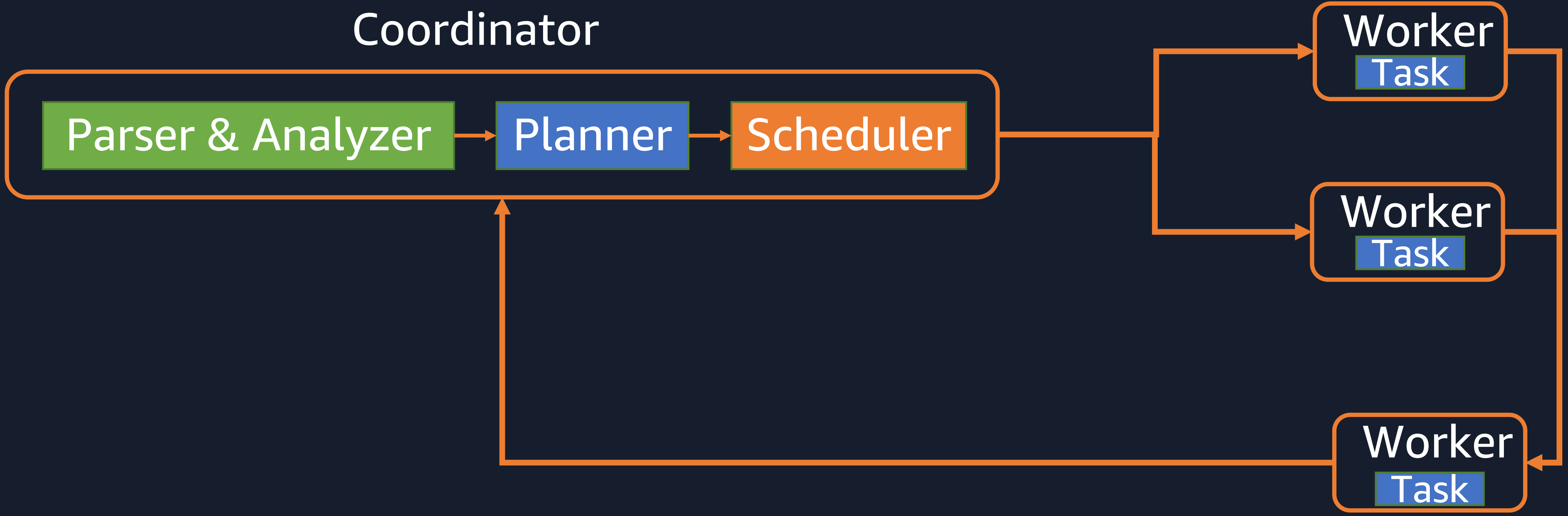

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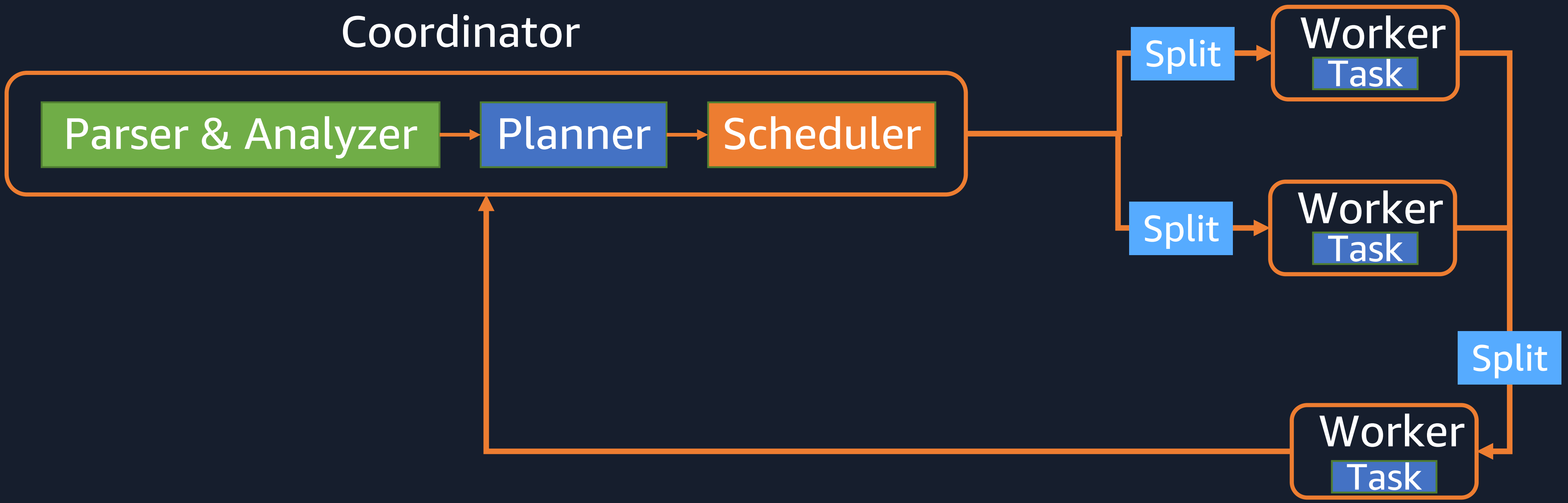

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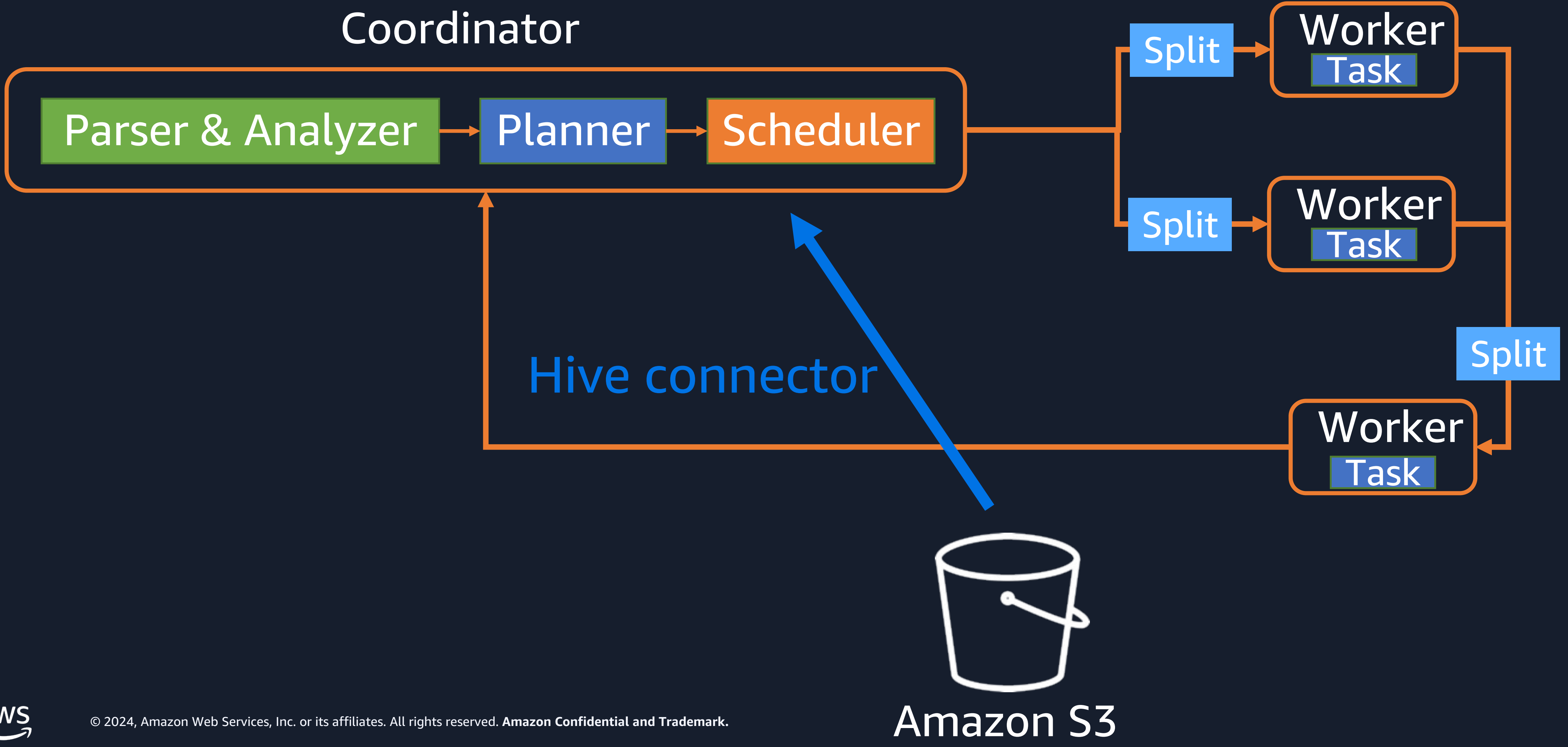

