Large-Scale Automated Storage on Kubernetes

Uber |

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SRE @ Uber

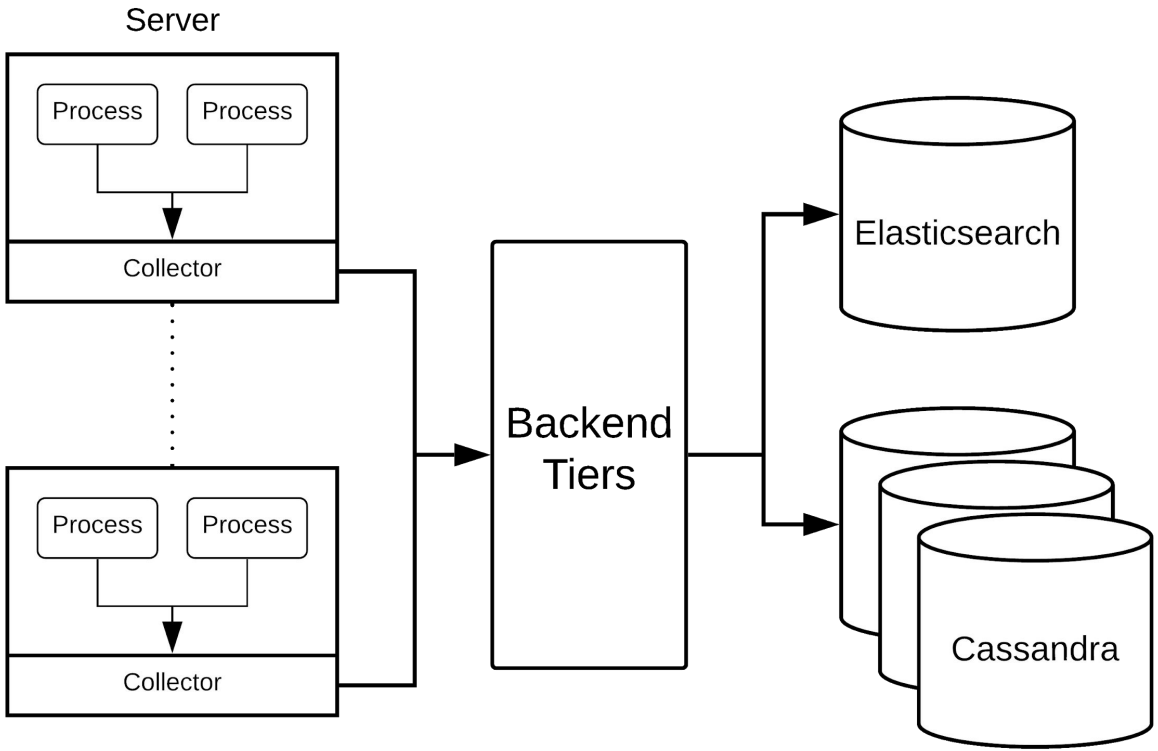
About Me

- SRE @ Uber since 2016
- M3 - Uber’s OSS Metrics Platform

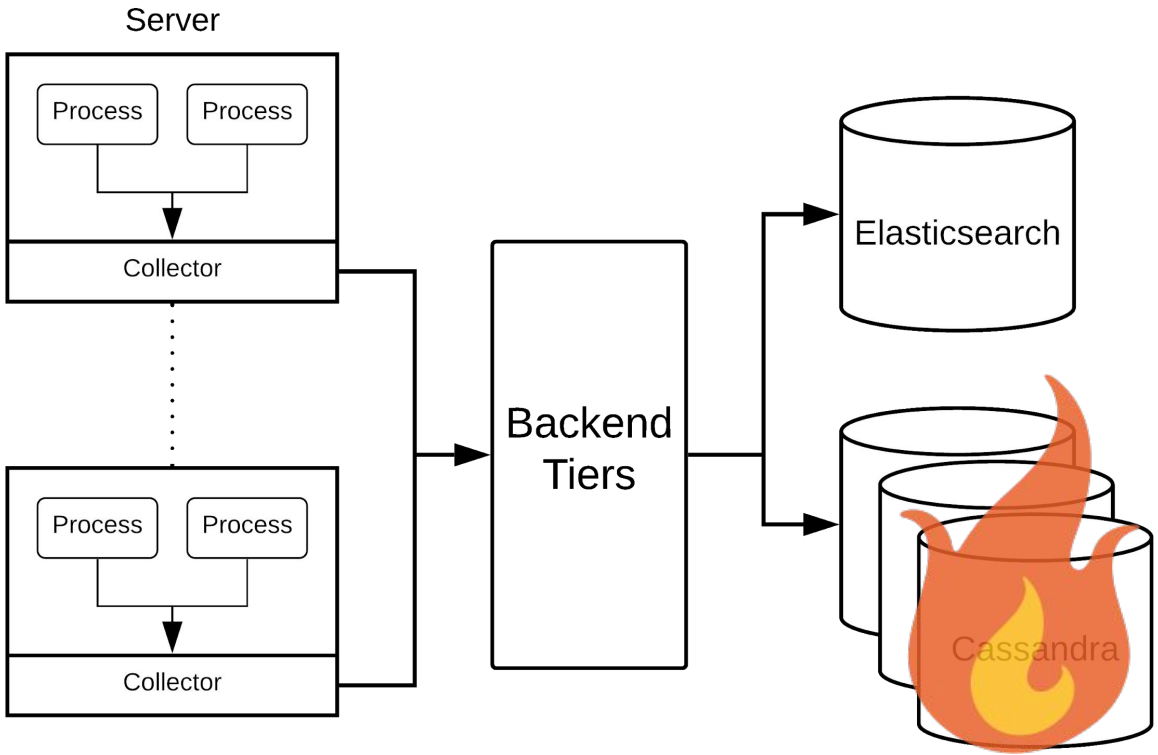
Agenda

- Background: Metrics @ Uber
- Scaling Challenges
- Automation
- M3DB on Kubernetes

2015



Mid 2016



Mid 2016

- Cassandra stack scaled to needs but was expensive
  - Human cost: operational overhead
  - Infra cost: lots of high-IO servers
- Scaling challenges inevitable, needed to reduce complexity

M3DB

- Open source distributed time series database
- Highly compressed (11x), fast, compaction-free storage
- Sharded, replicated (zone & rack-aware)
- Production late 2016

M3DB

- Reduced operational overhead
- Runs on commodity hardware with SSDs
- Strongly consistent cluster membership backed by etcd

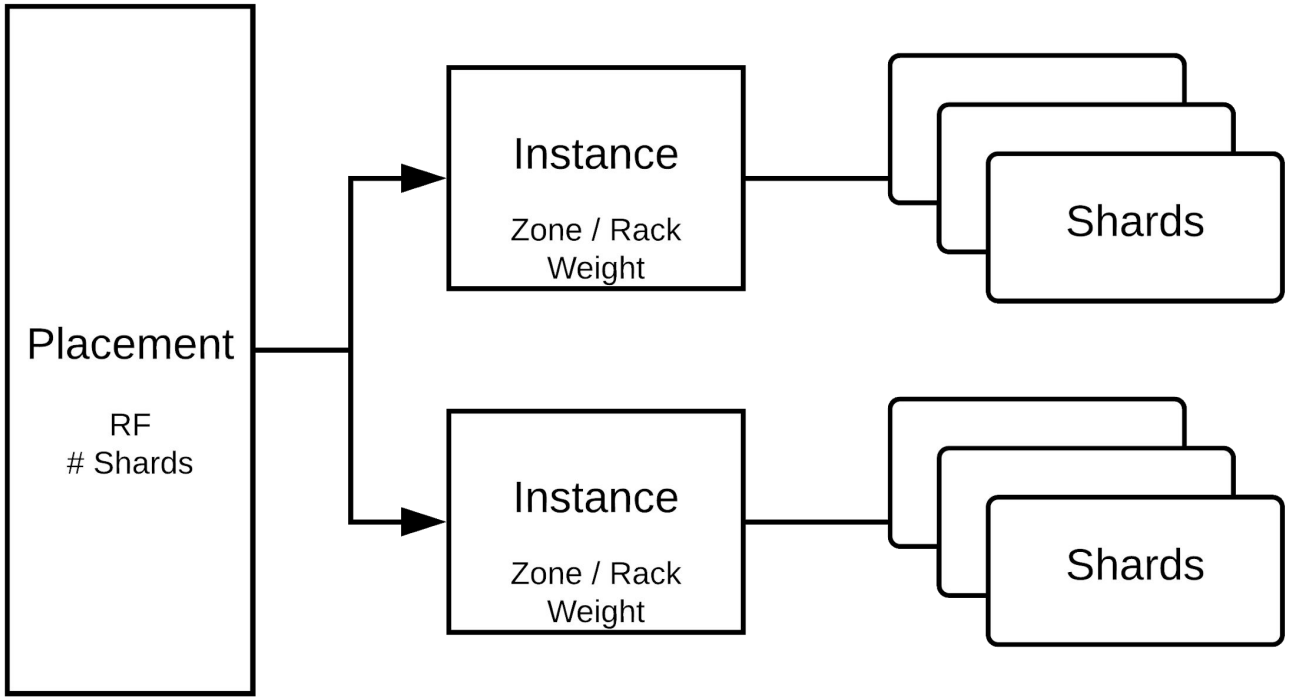
m3cluster

- Reusable cluster management libraries created for M3DB
  - Topology representation, shard distribution algos
  - Service discovery, runtime config, leader election
  - Etcd (strongly consistent KV store) as source of truth for all components
- Similar to Apache Helix
  - Helix is Java-heavy, we’re a Go-based stack

