AWS Lambda

(specifically container loading and snapstart)

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“AWS Lambda is a compute service that runs your code in response to events and automatically manages the compute resources.”

```python
import json

def lambda_handler(event, context):
    return {
        'statusCode': 200,
        'body': json.dumps('Hello 6.5840')
    }
```

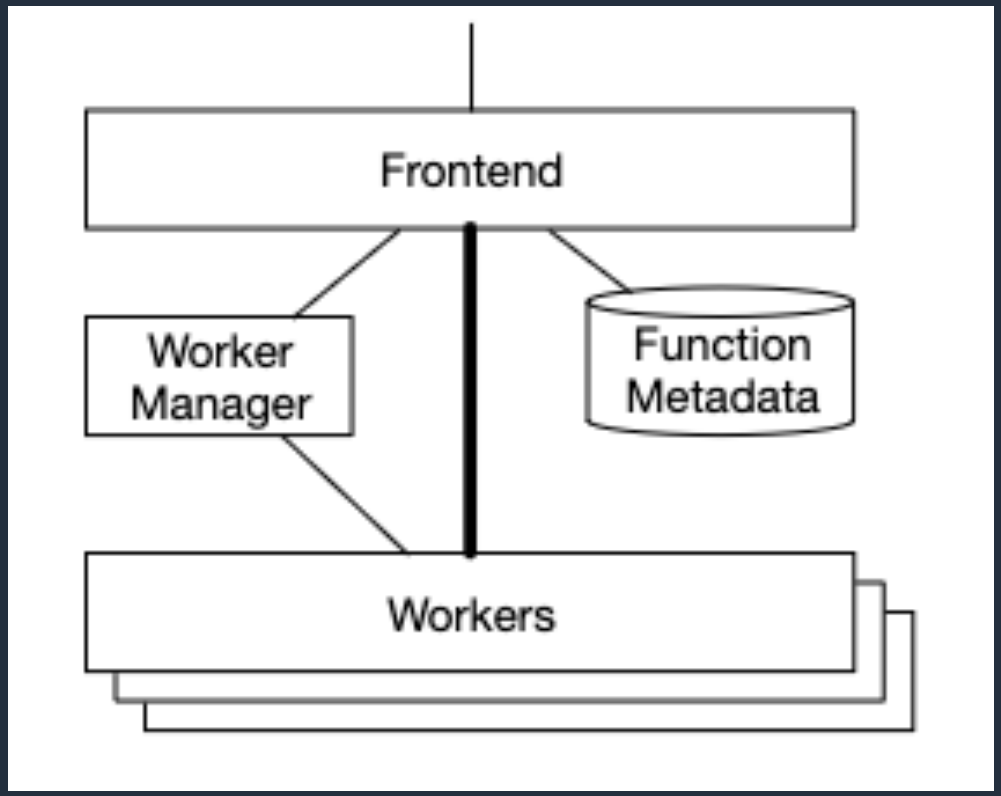

aws

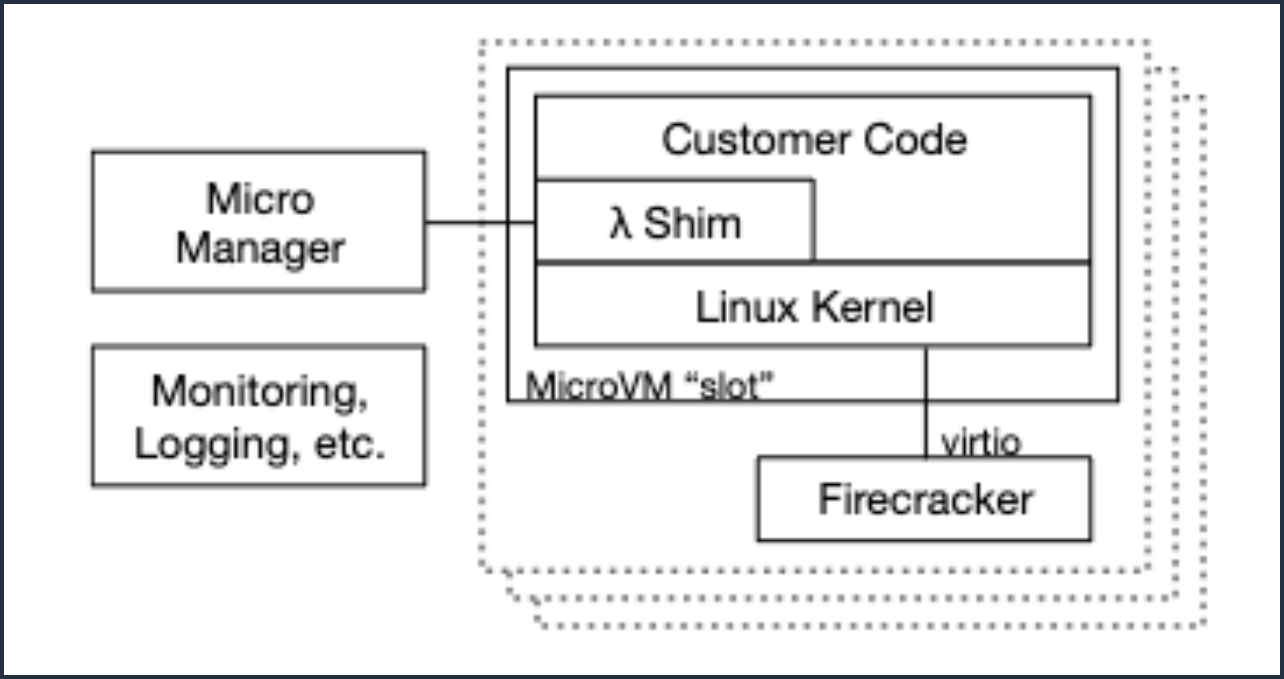
Why?

- Building scalable, fault-tolerant systems is hard.
- Driving high hardware utilization is hard.
    - Multi-tenancy makes it easier.
- The cloud needs *glue.*

- *Code close to data is more efficient?*

aws





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aws

“… simple …”

“… easy …”

“… fast …”

“… complex …”

“… complicated …”

“… difficult …”

Before	After
250MB max	10GB max
Code or .zip	Container image
Custom tools	Standard tools

aws

Before	After
250MB max	10GB max
Code or .zip	Container image
Custom tools	Standard tools

without slower cold starts!

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150 Pb/s

Harter et al: Only 6.4% of container data is needed at startup!

Harter et al, *Slacker: Fast Distribution with Lazy Docker Containers*, FAST'16

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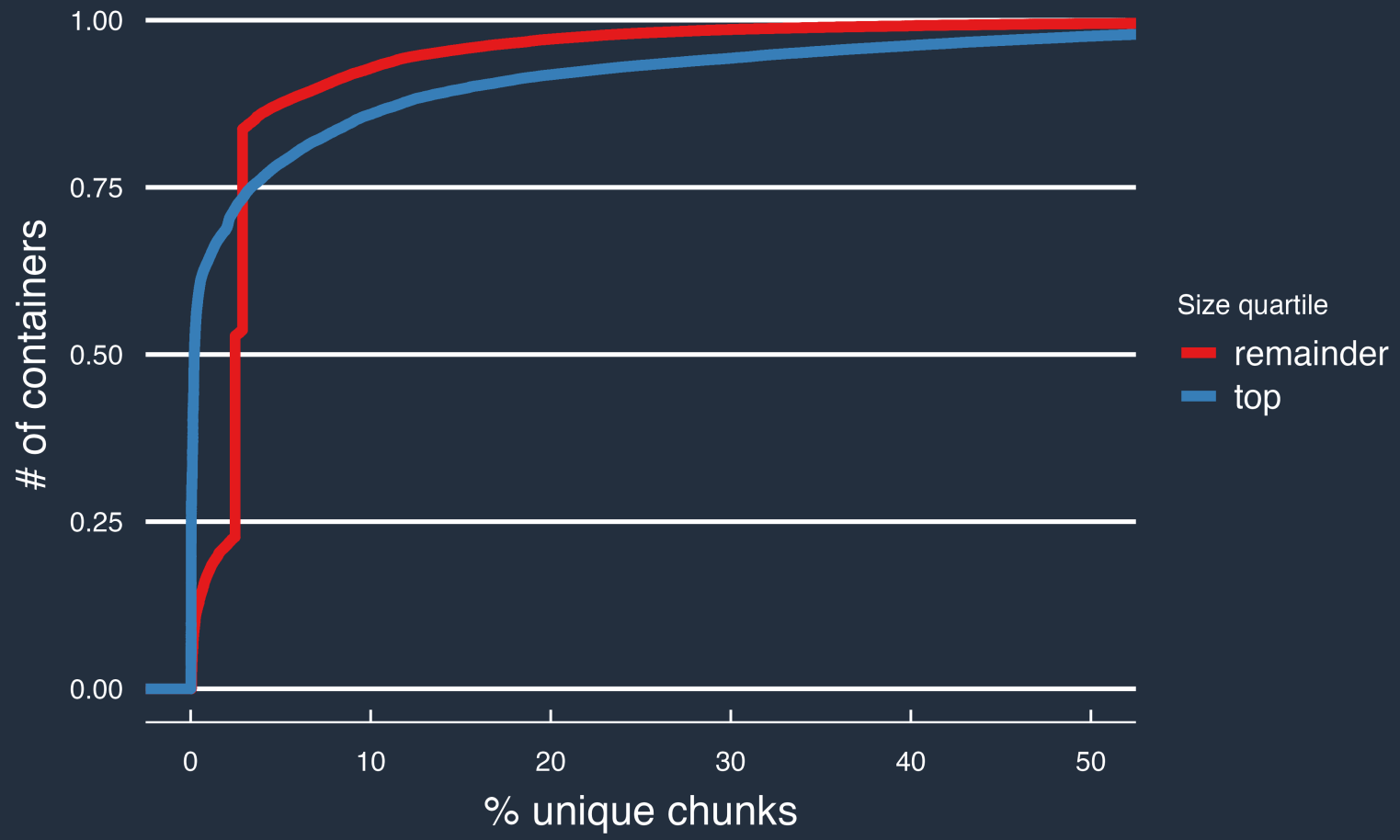

Find a way, invisible to applications, to load data on demand and deduplicate common data.

