Must Serverless = Stateless?

Anurag Khandelwal
Assistant Professor, Computer Science Department
Yale University

WHY SHOULD YOU CARE?

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SERVERLESS

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Streaming data	Real-time	Data	Event-driven

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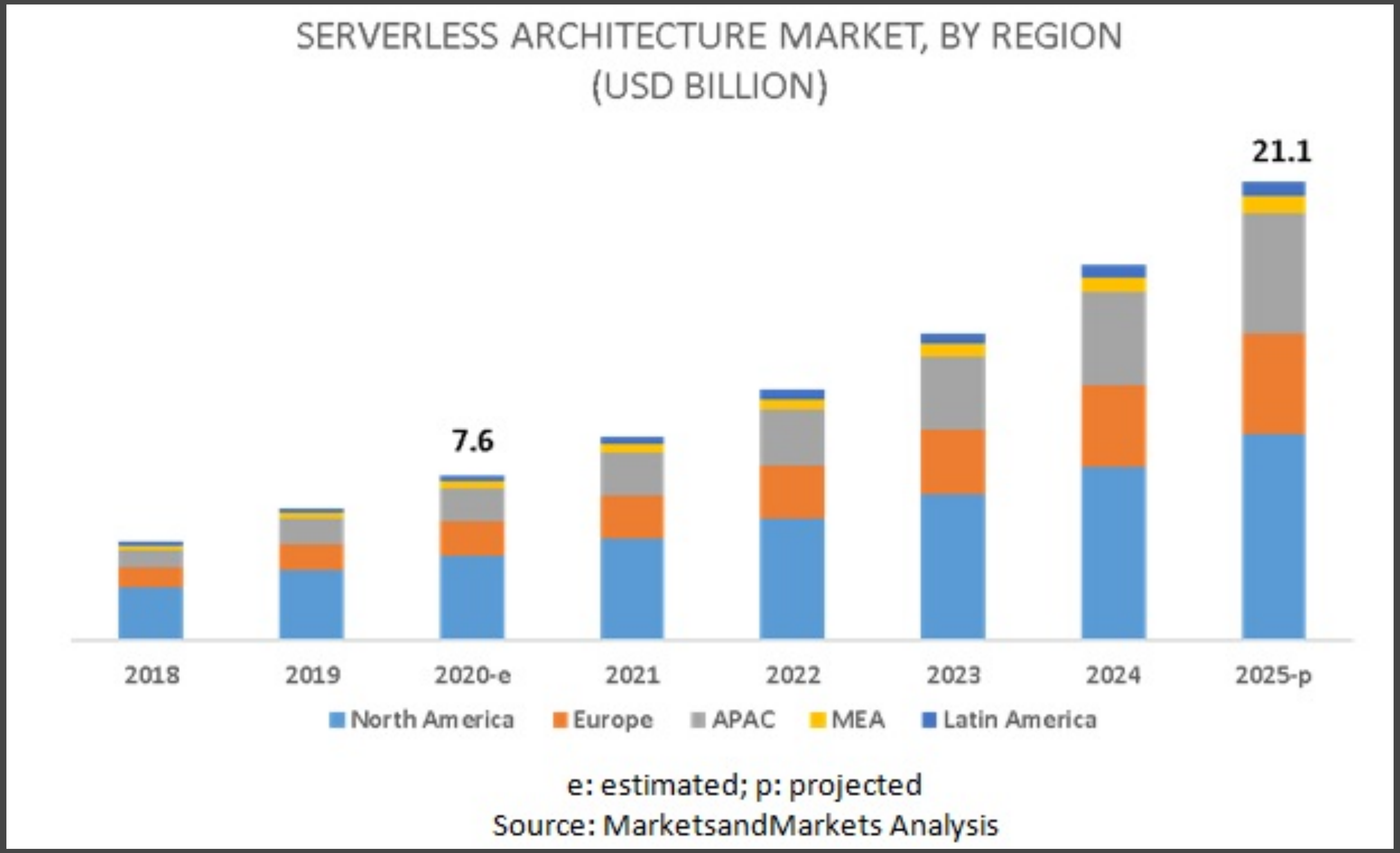

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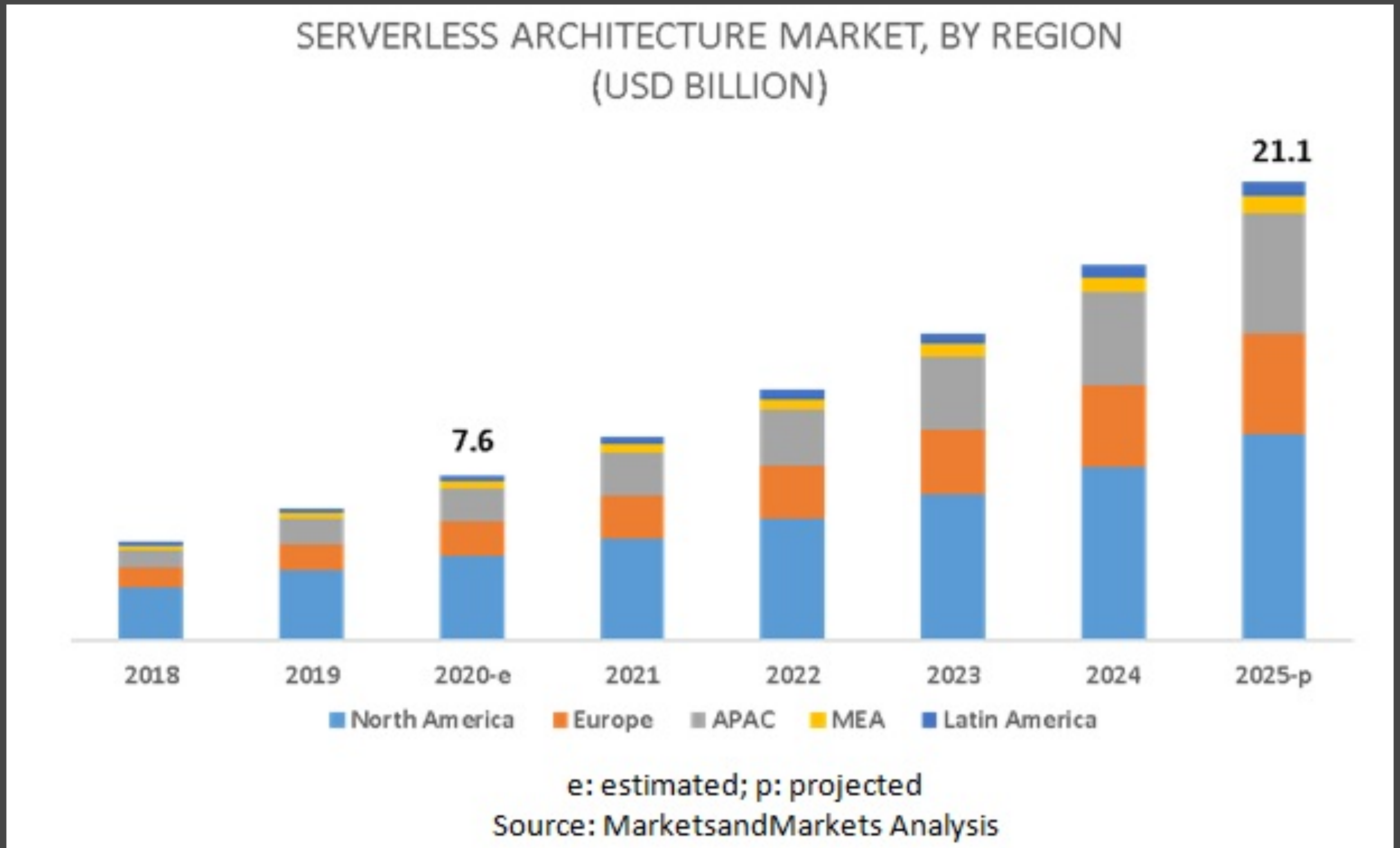

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This talk:

- ✦ What & why of serverless
- ✦ Today's Serverless = Stateless
- ✦ Stateless → Stateful serverless

WHAT & WHY OF SERVERLESS

WHAT IS SERVERLESS?

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DEVELOPMENT

EASE OF USE

High-level language (e.g., Python, SQL)

Zero management (fault-tolerance, load-balancing)

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Fine-grained resource elasticity

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BILLING

COST EFFICIENCY

Pay-as-you-go + fine-grained billing

SERVERLESS COMPUTING *SIMPLIFIES* CLOUD PROGRAMMING

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Upload Code

Run at any scale

Pay for what you use

A REAL USE-CASE: HOW FINANCIAL ENGINES CUT COSTS 90% USING SERVERLESS[1]

- Financial Engines: Independent Investment Advisor
  - 9 million people across 743 companies, $1.8 trillion in assets

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- Financial Engines: Independent Investment Advisor
  - 9 million people across 743 companies, $1.8 trillion in assets
- Automated portfolio management using computational engines
  - Core engine component: Integer programming optimizer (IPO)
  - Linear Programming to compute optimization/feasibility

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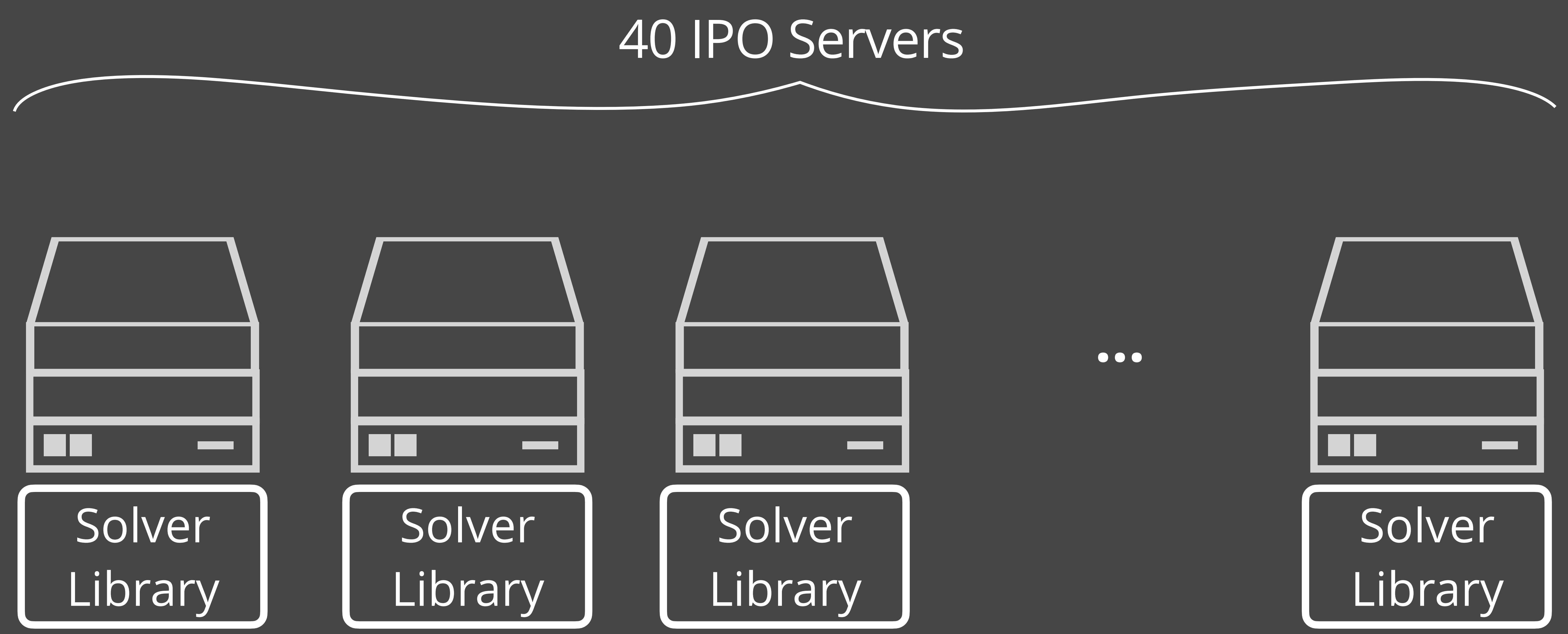
IPO SERVER FARM



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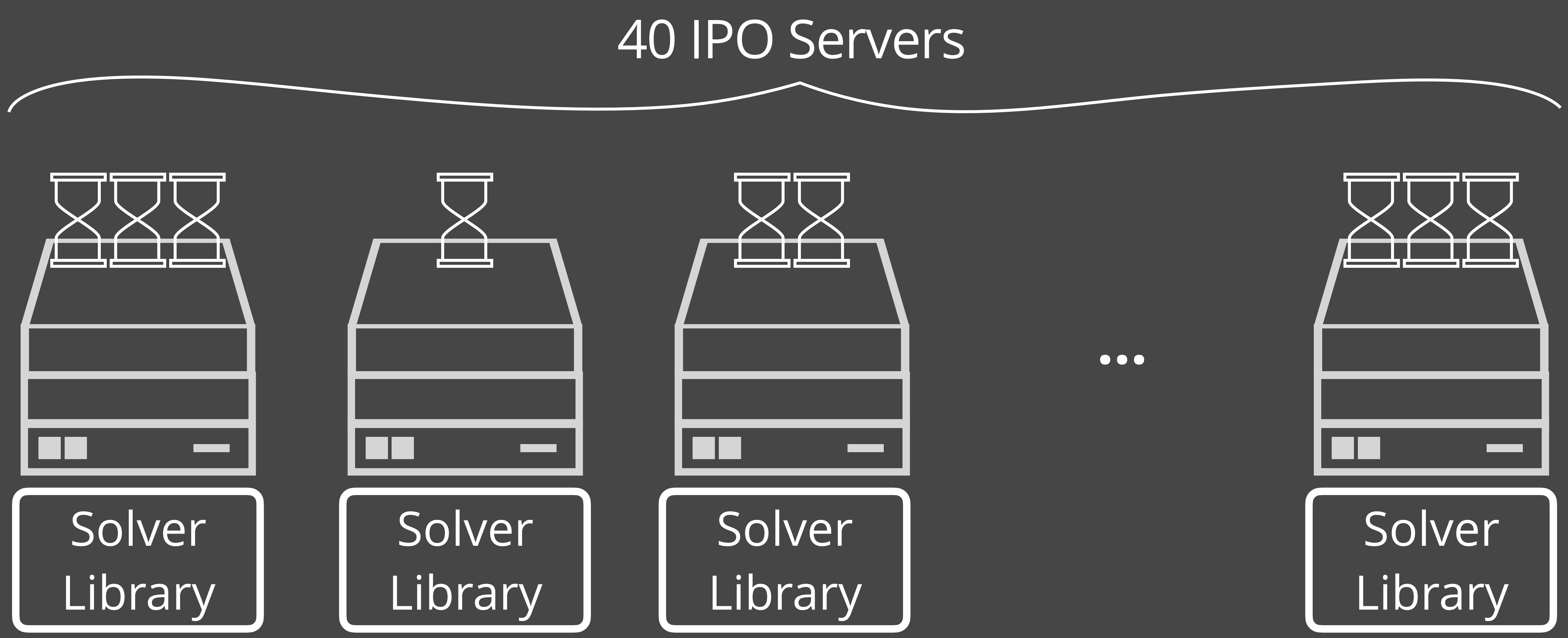

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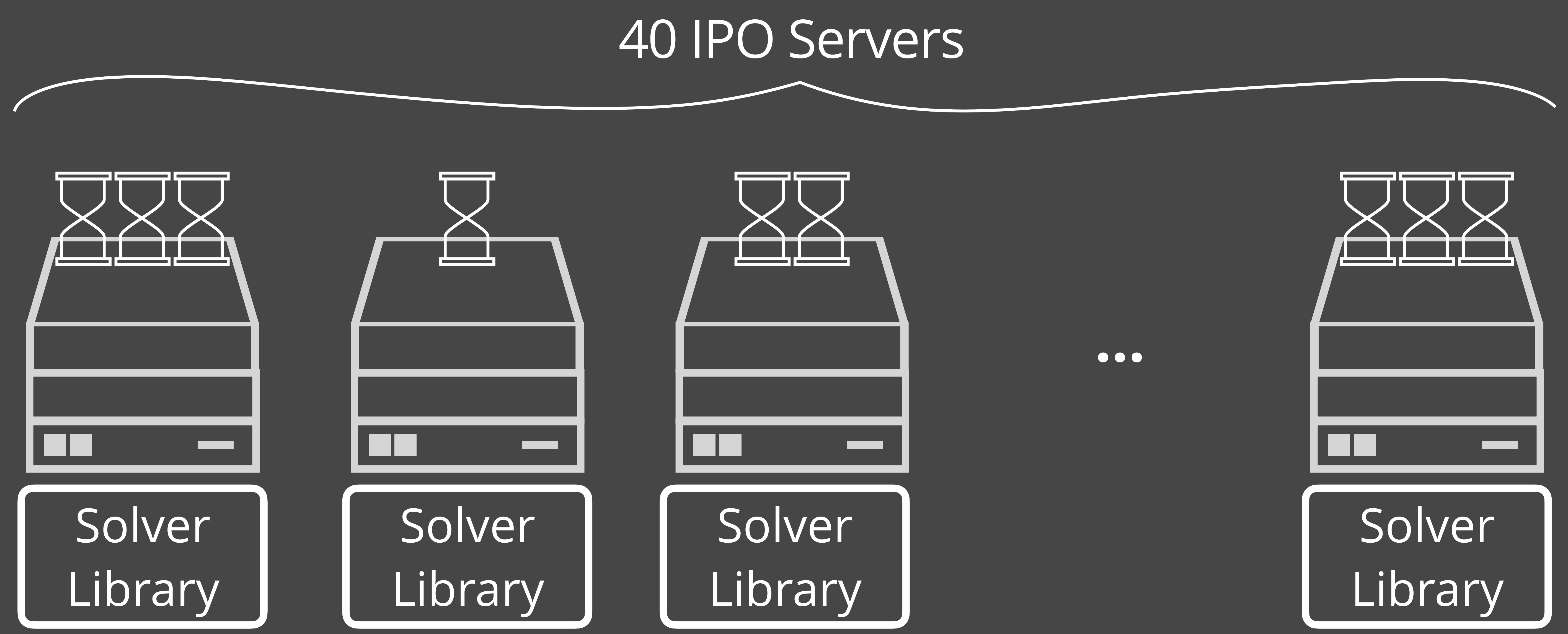

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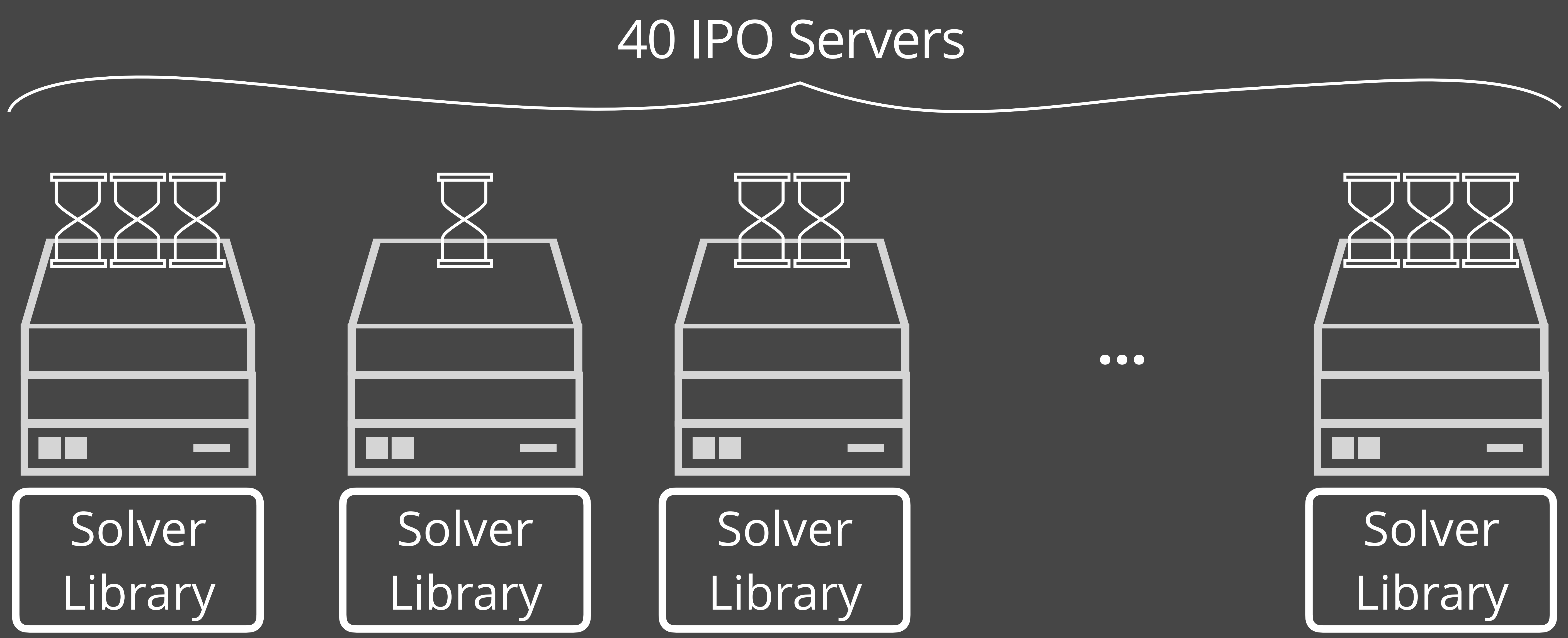

- IPO consumes > 30% of total CPU capacity
  - Spikes of up to 1000 requests/s, 100ms per request
  - Capacity planning during marketing campaigns that produce large traffic spikes is hard...

NEED TO DO A LOT OF WORK…

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- Scaling in response to load variations
- Request routing and load balancing
- Monitoring to respond to problems
- Provision servers based on budget, requirements
- System upgrades, including security patching
- Migration to new hardware as it becomes available

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Developer’s burden!