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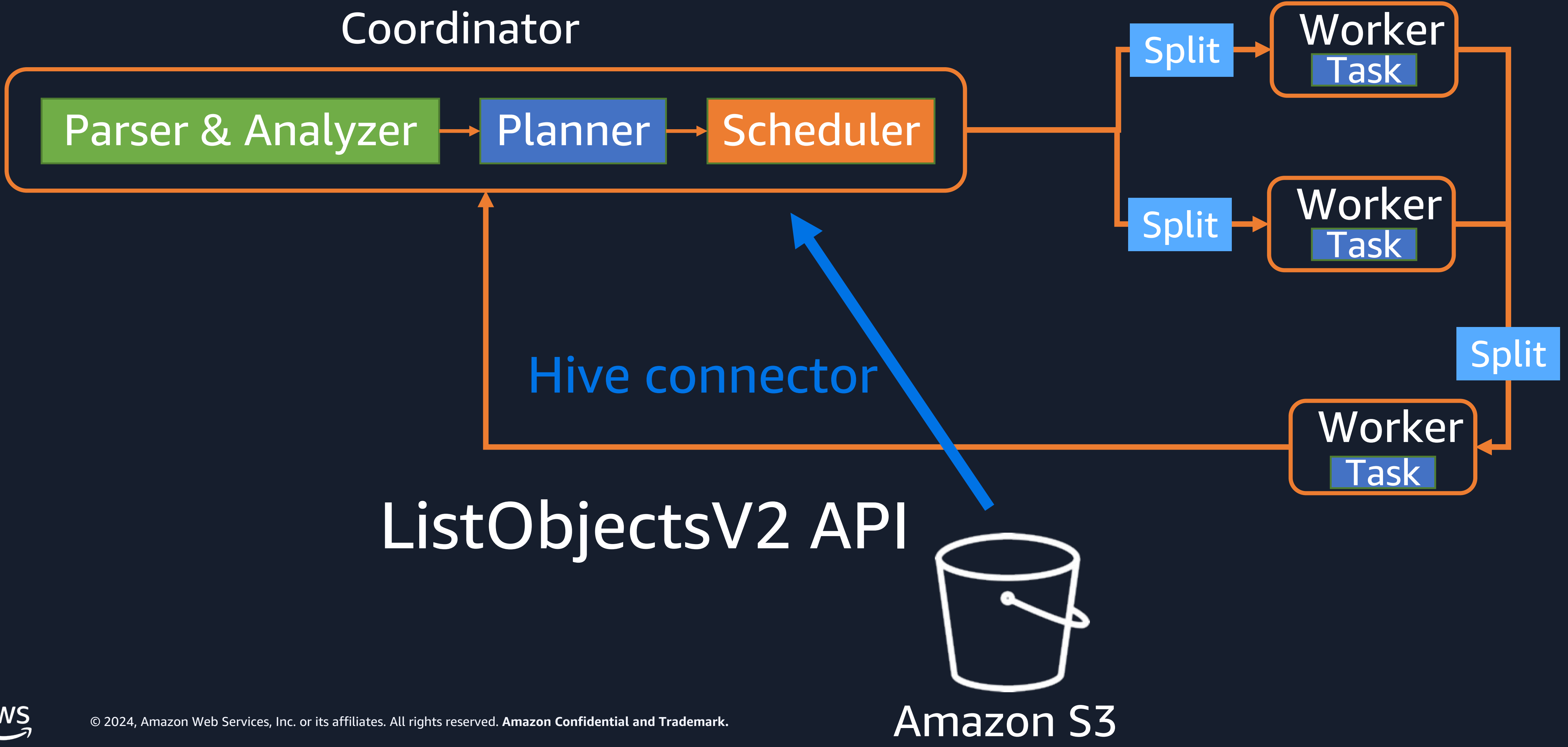

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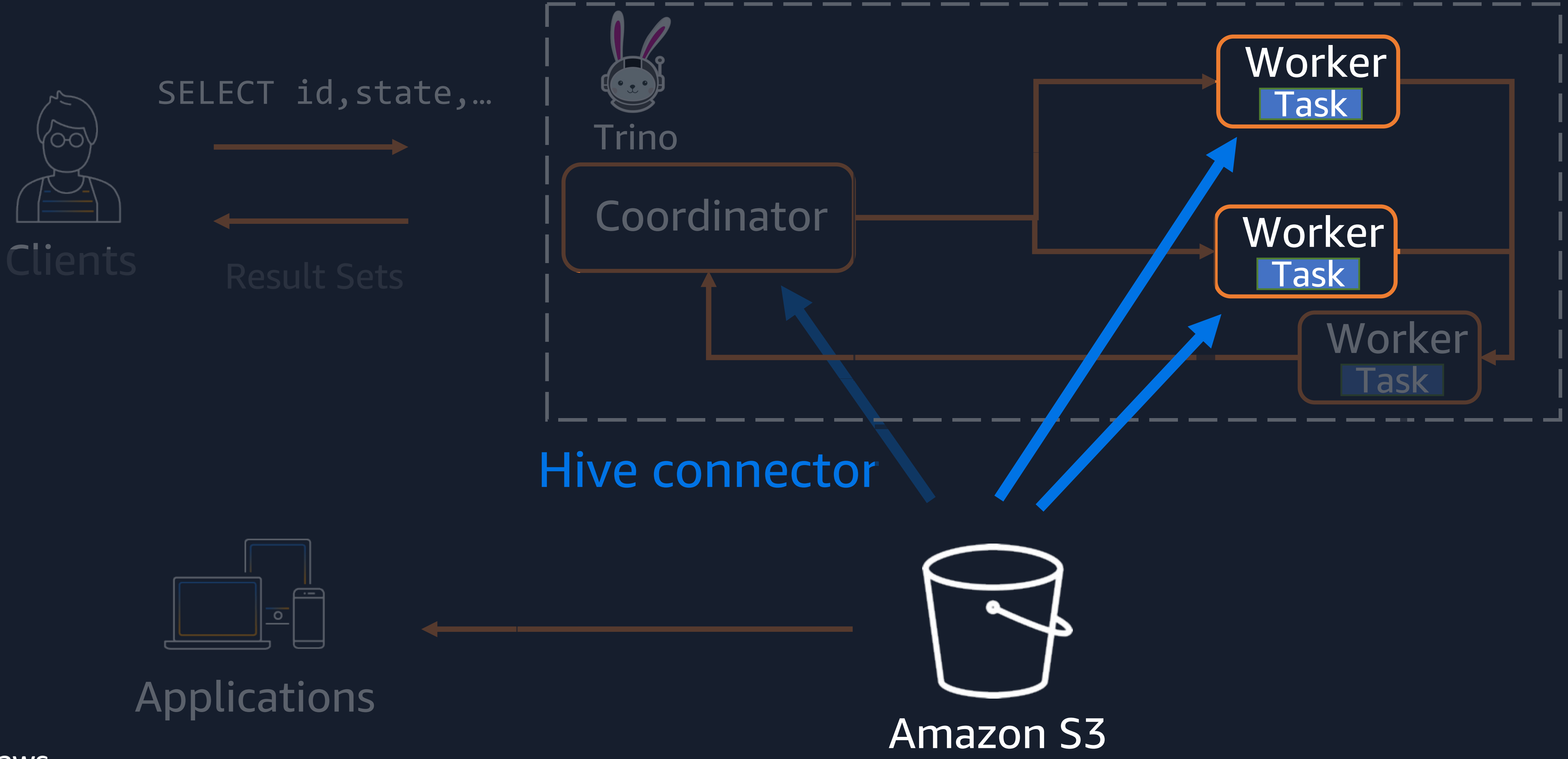