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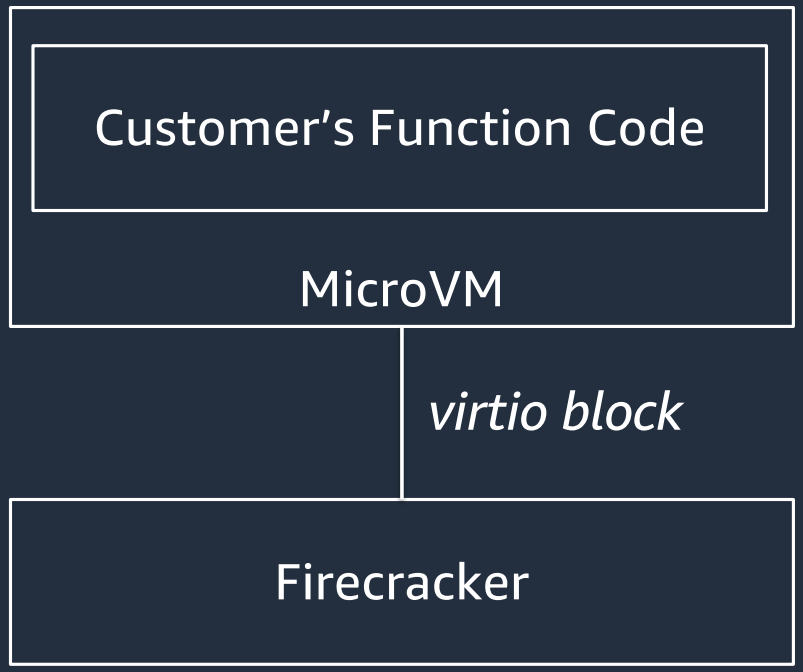
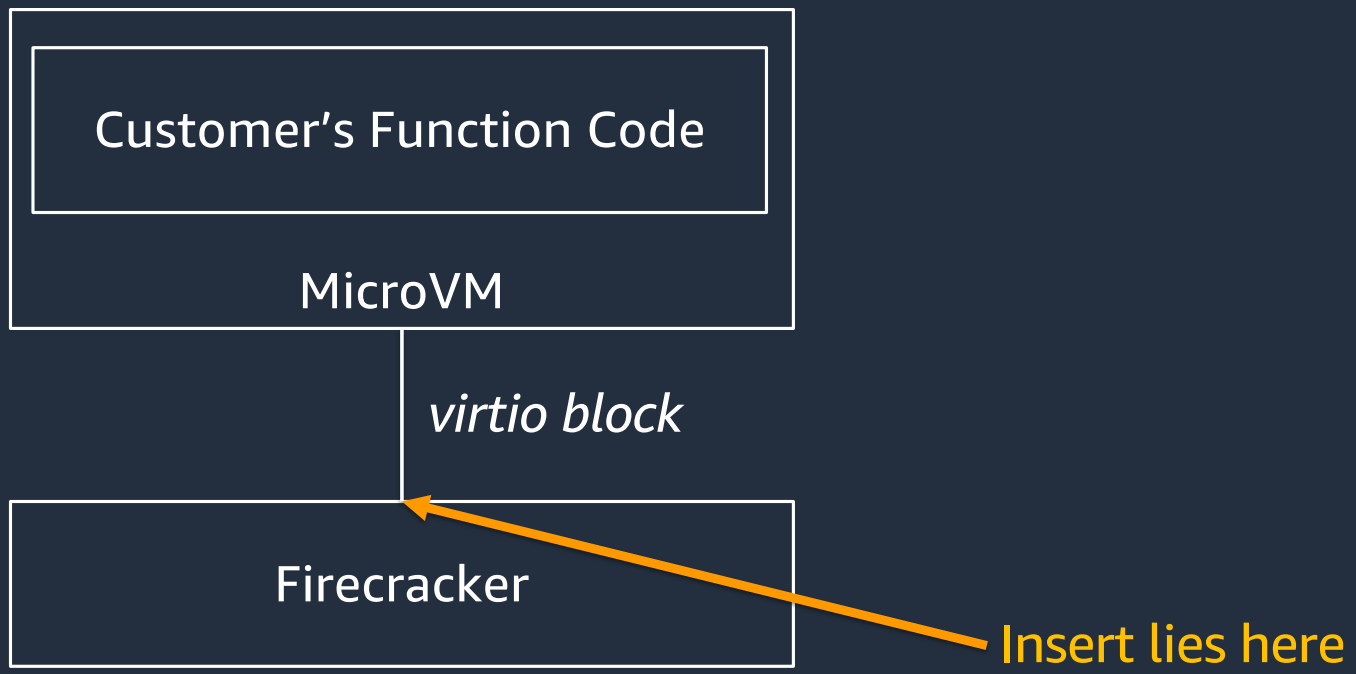


Agache et al, “Firecracker: Lightweight Virtualization for Serverless Applications”, AWS, 2020



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But…
Container images aren’t filesystems.

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Deterministic Flattening

Ext4 filesystem image

512kB chunks

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But…
Real storage is really fast (<100µs), so loading on demand must be really fast too.

Lambda worker

Amazon S3 Express One Zone

Delivers consistent single-digit millisecond request latency on hundreds of thousands of transactions per second for faster data processing

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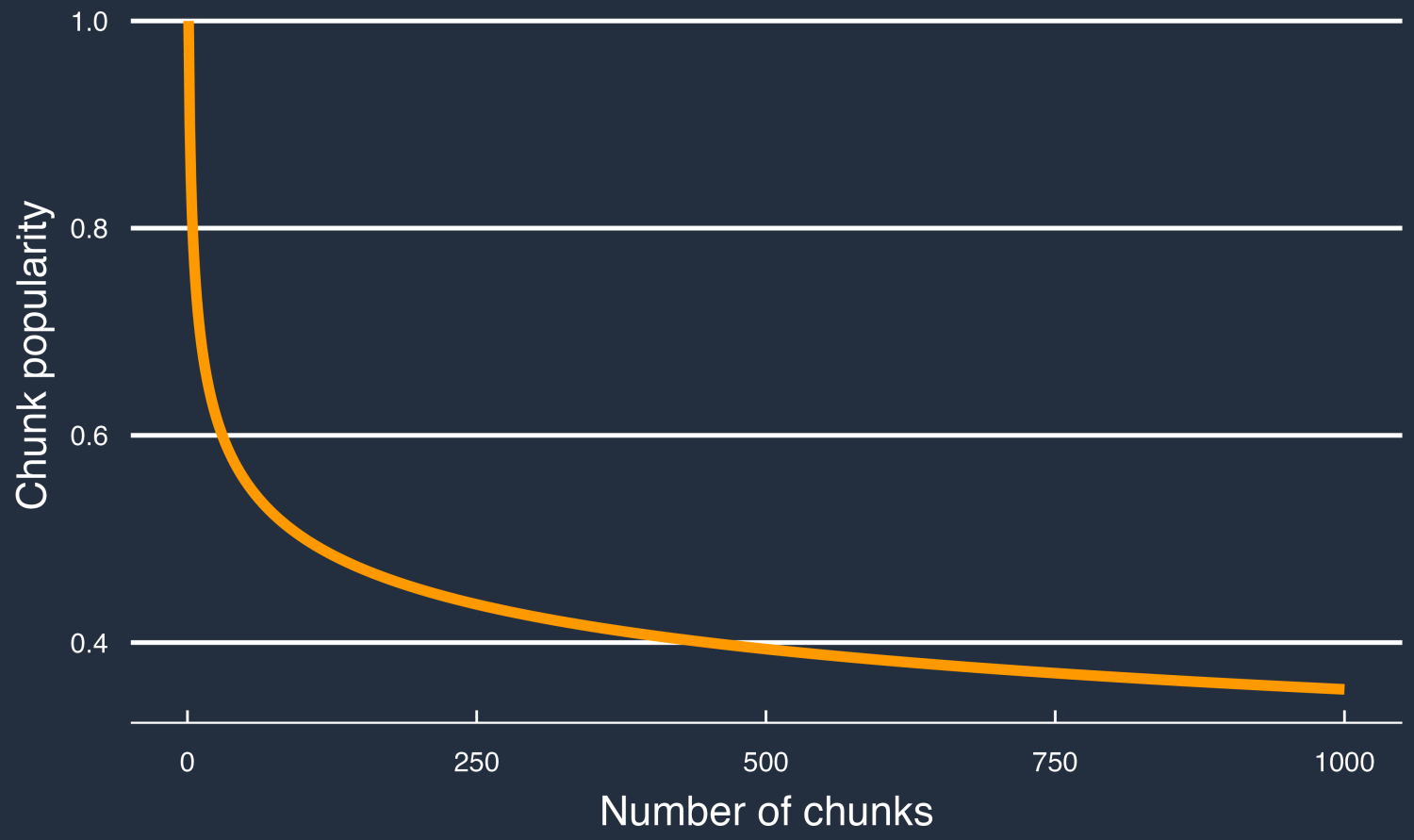
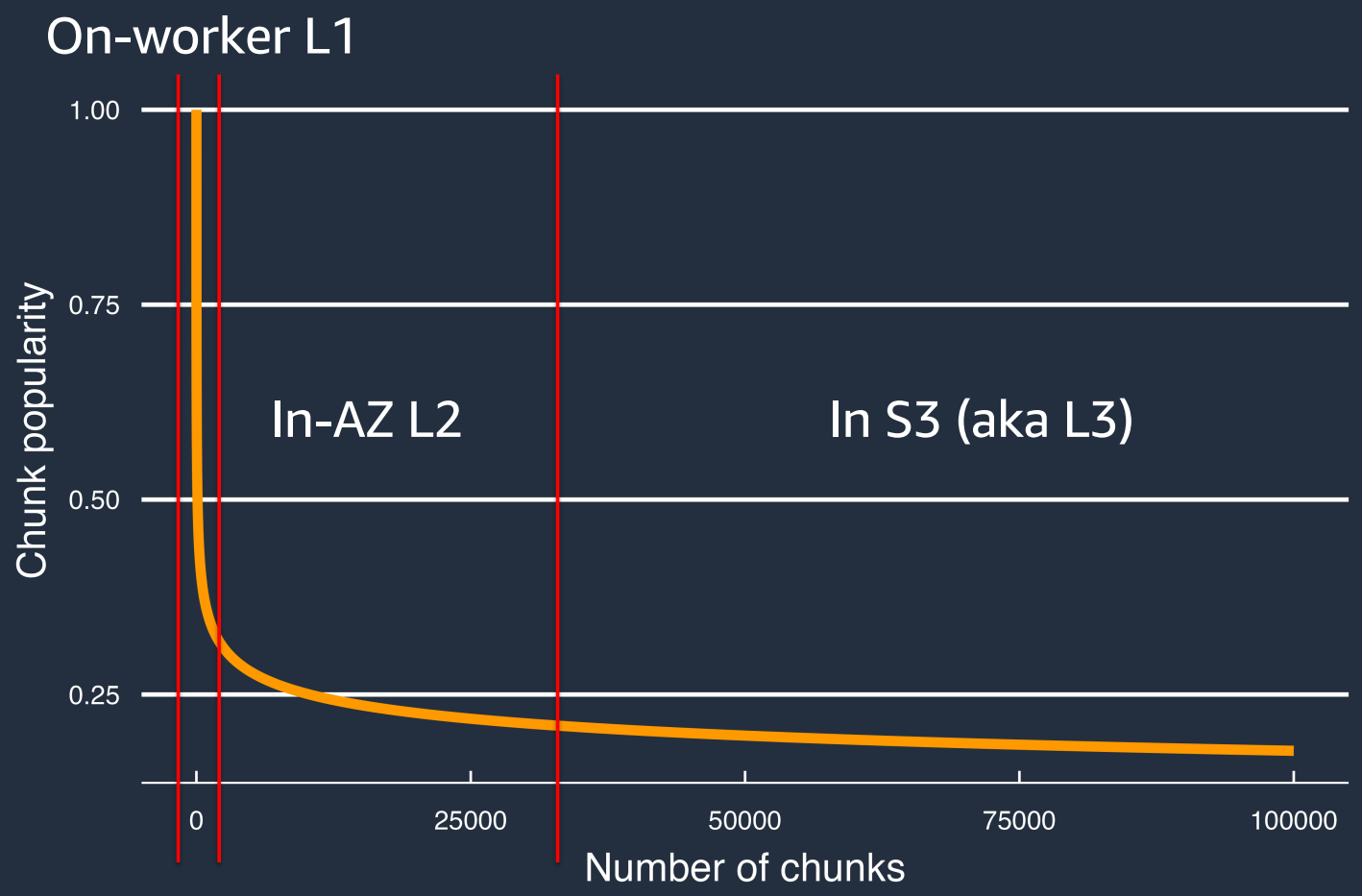