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- Serverless benefits
  - 200-300 M IPO requests/month, 60,000 per minute at peak
  - Up to 94% cost savings annually, *not* including operational savings
  - Increased reliability: just instantiate new lambda requests on crash

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SERVERLESS TODAY

EVOLUTION[1]

OF CLOUD PLATFORMS

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On-prem virtualization

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On-prem virtualization

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VMs in the cloud

- Easy switch from legacy infrastructure
- Added *cloud services* (e.g., storage, compute)

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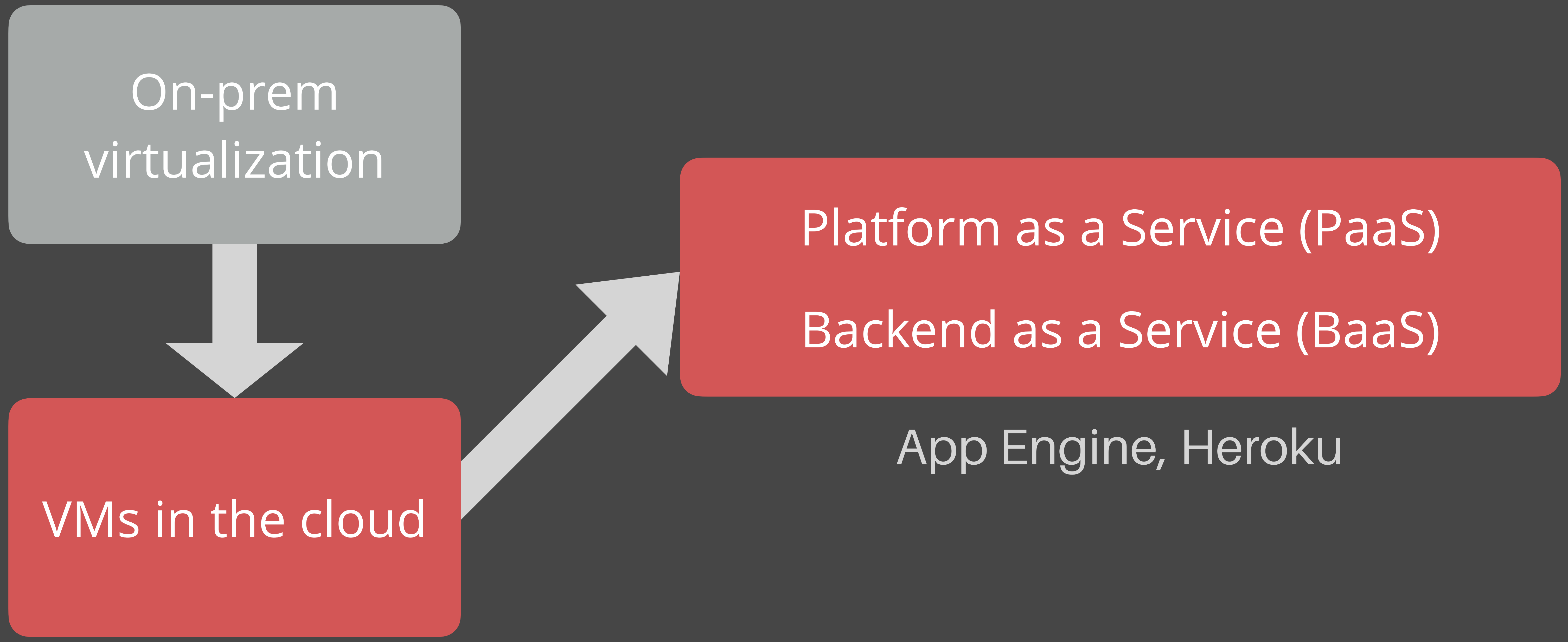

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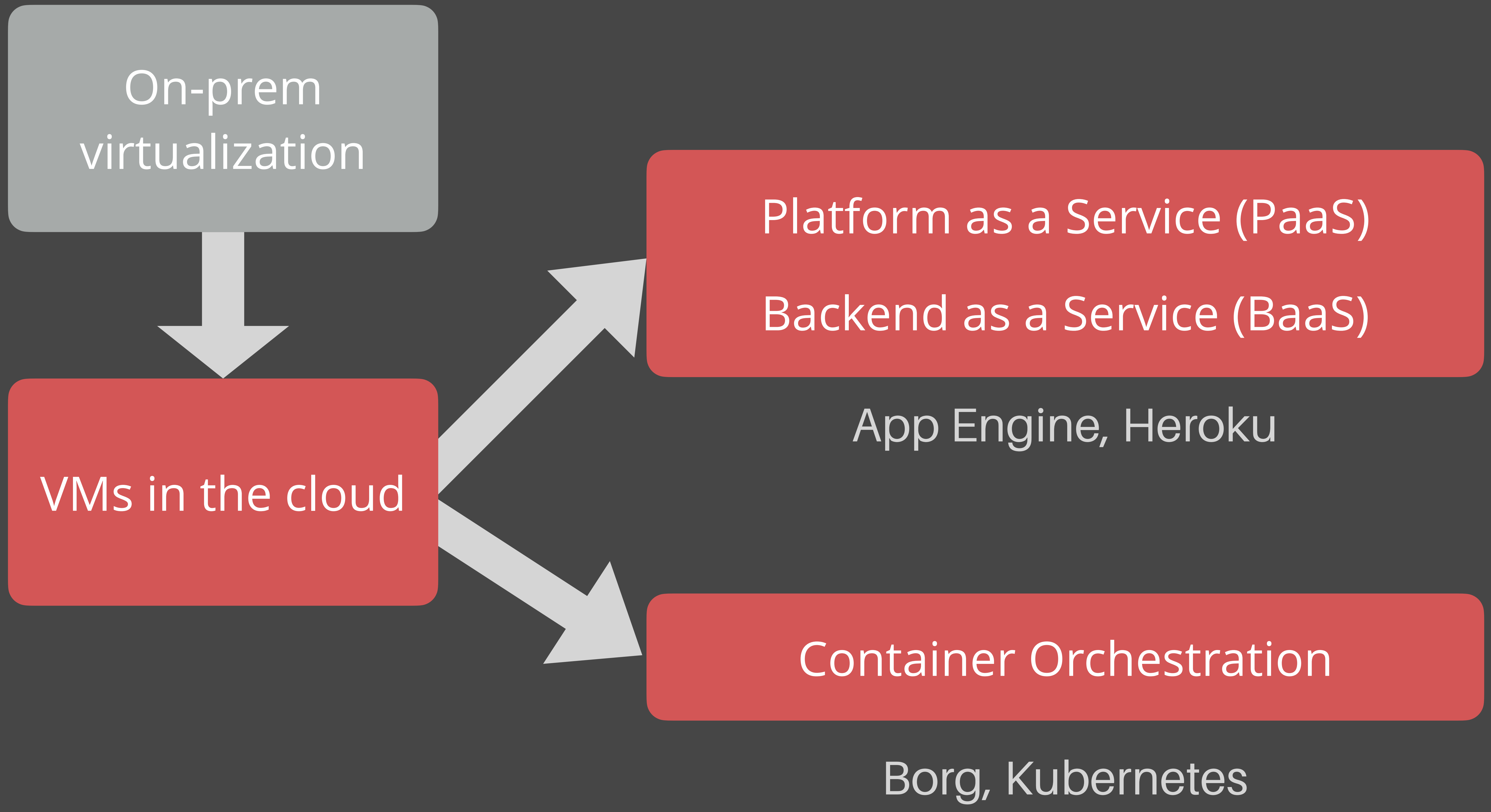

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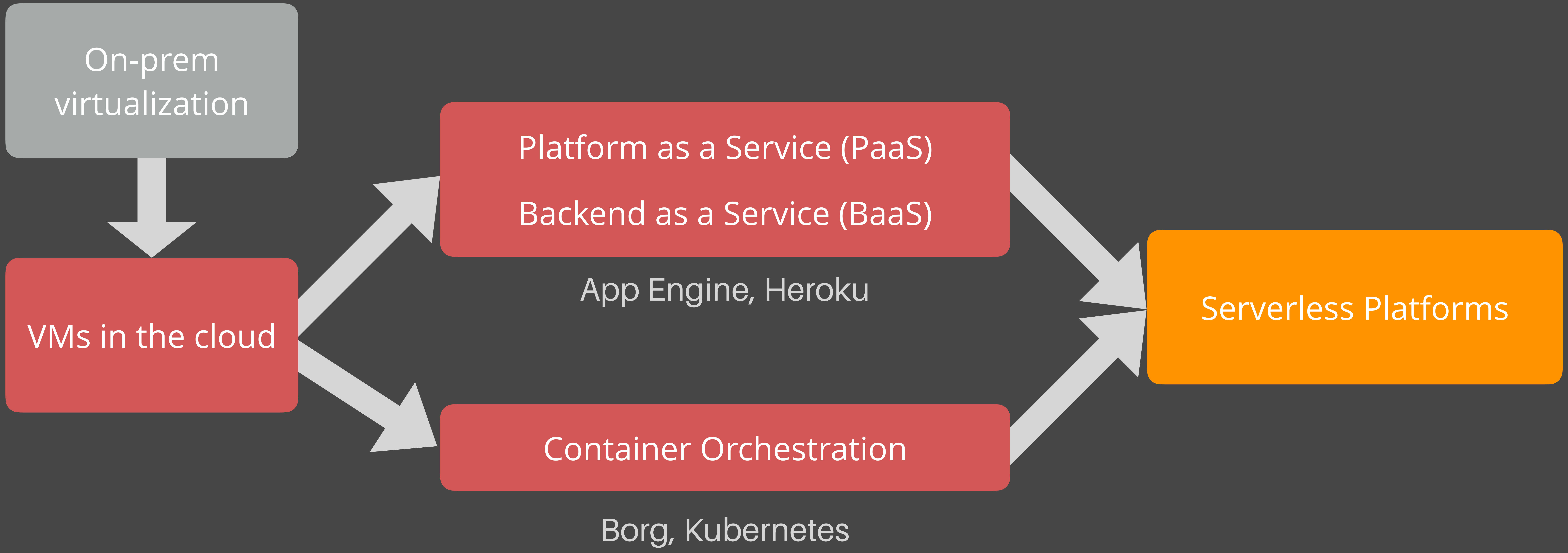

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- Many FaaS platforms

AWS Lambda | IBM Cloud Functions | Google Cloud Functions | Cloudflare Workers | Azure Functions | Alibaba Function Compute

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- Many FaaS orchestration frameworks:

AWS Step Functions | Microsoft Azure — Azure Durable Functions | IBM Composer

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- Different pricing models, resource allocations, security, isolation, programming language support, OS support, etc.[1,2]

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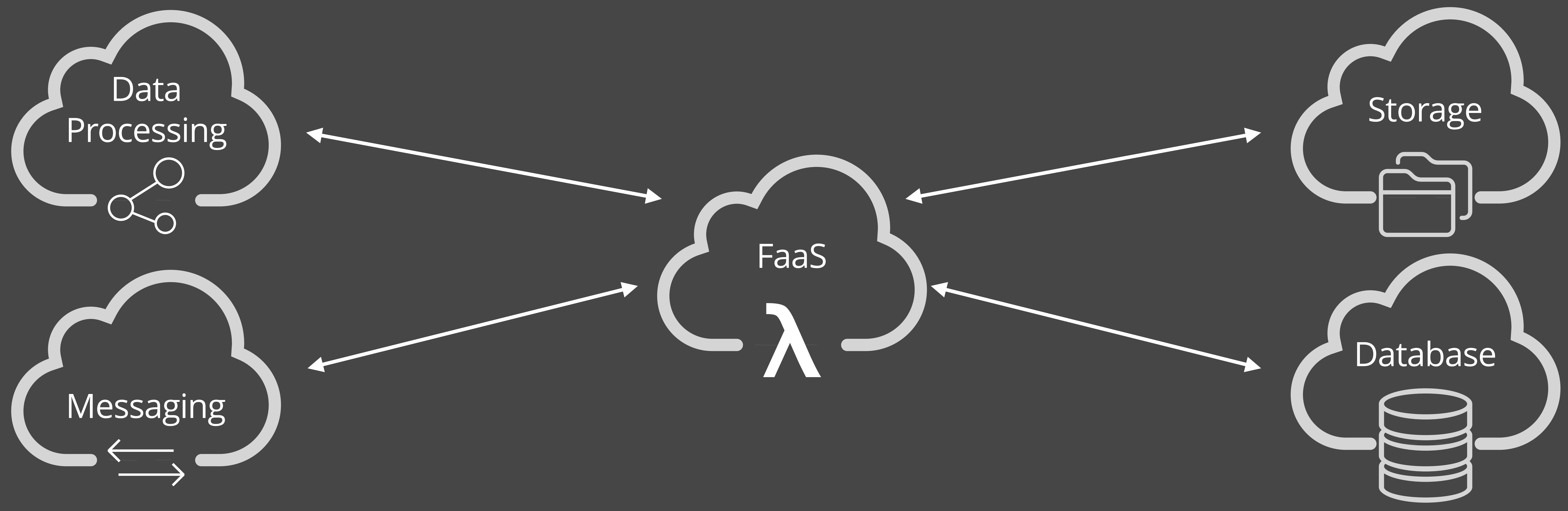

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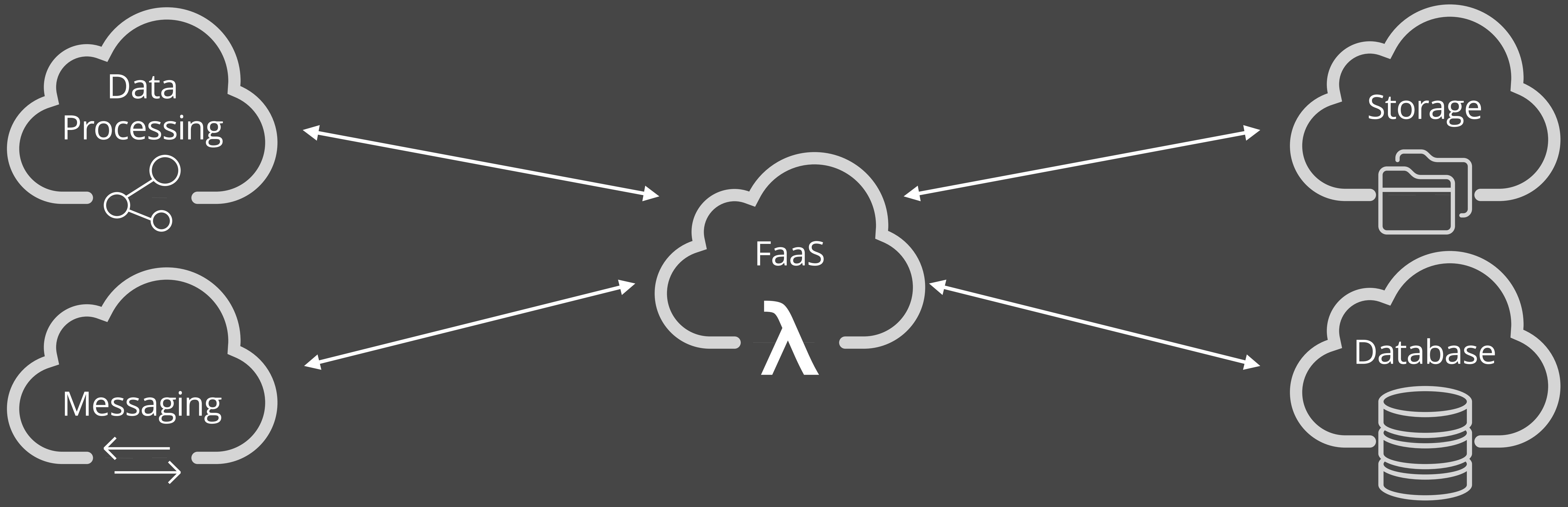

Serverless

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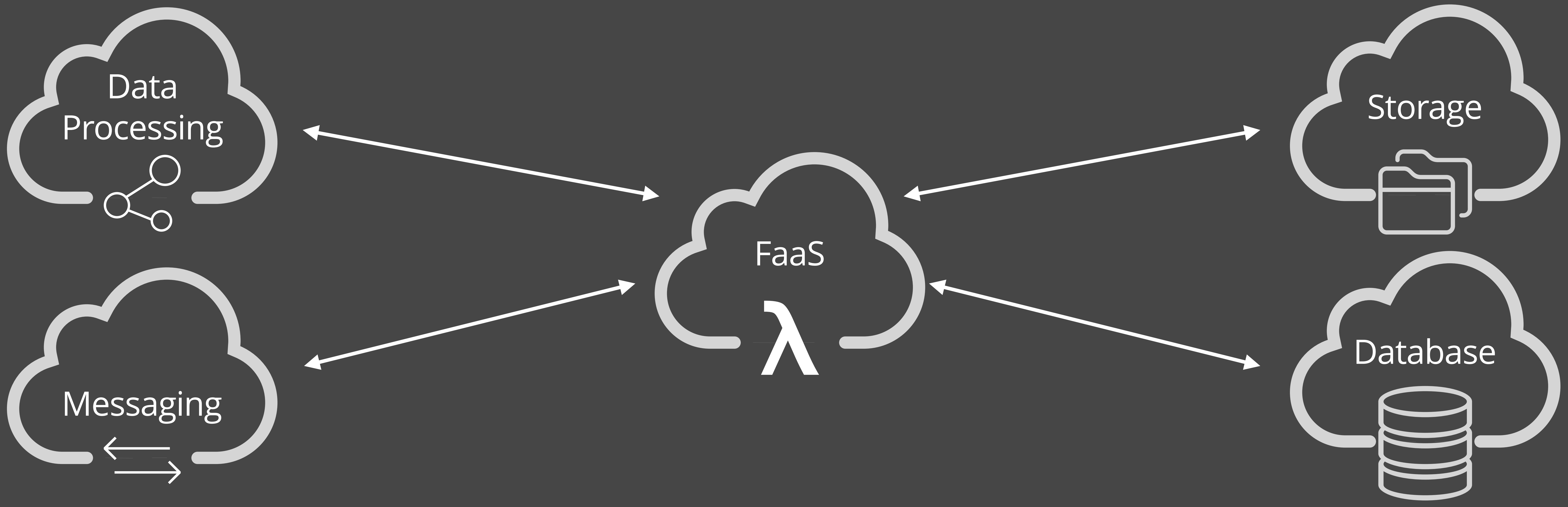

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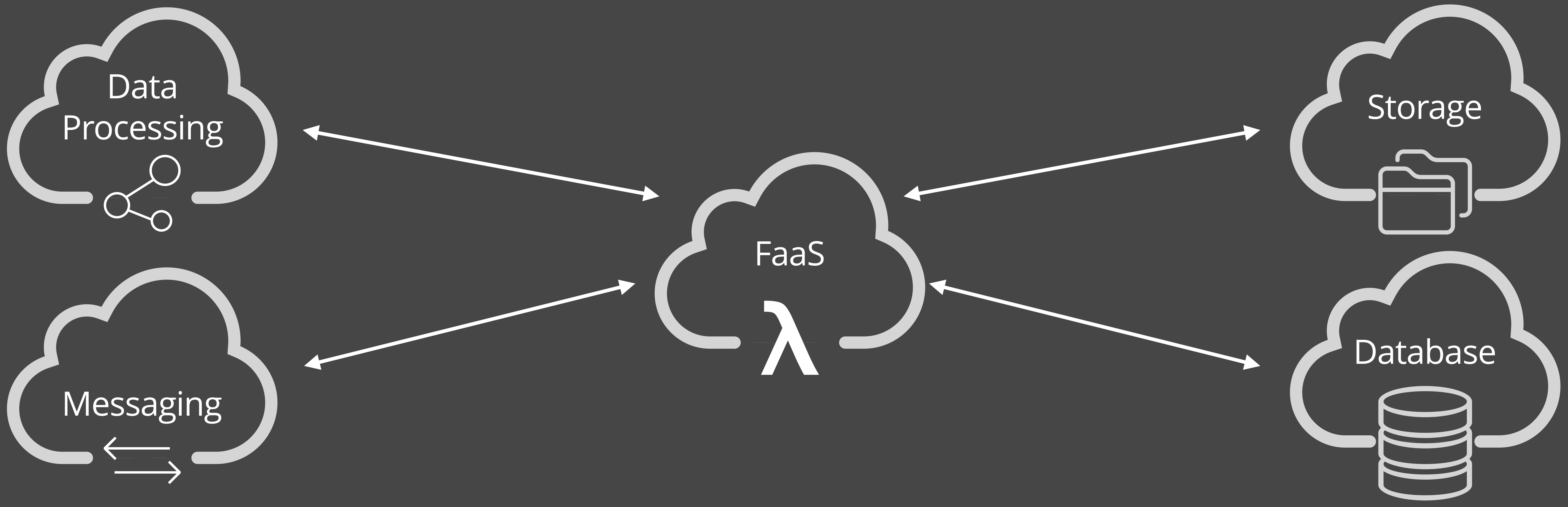

Serverless = FaaS + **BaaS**

- Object Storage (e.g., S3)
- Key-Value Stores (e.g., DynamoDB)
- Database (e.g., Cloud Firestore)
- Data Processing (e.g., Cloud Dataflow)

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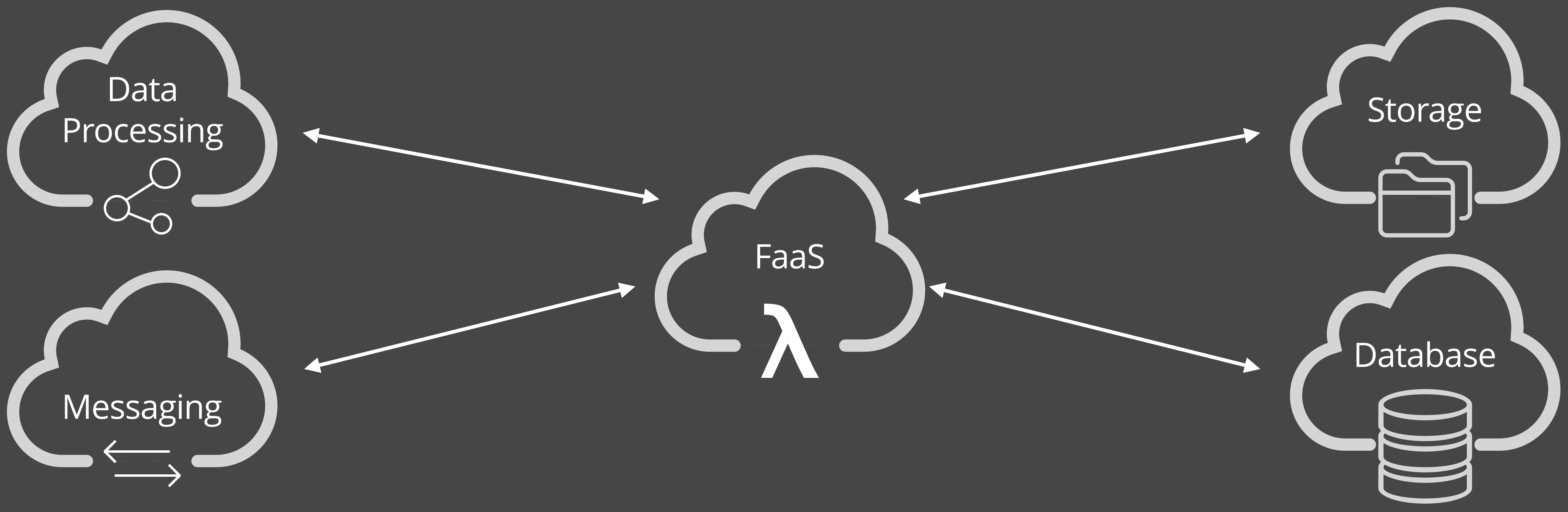

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- Complexity Hiding
- Consumption based billing
- Automatic scaling

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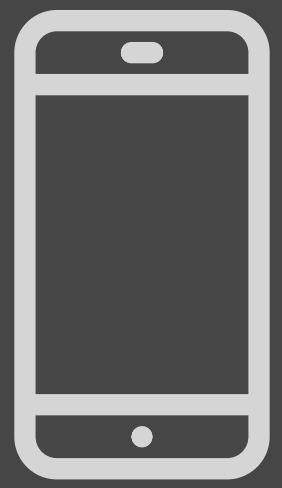

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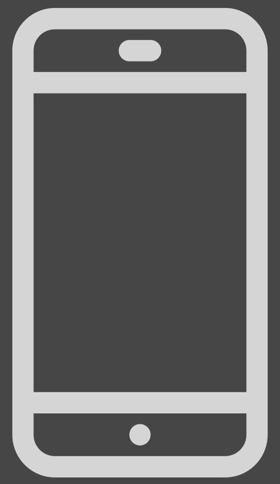

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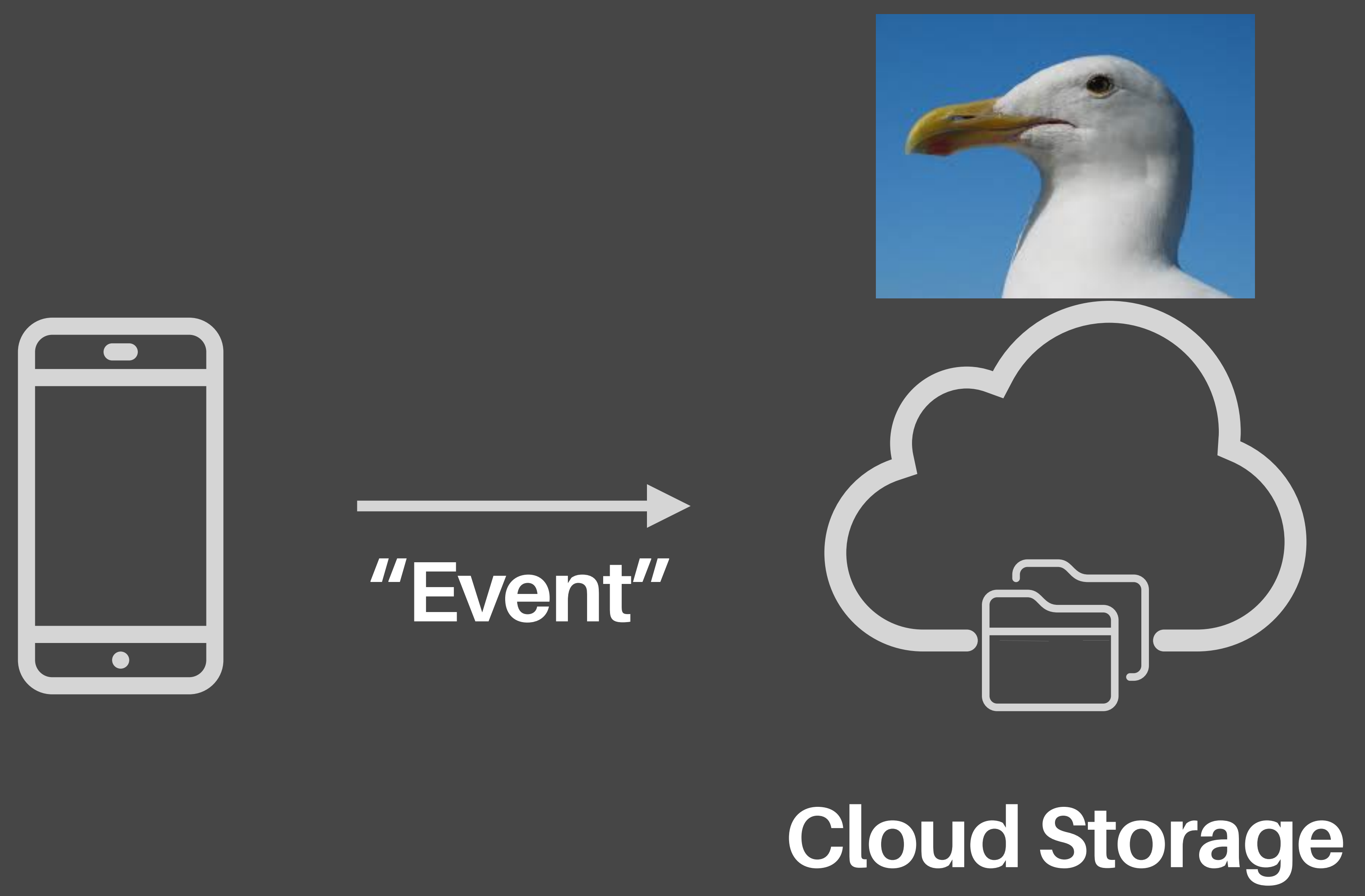