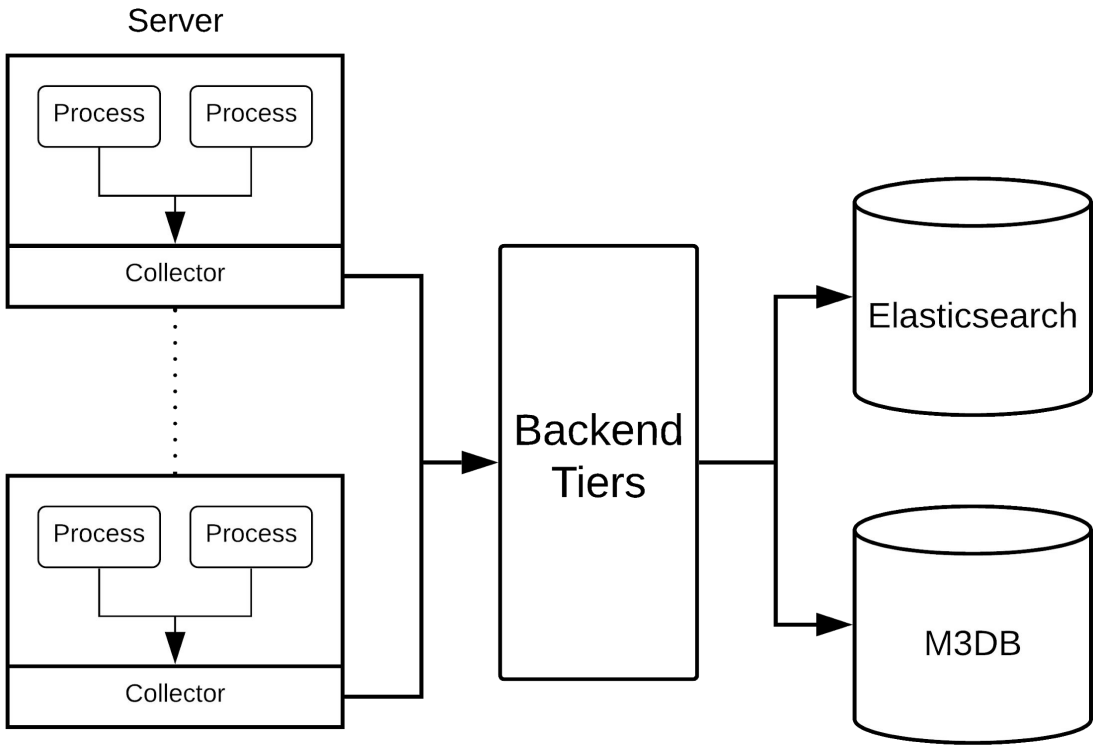
m3cluster

- Topologies represented as desired goal states, M3DB converges

m3cluster: Placement



Late 2016

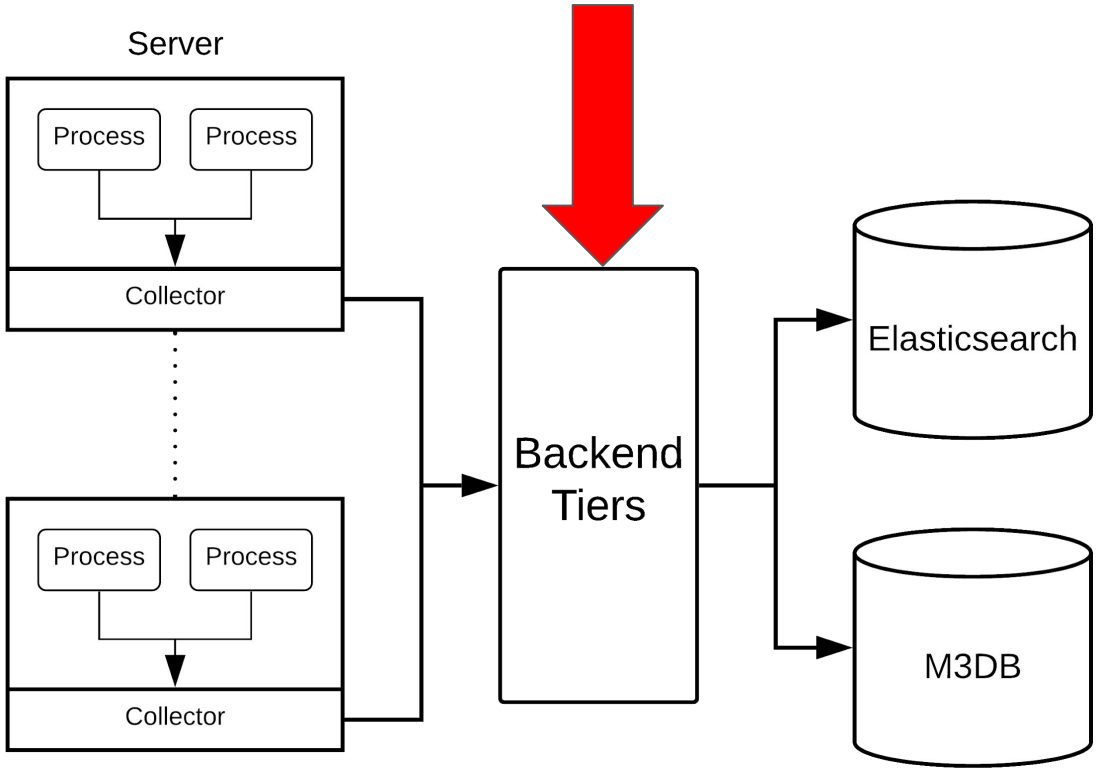


Post-M3DB Deployment

- M3DB solved most pressing issue (Cassandra)
  - Improved stability, reduced costs
- System as a whole: still a high operational overhead

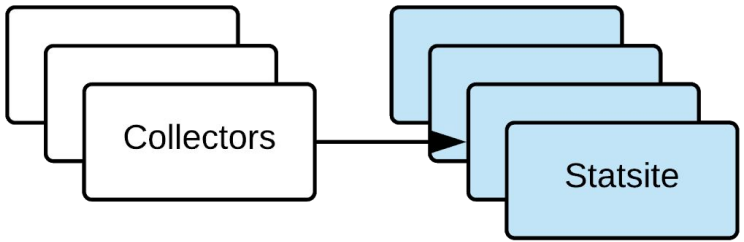
Fragmented representation of components

System Representation (2016)



System Representation (2016)

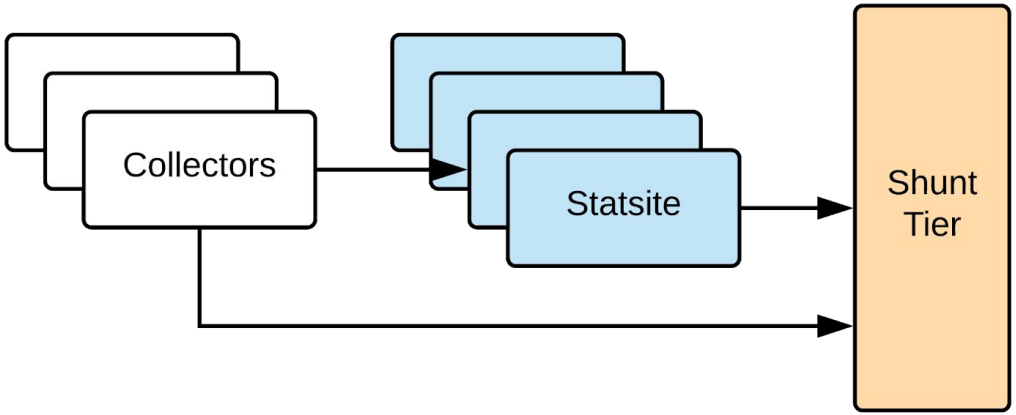
Config service



System Representation (2016)

Config service

Static lists via Puppet



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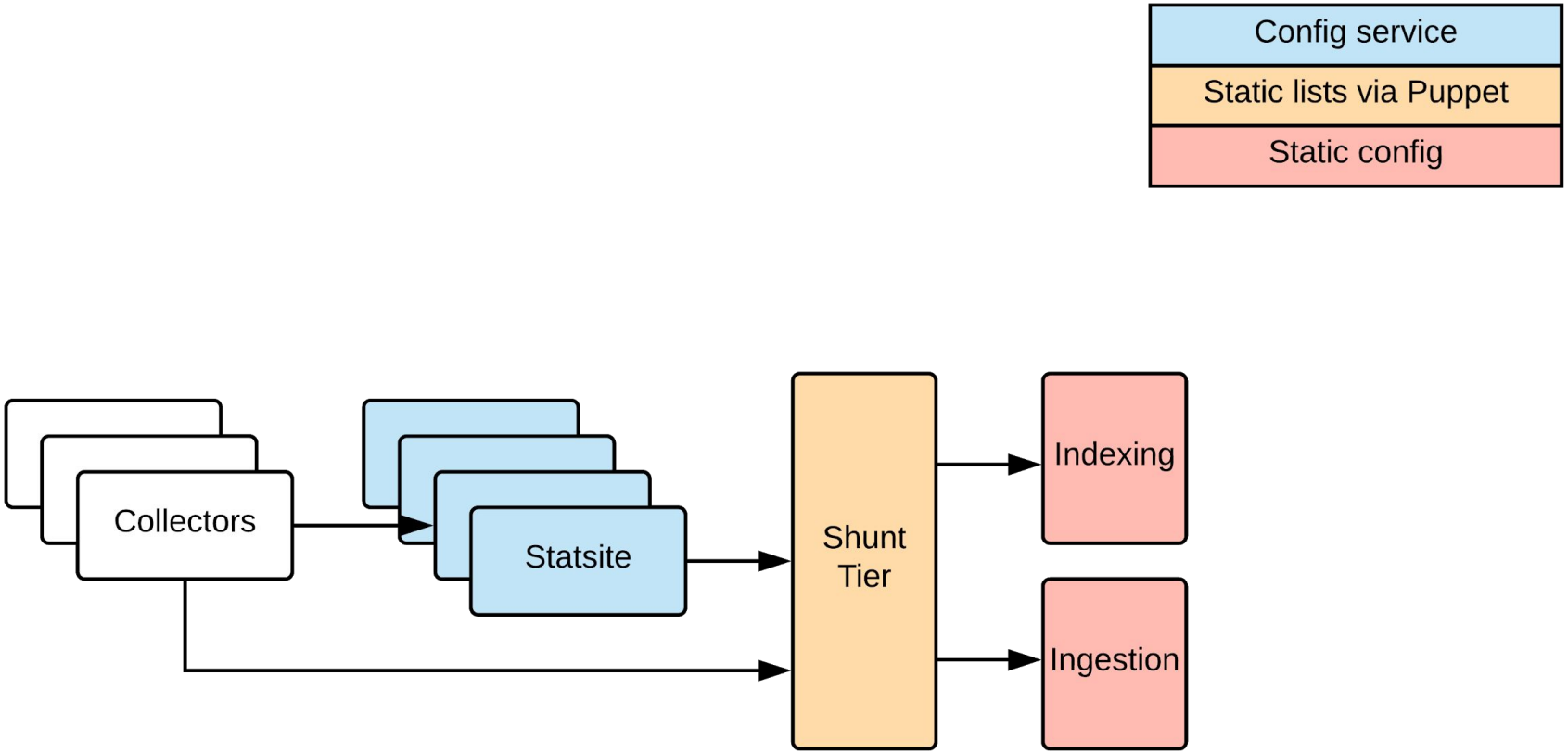

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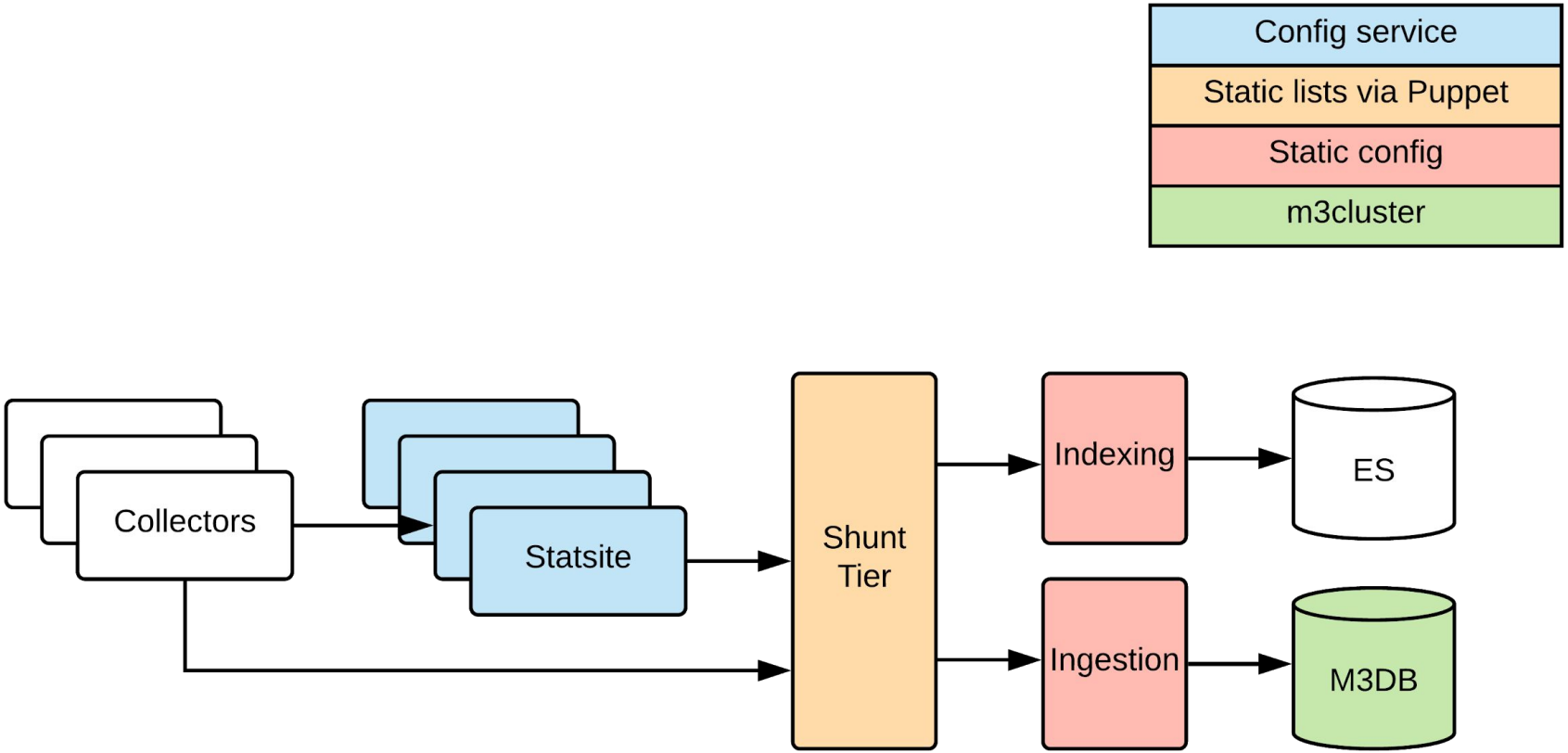