This is fake data, aimed to give the general idea, because I can't share the real numbers.



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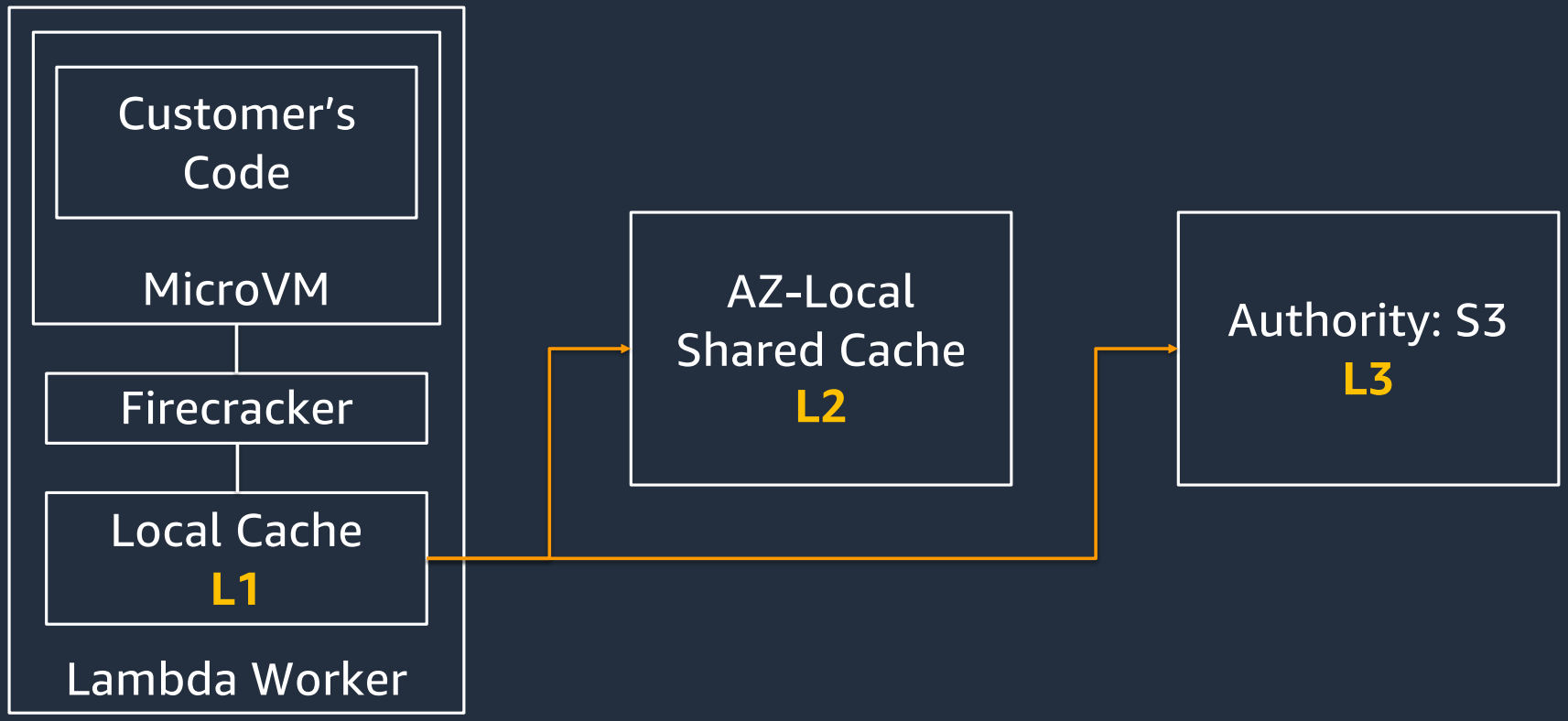