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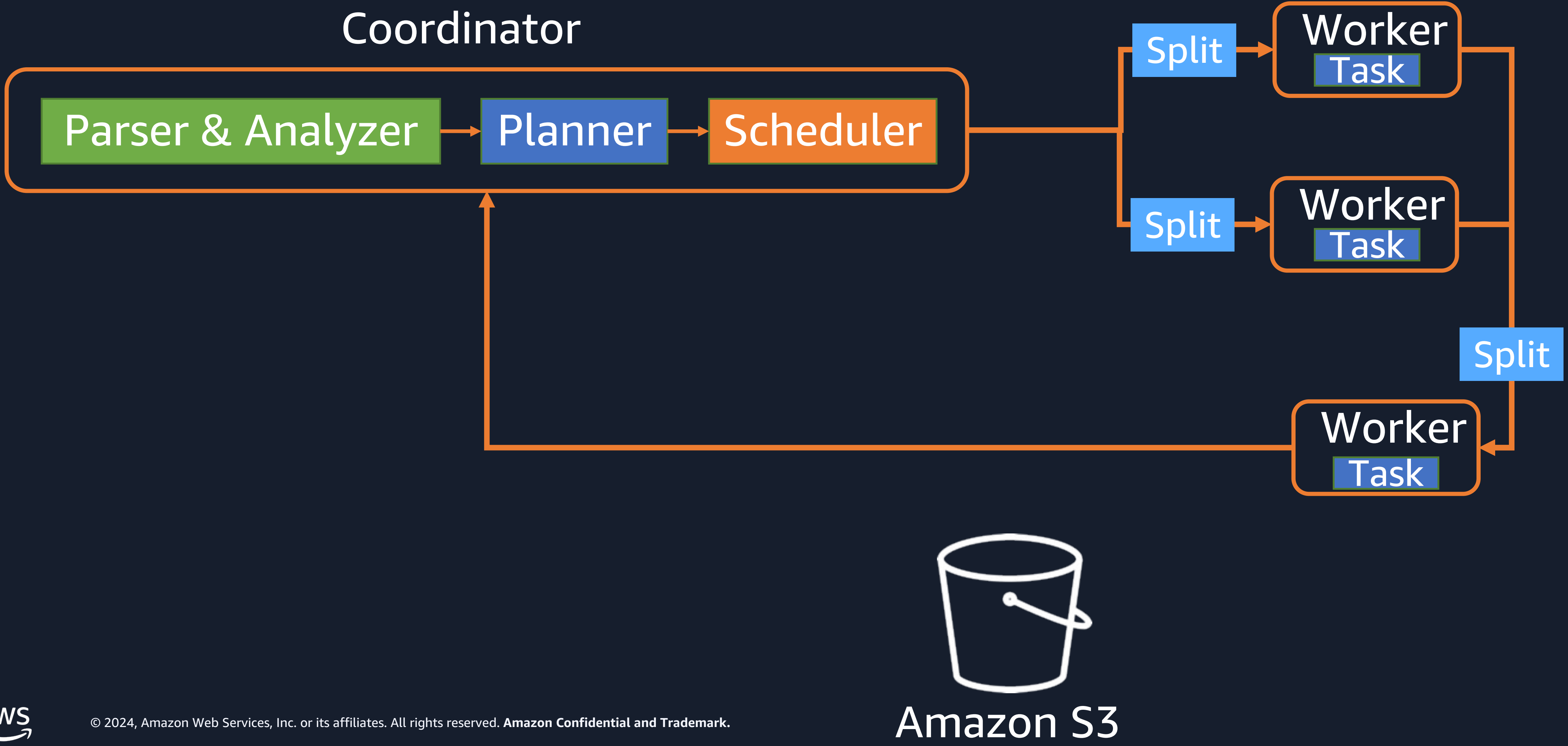

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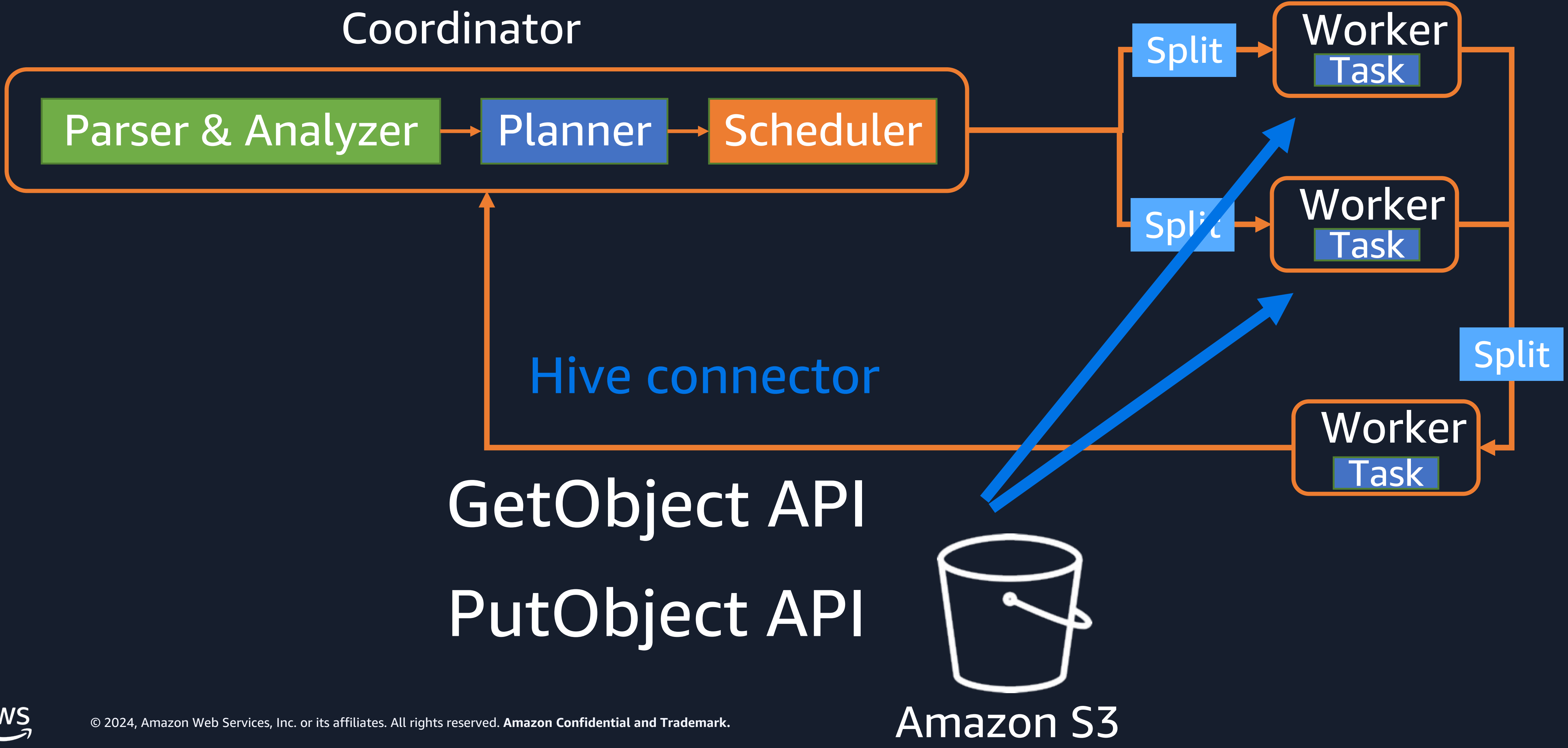