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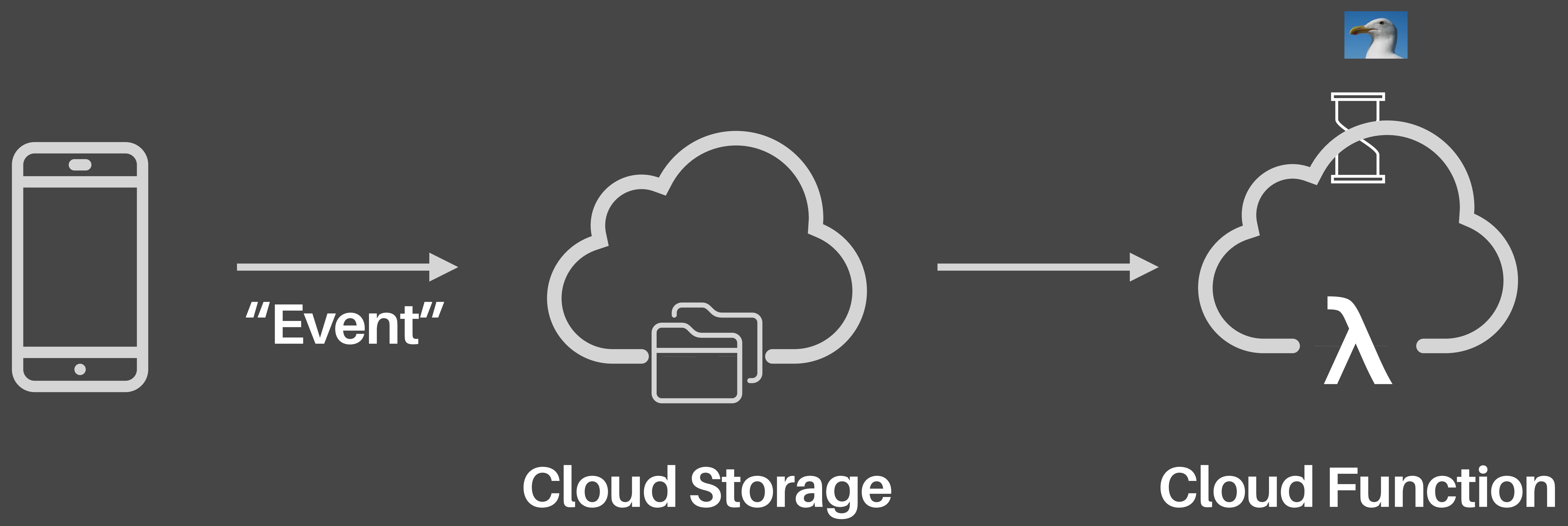

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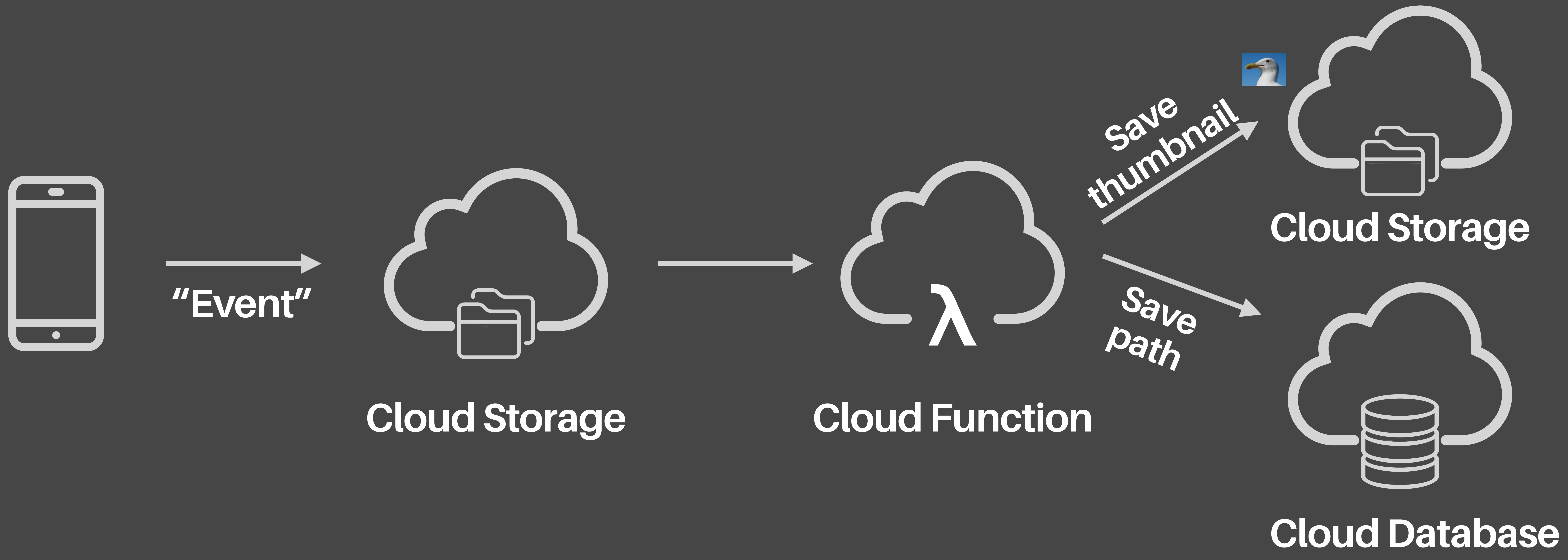

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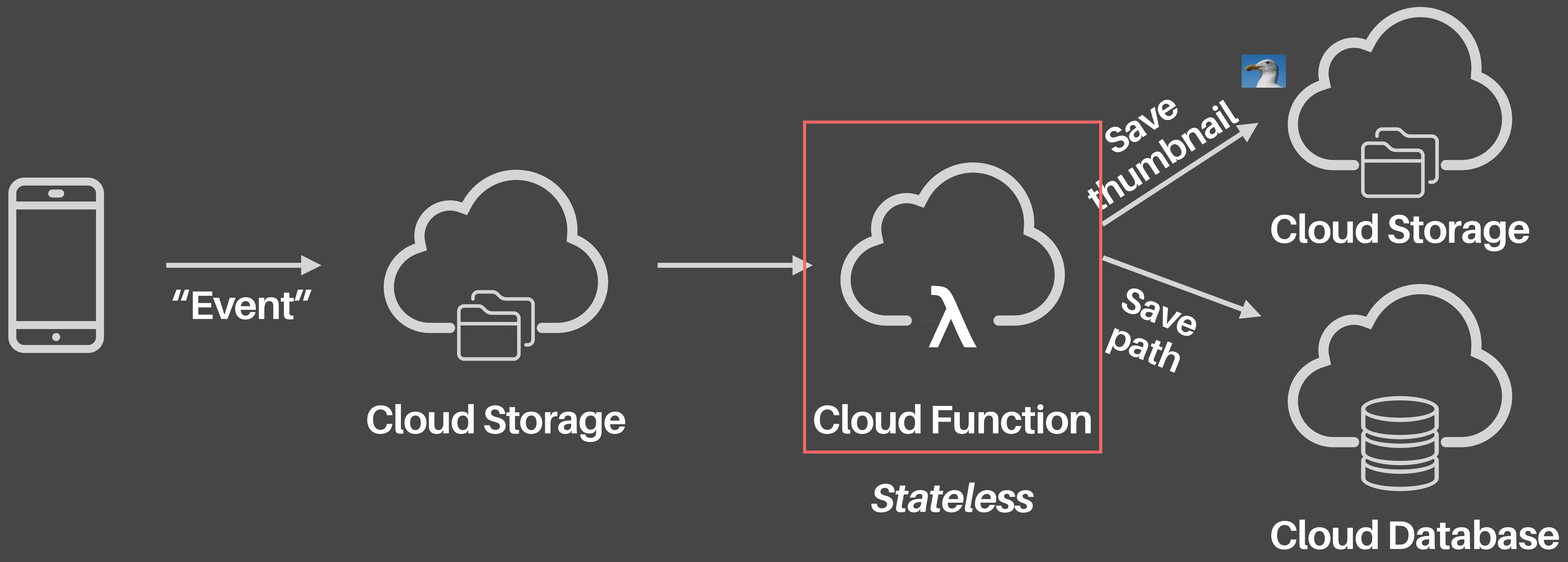

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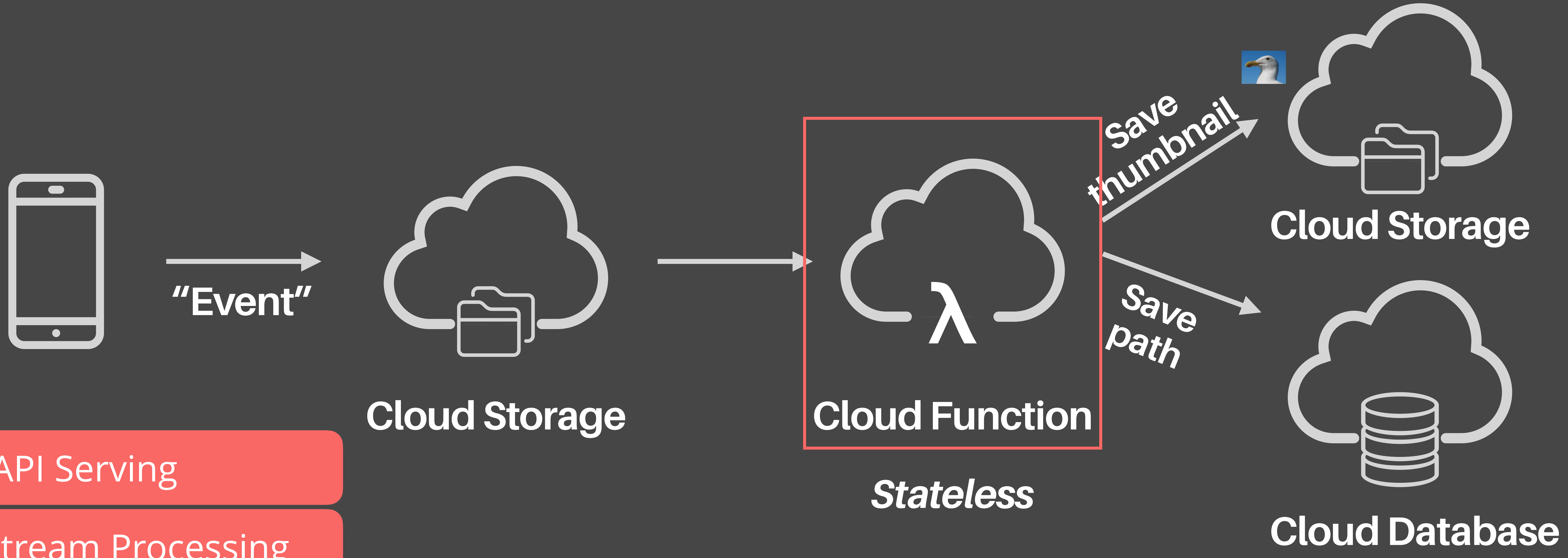

API Serving

Event Stream Processing

ETL

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Generate, exchange and consume *intermediate data*

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SQL Analytics

Video Analytics

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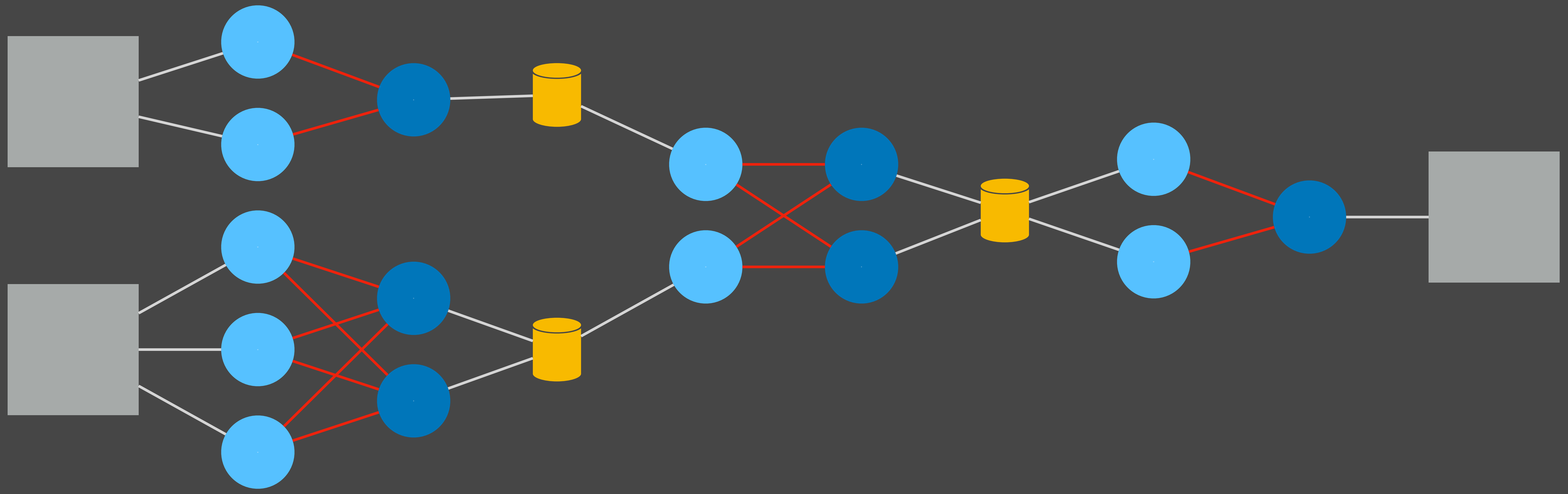

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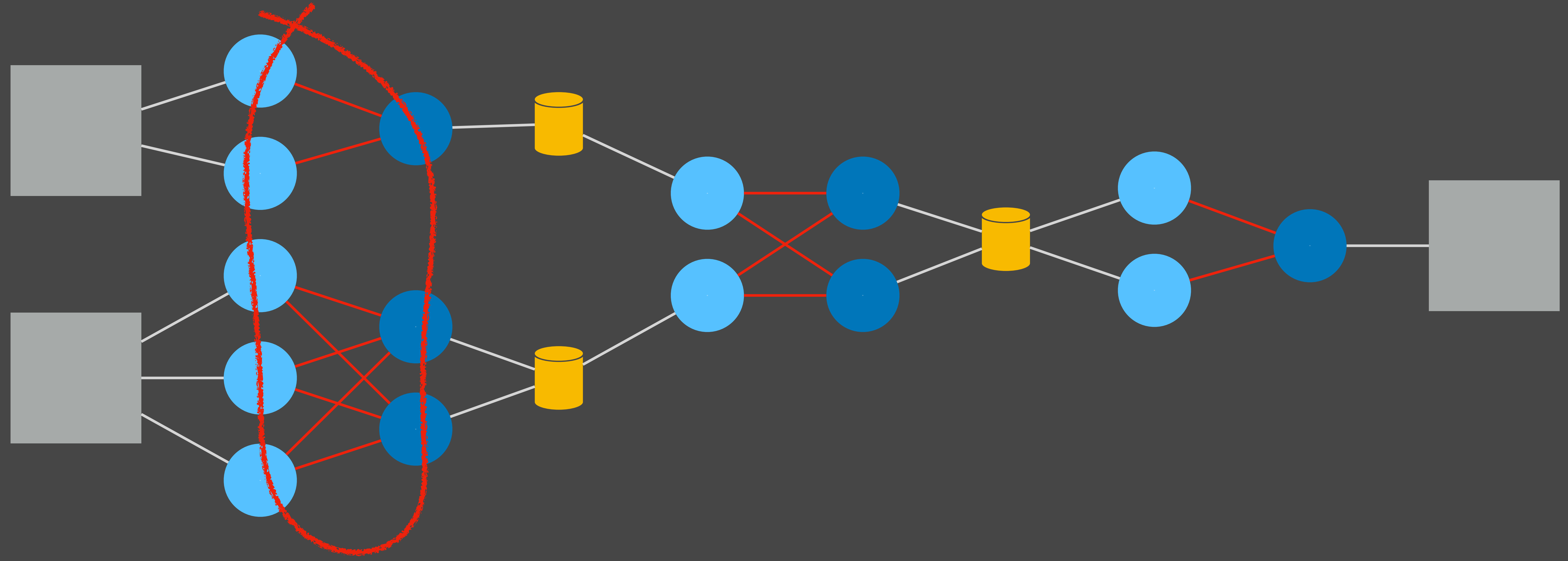

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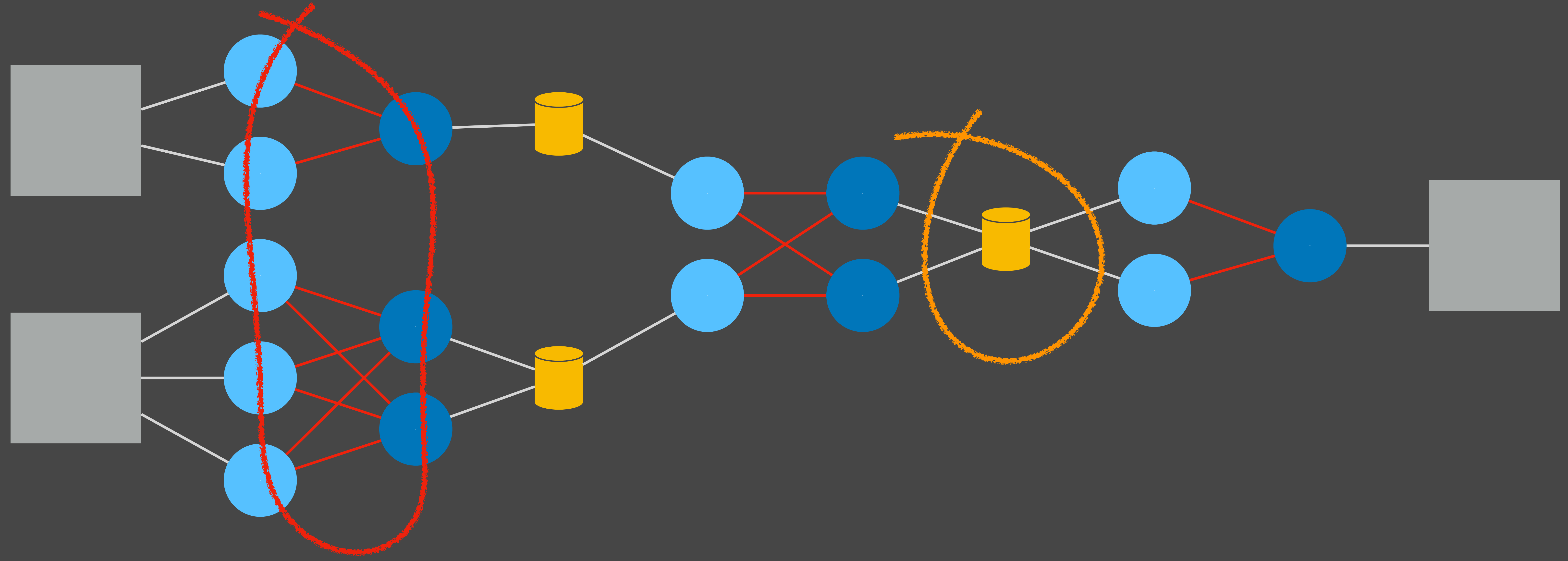

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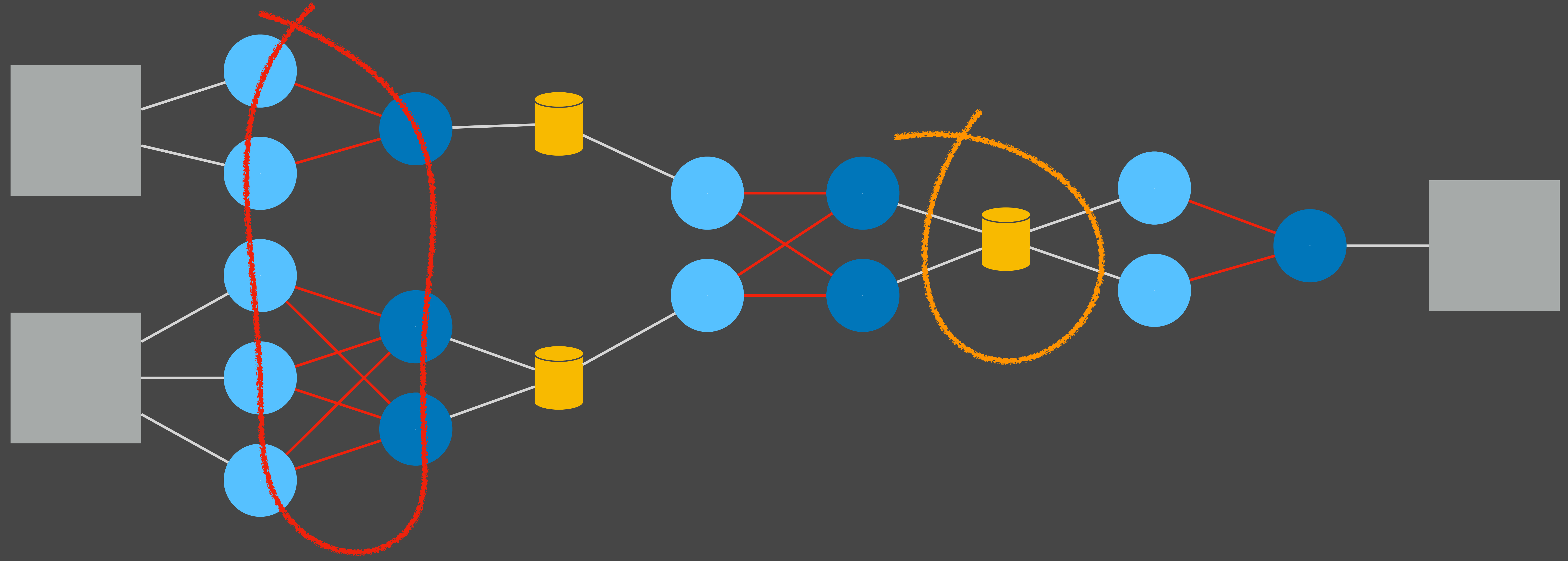

How can we efficiently support stateful applications on serverless?