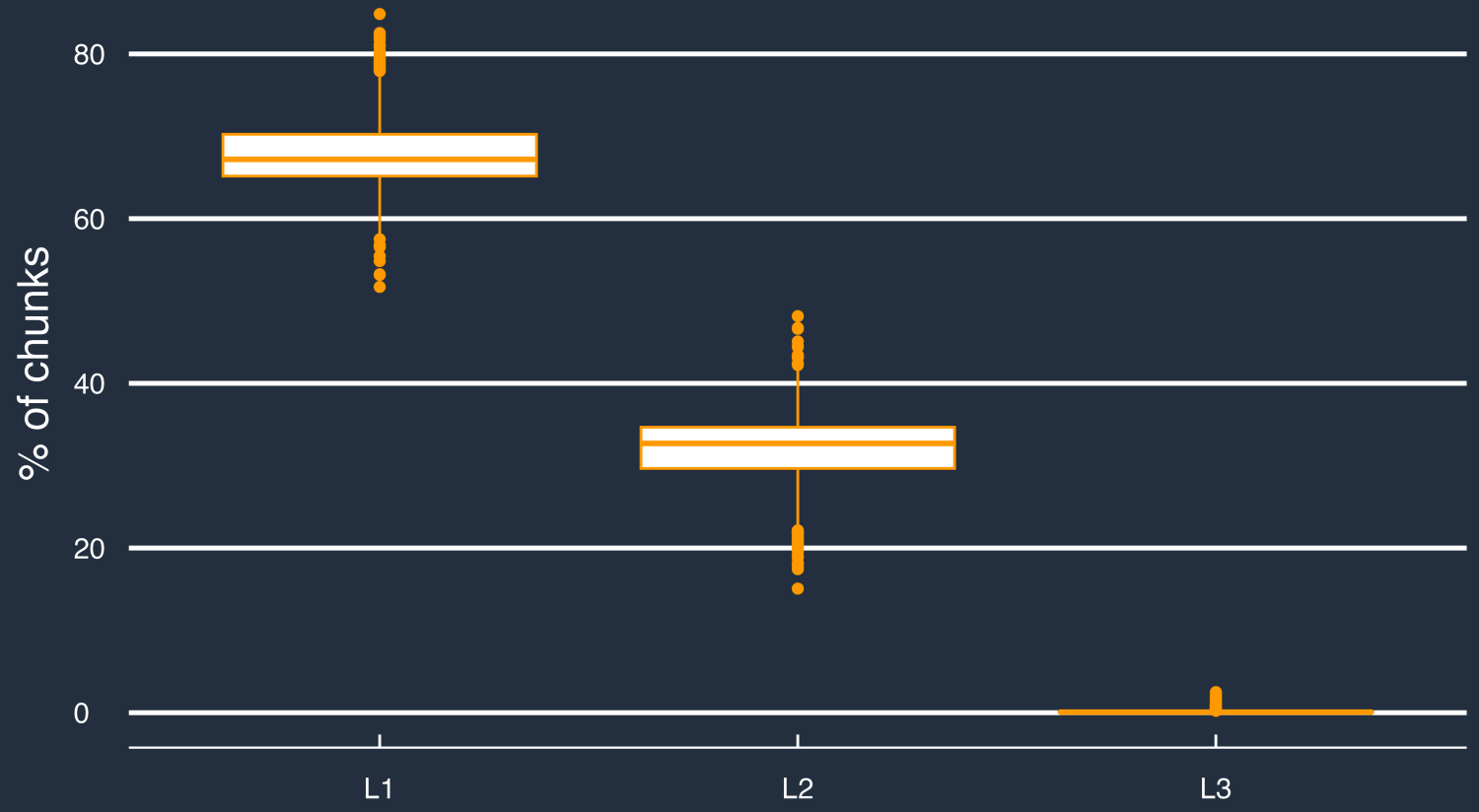
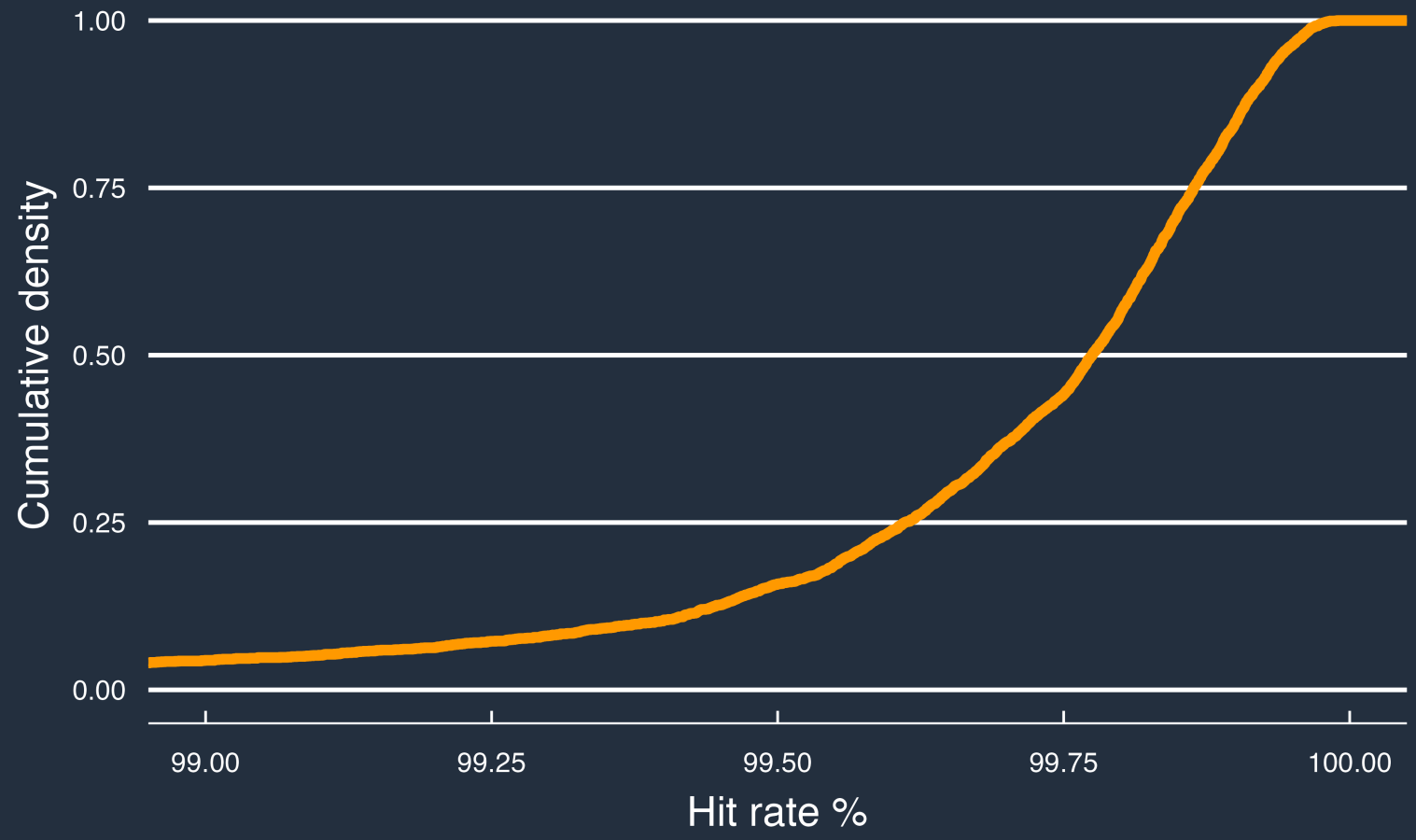
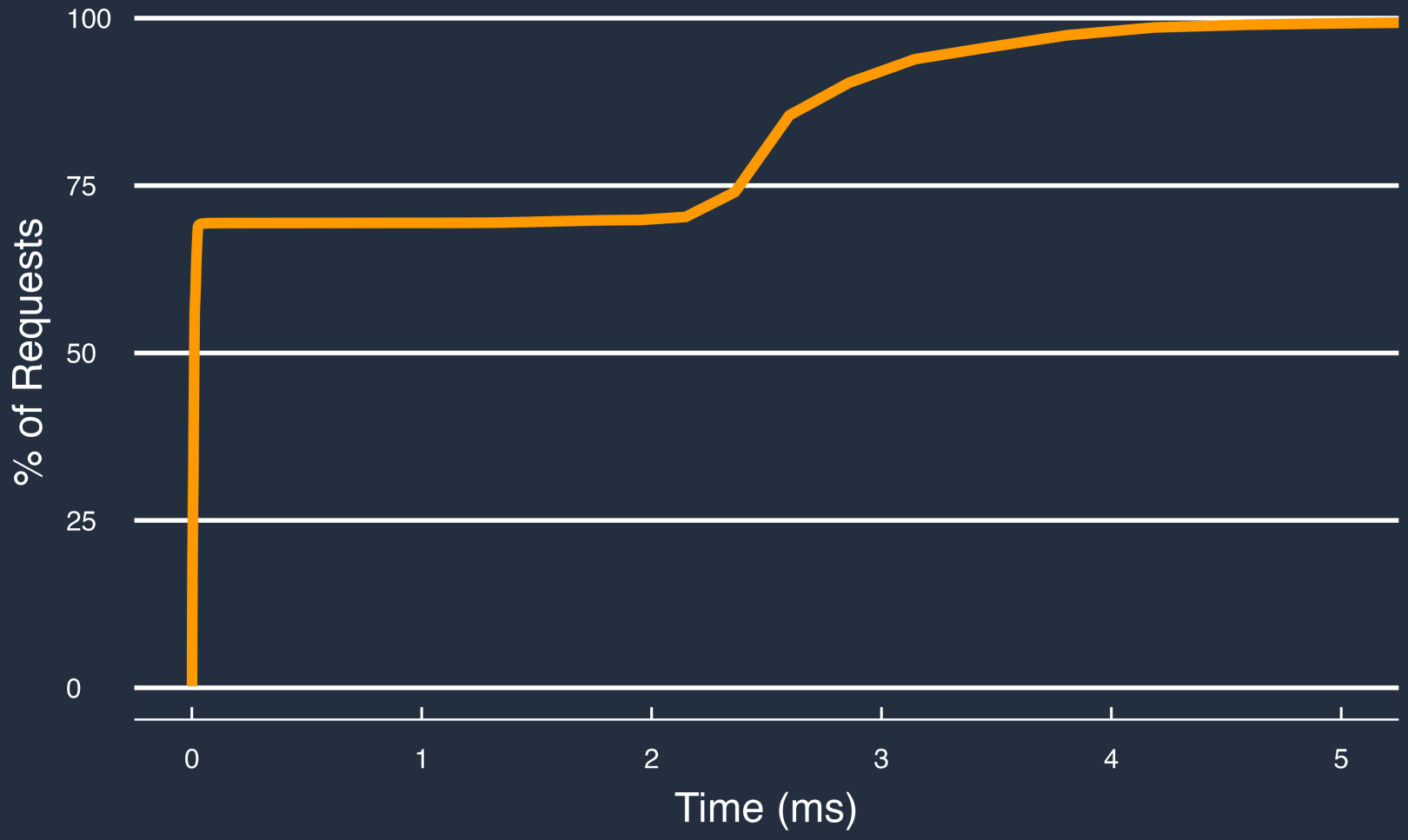
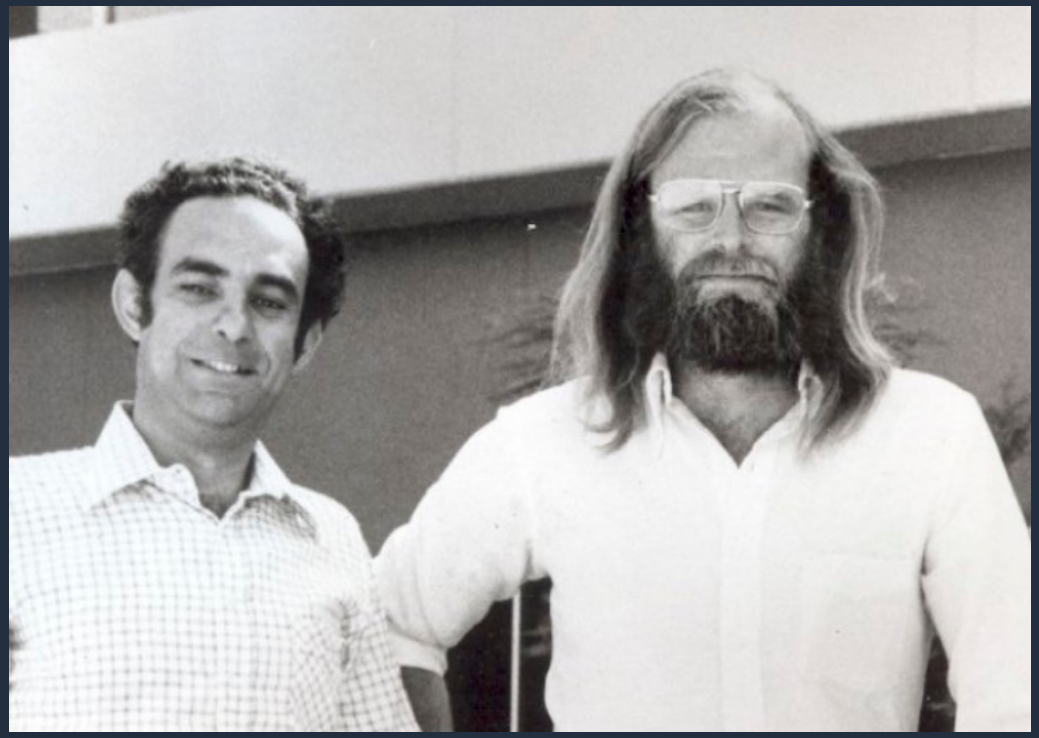