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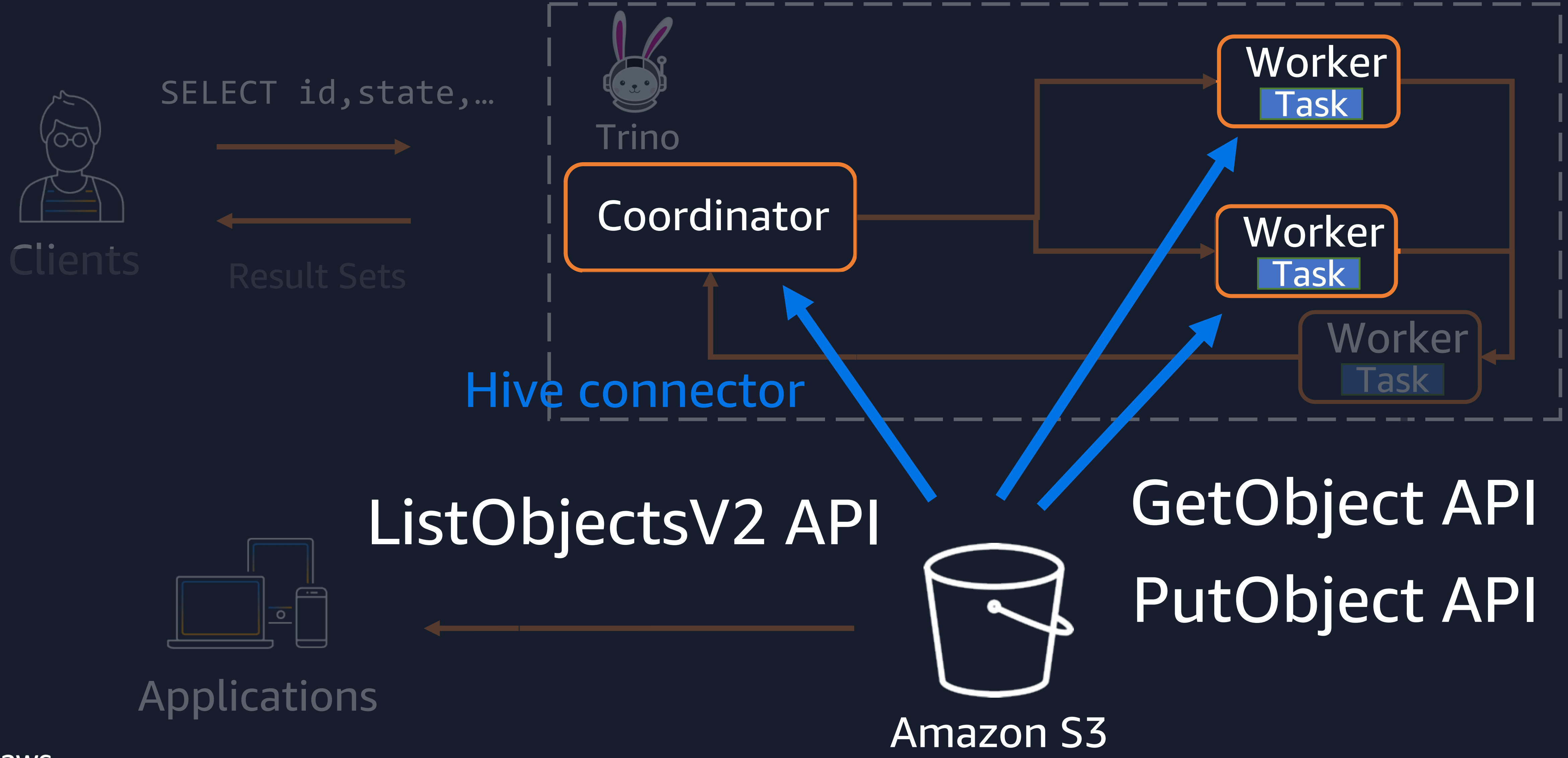
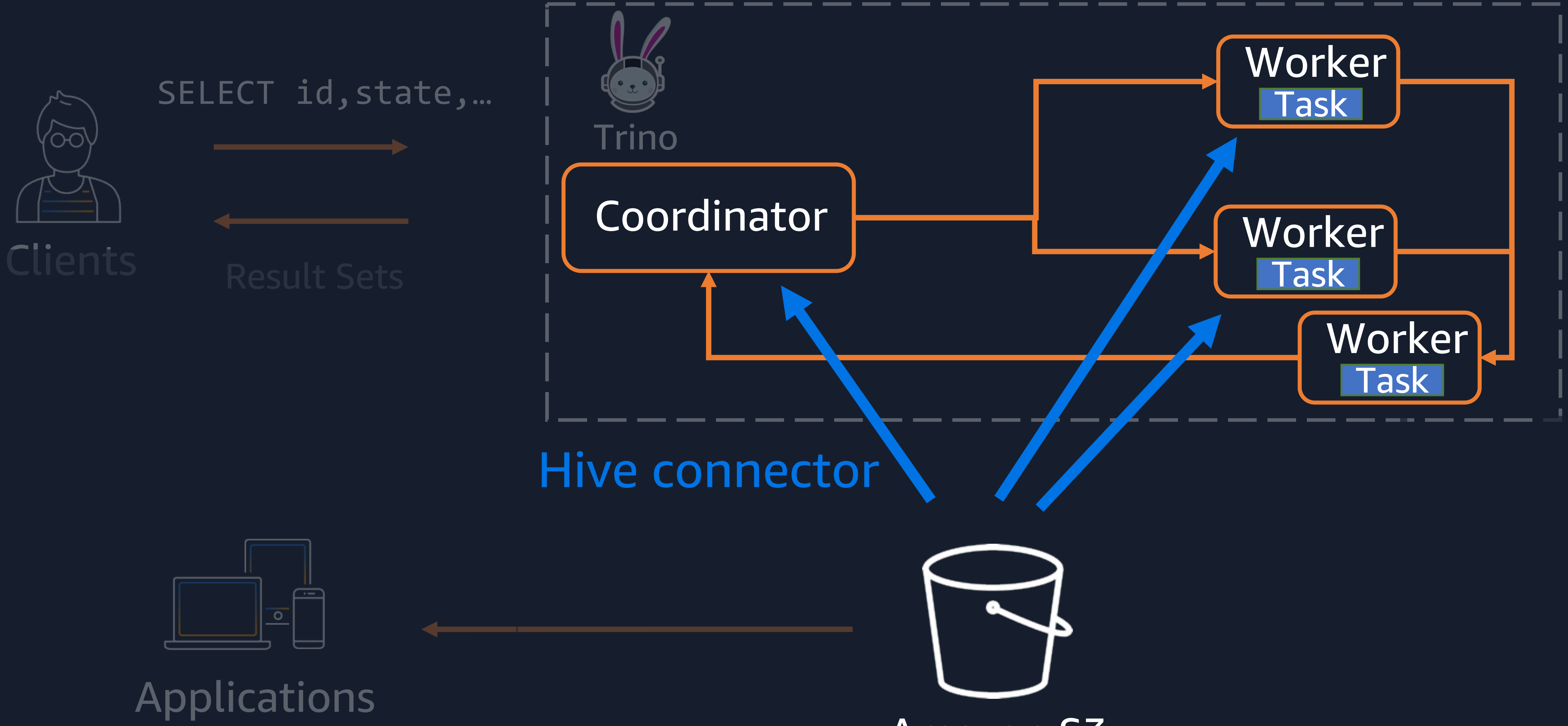
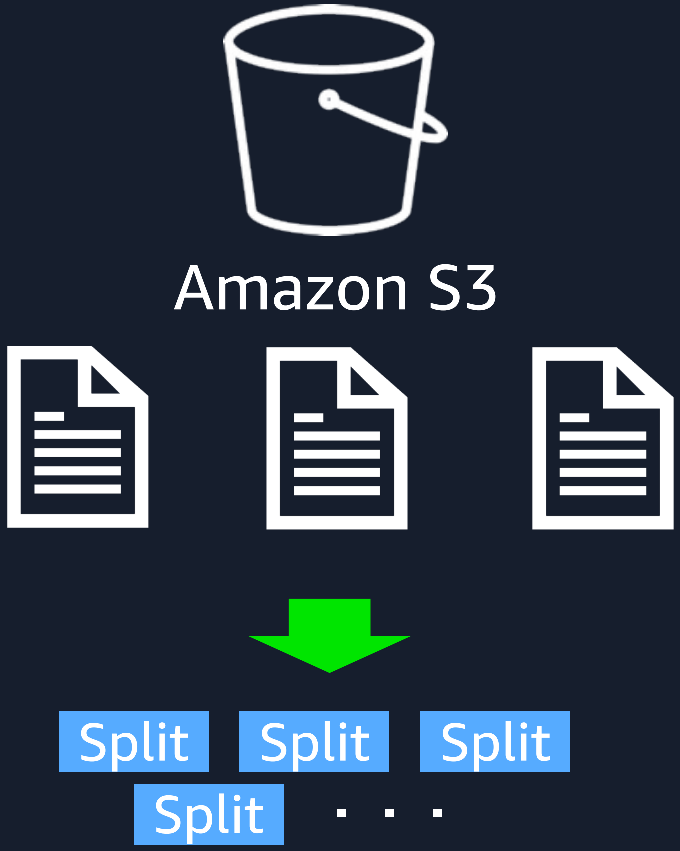


Challenge 3: Many small files issue



Split



- Splits are the smallest unit of work assignment
- Number of splits are related to parallelism
- For query performance, number of splits are important
- Roughly, number of splits can be calculated by below parameters

`hive.max-initial-splits`	Default: 200
`hive.max-initial-split-size`	Default: 32MB
`hive.max-split-size`	Default: 64MB