EMERGING & FUTURE SUPPORT FOR STATEFUL APPLICATIONS

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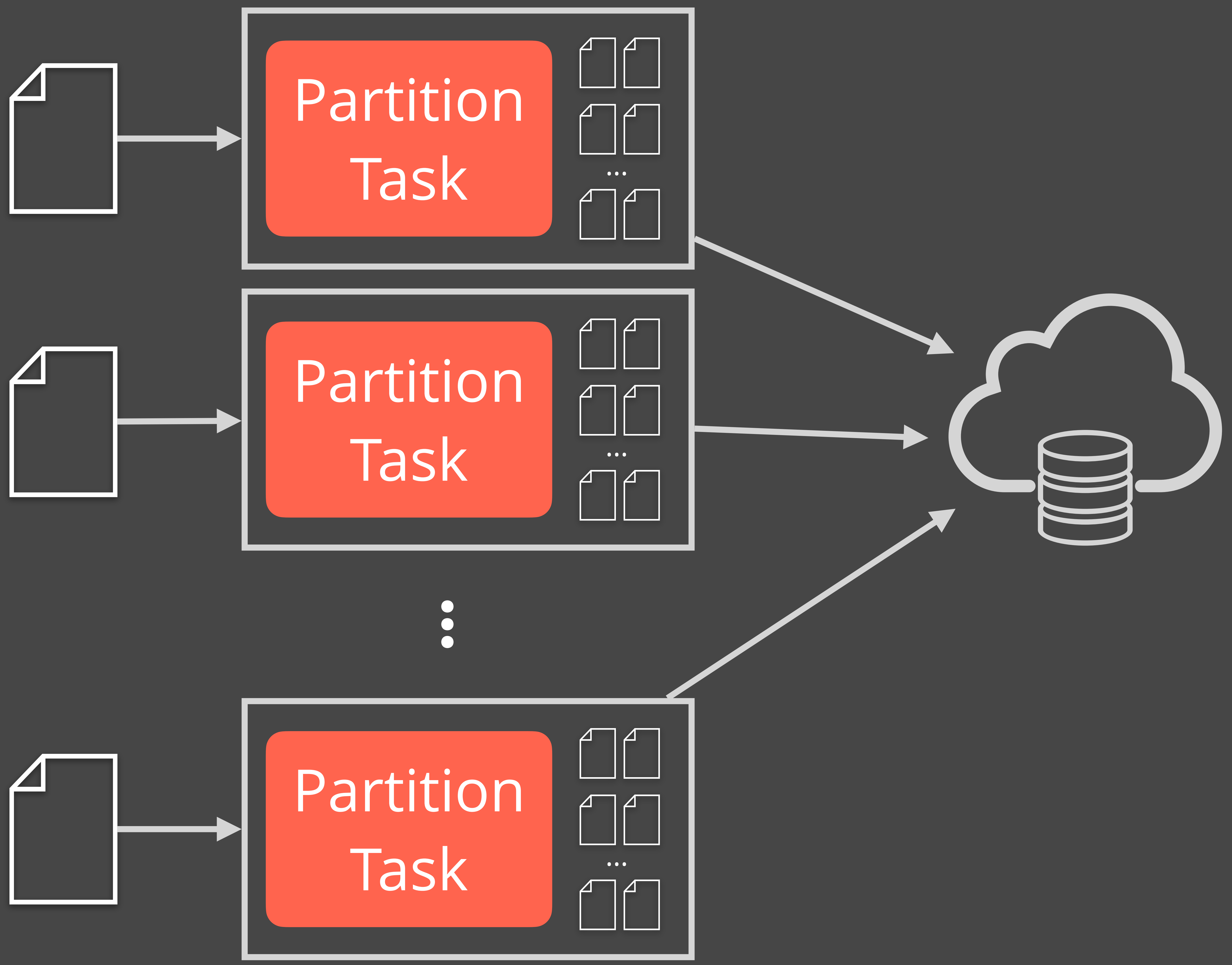

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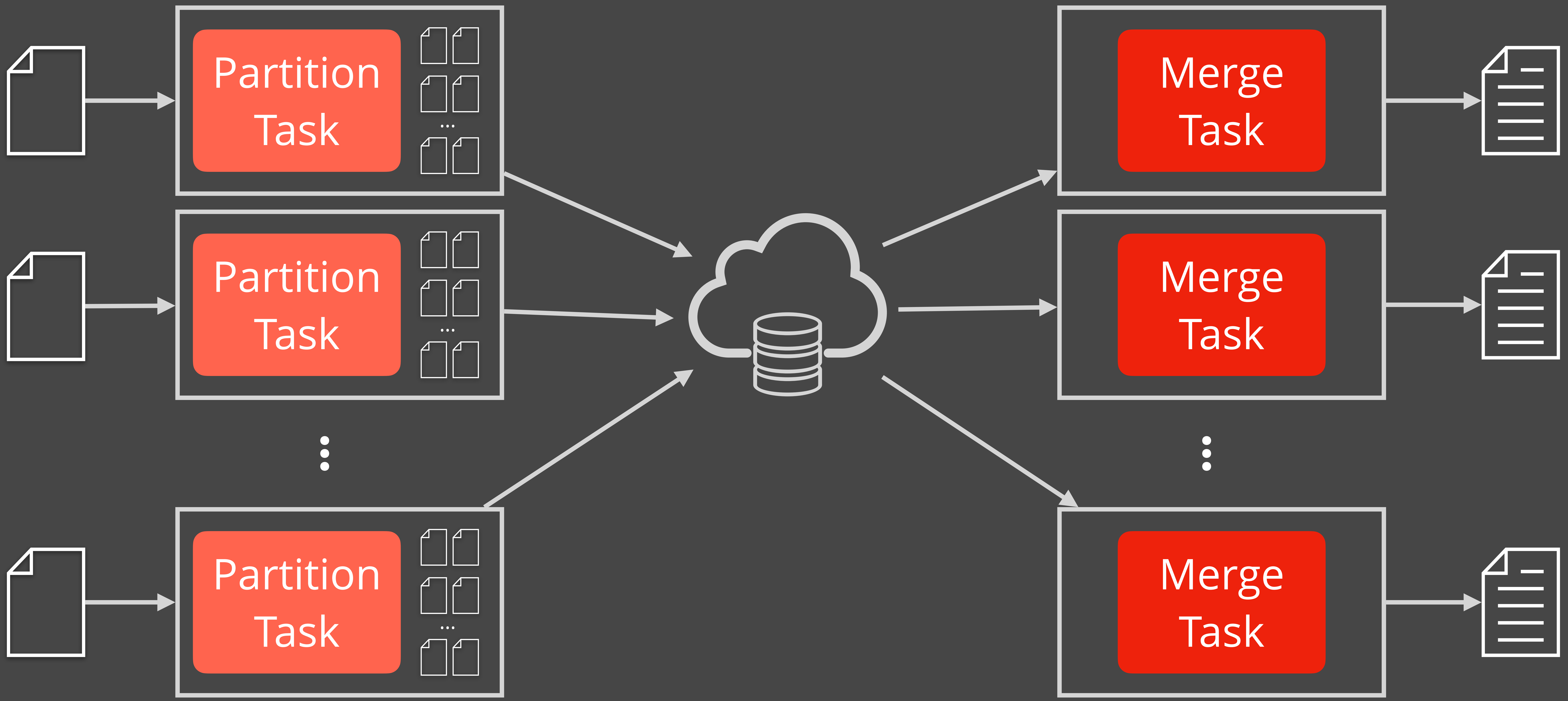

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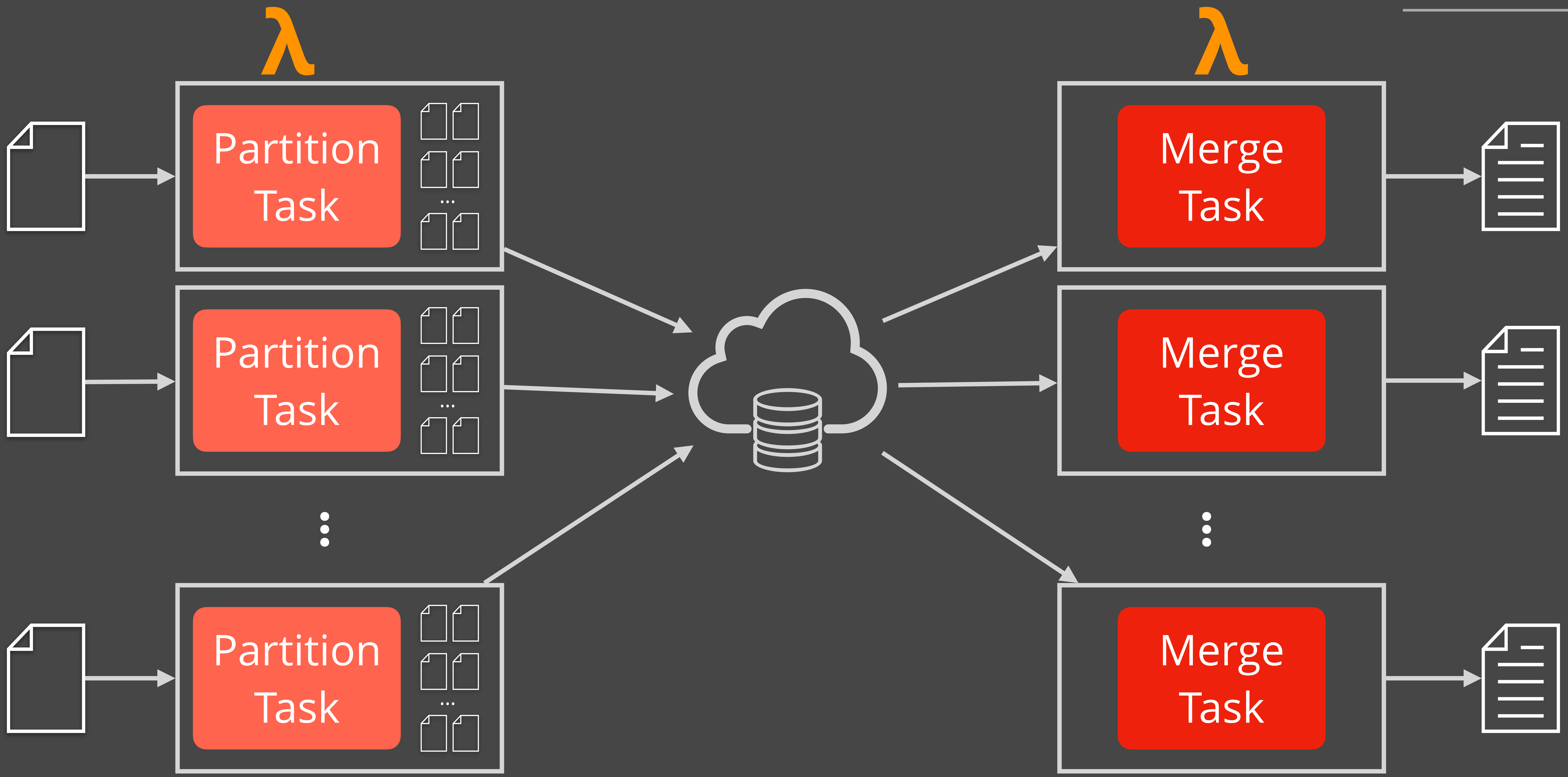

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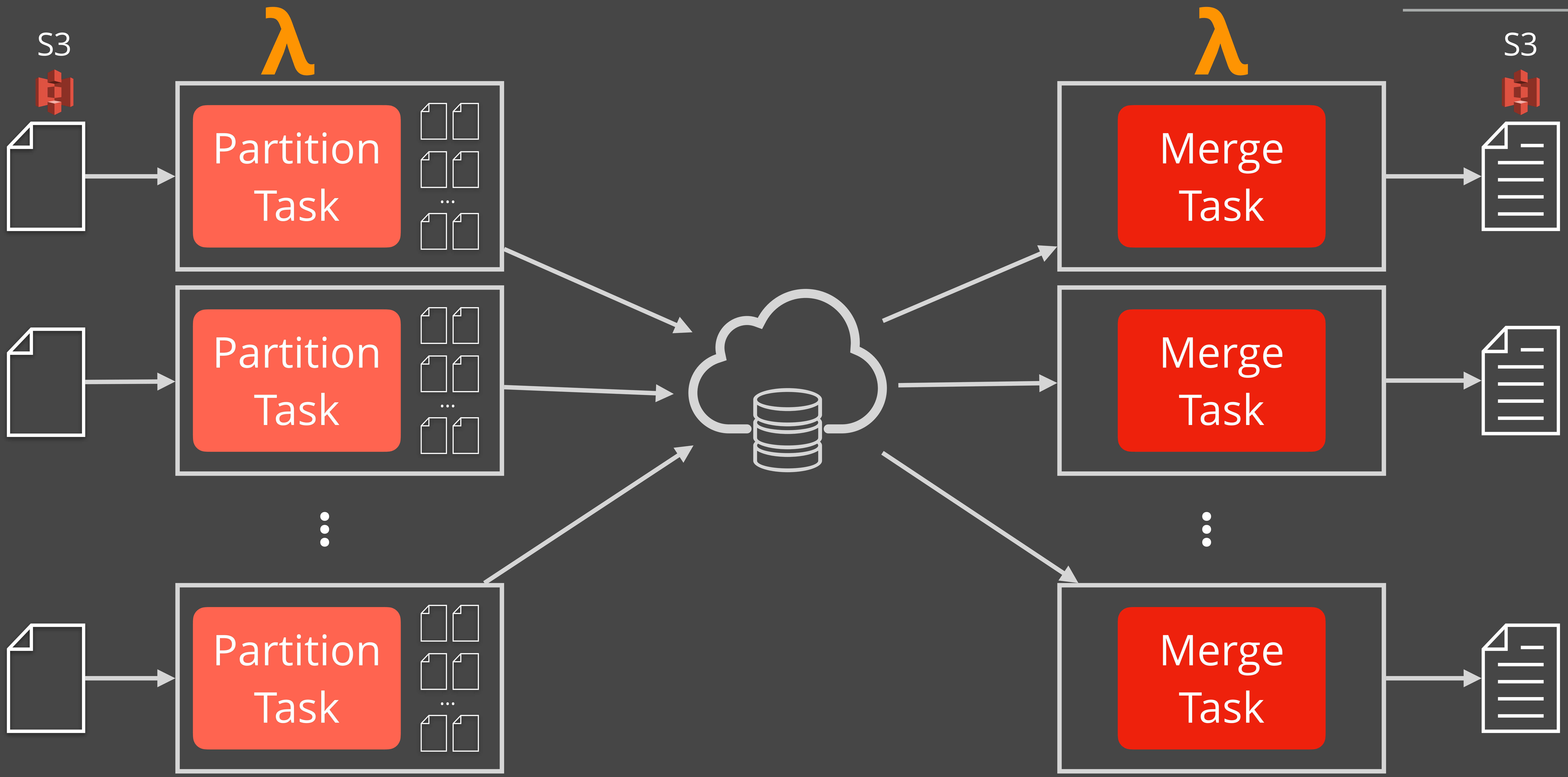

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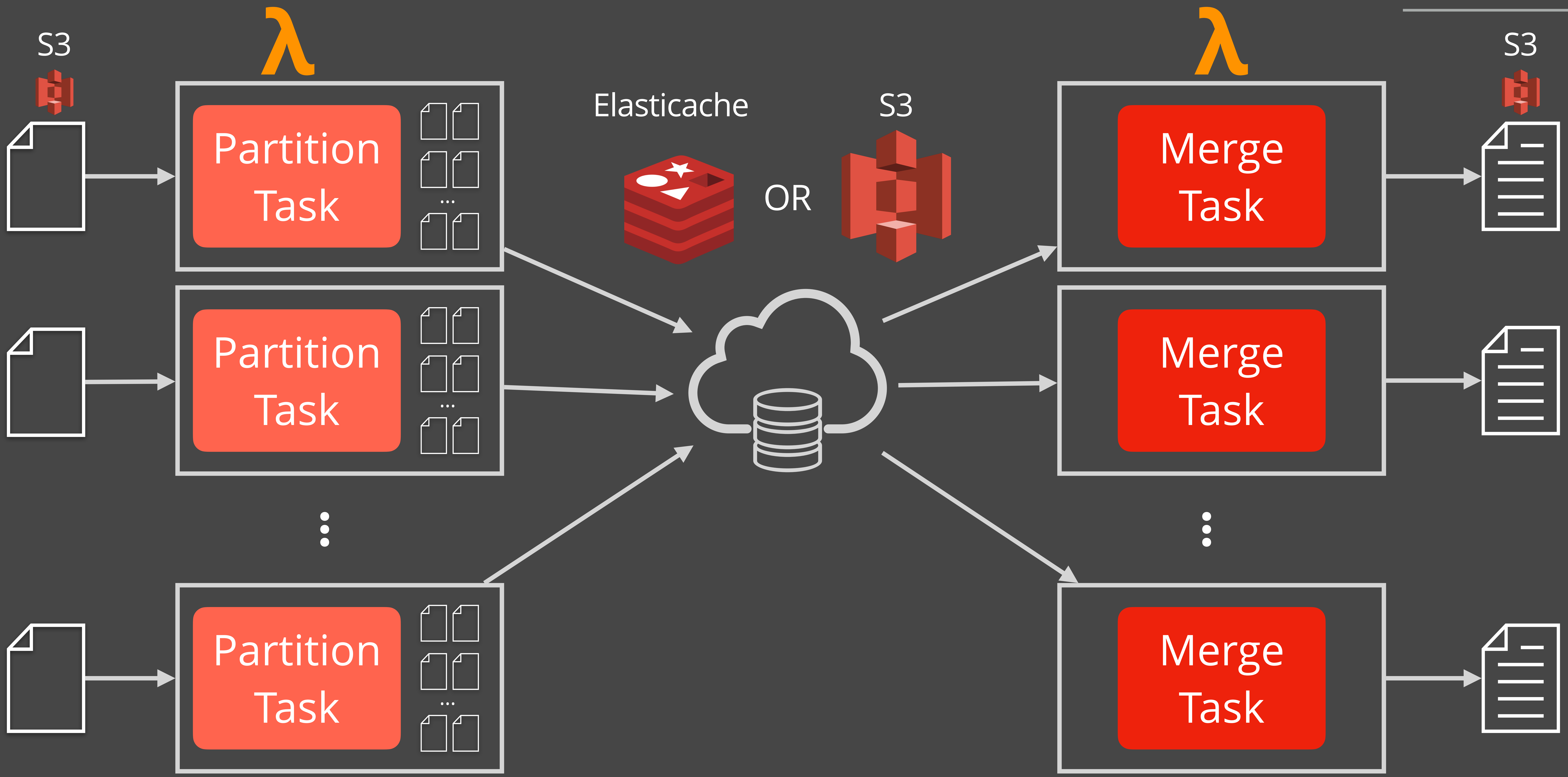

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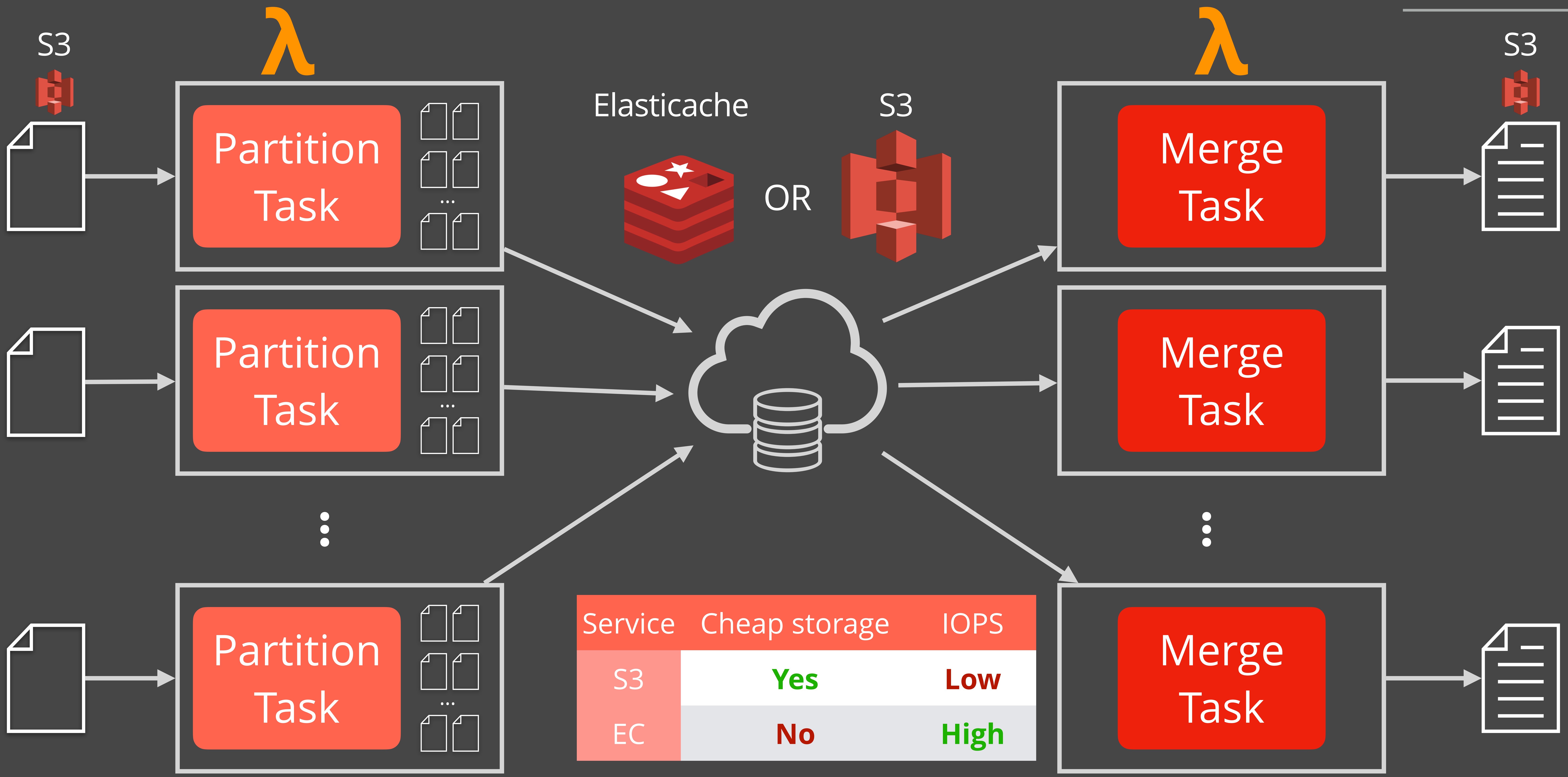

Service	Cheap storage	IOPS
S3	Yes	Low
EC	No	High

SERVERLESS ANALYTICS: LOCUS

Hybrid Sort

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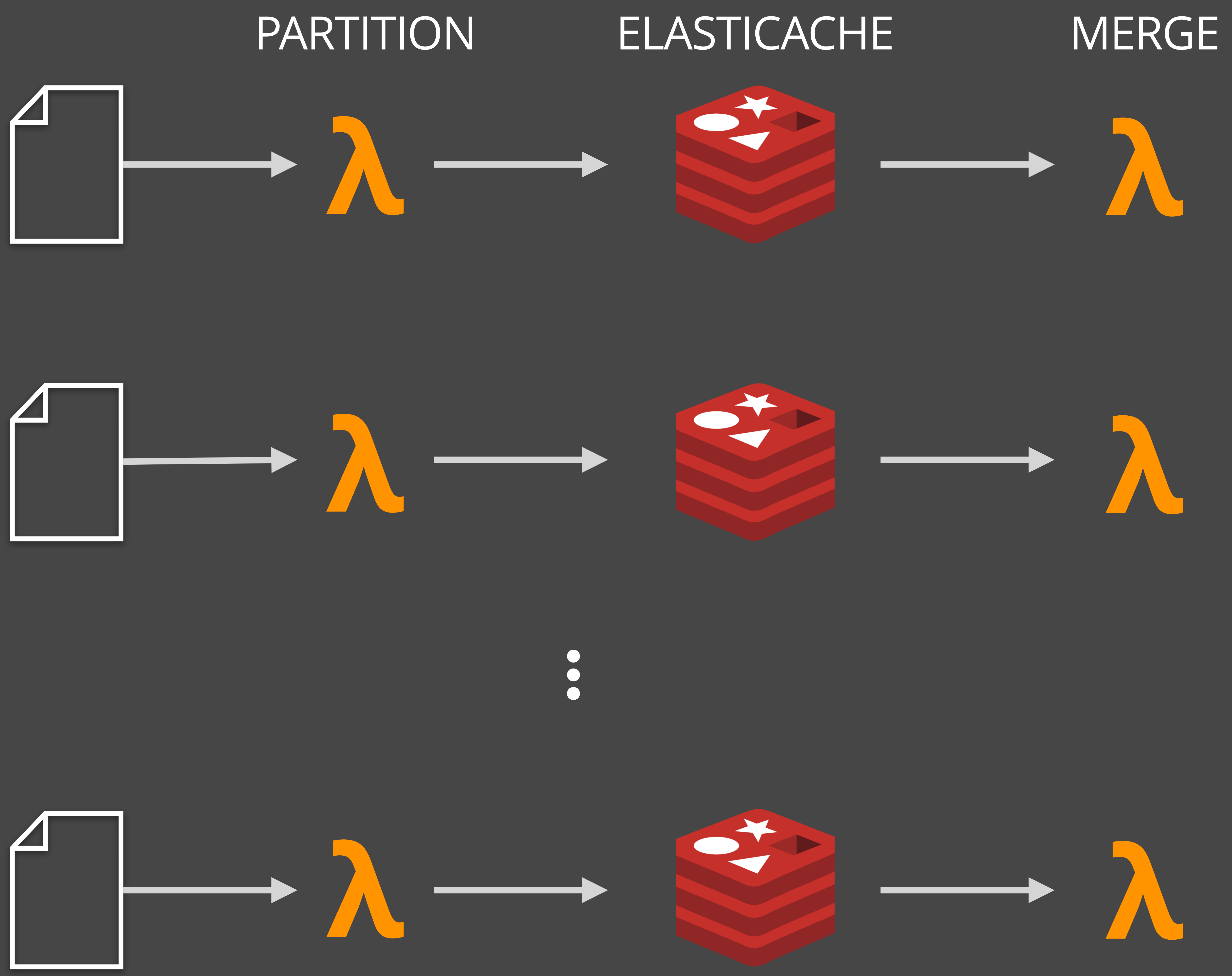