How Big?



cost of caching = cost of reloading

Jim Gray and Franco Putzolu, IBM Research, 1977 (picture thanks to Pat Helland)

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Max(size needed for cost,
size needed for latency)

What about failures?

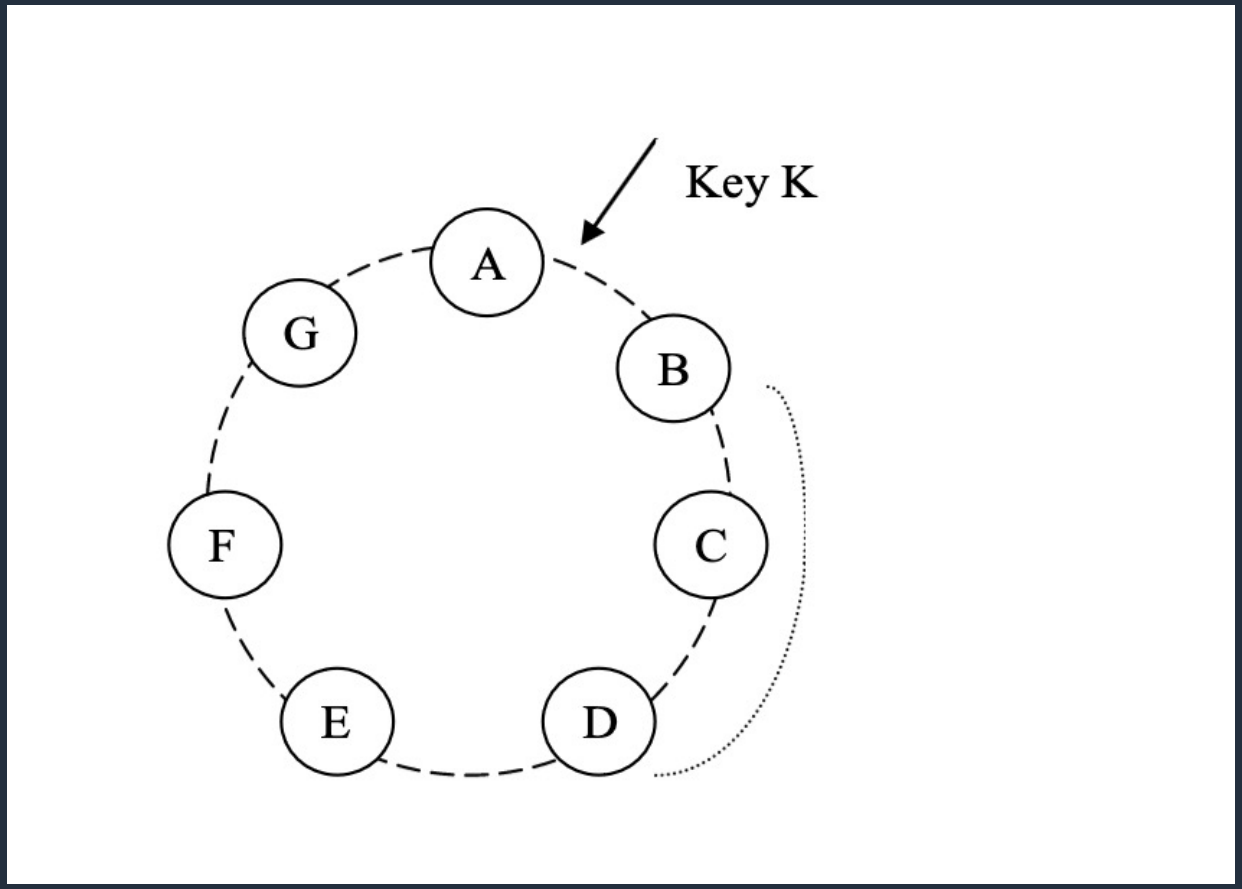
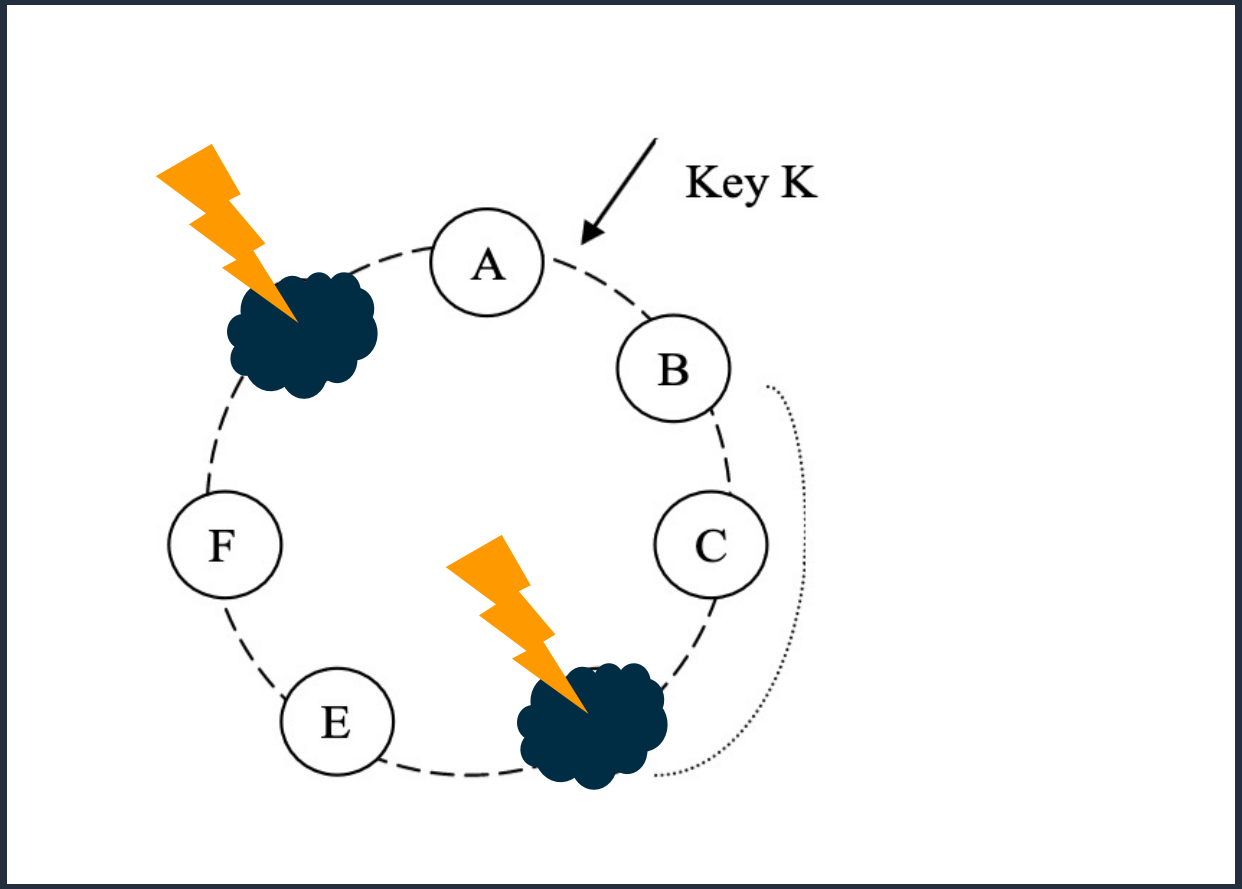
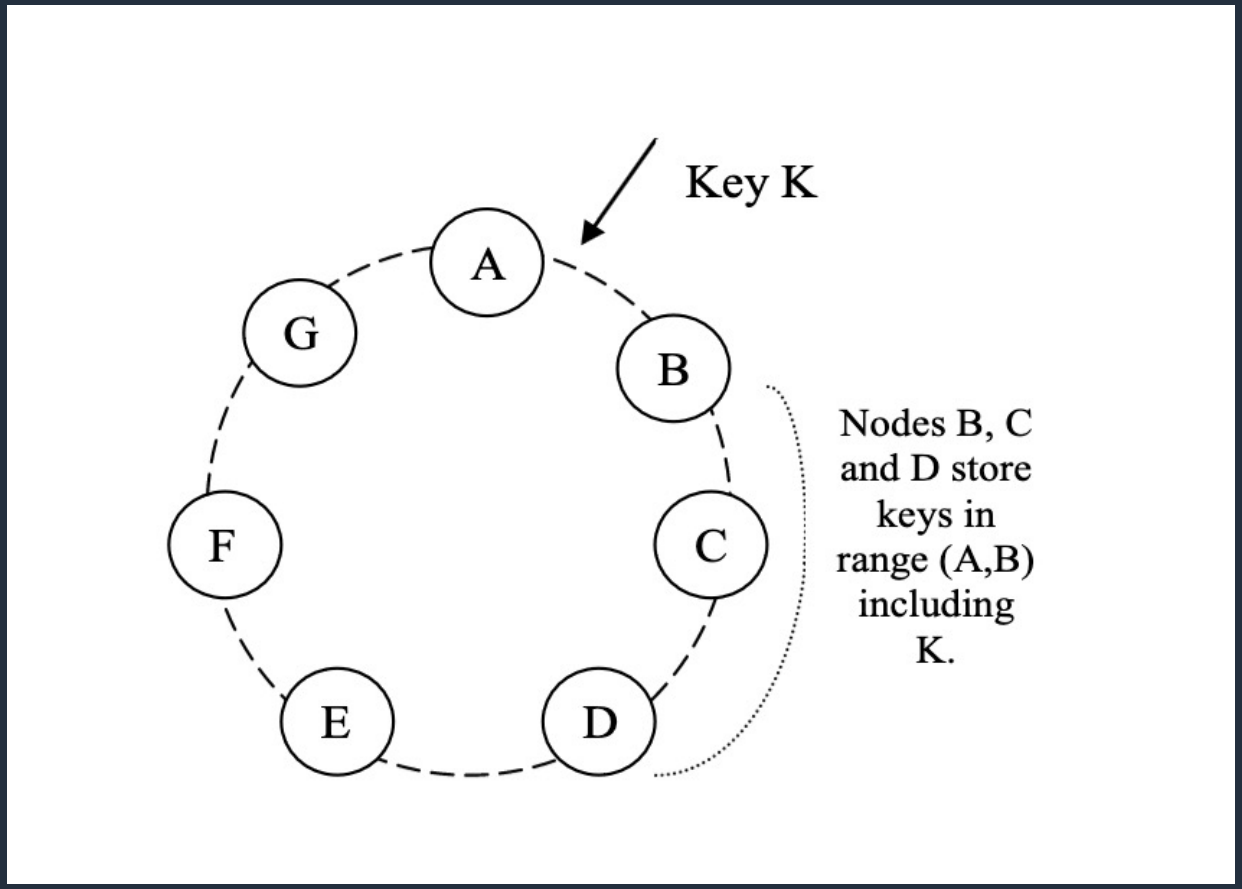