How to estimate parallelism

Example1: 1000 files, each file size is 10 KB

1. Initial 200 files are smaller than `hive.max-initial-split-size`

   First 200 files are 200 splits

2. Each of the remaining 800 files are smaller than `hive.max-split-size`

   Remaining 800 files are 800 splits

Total: 1000 splits

`hive.max-initial-splits`	Default: 200
`hive.max-initial-split-size`	Default: 32MB
`hive.max-split-size`	Default: 64MB

How to estimate parallelism

Example2: 10 files, each file size is 1000 KB

1. 10 files are smaller than `hive.max-initial-split-size`

Total: 10 splits

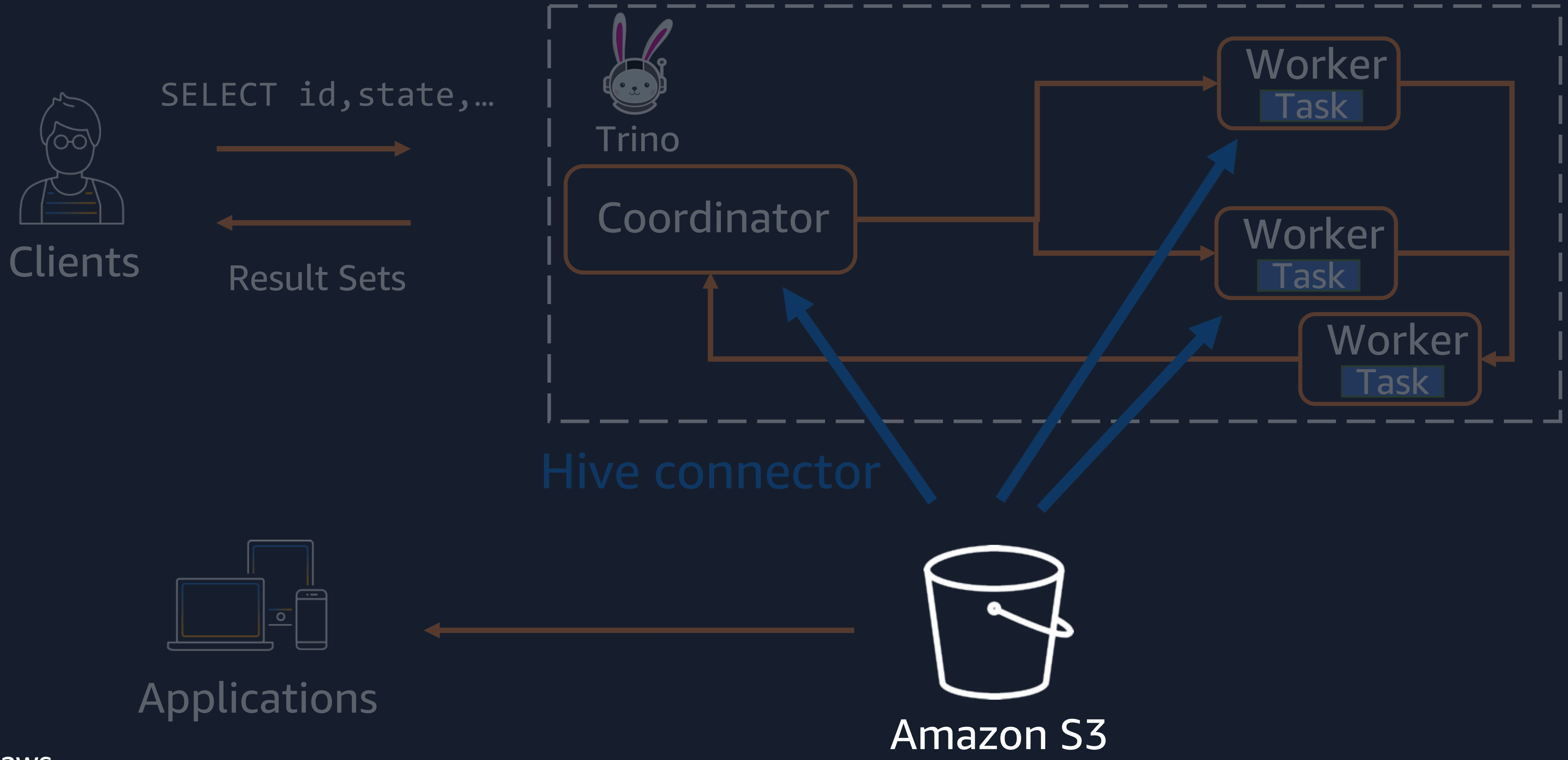
`hive.max-initial-splits`	Default: 200
`hive.max-initial-split-size`	Default: 32MB
`hive.max-split-size`	Default: 64MB

Challenge 3: Many small files issue

What happen when reading many small files?

- Heavy I/O load to Amazon S3 due to LIST/GET requests
- Generates many splits and it generates computational overhead

Challenge 4: Unneeded data is stored



Challenge 4: Unneeded data is stored

Data is growing

- The storage cost is getting higher
- There are data with know or predictable access patterns and data with unknow or changing access patterns.
- How to delete irrelevant data ?

Common challenges in scaling Trino workload

Huge data scan

HTTP Slow Down error

Many small files issue

Unneeded data is stored

Best practices to scale workload with Amazon S3

Best practices to scale workload with Amazon S3

- Optimizing data layout
  - Partitioning 🟩 🟪
  - Bucketing 🟩 🟪
  - Managing S3 prefixes 🟪
- Optimizing data size 🟪 🟦
- Making well-designed retries 🟪
- Taking advantage of Amazon S3 Storage Class 🟧
- Reducing latency with Amazon Express One Zone 🟪
- Managing data life cycle 🟧

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Partitioning

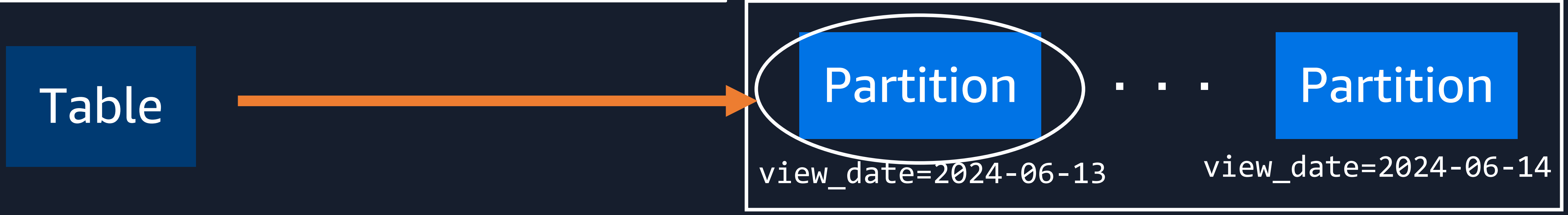
🟩 Huge data scan 🟪 HTTP Slow Down error

- Partitioning divides your table into parts and keeps the related data together based on column values
- By using partitioning, you can reduce the amount of data scanned per query

```
partitioned_by = ARRAY['view_date’]
```

```
SELECT * FROM example.web.request_logs
     WHERE view_date=2024-06-13
```

s3://mybucket/daily_uploads/



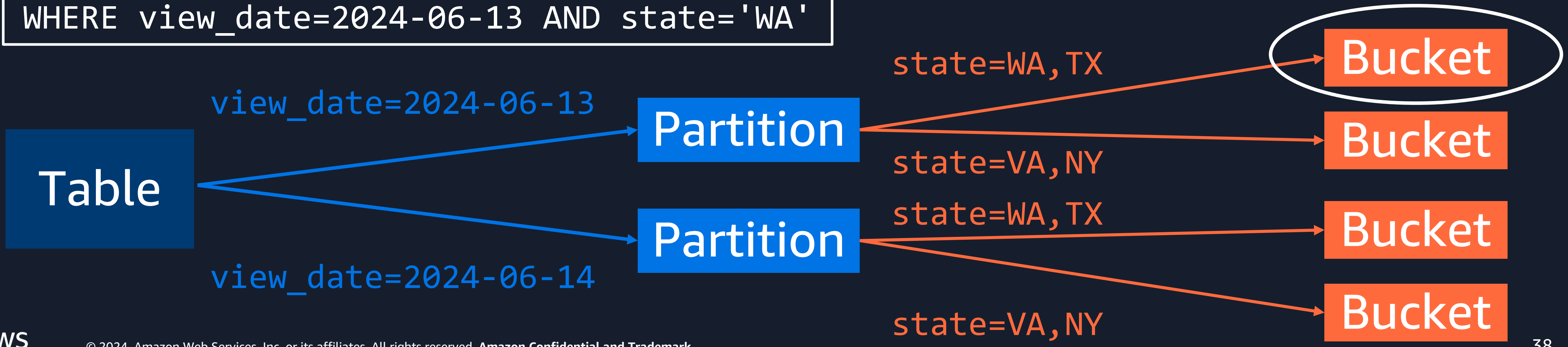
Bucketing

🟩 Huge data scan 🟪 HTTP Slow Down error

- With bucketing, you can specify one or more columns containing rows that you want to group together, and put those rows into multiple buckets.

```
partitioned_by = ARRAY['view_date']
bucketed_by = ARRAY['state'],
bucket_count = 50
```

```
 SELECT * FROM example.web.request_logs
WHERE view_date=2024-06-13 AND state='WA'
```