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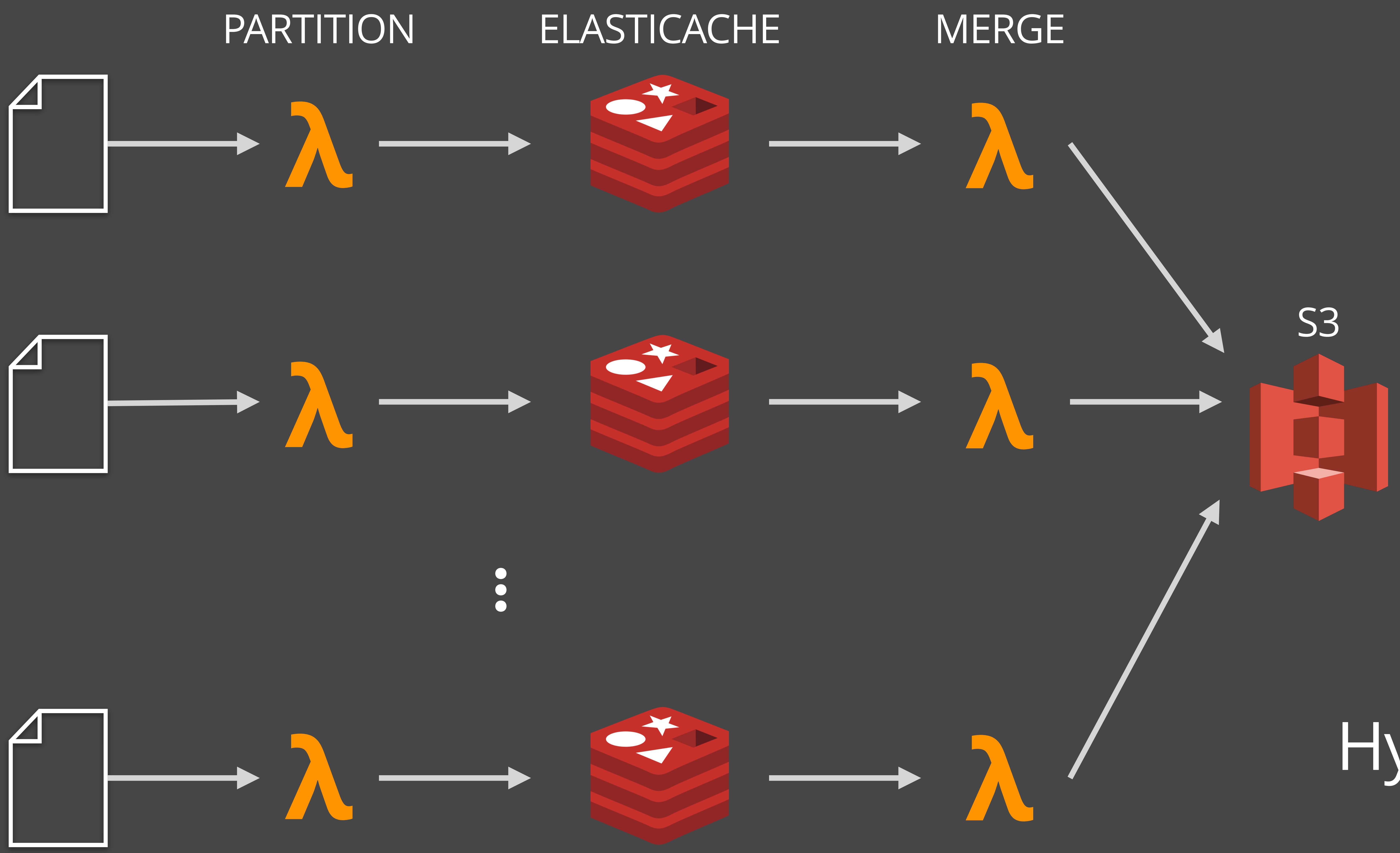

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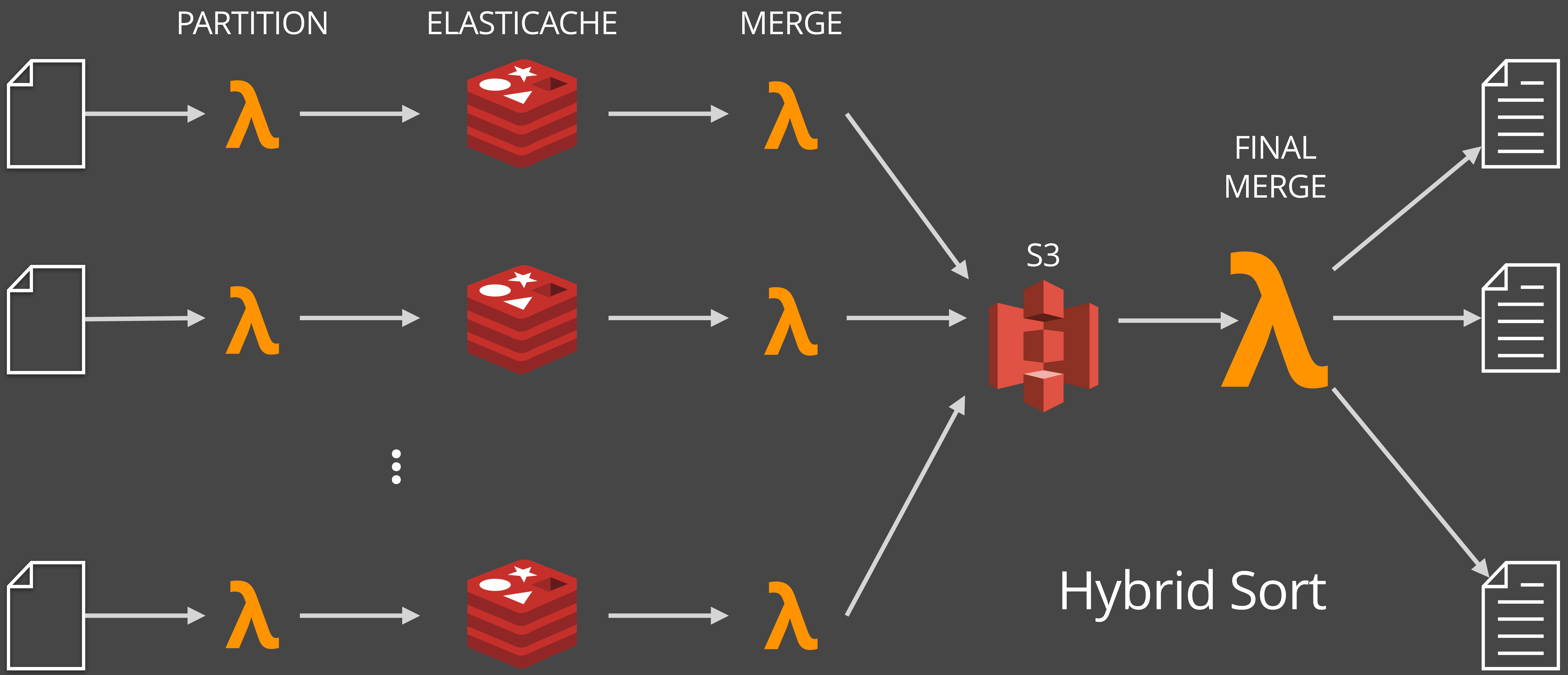

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How is it done today?

- Video = Series of Chunks
  - Chunk = KeyFrame (large) + InterFrames (small deltas from KeyFrame)

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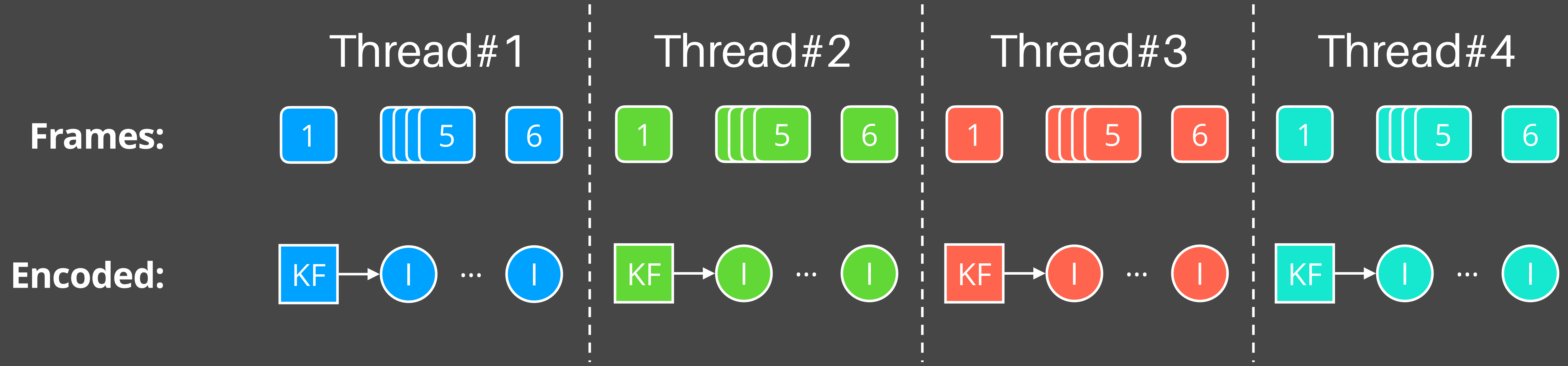

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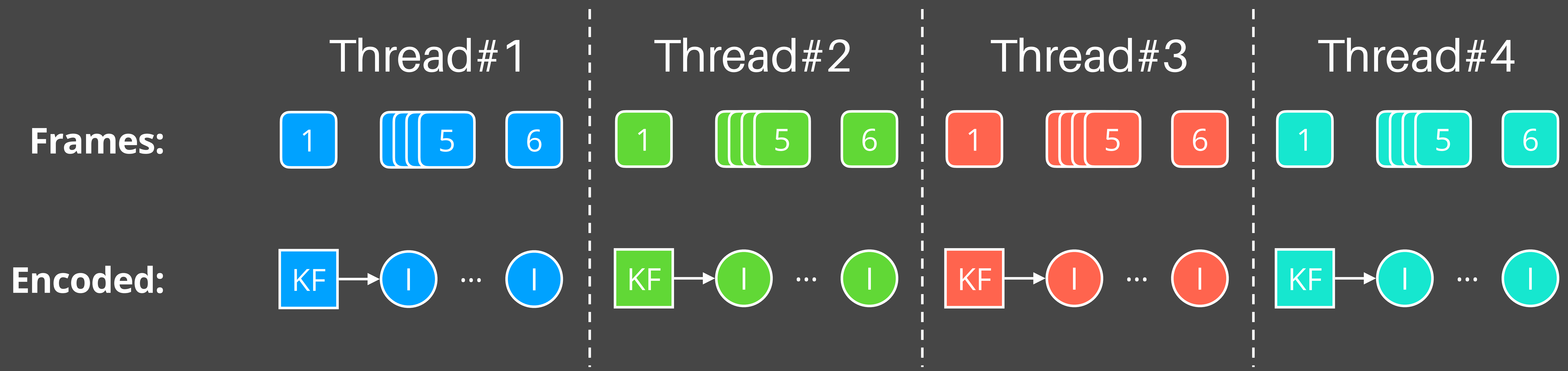
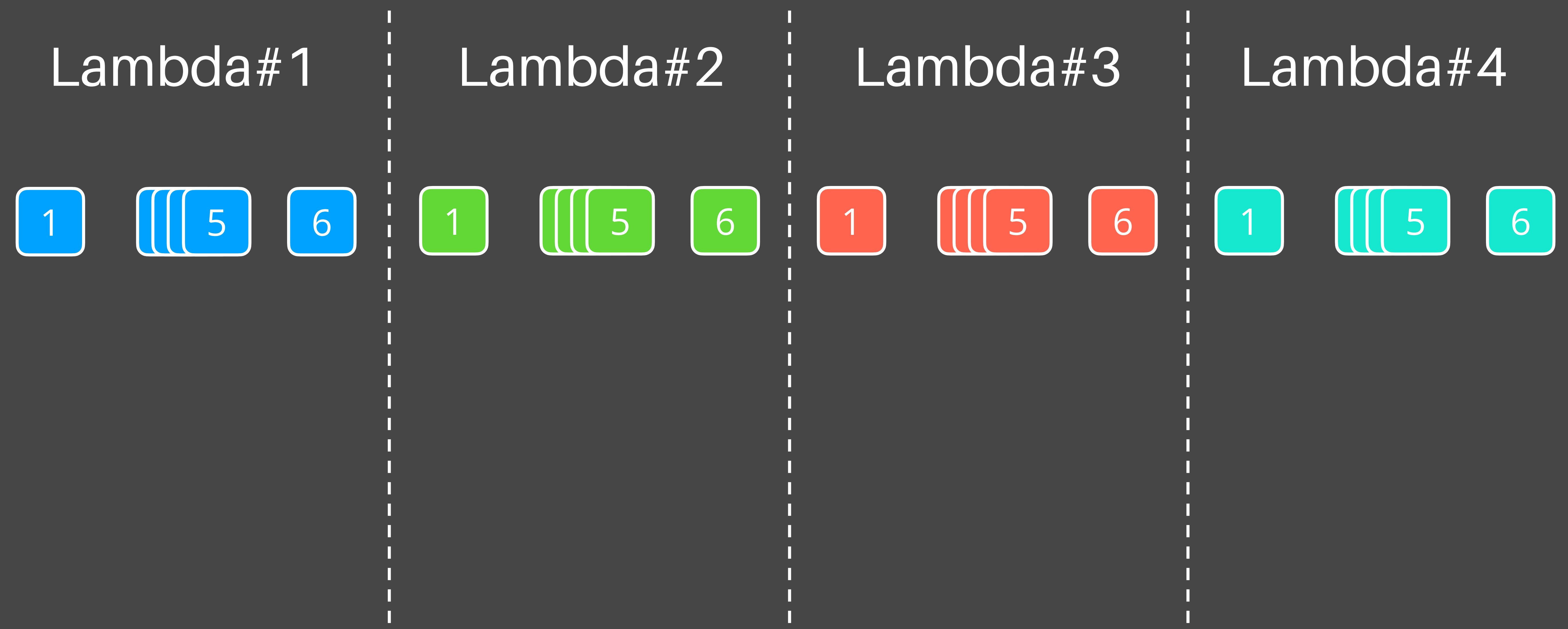


- High parallelism = worse compression (more KeyFrames)

VIDEO ANALYTICS: EXCAMERA

VIDEO ENCODING/DECODING ON AWS LAMBDA



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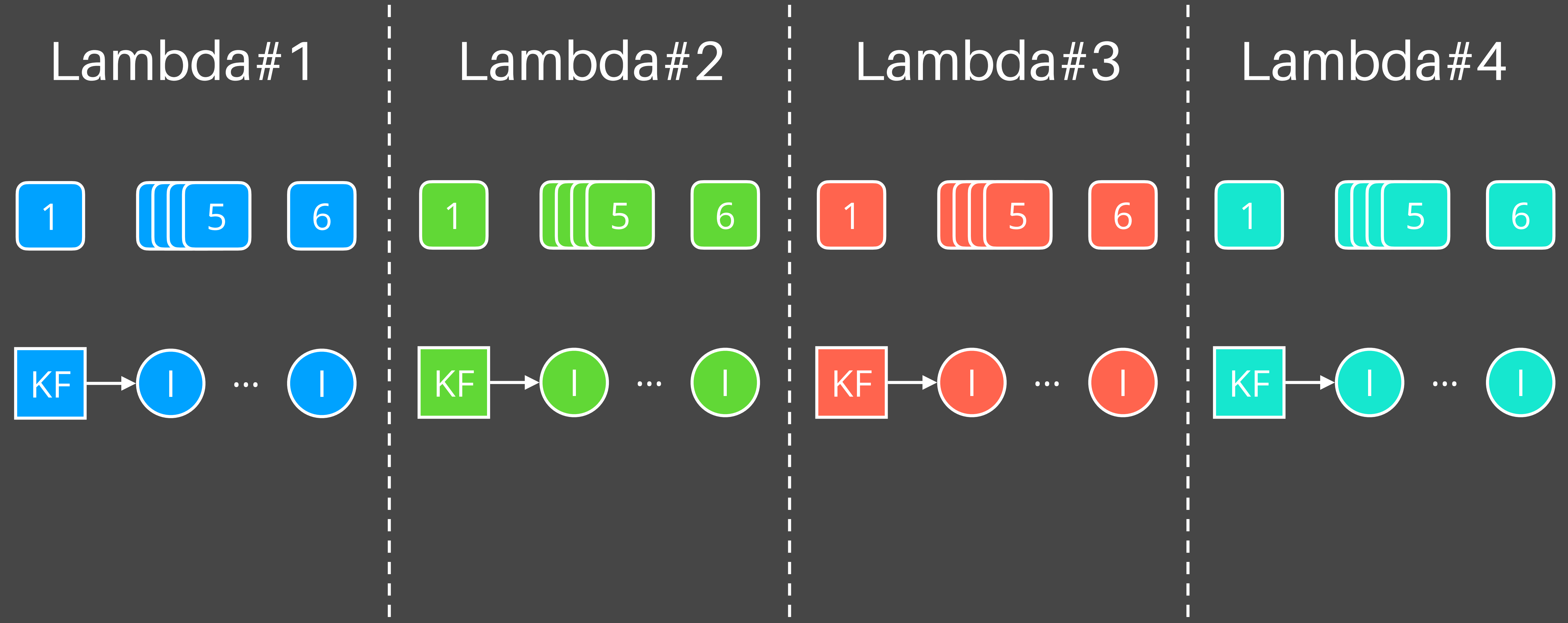

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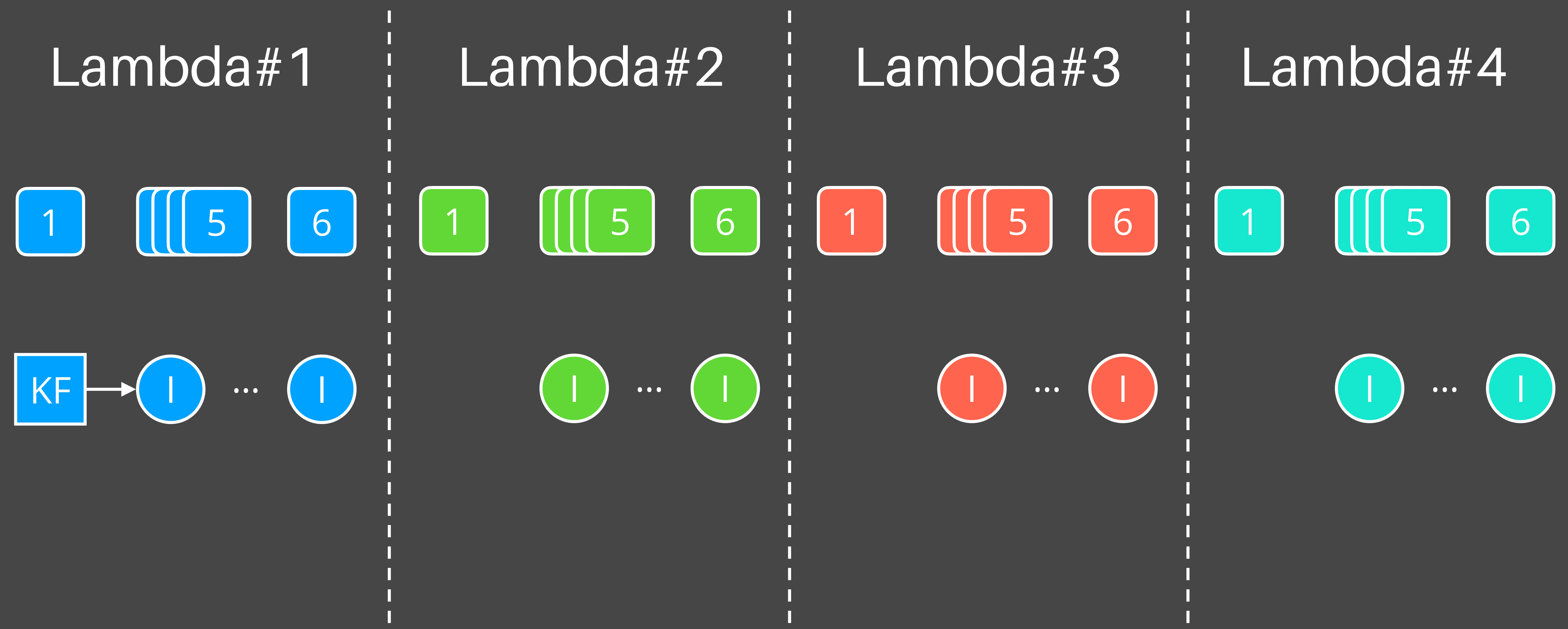

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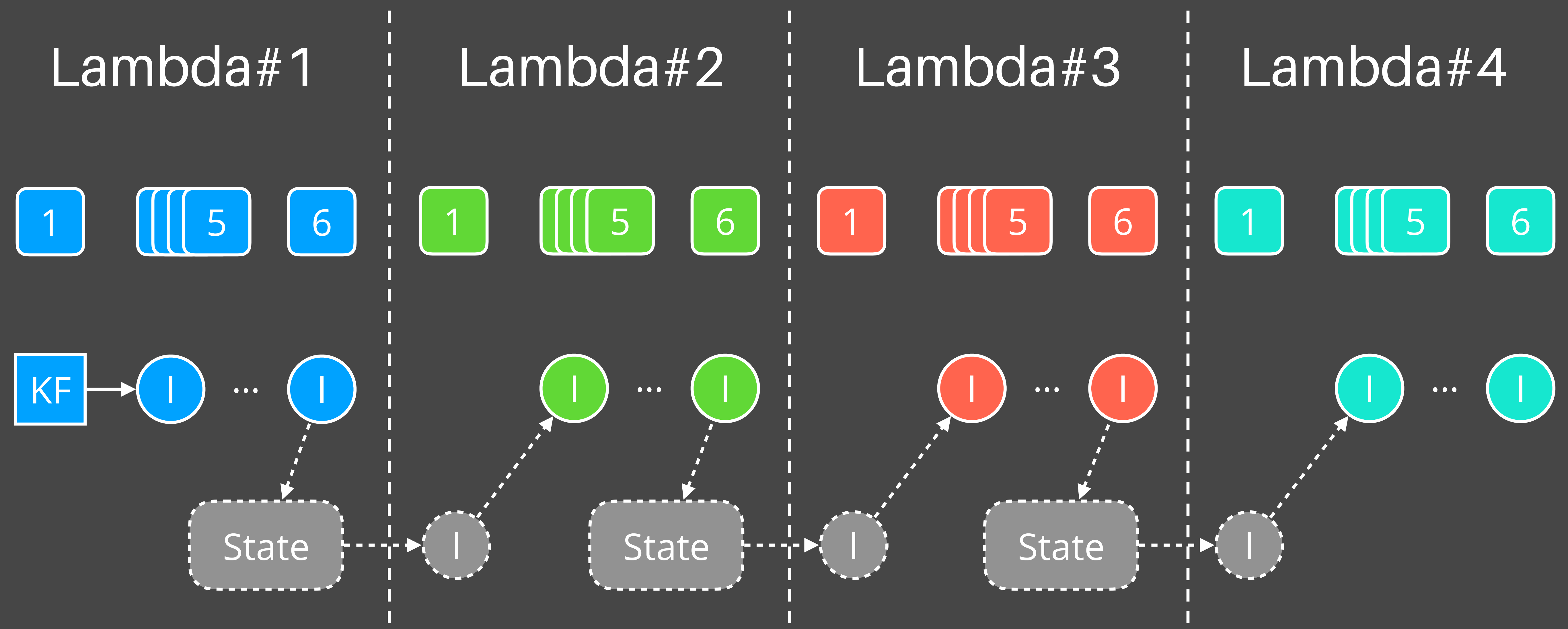