Figure shamelessly borrowed from Decandia et al, *Dynamo: Amazon's Highly Available Key-value Store*, SOSP'07





- One Copy
  - Not durable enough.

- Two Copies
  - 2x the cost! (or, half the effective cache size)

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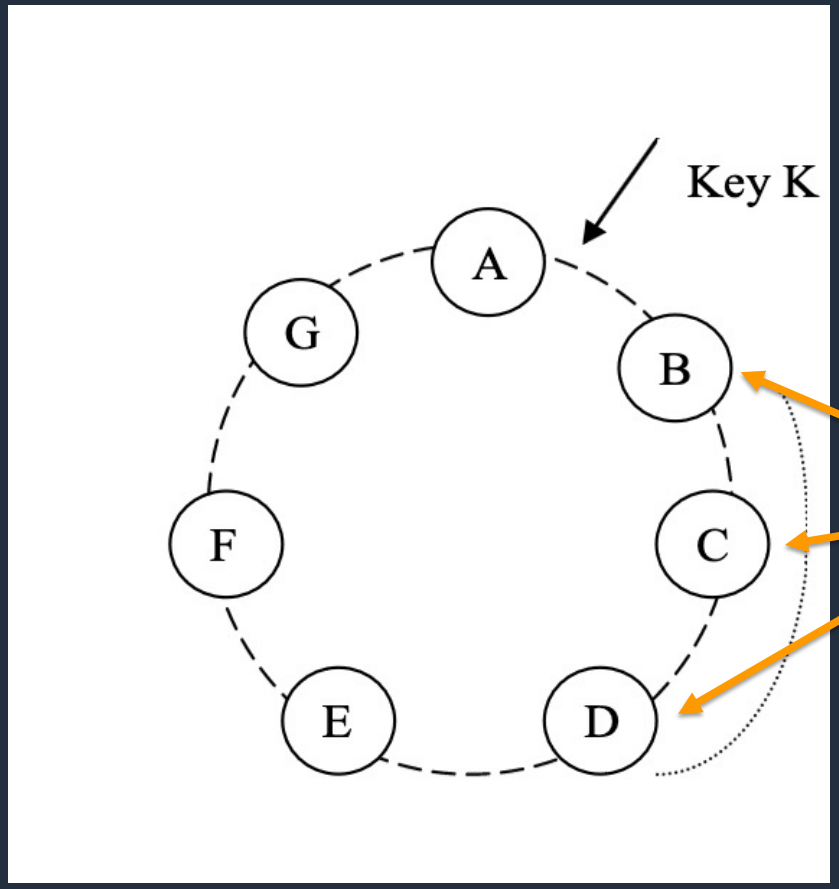
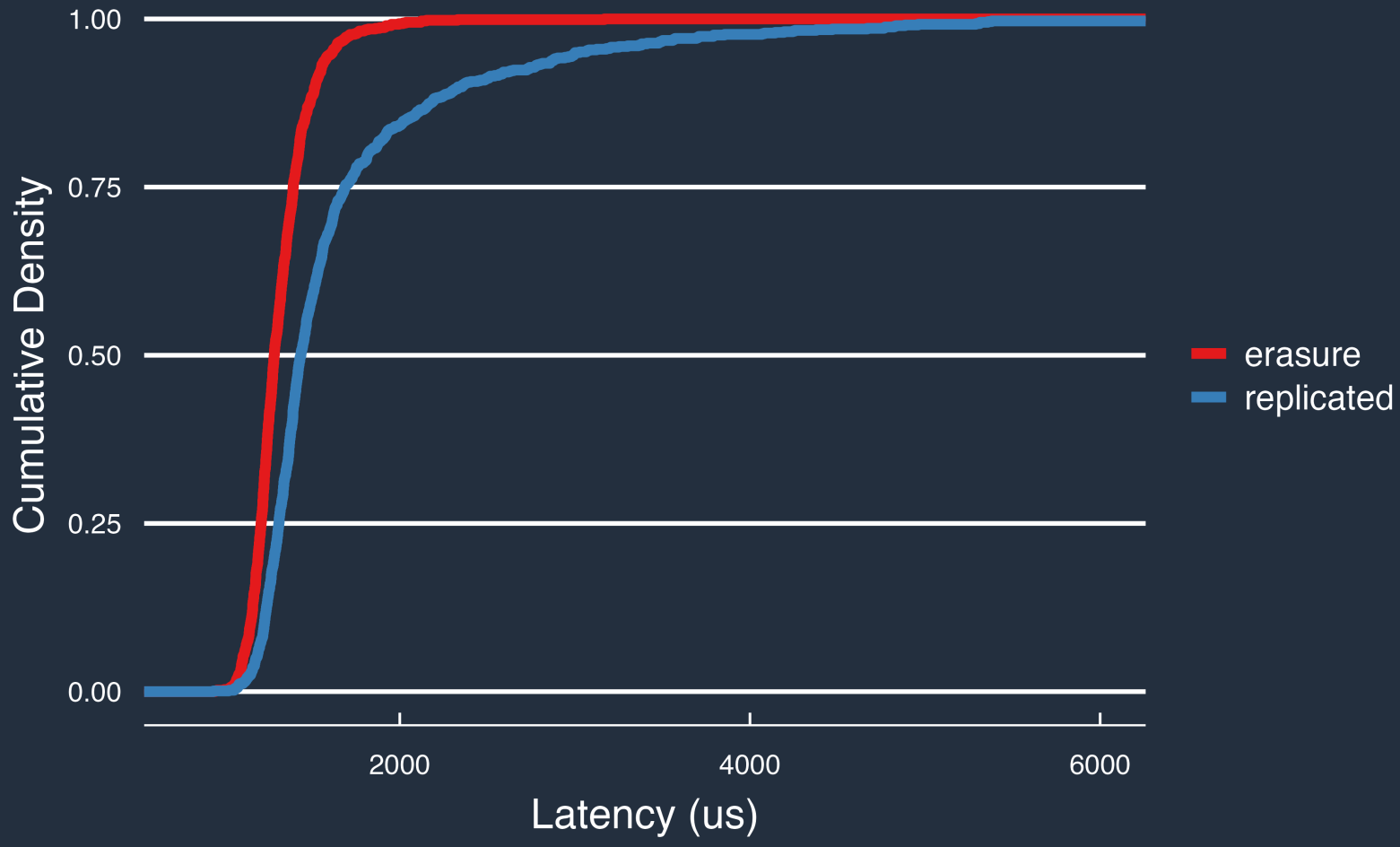


Erasure Code
“Any 4 of 6”