Partitioning / Bucketing

🟩 Huge data scan 🟪 HTTP Slow Down error

Partition columns

- Pick partition keys based on common query pattern
- Partition keys should have a relatively low cardinality

Columns to bucket on

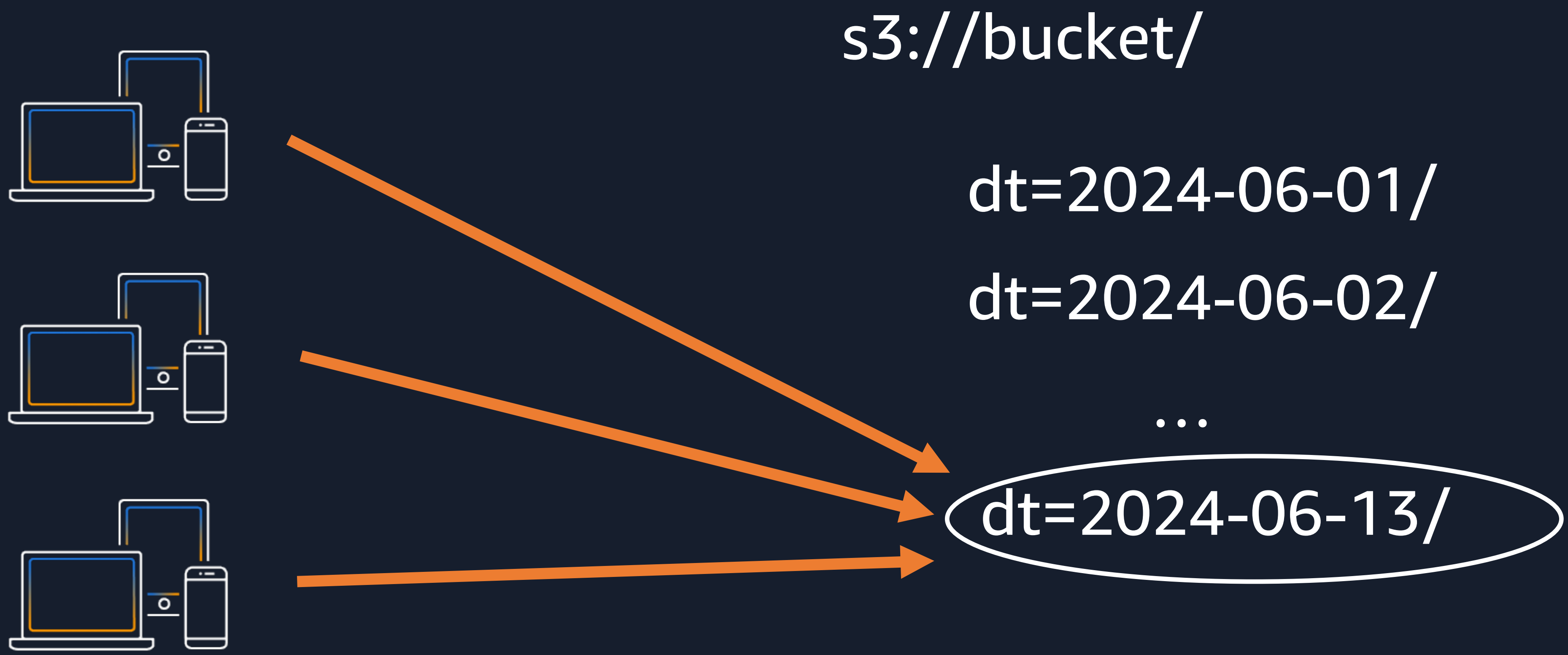
- Choose columns that have high cardinality
- Many of your queries look up speficic values of the key

Managing S3 prefixes

🟪 HTTP Slow Down error

Add S3 prefixes to scale S3 performance

Example:



s3://bucket/

dt=2024-06-01/

dt=2024-06-02/

...

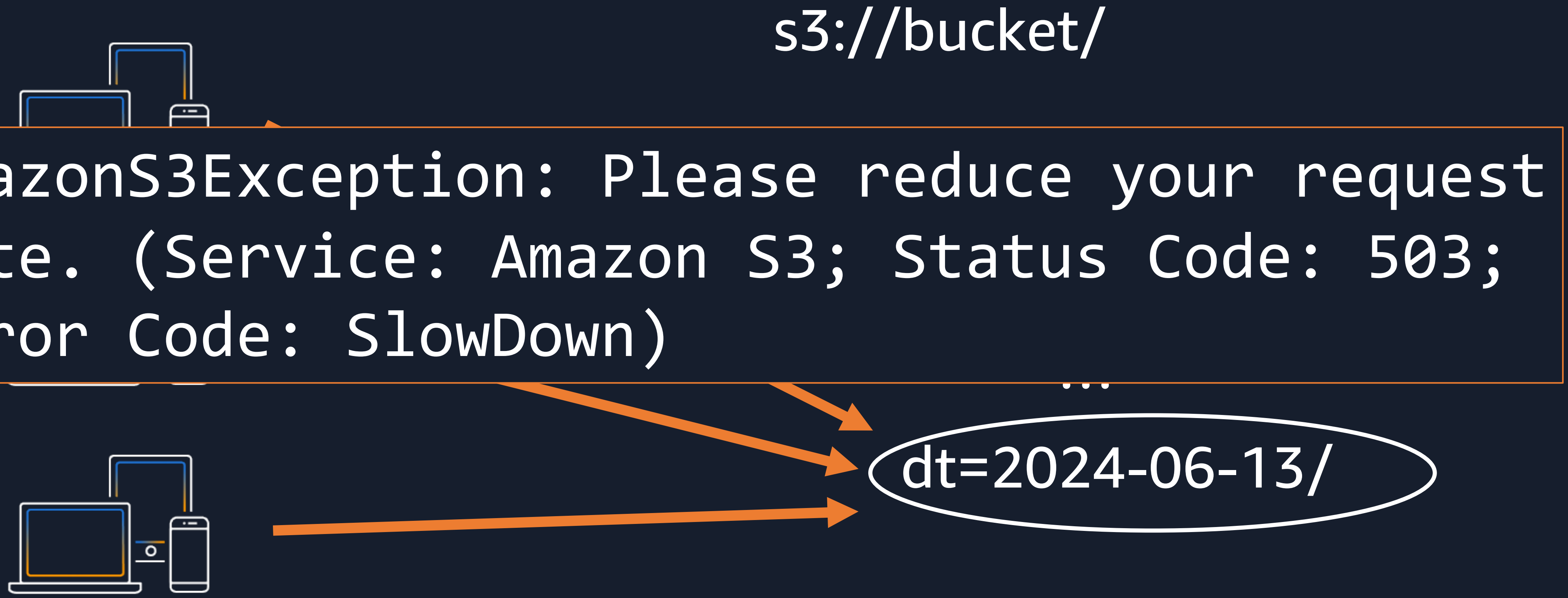
dt=2024-06-13/

Managing S3 prefixes

🟪 HTTP Slow Down error

Add S3 prefixes to scale S3 performance

Example:



```
AmazonS3Exception: Please reduce your request rate. (Service: Amazon S3; Status Code: 503; Error Code: SlowDown)
```