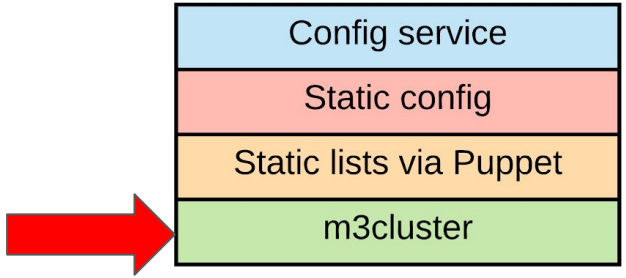
System Representation

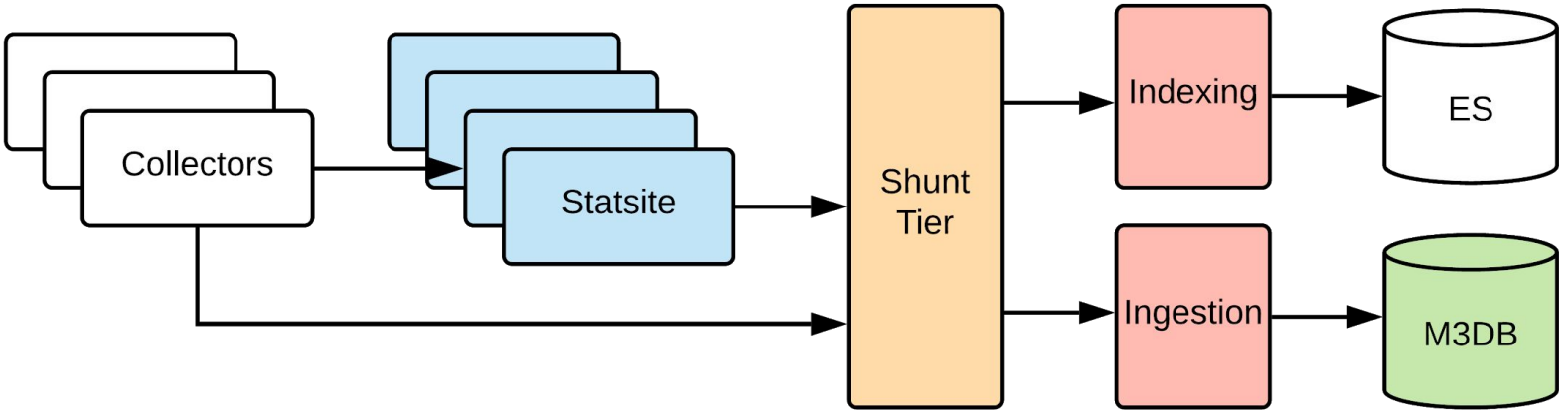
- Systems represented as…
  - Lists fetched from Uber config service
  - Static lists deployed via Puppet
  - Static lists coupled with service deploys
  - m3cluster placements

Fragmentation

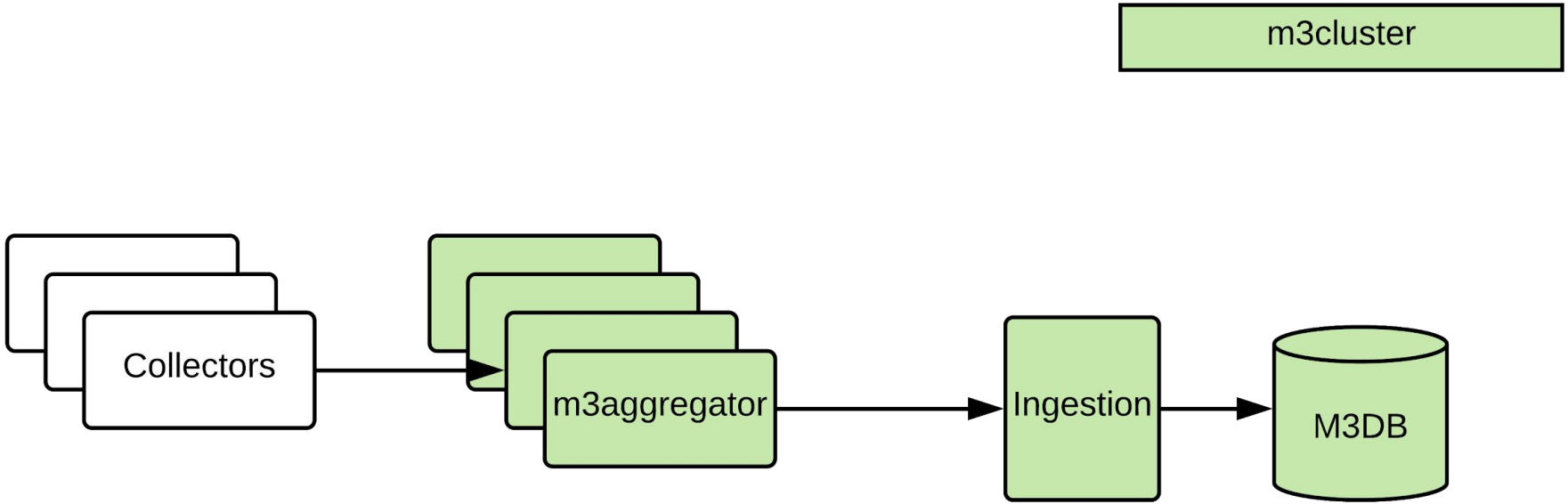
- Had smaller components rather than one unifying view of the system as a whole
- **Difficult to reason about**
  - “Where do I need to make this change?”
  - Painful onboarding for new engineers
- **Impediment to automation**
  - Replace host: update config, build N services, deploy

System Representation (2016)





System Representation: 2018



m3cluster benefits

- Common libraries for all workloads: stateful (M3DB), semi-stateful (aggregation tier), stateless (ingestion)
  - Implement “distribute shards across racks according to disk size” once, reuse everywhere
- Single source of truth: everything stored in etcd

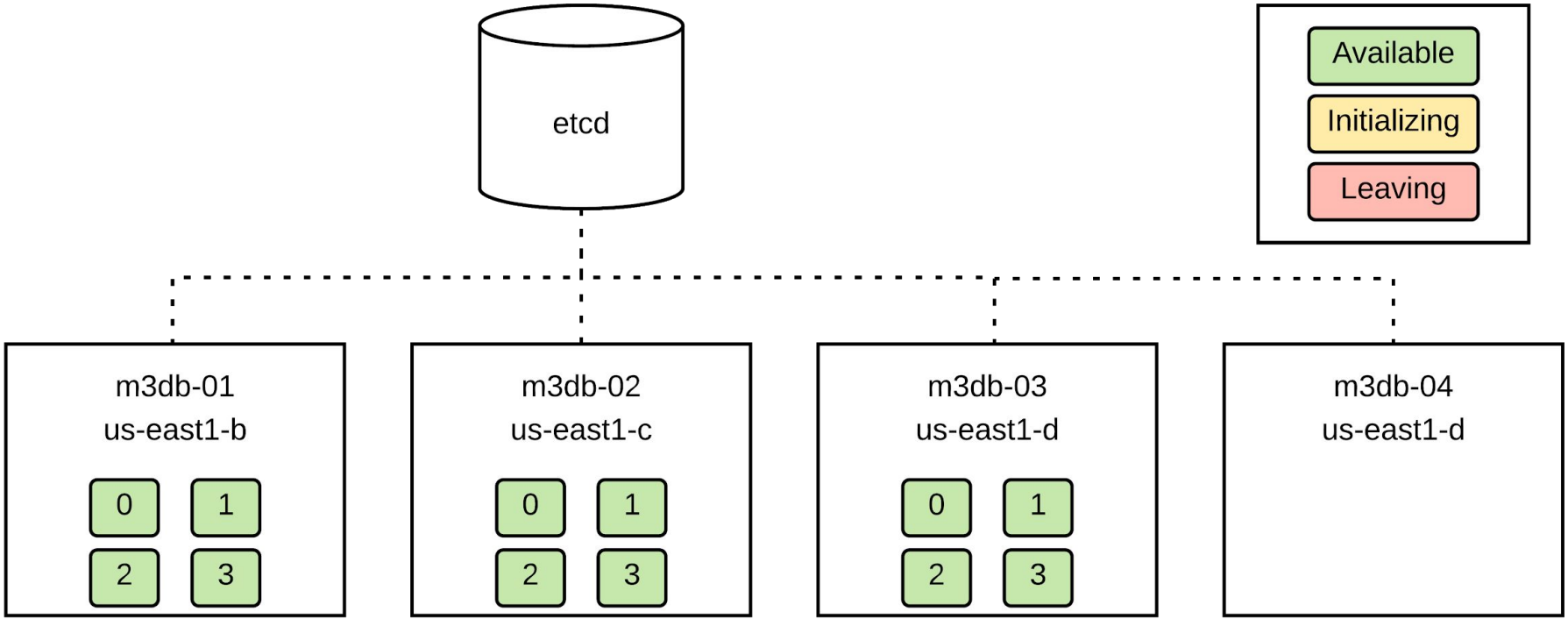
Operational Improvements

- Easier to reason about the entire system
  - Unifying view: Placements
- Operations much easier, possible to automate
  - Just modifying goal state in etcd
- One config per deployment (no instance-specific)
  - Cattle vs. pets: instances aren’t special, treat them as a whole

M3DB Goal State

- Shard assignments stored in etcd
  - M3DB nodes observe desired state, react, update shard state
- Imperative actions such as “add a node” are really changes in declarative state
  - Easy for both people or tooling to interact with