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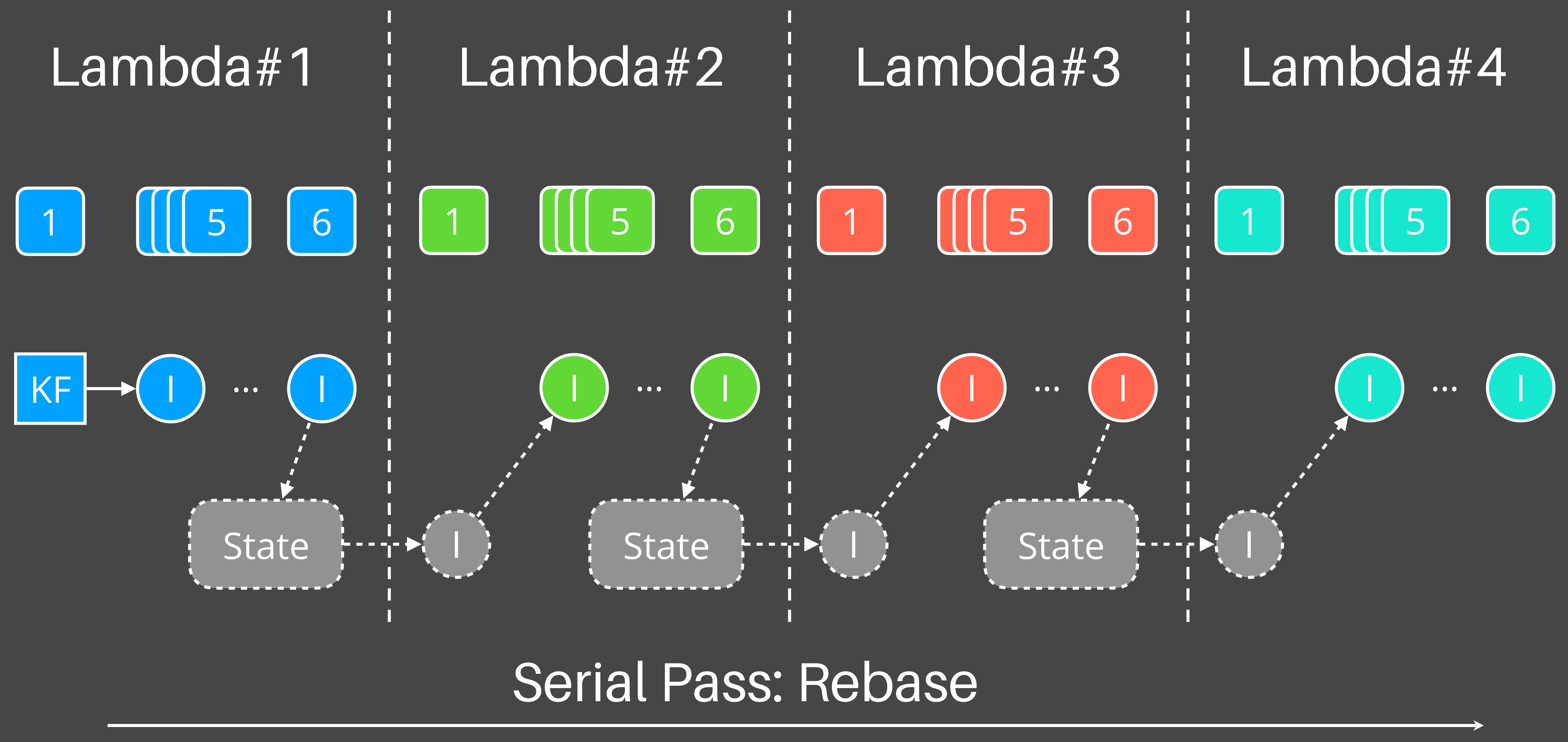

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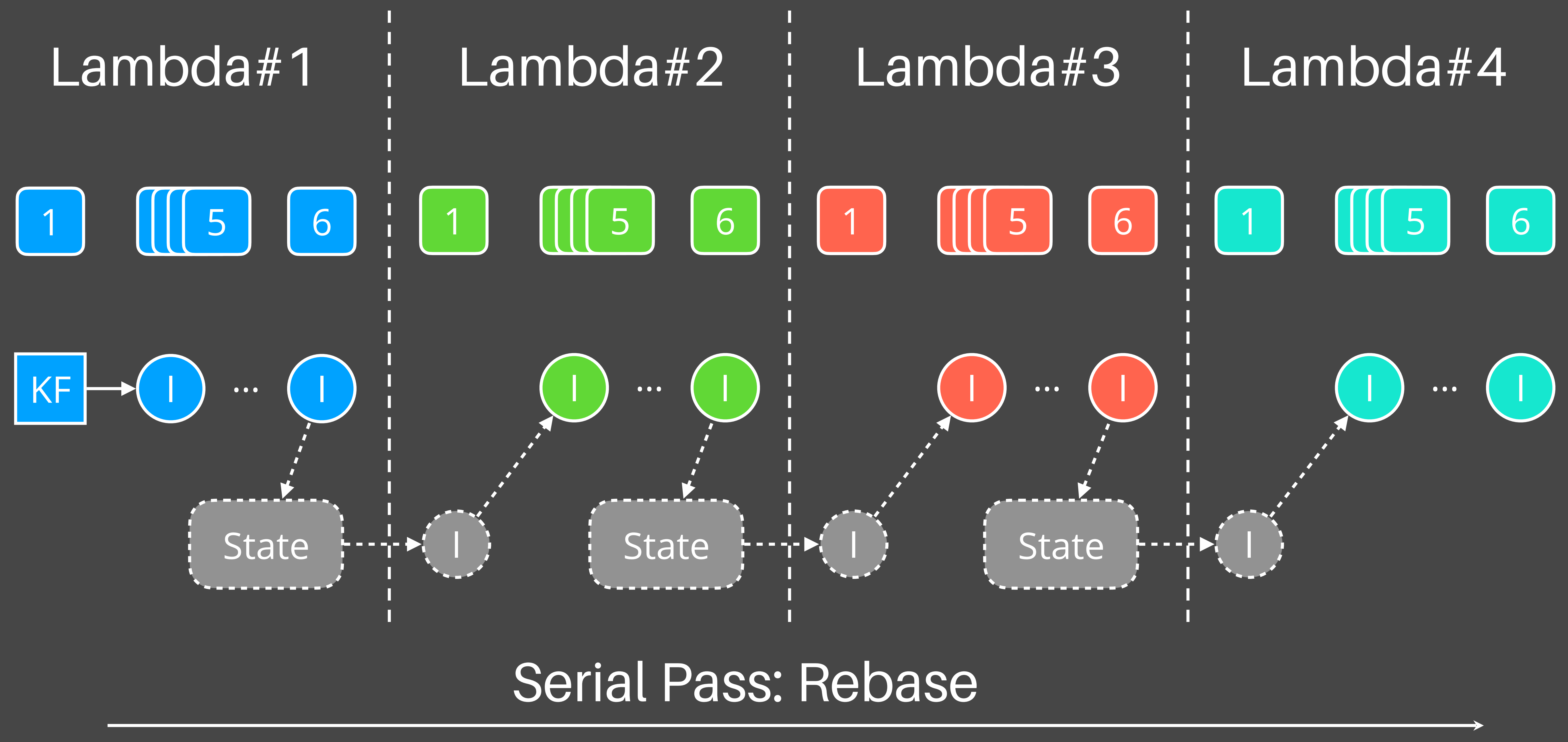
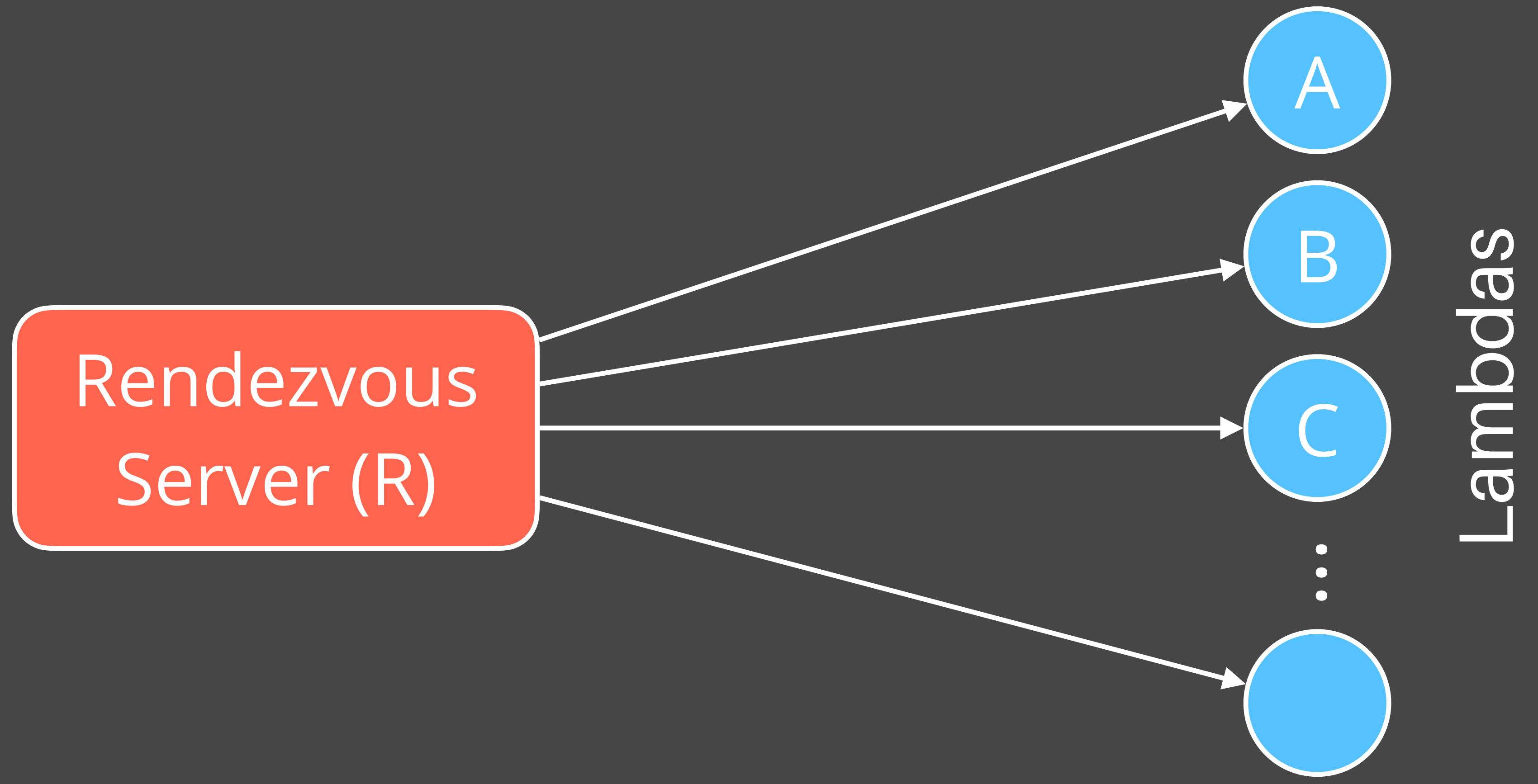


- 60X faster and 6x cheaper than Google's **`vpxenc`** on 128 cores

VIDEO ANALYTICS: EXCAMERA

Making lambdas talk to each other



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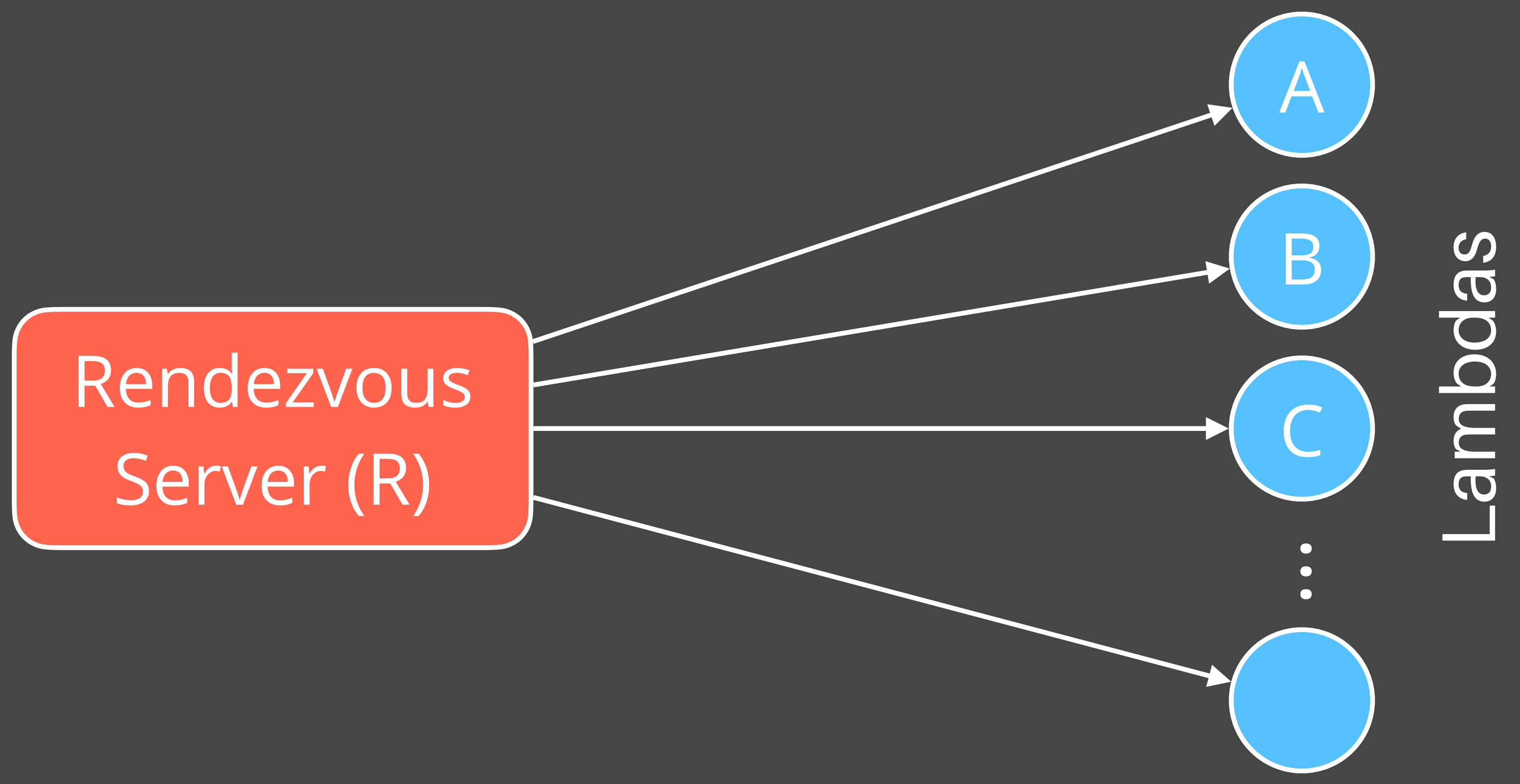

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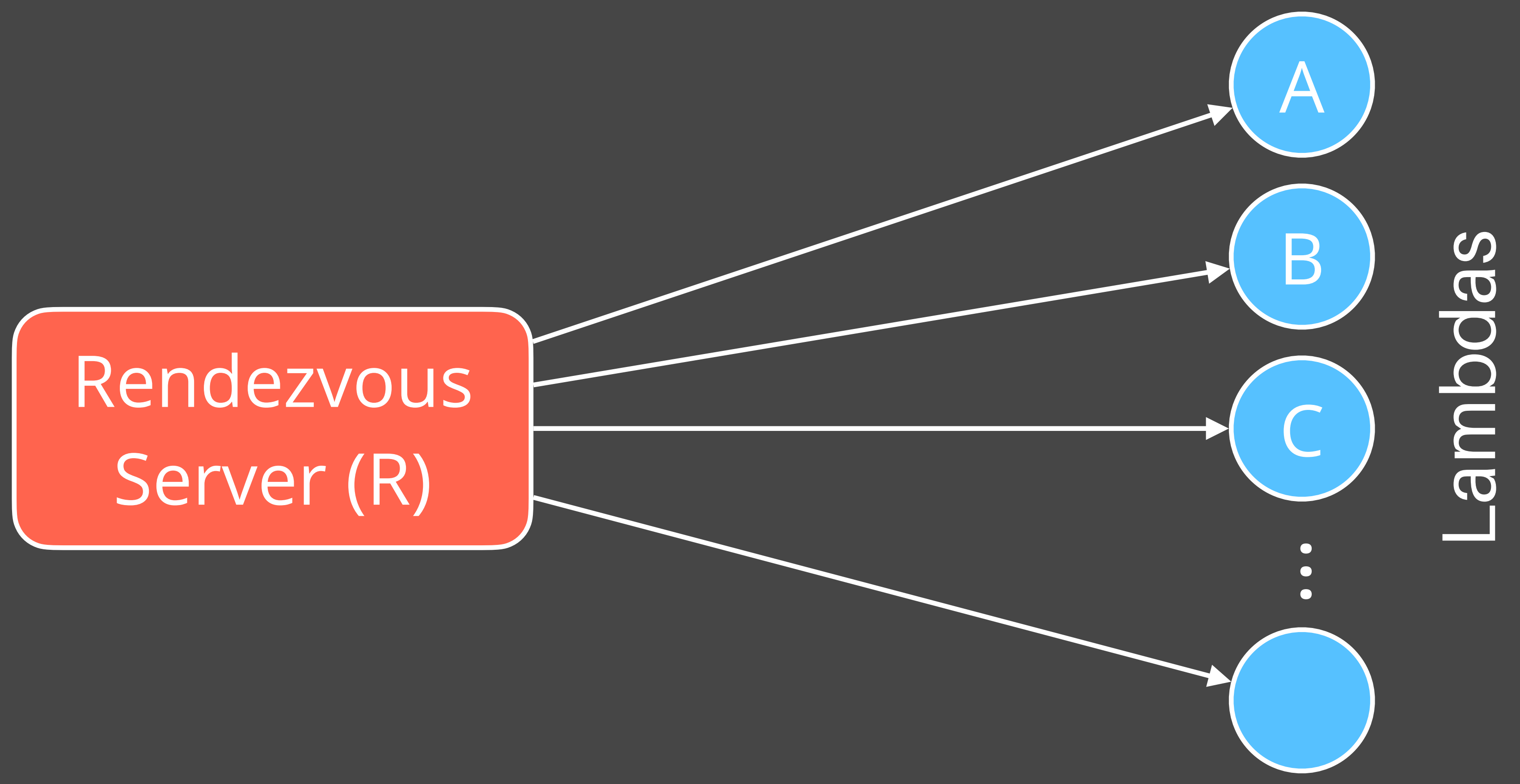

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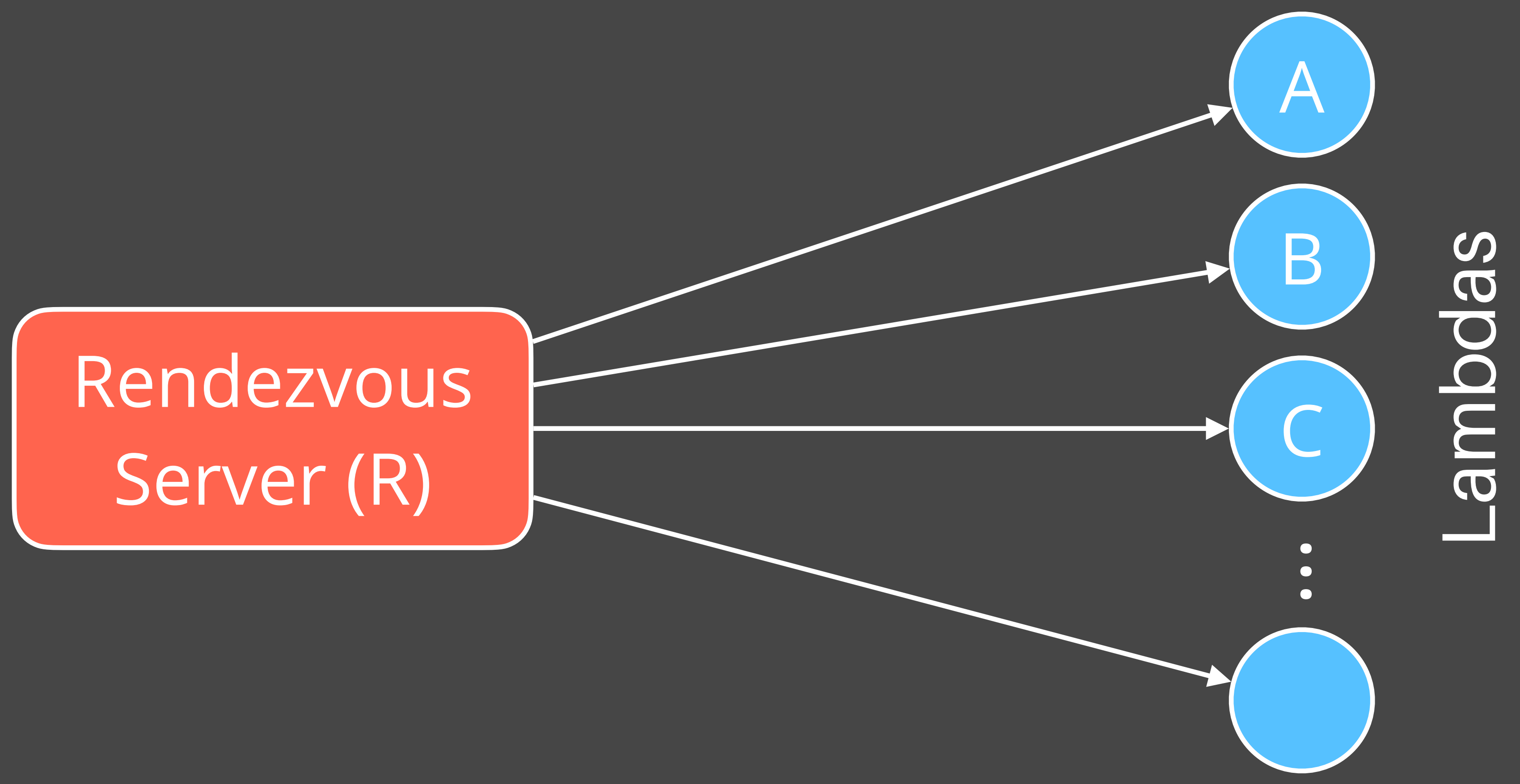

- Lambdas are only permitted ***outbound*** TCP/IP connections
- Establish outbound cxns to rendezvous server (R) at init
- If A wants to talk to B, it sends R an init msg connect(A, B)
  - R forwards all of A's subsequent msgs to B

STATE STORAGE: CURRENT SOLUTIONS

Requirements

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Requirements

Low Latency,
High IOPS

STATE STORAGE: CURRENT SOLUTIONS

Requirements

Low Latency, High IOPS	Lifetime Management

STATE STORAGE: CURRENT SOLUTIONS

Requirements	Low Latency, High IOPS	Lifetime Management	Fine-grained Elasticity

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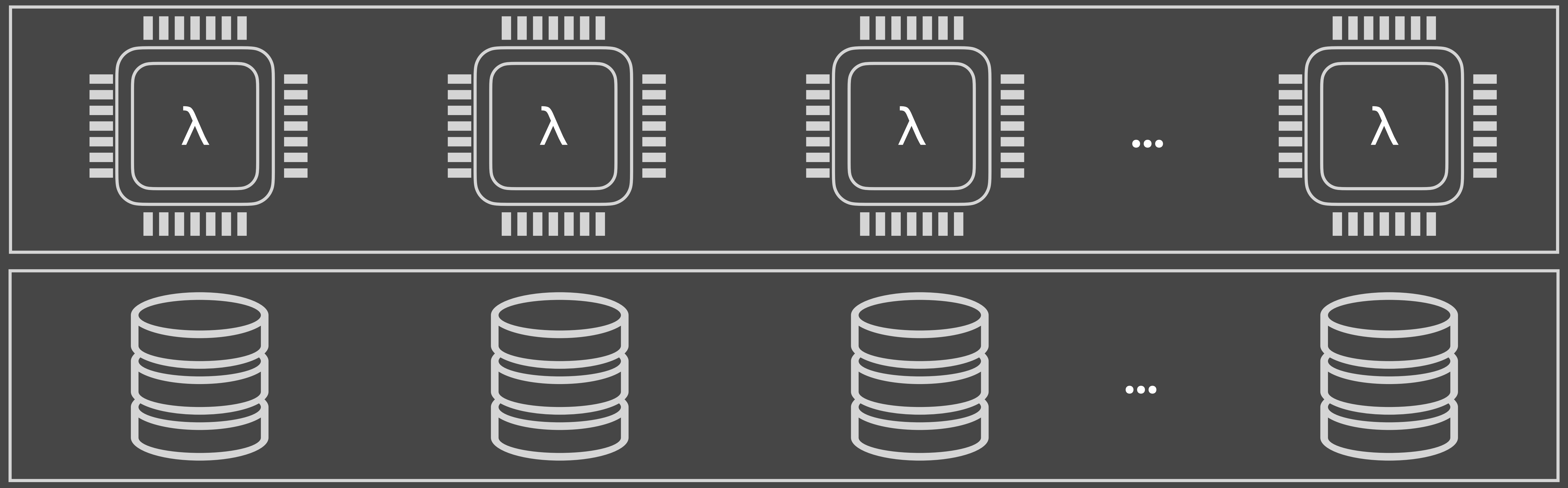
Fine-grained Elasticity