Managing S3 prefixes

🟪 HTTP Slow Down error

Add S3 prefixes to scale S3 performance

Example:

s3://bucket/dt=2024-06-13

⬇

s3://bucket/country=US/dt=2024-06-13

s3://bucket/country=CA/dt=2024-06-13

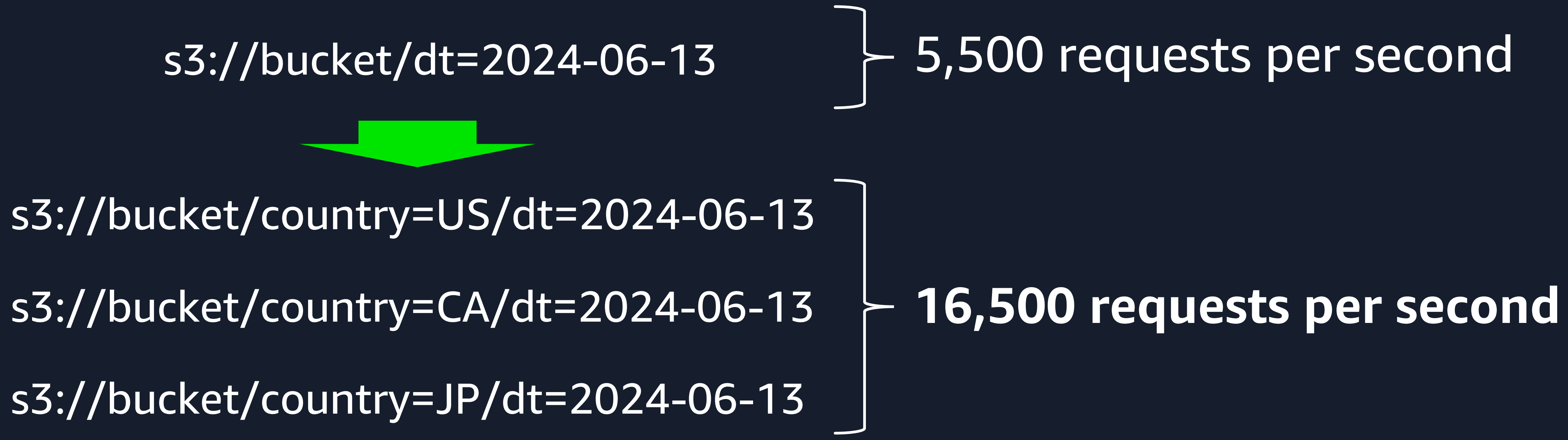
s3://bucket/country=JP/dt=2024-06-13

Managing S3 prefixes

🟪 HTTP Slow Down error

Add S3 prefixes to scale S3 performance

Example:



s3://bucket/dt=2024-06-13

5,500 requests per second

s3://bucket/country=US/dt=2024-06-13

s3://bucket/country=CA/dt=2024-06-13

s3://bucket/country=JP/dt=2024-06-13

16,500 requests per second

Managing S3 prefixes

🟪 HTTP Slow Down error

Add S3 prefixes to scale S3 performance

Which columns from data should we select when adding s3 prefixes?

- Choose the columns which has multiple different values over recent records
- Choose the columns which are frequently used as a predicate in your queries

Best practices to scale workload with Amazon S3

- Optimizing data layout
  - Partitioning 🟩 🟪
  - Bucketing 🟩 🟪
  - Managing S3 prefixes 🟪
- **Optimizing data size** 🟪 🟦
- Making well-designed retries 🟪
- Taking advantage of Amazon S3 Storage Class 🟧
- Reducing latency with Amazon Express One Zone 🟪
- Managing data life cycle 🟧

🟩	Huge data scan
🟪	HTTP Slow Down error
🟦	Many Small files issue
🟧	Unneeded data is stored

Optimizing data size

🟪 HTTP Slow Down error 🟦 Many Small files issue

- Run OPTIMIZE commnad

(0. If you run OPZIMIZE command against Hive external tables, set this parameter)

```
hive.non-managed-table-writes-enabled=true
```

1. Set session parameter

```
SET SESSION <catalog>.non_transactional_optimize_enabled=true
```

2. Run OPTIMIZE command

```
ALTER TABLE <catalog>.<schama>.<table> EXECUTE
optimize(file_size_threshold => '128MB')
```

* `file_size_threshold` is 100 MB by default

Optimizing data size

🟪 HTTP Slow Down error 🟦 Many Small files issue

If you use Trino on Amazon Athena, and your table is a hive external table

- Migrate the table to Iceberg table

```
CREATE TABLE iceberg_table
WITH (table_type = 'ICEBERG',
      format = 'PARQUET',
      location = 's3:// bucket /iceberg/',
      is_external = false,
      partitioning = ARRAY['country_code'])
AS SELECT id, name, country_code FROM table1;
```

- Use automatic compatcion feature on Glue Data Catalog

Best practices to scale workload with Amazon S3

- Optimizing data layout
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🟩 Huge data scan

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Making well-designed retries

🟪 HTTP Slow Down error

Increase retry limit for Amaon S3 requests in Trino

Native implementation (`fs.native-s3.enable=true`)

`s3.max-error-retries` From Trino 449

Legacy version (fs.native-s3.enable=false)

`hive.s3.max-client-retries`

Making well-designed retries

🟪 HTTP Slow Down error

Increase retry limit in Trino on Amazon EMR

EMRFS

```
fs.s3.maxRetries
```

Best practices to scale workload with Amazon S3

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Taking advantage of Amazon S3 Storage Class

🟧 Unneeded data is stored

S3 Express One Zone	S3 Intelligent-Tiering	S3 Standard	S3 Standard-IA	S3 One Zone-IA	S3 Glacier Instant Retrieval	S3 Glacier Flexible Retrieval	S3 Glacier Deep Archive
Most frequently accessed data	Changing access patterns	Frequently accessed data	Infrequently accessed data	Re-creatable, less accessed data	Rarely accessed data	Archive data	Long-term archive data
Single-digit millisecond access	Milliseconds access					Minutes to hours	

Taking advantage of Amazon S3 Storage Class

🟧 Unneeded data is stored

1 Data with **known** or **predictable** access patterns

2 Data with **unknown** or **changing** access patterns

Taking advantage of Amazon S3 Storage Class

🟧 Unneeded data is stored

1 Data with known or predictable access patterns

2 Data with unknown or changing access patterns

Data with known or predictable access patterns

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S3 Express One Zone	S3 Standard	S3 Standard-IA	S3 One Zone-IA	S3 Glacier Instant Retrieval	S3 Glacier Flexible Retrieval	S3 Glacier Deep Archive
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Single-digit millisecond access	Milliseconds access				Minutes to hours	

Data with known or predictable access patterns

🟧 Unneeded data is stored

S3 Standard	S3 Standard-IA
Frequently accessed data	Infrequently accessed data

- Storage cost for S3 Standard-IA is cheaper than S3 Standard
- S3 request cost for S3 Standard-IA is higher than S3 Standard

S3 Standard-IA is suitable for infrequently accessed data

Data with known or predictable access patterns

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S3 Express One Zone	S3 Standard	S3 Standard-IA	S3 One Zone-IA	S3 Glacier Instant Retrieval	S3 Glacier Flexible Retrieval	S3 Glacier Deep Archive
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Data with known or predictable access patterns

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S3 Express One Zone

Most frequently accessed data

Single-digit millisecond access

- Lowest latency
- Most expensive for storage cost
- Cheapest for request cost
- Less available

Data with known or predictable access patterns

🟧 Unneeded data is stored

S3 Express One Zone

Most frequently accessed data

Single-digit millisecond access

Trade off

Latency

Storage cost

Request cost

Availability

Data with known or predictable access patterns

🟧 Unneeded data is stored

Situation

- You create a daily report by using Trino
- The data is stored in S3 Standard
- You frequently access the data for a short period
- The data is rarely accessed again after a month or two