M3DB: Adding a Node



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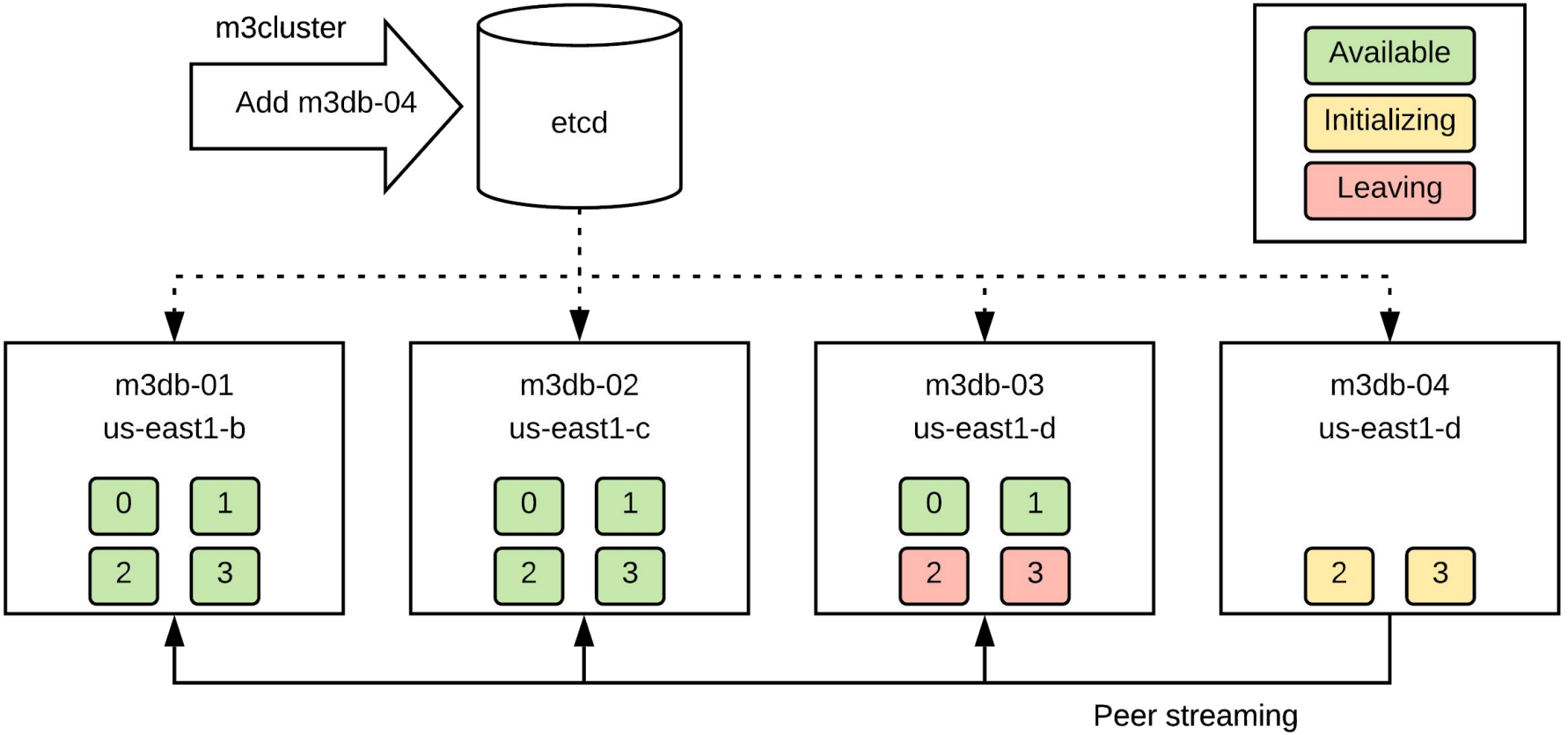
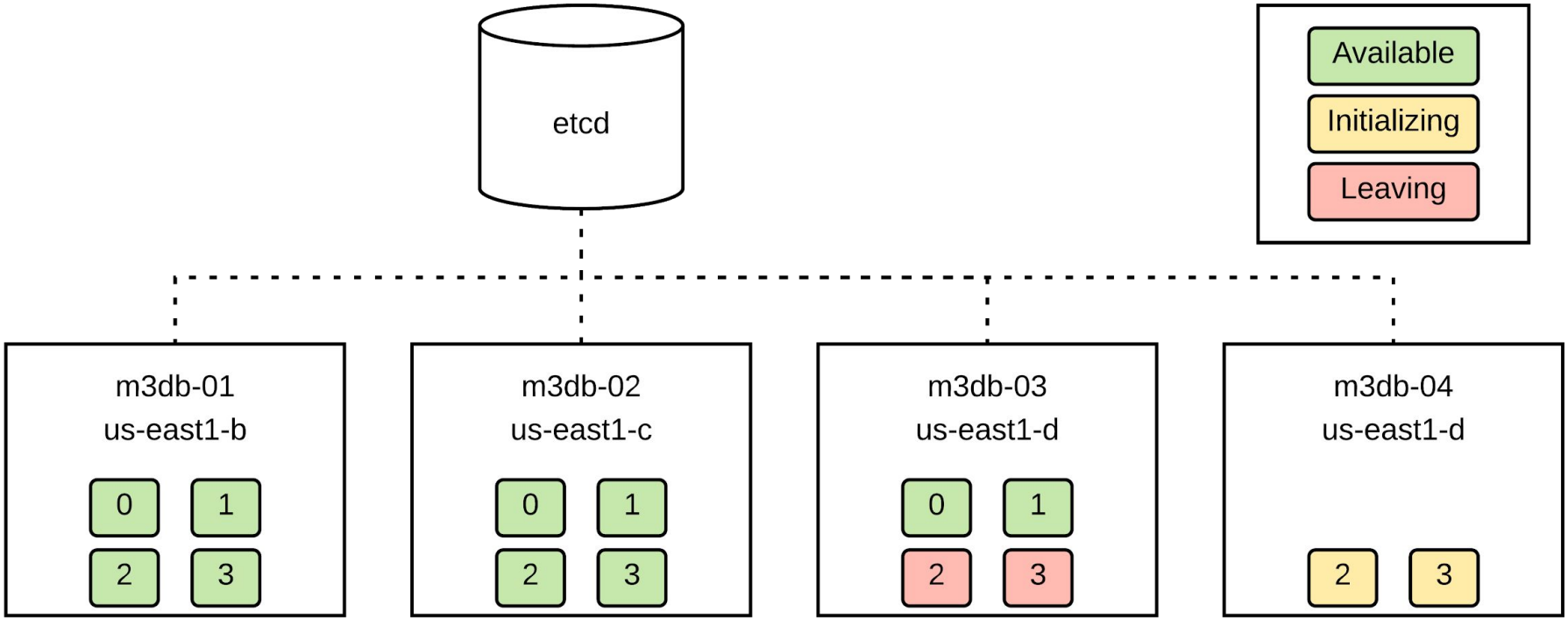
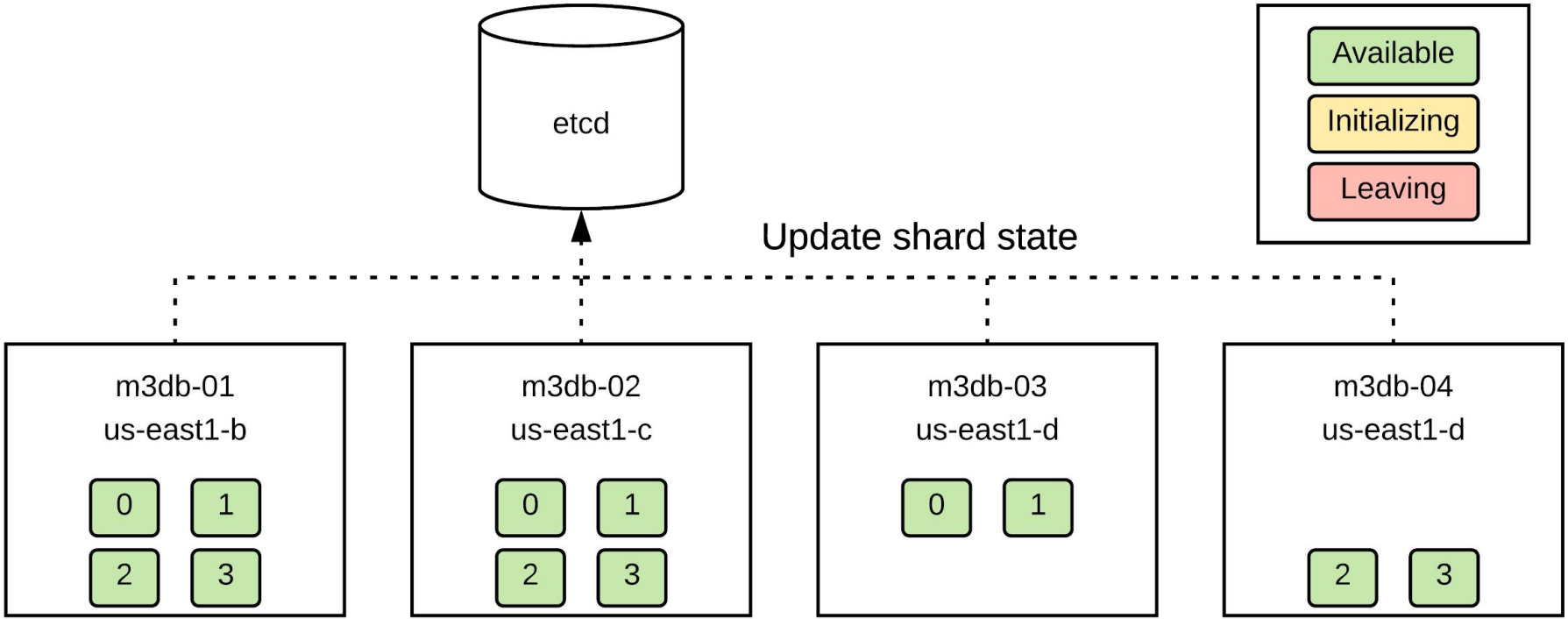


M3DB: Adding a Node



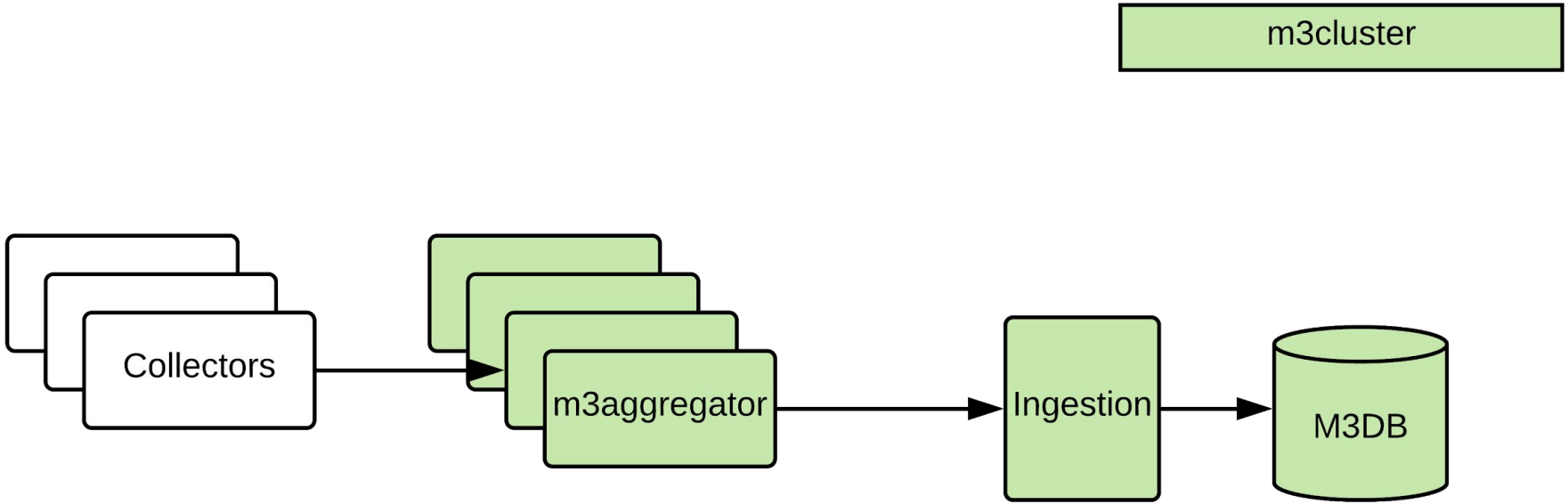
M3DB: Adding a Node



M3DB Goal State

- Goal-state primitives built with future automation in mind
- m3cluster interacts with single source of truth
- Vs. imperative changes:
  - No instance-level operations
  - No state or steps to keep track of: can always reconcile state of world (restarts, etc. safe)