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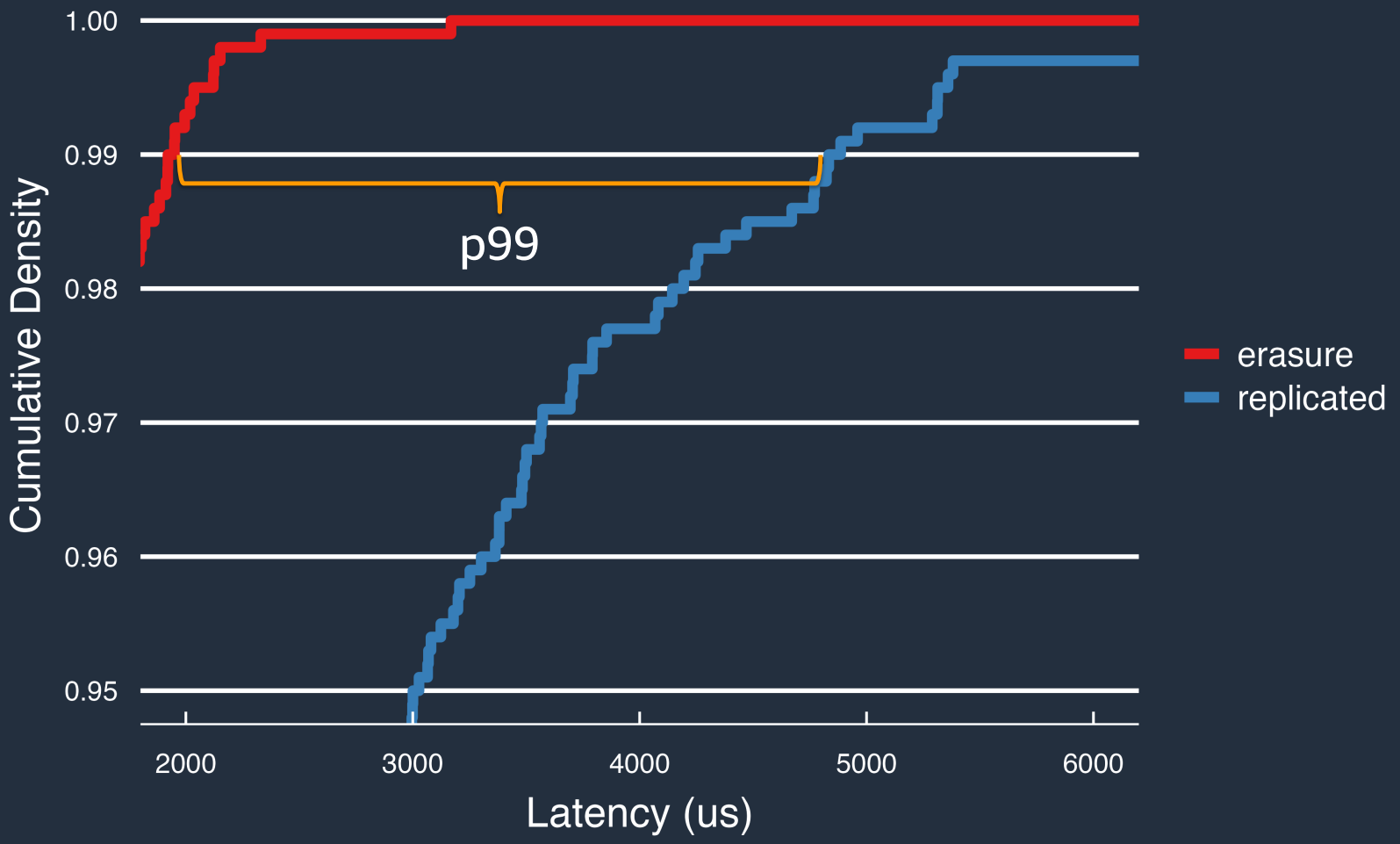

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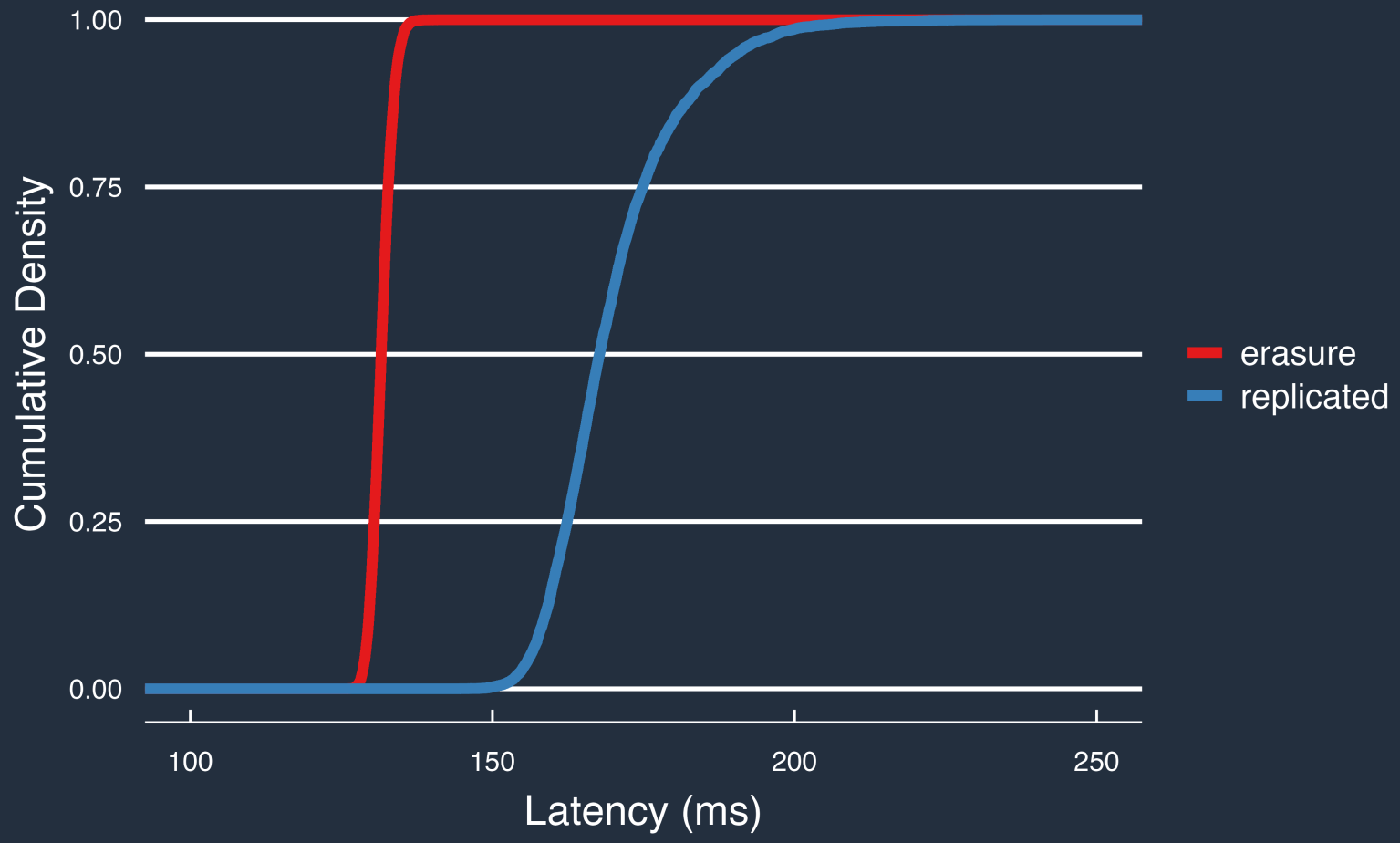

What about chunks of other stuff? Like memory?

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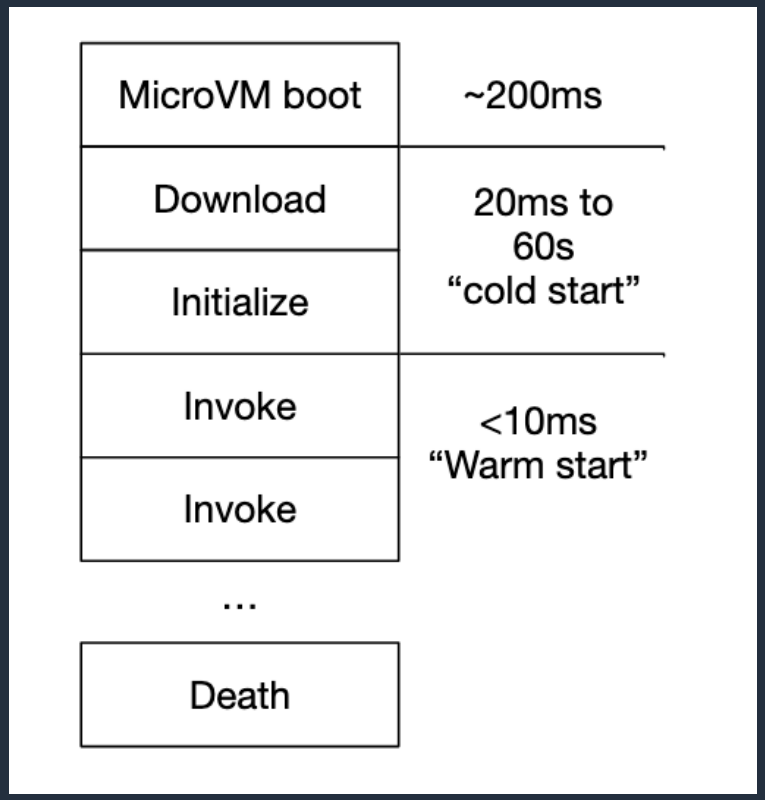
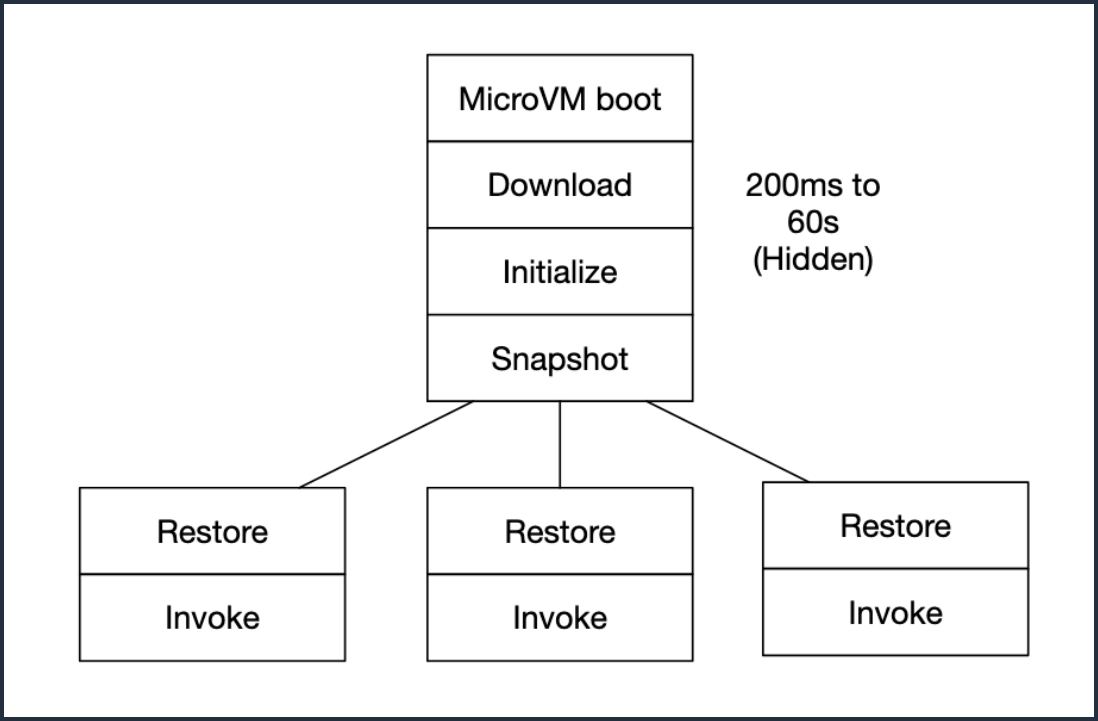