You can consider moving to another S3 class

Taking advantage of Amazon S3 Storage Class

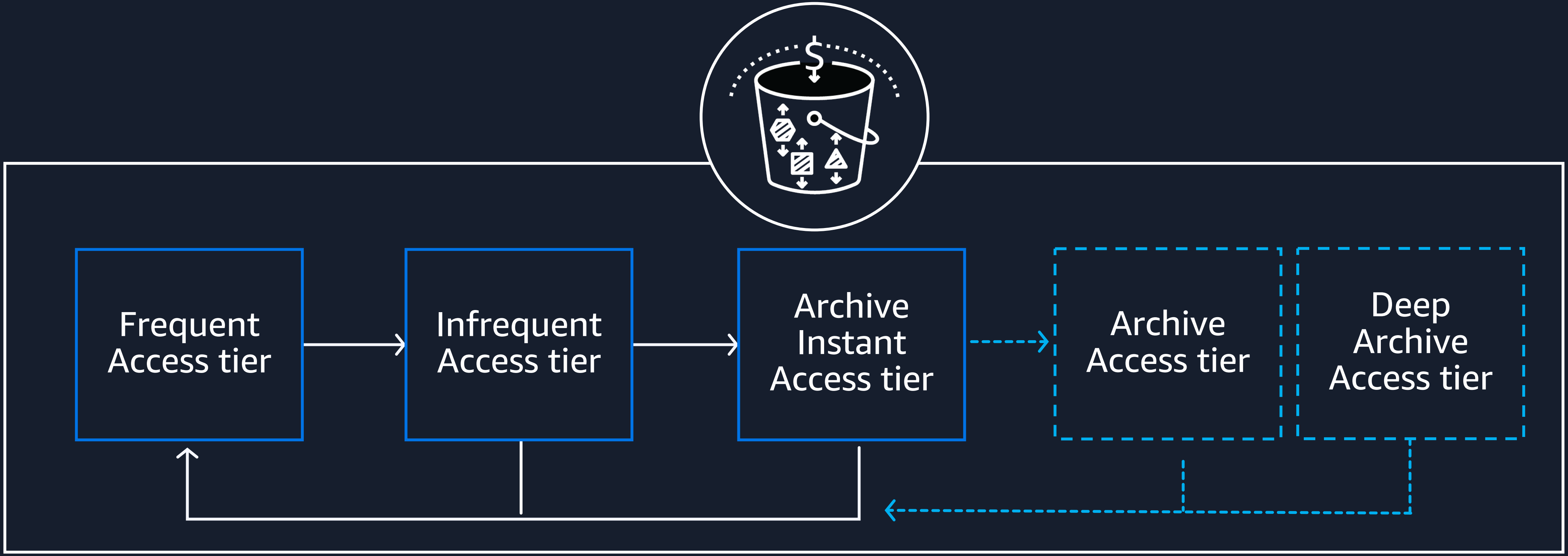
🟧 Unneeded data is stored

1 Data with **known** or **predictable** access patterns

2 Data with **unknown** or **changing** access patterns

S3 Intelligent-Tiering storage class

🟧 Unneeded data is stored



Milliseconds access (automatic)

Minutes to hours (optional)

How to read/write data in different storage class in Trino

🟧 Unneeded data is stored

- You can read objects stored in S3 Standard/S3 Standard-IA/S3 Intelligent-Tiering/S3 Glacier Instant Retrieval storage class without additional parameters

Native implementation (`fs.native-s3.enable=true`)

- You can read restored glacier objects by default

Legacy version (fs.native-s3.enable=false)

- Skip glacier objects by setting `hive.s3.skip-glacier-objects`
- You can read restored glacier objects by default
- You can write data in Intelligent-Tiering by setting `hive.s3.storage-class`

How to read/write data in different storage class in Trino

🟧 Unneeded data is stored

Athena

- Skip glacier objects by default
- You can read restored glacier objects by setting `hive.restored_glacier_objects`

EMR

- You can read restored glacier objects by default

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🟪 HTTP Slow Down error

Reducing latency with Amazon Express One Zone

NEW S3 Express One Zone	S3 Standard	S3 Standard-IA	S3 One Zone-IA	S3 Glacier Instant Retrieval	S3 Glacier Flexible Retrieval	S3 Glacier Deep Archive
Most frequently accessed data	Frequently accessed data	Infrequently accessed data	Re-creatable, less accessed data	Rarely accessed data	Archive data	Long-term archive data
Single-digit millisecond access	Milliseconds access				Minutes to hours	

🟪 HTTP Slow Down error

Reducing latency with Amazon S3 Express One Zone

Scalable

- No per-prefix transaction limits
- Support hundreds of thousands of transactions per second (TPS)

How to use Amazon Express One Zone

Application/Service	Parameter
Trino	fs.native-s3.enabled=true
Amazon Athena	Not required

Amazon EMR	fs.native-s3.enabled=true
	hive.s3-file-system-type=TRINO

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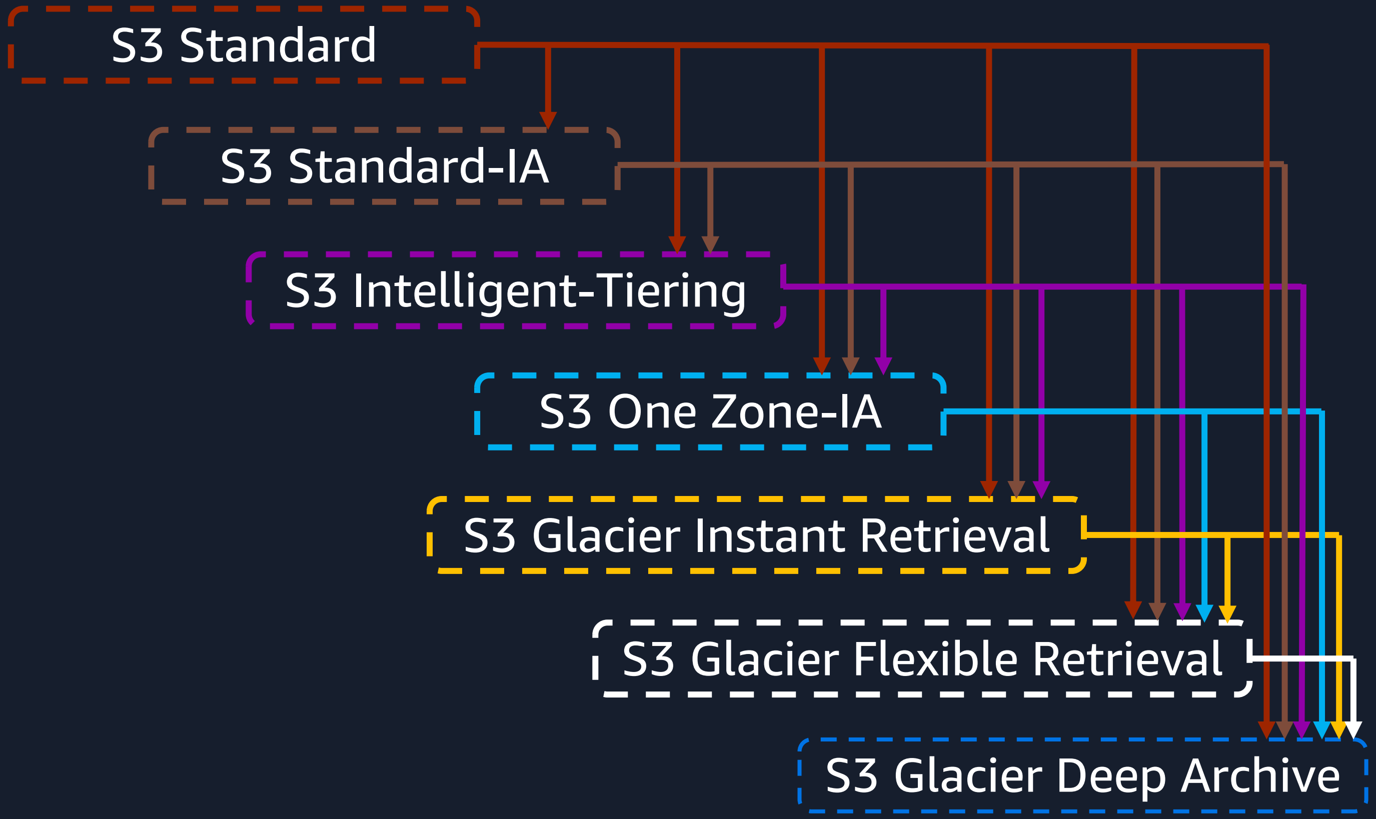
Managing data life cycle

🟧 Unneeded data is stored

- Lifecycle rules take action based on object age

Transition actions: Define when objects transition to other Amazon S3 storage classes as they age

Expiration actions: Define when objects expire; Amazon S3 deletes expired objects on your behalf



Summary

Summary

Common challenges

- 🟩 Huge data scan
- 🟪 HTTP Slow Down error
- 🟦 Many Small file issues
- 🟧 Unneeded data is stored

Best practices

- Optimizing data layout
  - Partitioning 🟩 🟪
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- Making well-designed retries 🟪
- Taking advantage of Amazon S3 Storage Class 🟧
- Reducing latency with Amazon Express One Zone 🟪
- Managing data life cycle 🟧

Summary

For other challenges, contact AWS Support!

Thank you!

Dai Ozaki

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