System Representation: 2018



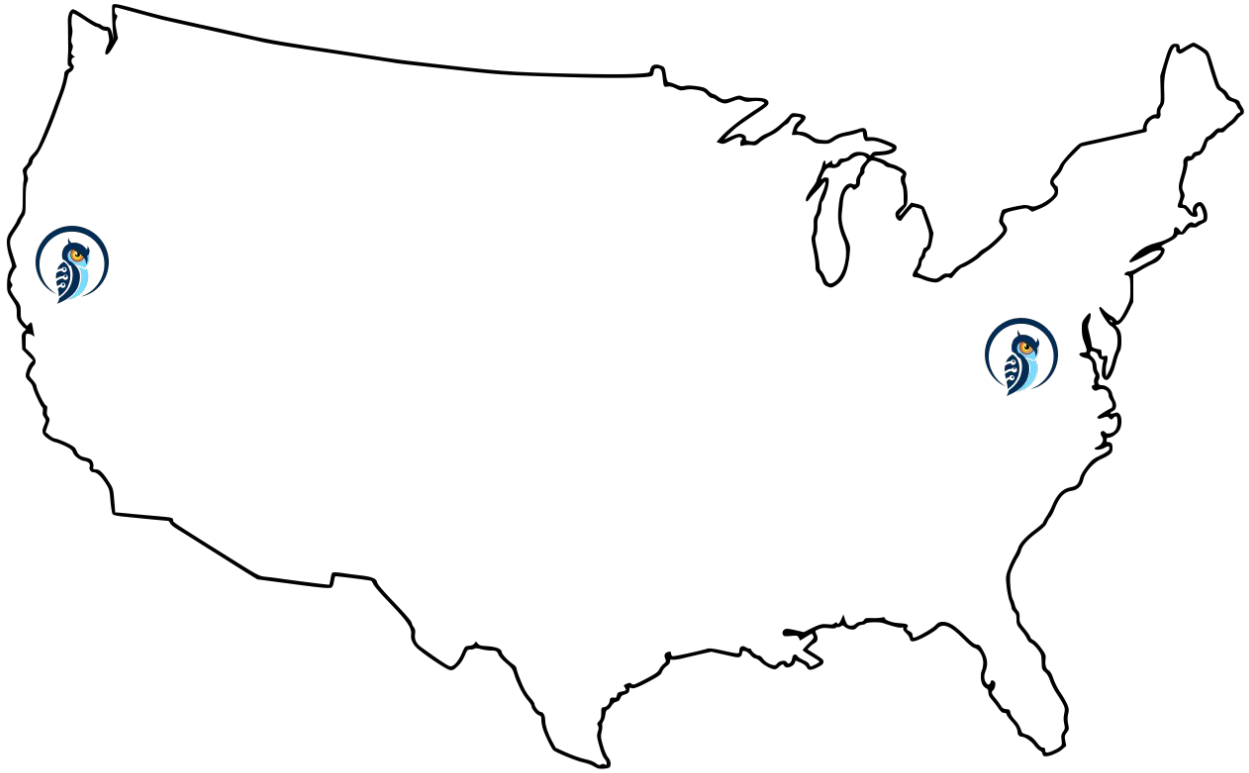
M3DB Operations

- Retooled entire stack as goal state-driven, dynamic
  - Operations simplified, but still triggered by a person
- M3DB requires more care to manage than stateless
  - Takes time to stream data

2016

2

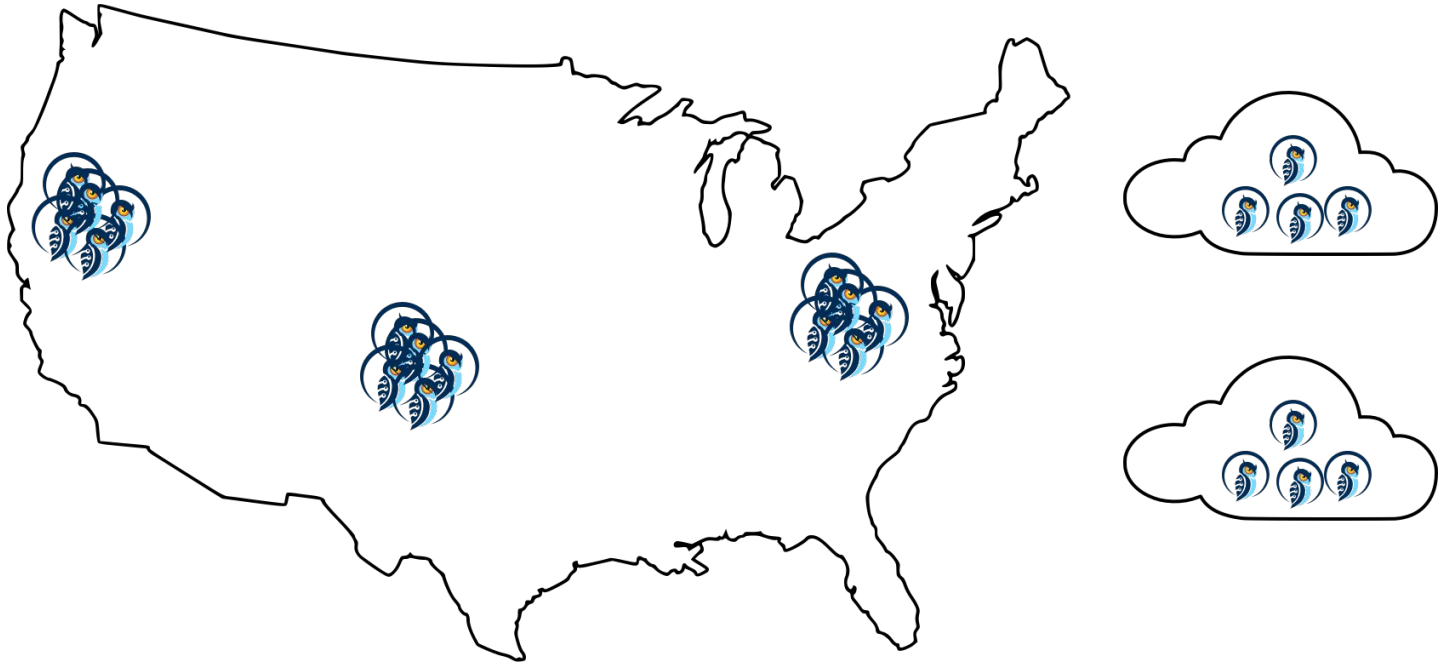
Clusters



2018

40+

Clusters



Automating M3DB

- Wanted goal state at a higher level
  - Clusters as cattle
- M3DB can only do so much; needed to expand scope
- Chose to build on top of **Kubernetes**
  - Value for M3DB OSS community
  - Internal Uber use cases

Kubernetes @ 35,000 ft

- Container orchestration system
- Support for stateful workloads
- Self-healing
- Extensible
  - CRD: define your own API resources
  - Operator: custom controller

Kubernetes Driving Principles

- Pod: base unit of work
  - Group of like containers deployed together
- Pods can come and go
  - Self-healing → pods move in response to failures
- No pods are special

Kubernetes Controllers

```
for {
  desired := getDesiredState()
  current := getCurrentState()
  makeChanges(desired, current)
}
```

Writing Controllers Guide

M3DB & Kubernetes

M3DB:

- Goal state driven
- Single source of truth
- Nodes work to converge

Kubernetes:

- Goal state driven
- Single source of truth
- Components work to converge

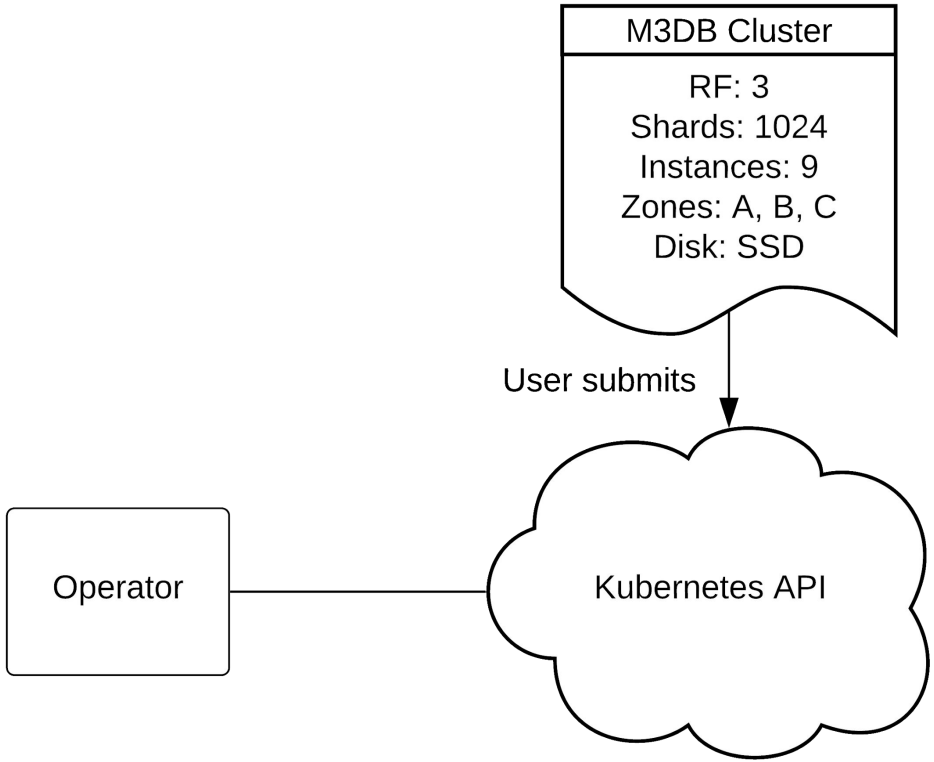
M3DB Operator

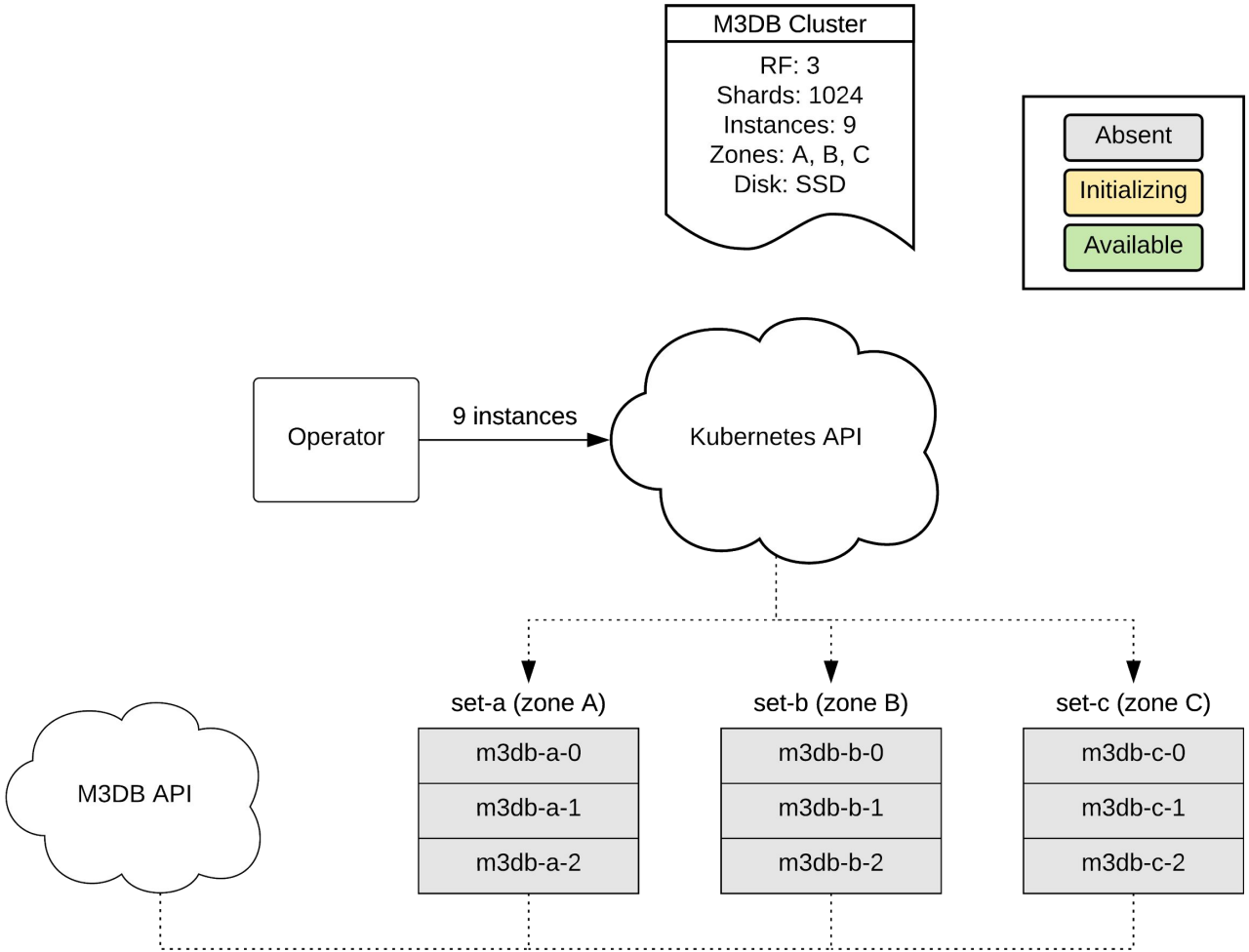
- Manages M3DB clusters running on Kubernetes
  - Creation, deletion, scaling, maintenance
- Performs actions a person would have to do in full cluster lifecycle
  - Updating M3DB clusters
  - Adding more instances

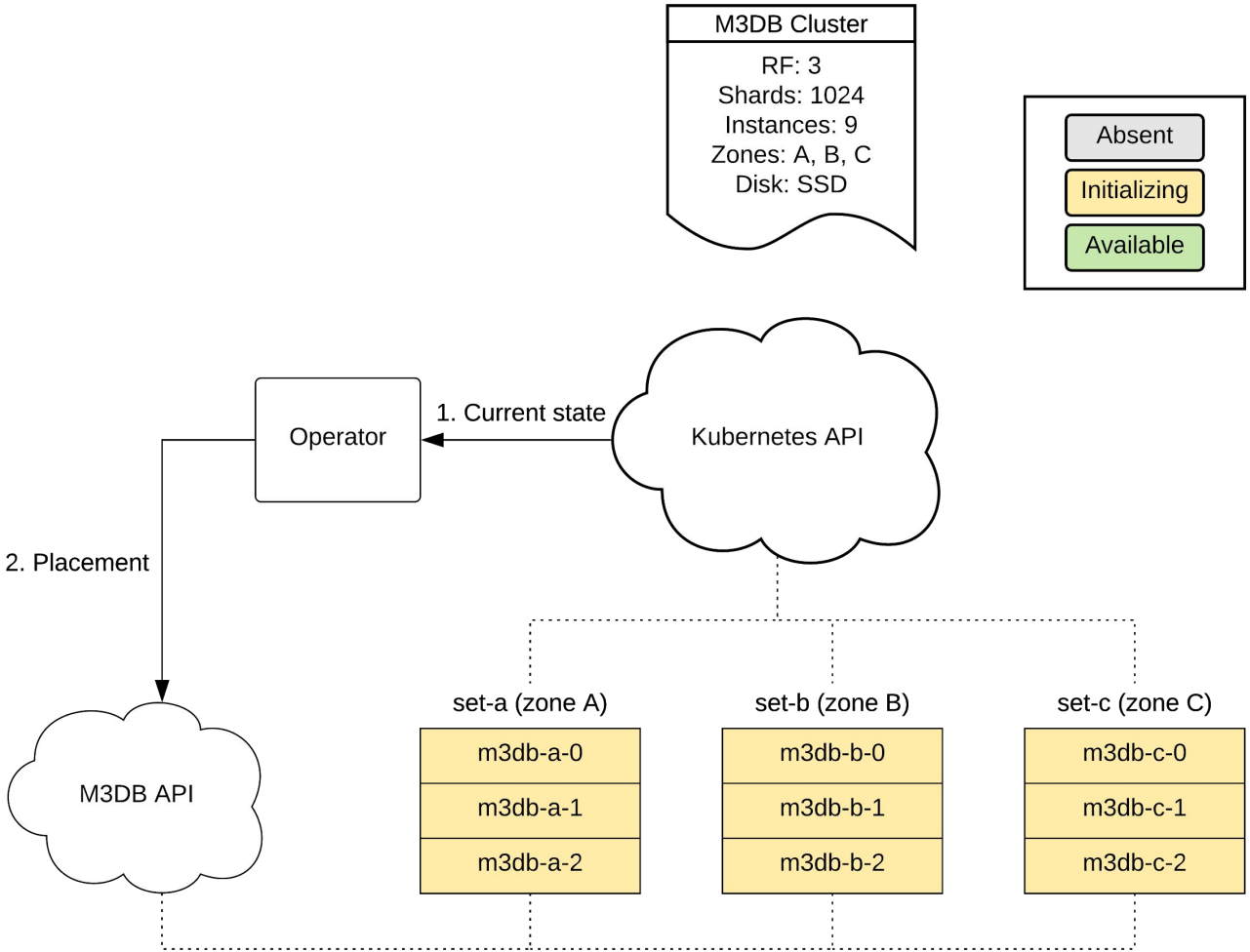
M3DB Operator

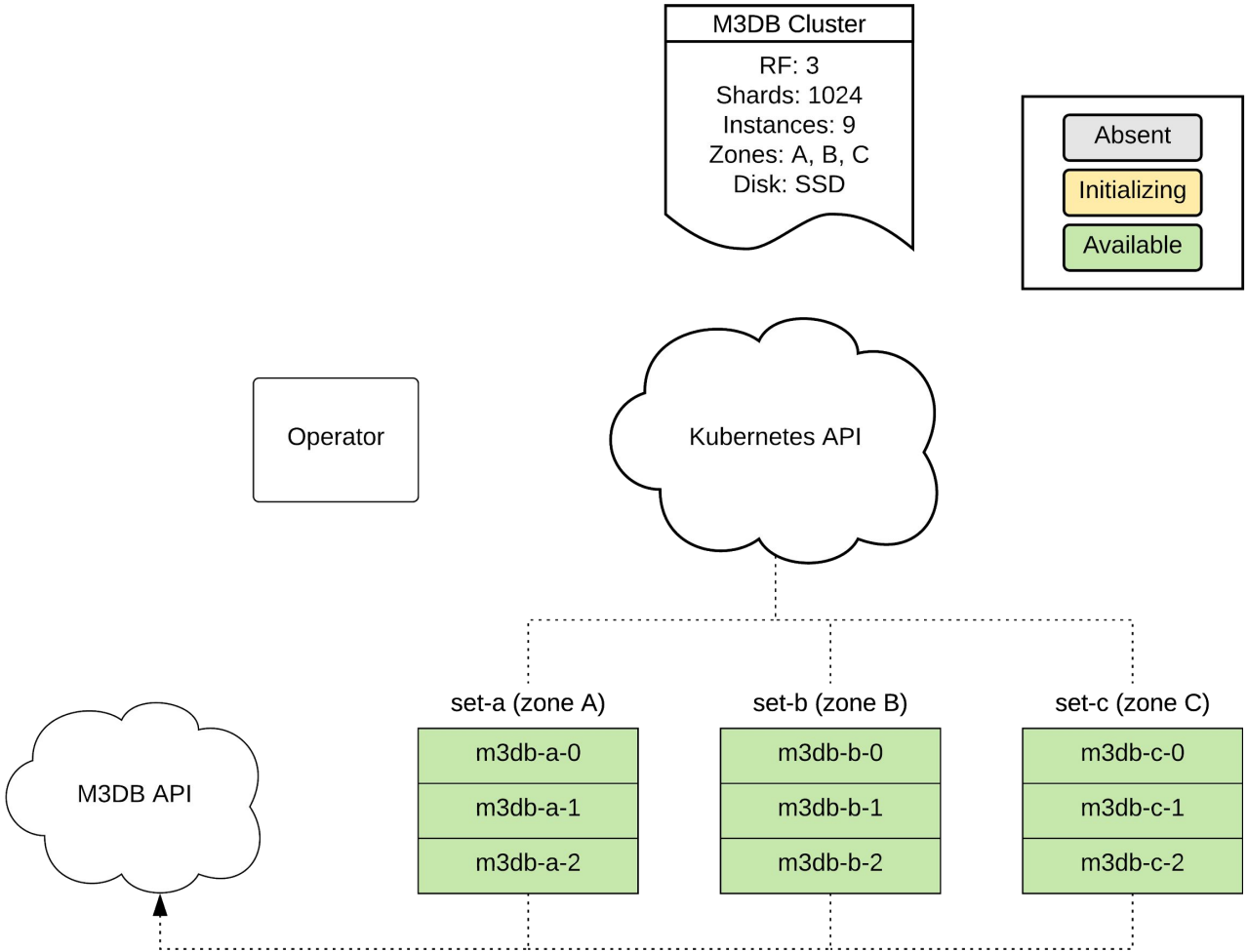
- Users define desired M3DB clusters
  - “9 node cluster, spread across 3 zones, with remote SSDs attached”
- Operator updates desired Kubernetes state, waits for convergence, updates M3DB desired state

M3DB Operator: Create Example









M3DB Operator: Day 2 Operations

- Scaling a cluster
  - M3DB adds 1-by-1, operation handles many
- Replacing instances, updating config, etc.
- All operations follow same pattern
  - Look at Kubernetes state, look at M3DB state, affect change

M3DB Operator: Success Factors

- Bridge between goal state-driven APIS (anti-footgun)
  - Can’t accidentally remove more pods than desired
  - Can’t accidentally remove two M3DB instances
  - Operator can be restarted, pick back up
- Share similar concepts, expanded scope
  - Failure domains, resource quantities, etc.