Stateful Tasks

Remote Persistent Storage (e.g., S3)



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- ~~Lifetime Management~~
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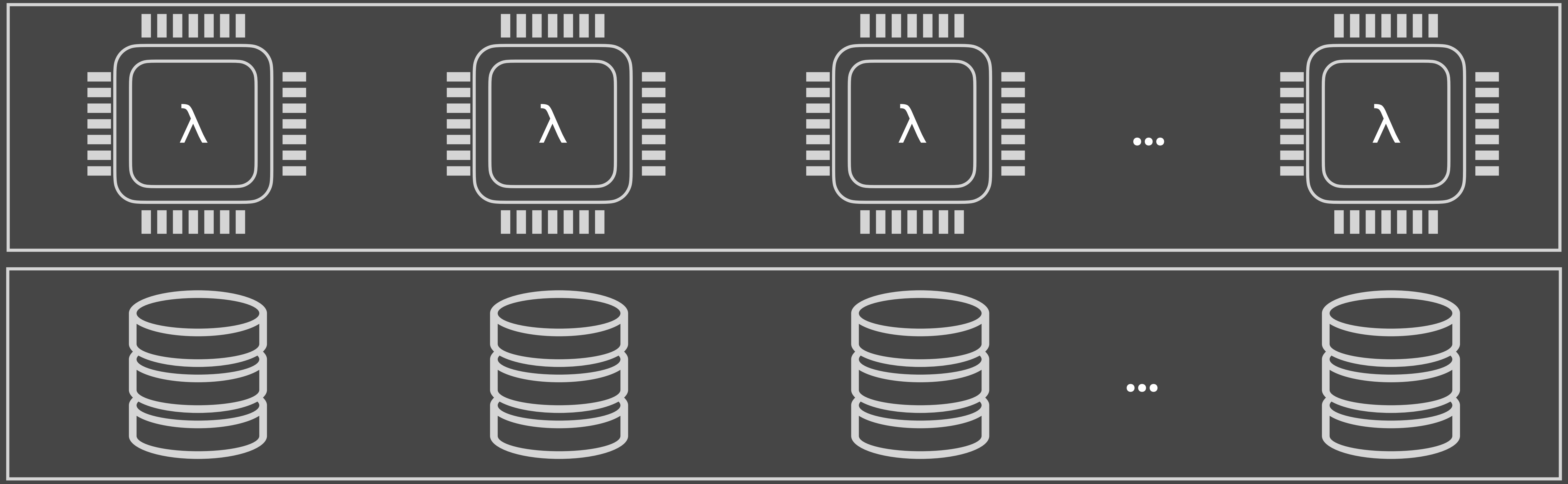

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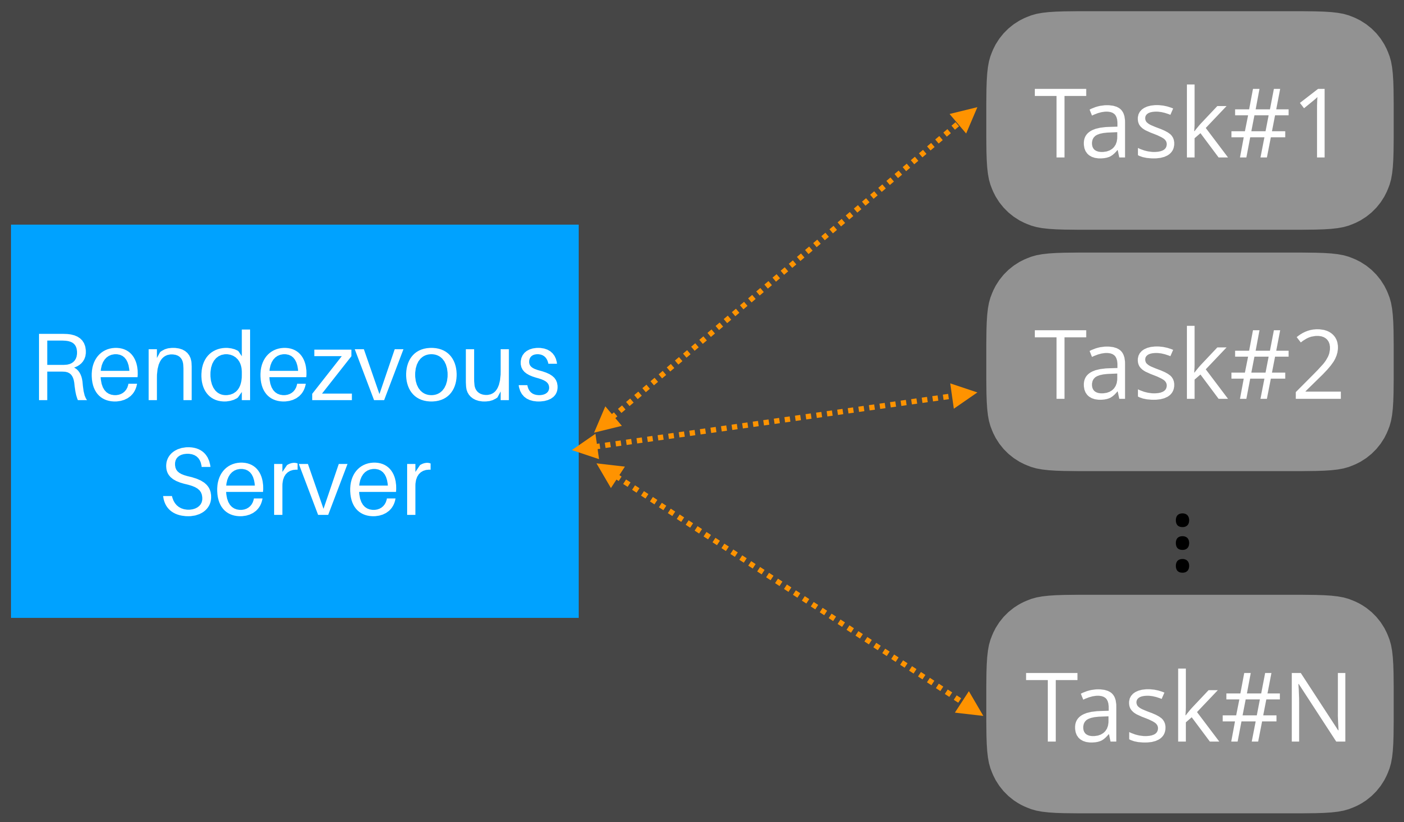
Adhoc

Video Encoding in ExCamera [NSDI'17]



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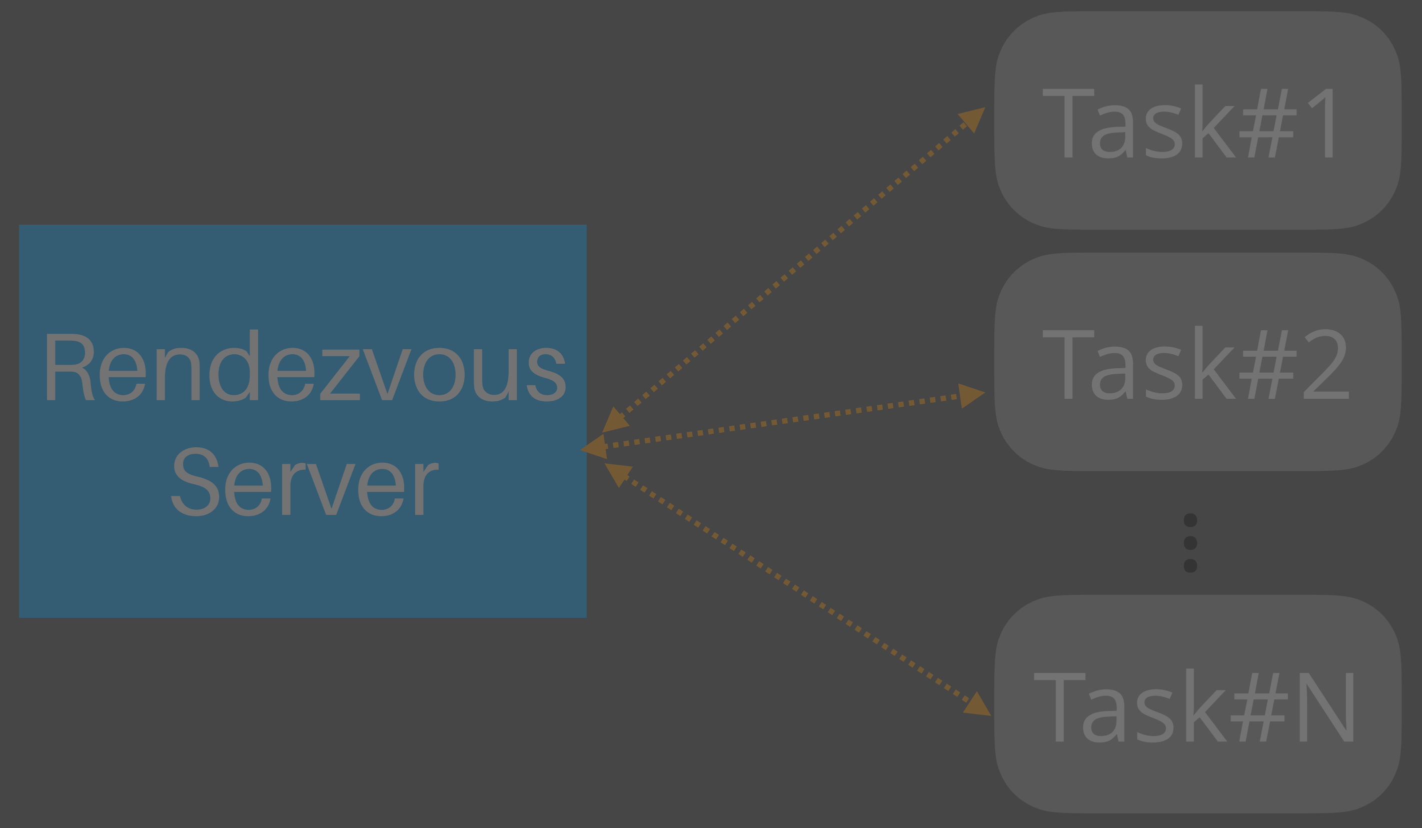
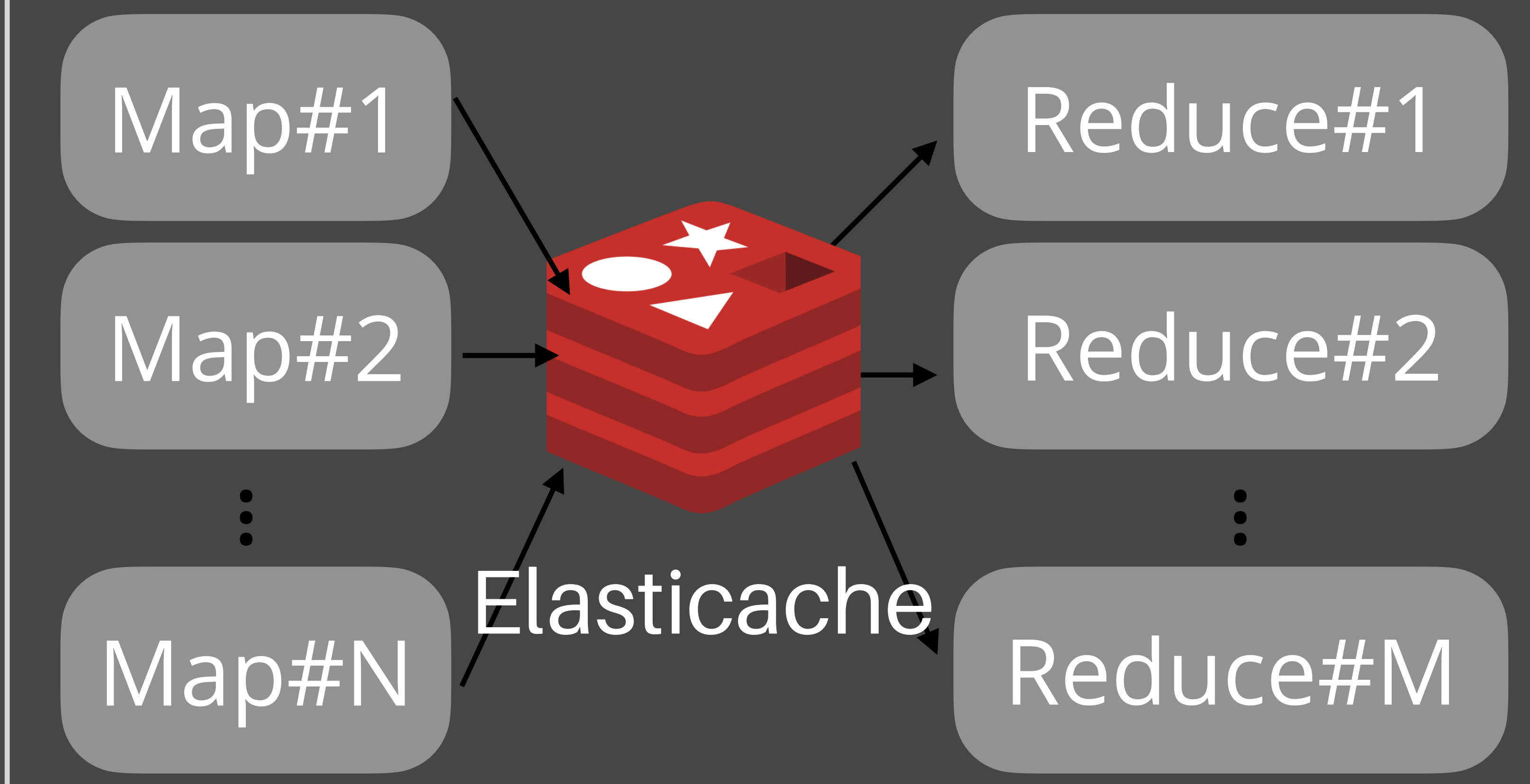


Sorting data on PyWren using Locus [NSDI'19]



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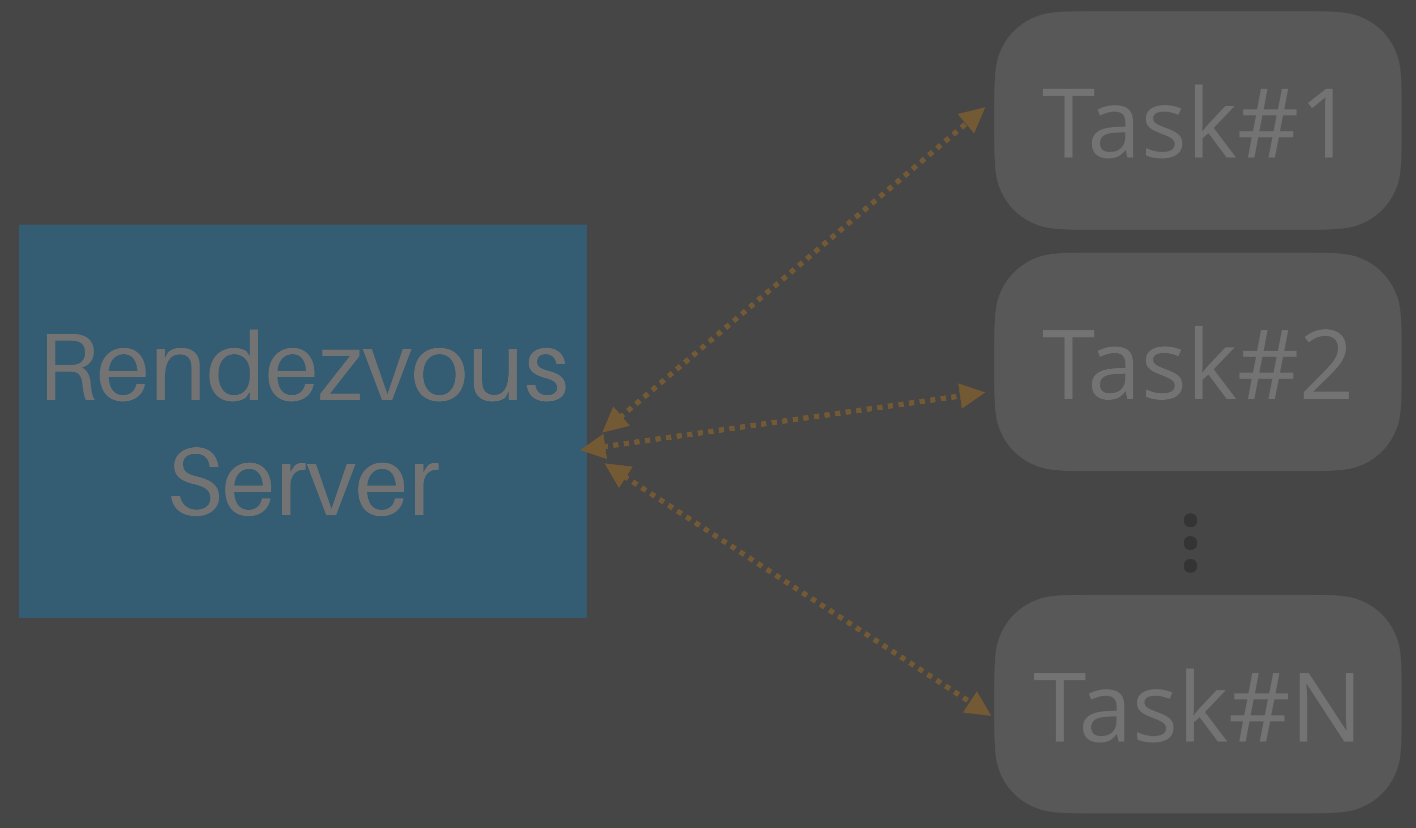

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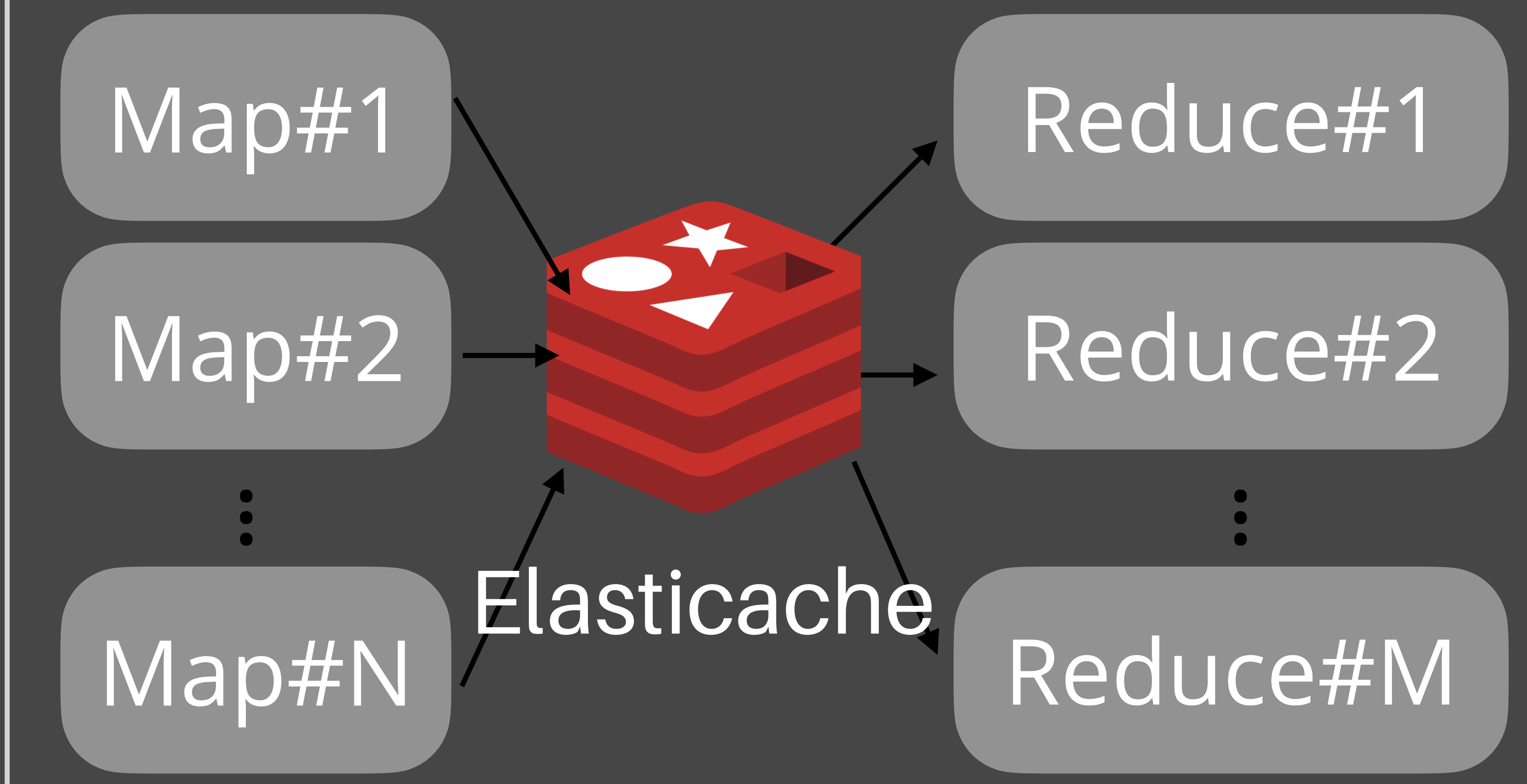

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General

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Anna [VLDB'19, IEEE TKDE'19]

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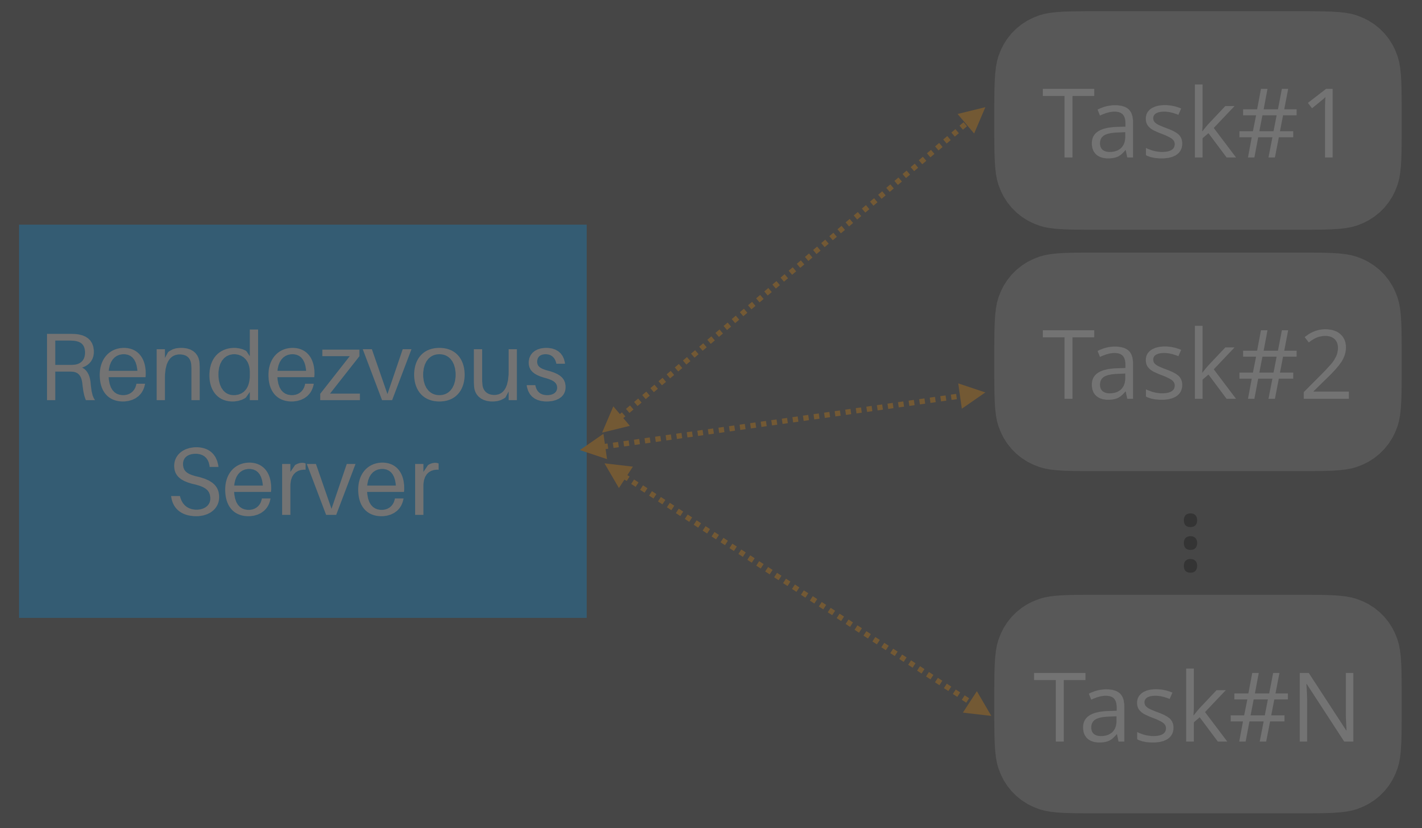