Brooker, et al, *Restoring Uniqueness in MicroVM Snapshots, https://arxiv.org/pdf/2102.12892*



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userfaultfd - create a file descriptor for handling page faults in user space

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Not only cold starts!

Tenant Isolation (for multi-tenant services handling untrusted code).

Session isolation (e.g. for AI agents).

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Questions

Erasure Coding
vs
Complexity

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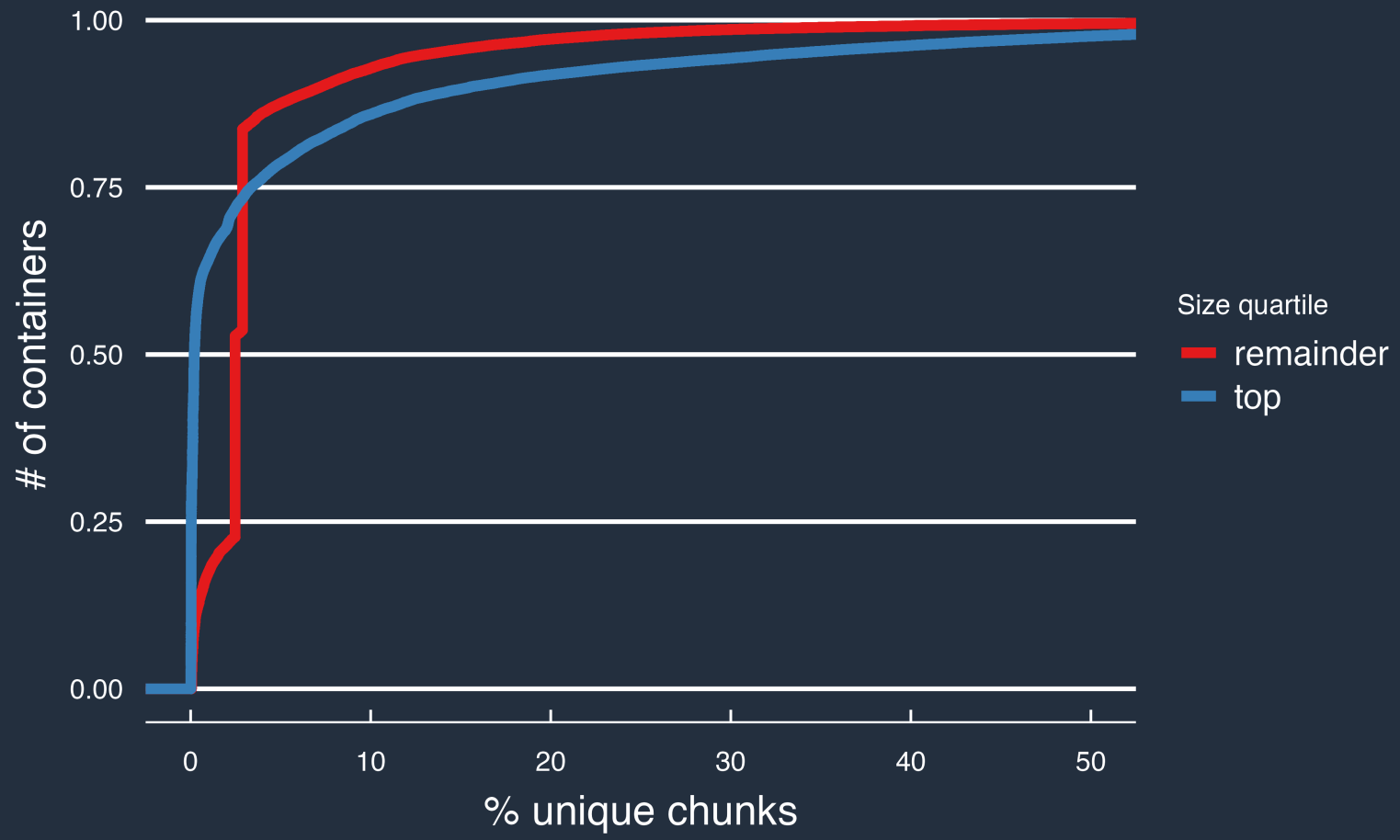

- Deterministic Flattener
    - Can only put chunks, not read them.
- Worker
    - Can only read chunks for the functions it is running.
- Everybody else
    - Can do basically nothing.

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Chunk name =

SHA2(Chunk data)

Chunk name =

SHA2(AES(Chunk data | Key | IV))

Chunk ciphertext =

$$AES_{gcm}(\boxed{\text{Chunk data}},\ key = f(\boxed{\text{Chunk data}}),\ iv = [0,\ldots])$$

Douceur et al, “Reclaiming Space from Duplicate Files in a Serverless Distributed File System”, Microsoft, 2002

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Chunk name =

SHA2(chunk ciphertext)

Chunk name =

SHA2(chunk ciphertext)

Q: Why not use the GCM *tag*?

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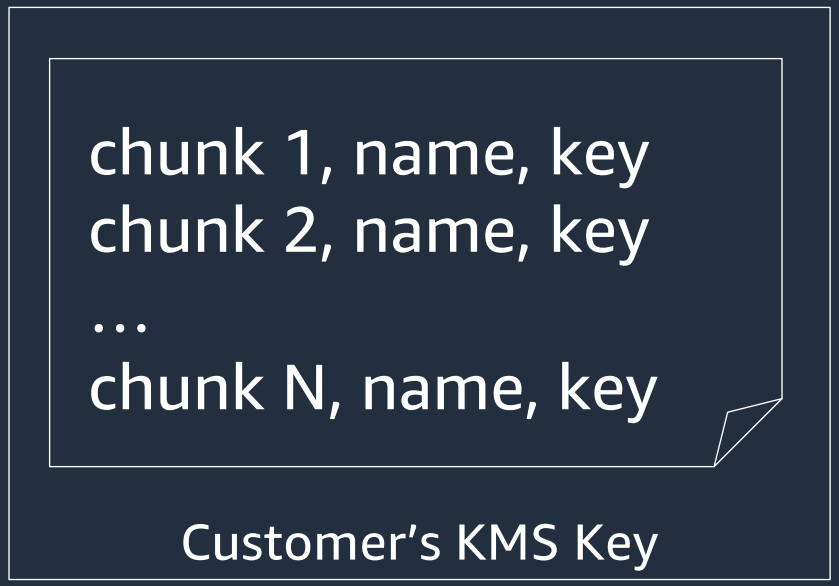
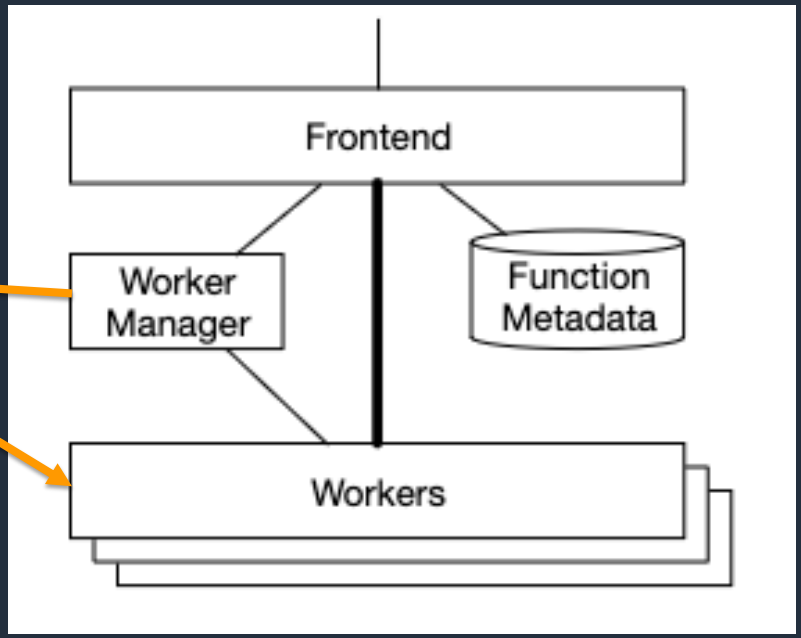


chunk 1, name, key
chunk 2, name, key
…
chunk N, name, key

Customer's KMS Key



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