Lessons Learned: M3

- Finding common abstractions made mental model easier
  - Implementation can be separate, interface the same
- + Goal-state driven approach simplified operations
  - External factors (failures, deploys) don’t disrupt steady state

Lessons Learned: Kubernetes

- Embracing Kubernetes principles in M3DB made Kubernetes onboarding easier
  - No pods are special, may move around
  - Self-healing after failures
- Instances as cattle, not pets
  - No instance-level operations or config

Considerations

- Any orchestration system implies complexity
  - **Your own context**: is it worth it?
  - How does your own system respond to failures, rescheduling, etc.?
- Maybe not a good fit if have single special instances
  - M3DB can tolerate failures

Considerations

- Requirements & guarantees of your system will influence your requirements for automation
  - M3DB strongly consistent: wanted strongly consistent cluster membership

Recap

- Building common abstractions for all our workloads

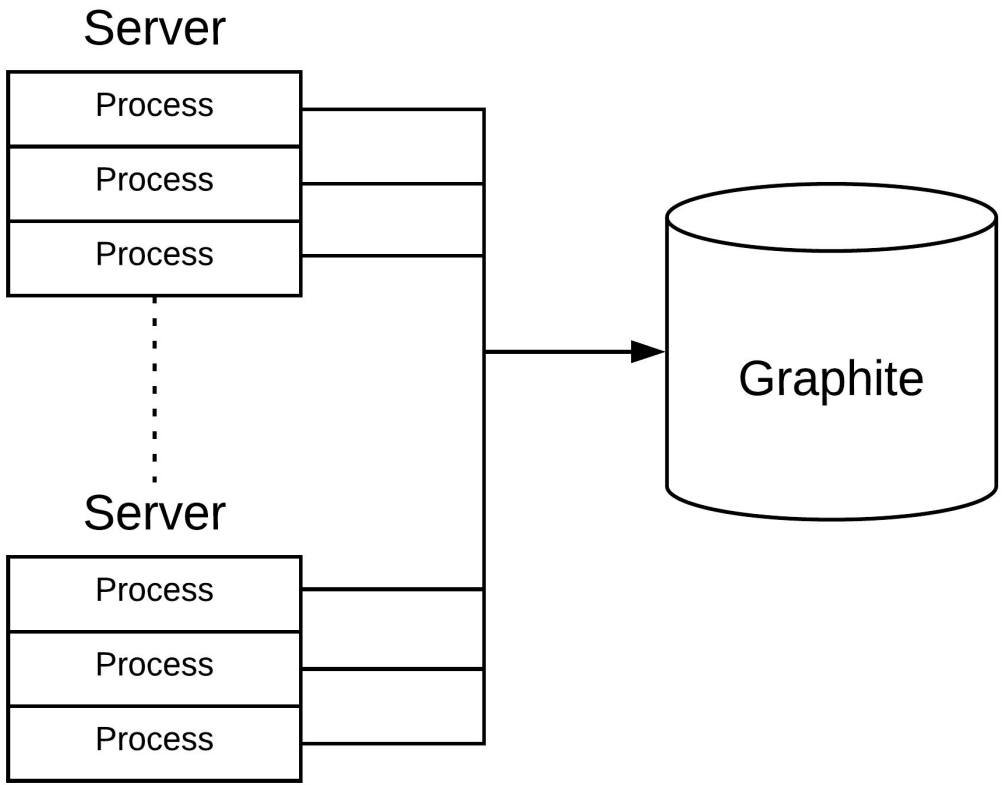
  eased mental model
- Following goal-state driven approach eased automation
- Closely aligned with Kubernetes principles

Thank you!

- github.com/m3db/m3
  - M3DB, m3cluster, m3aggregator
  - github.com/m3db/m3db-operator
- m3db.io & docs.m3db.io
- Please leave feedback on O'Reilly site!

@mattschallert

Pre-2015


Server
Process
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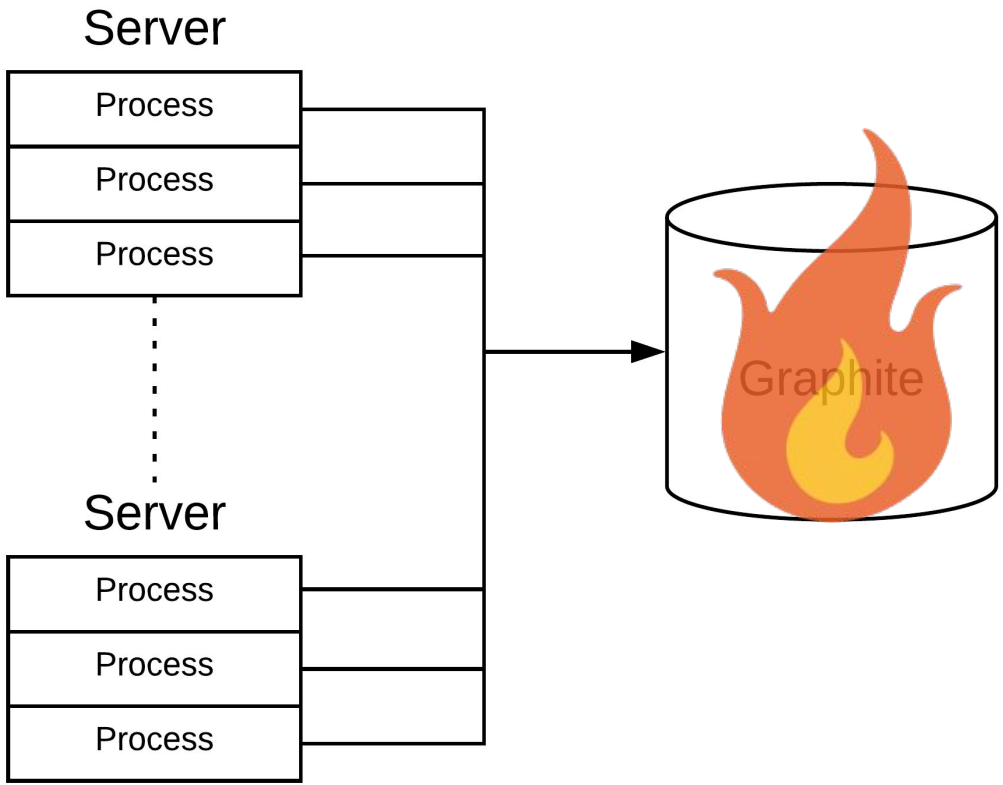
Early 2015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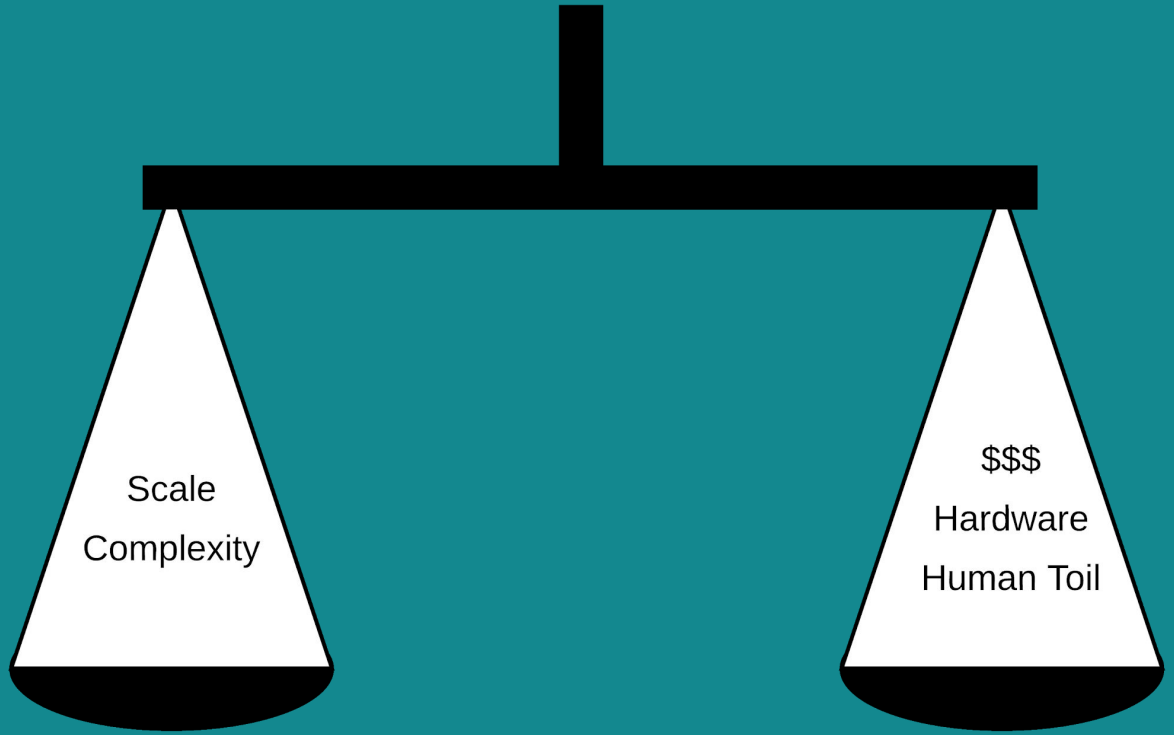
M3DB Operator: Today

- [THIS SLIDE IS SKIPPED]
- https://github.com/m3db/m3db-operator
- Managing 1 M3DB clusters ~as easy as 10