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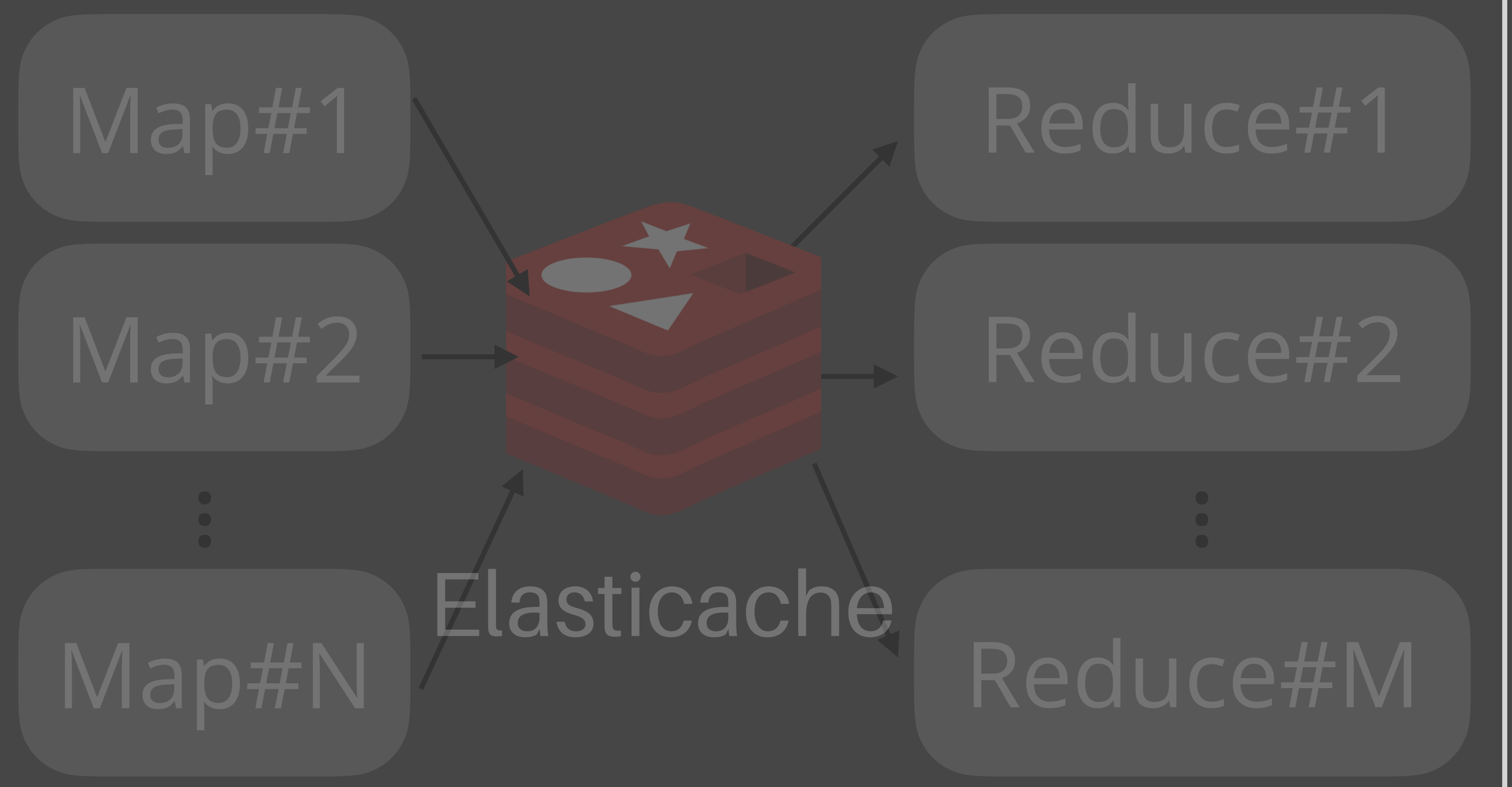

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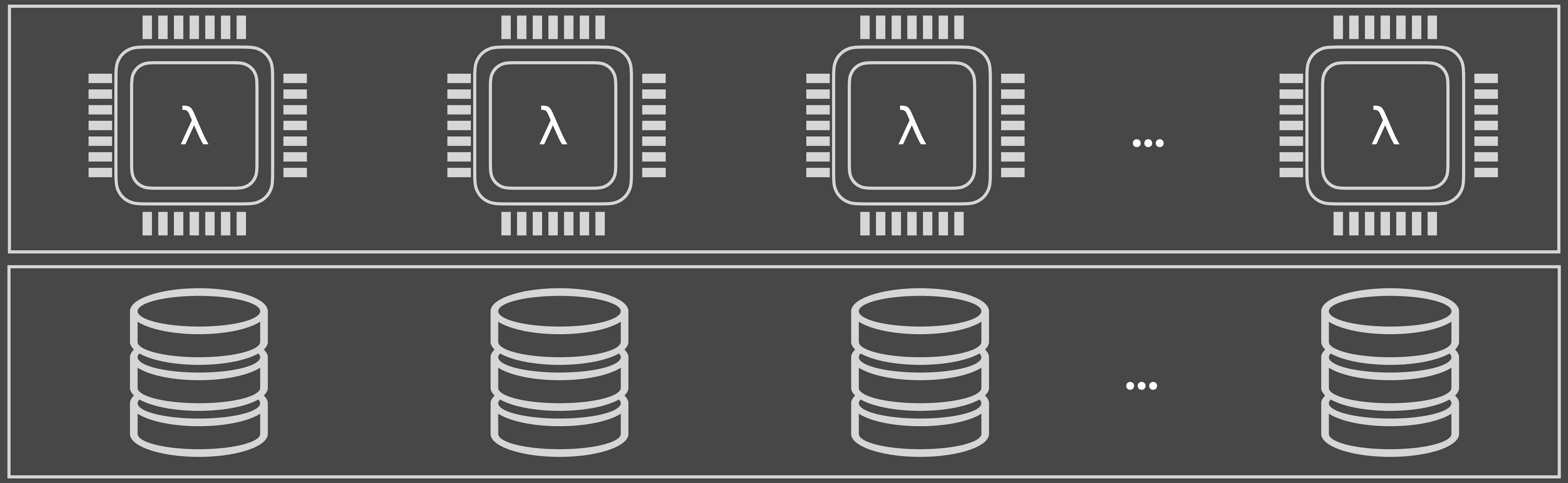
Pocket [OSDI'18]

JIFFY: INTERMEDIATE STATE STORAGE & MANAGEMENT



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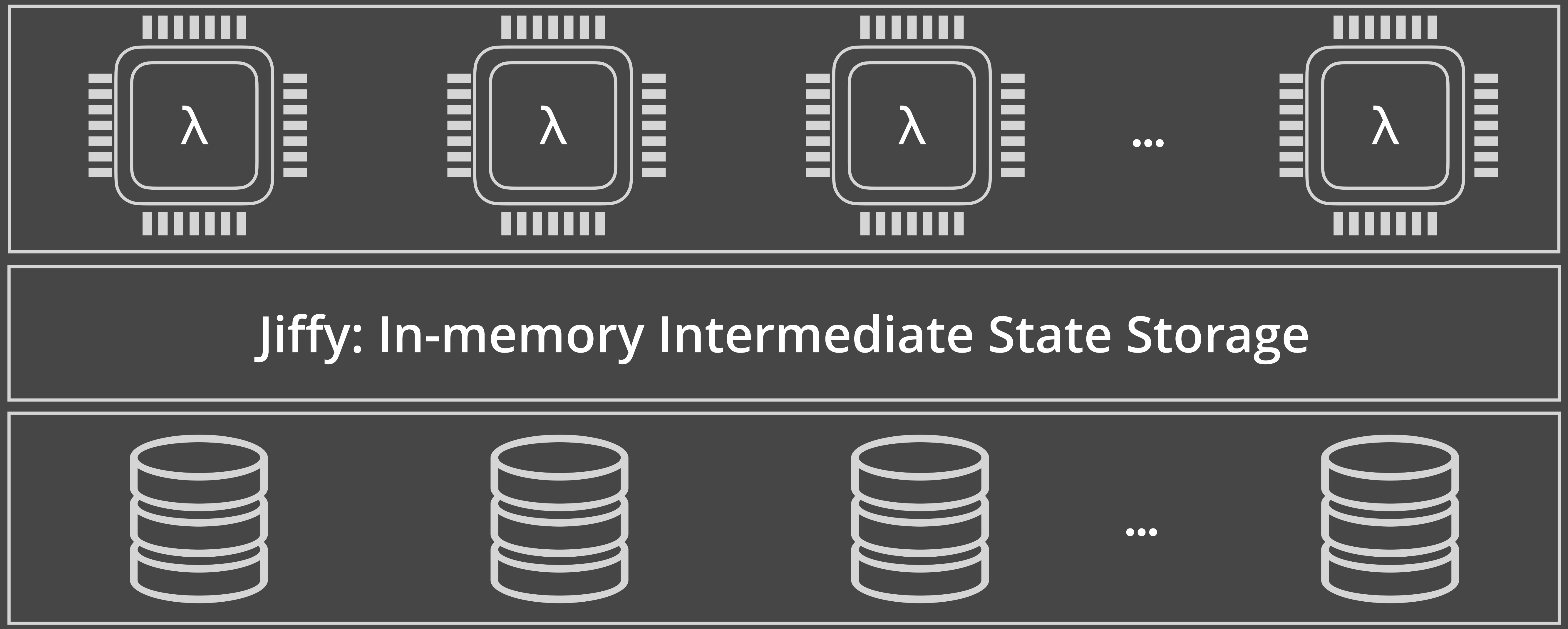

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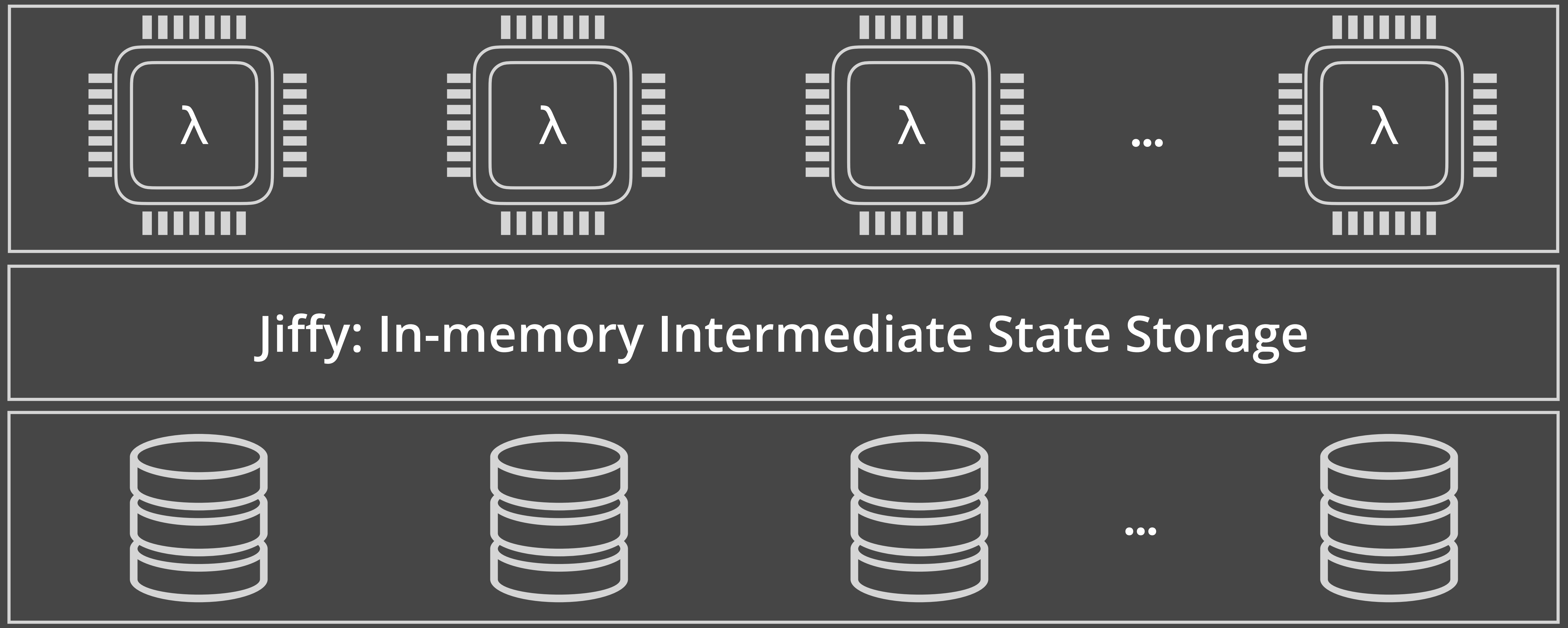

Application: Scale intermediate storage resources independent of other resources

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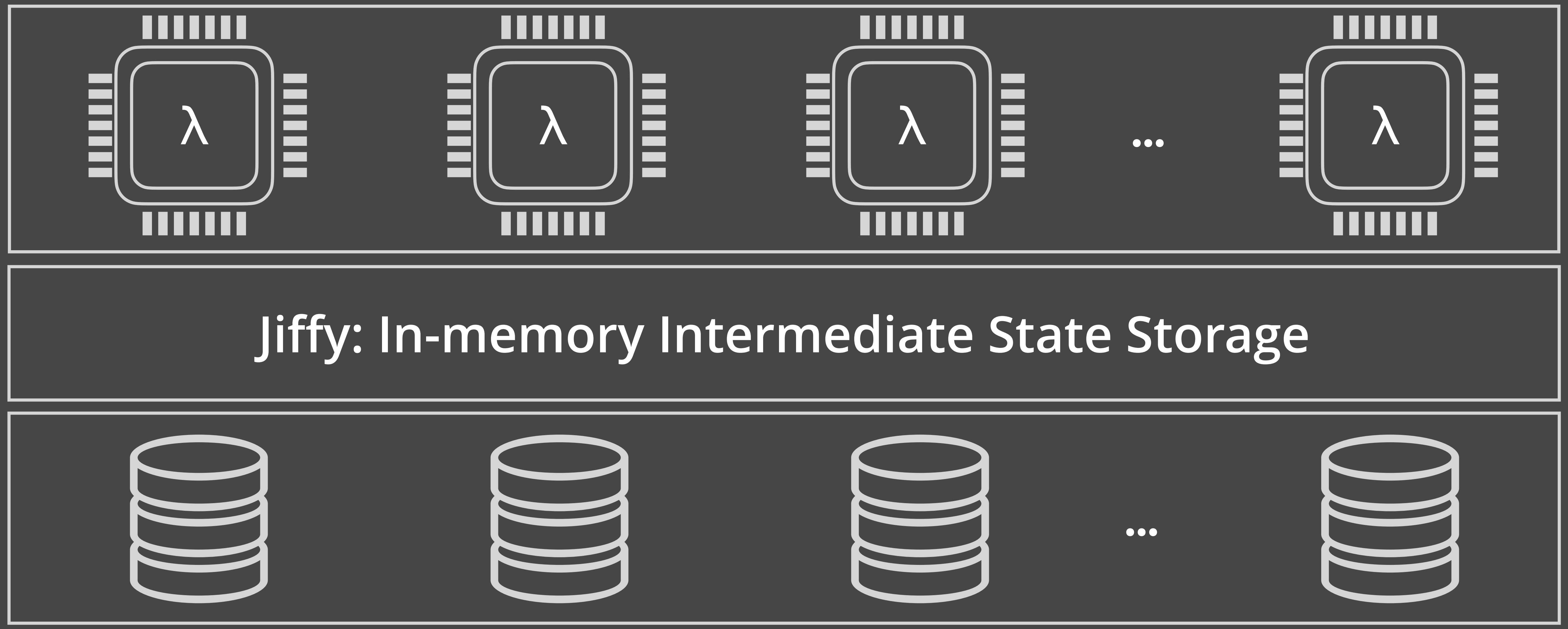

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Challenges:

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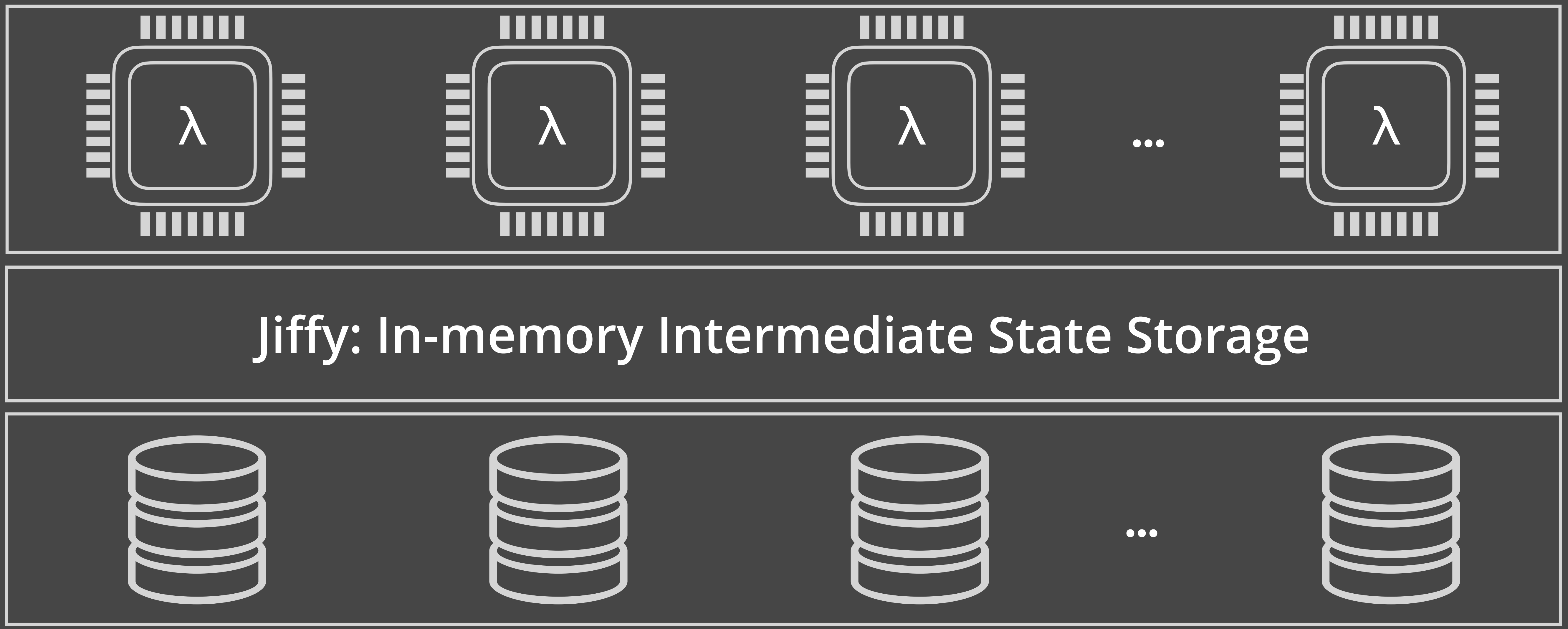

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Challenges:

- What is the right interface?
- How can we share intermediate storage across applications with isolation?
- How should we manage lifetimes of application storage?
- How to facilitate efficient communication across tasks?

SERVERLESS: BEYOND STATE MANAGEMENT

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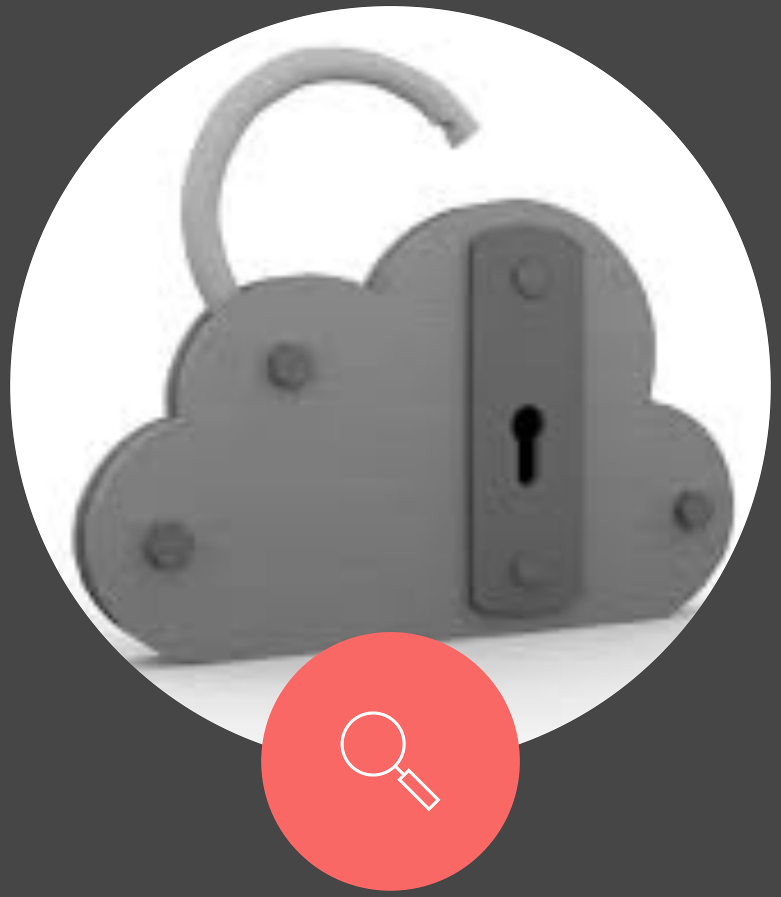
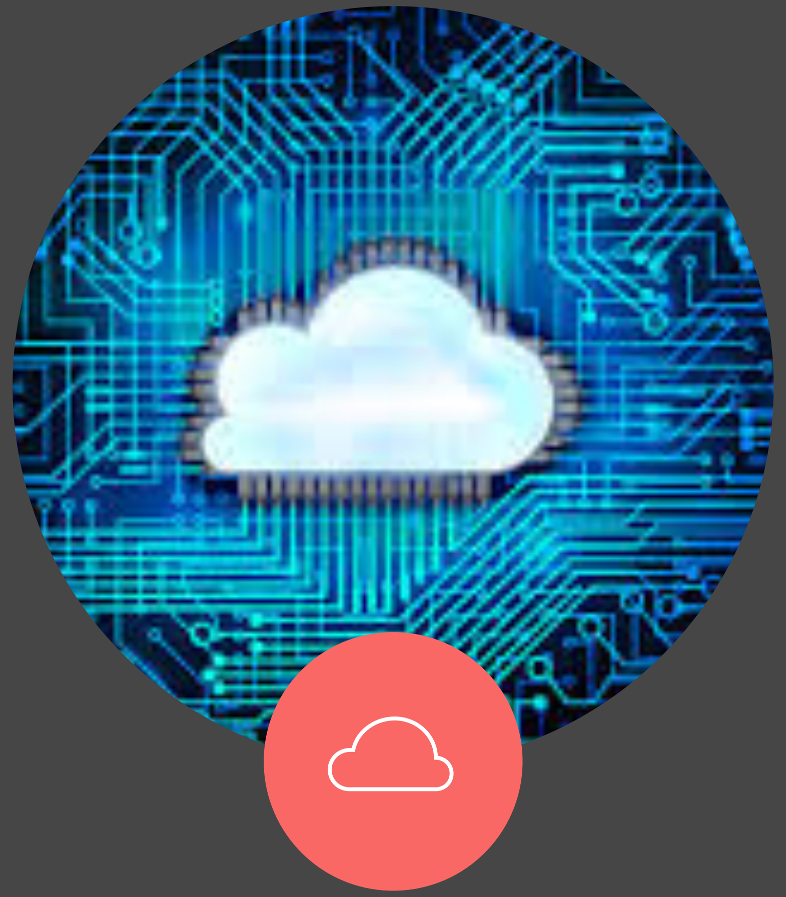


Security

Side-channels, Information leakage via network communications

SLA Guarantees

Performance guarantees, Performance isolation



Heterogenous Hardware

FPGAs, GPUs, TPUs, etc

SERVERLESS IS THE FUTURE

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- Serverless cloud hides management complexity, facilitates consumption-based billing and automatic scaling, benefiting:
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Questions?