Late 2015



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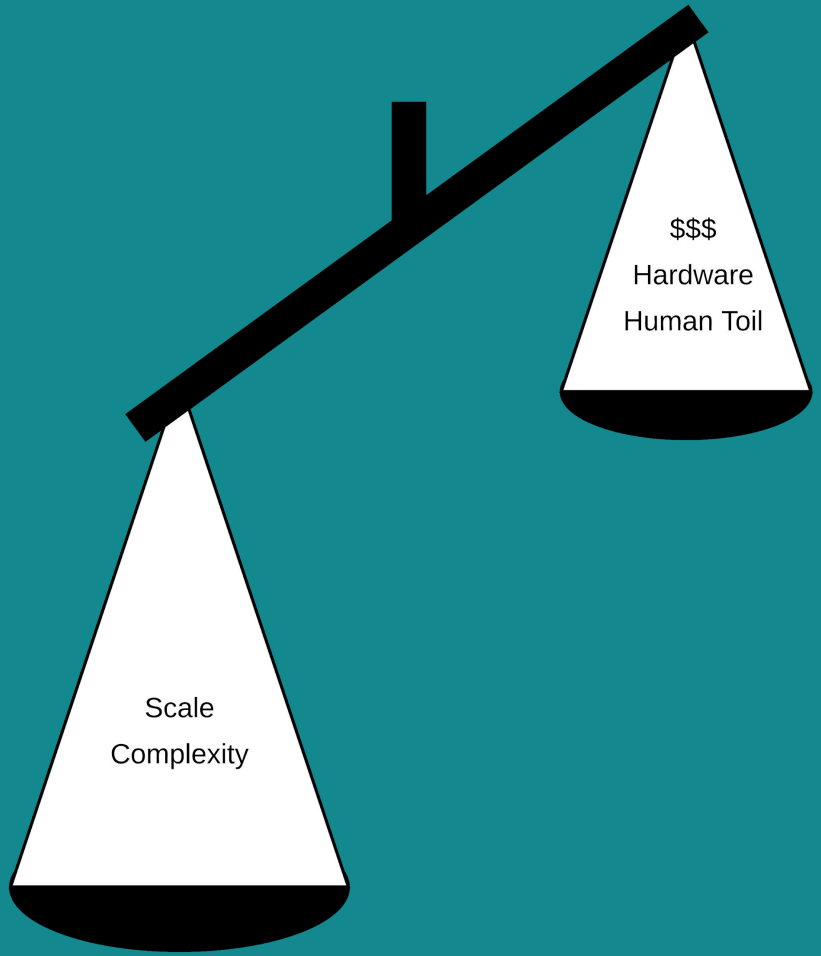
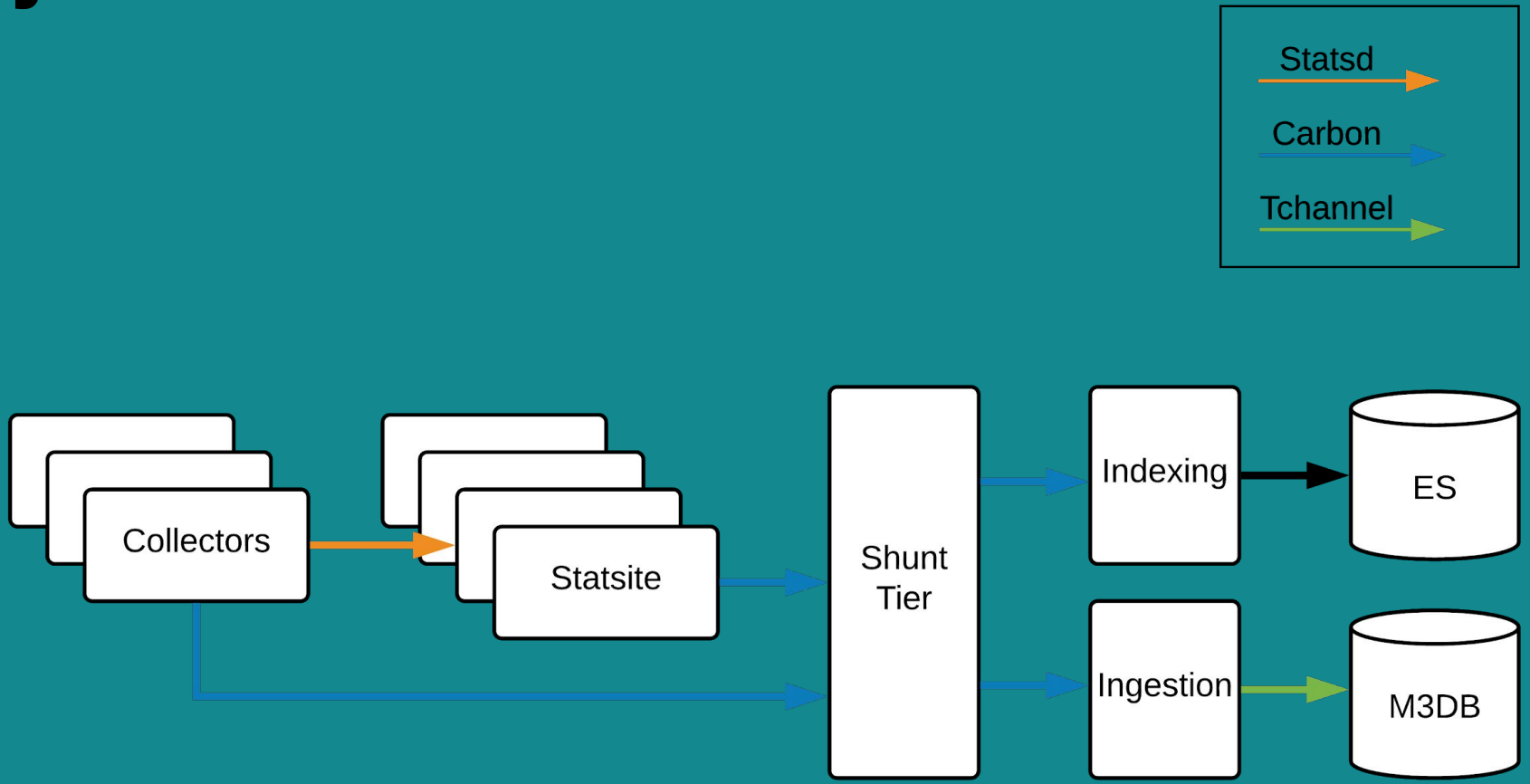


Post-M3DB Deployment

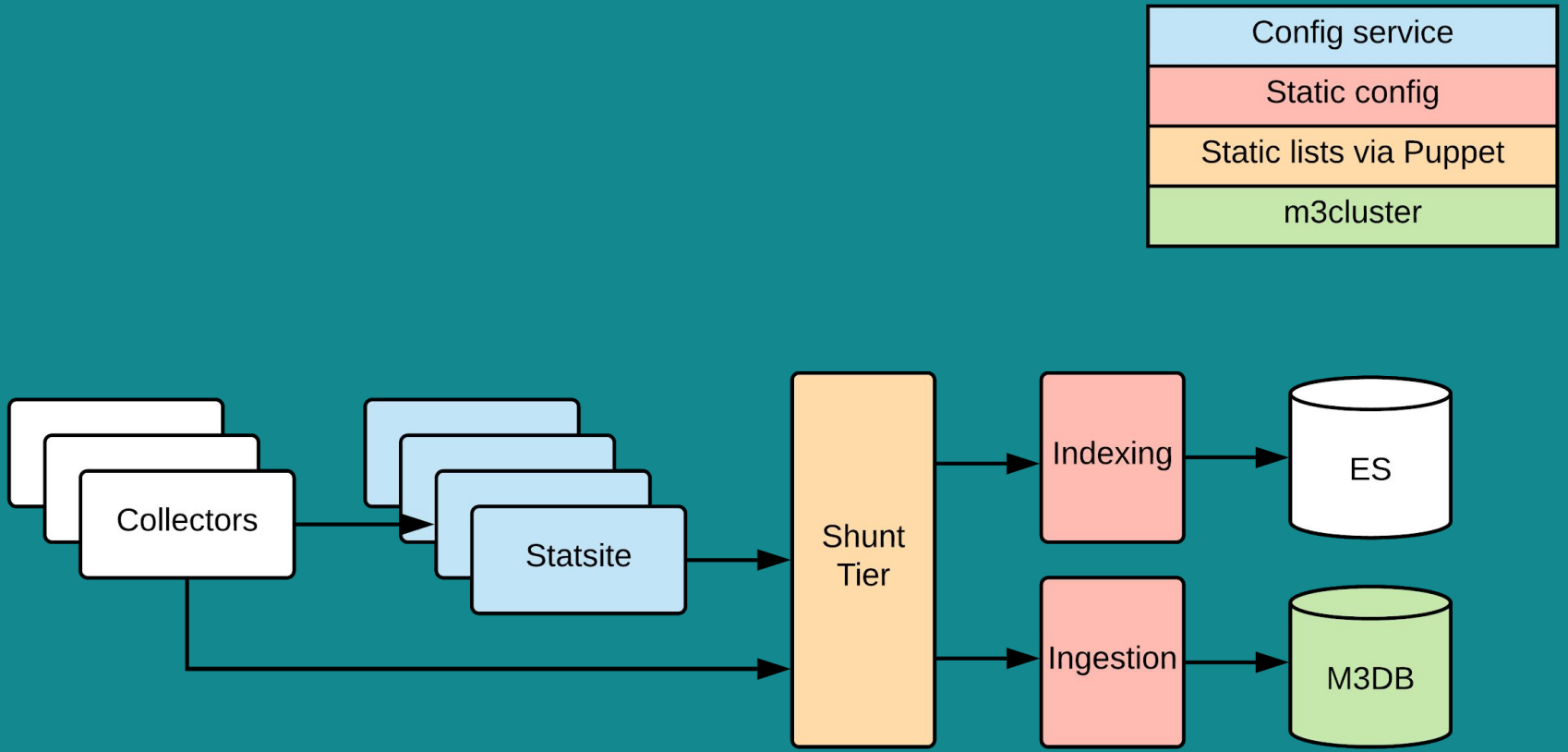
System Interfaces



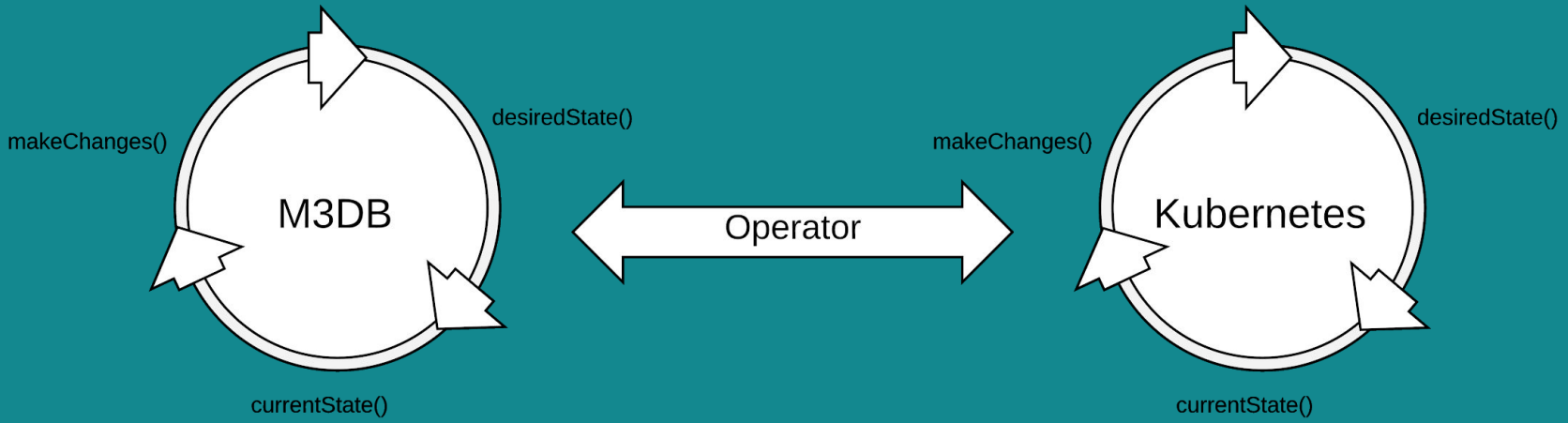
System Interfaces

- Ingestion path used multiple text-based line protocols
  - Difficult to encode metric metadata
  - Redundant serialization costs
- Storage layers used various RPC formats

System Representation (2016)



M3DB Operator [SLIDE SKIPPED]



ROUGH DRAFT DIAGRAM

Edge vs. Level Triggered Logic

- [Transition to Kubernetes, possibly using edge vs. level triggered]
  - Level triggered: reacting to current state. Actions such as “replace this node” can’t be missed.
  - Edge triggered: reacting to events. Events can be missed.
- [Maybe something about idempotency requirement ?]

m3cluster: Placement

```
message Placement {
 map<string, Instance> instances
 uint32 replica_factor
 uint32 num_shards
 bool is_sharded
}
```

```
message Instance {
 string id
 string isolation_group
 string zone
 uint32 weight
 string endpoint
 repeated Shard shards
 ...
}
```

m3cluster: Shard

```
message Shard {
 uint32 id = 1;
 ShardState state = 2;
 string source_id = 3;
}
```

```
enum ShardState {
 INITIALIZING = 0;
 AVAILABLE = 1;
 LEAVING = 2;
}
```

M3cluster: all

```
enum ShardState {
 INITIALIZING = 0;
 AVAILABLE = 1;
 LEAVING = 2;
}
```

```
message Shard {
 uint32 id = 1;
 ShardState state = 2;
 string source_id = 3;
}
```

```
message Instance {
 string id = 1;
 string isolation_group = 2;
 string zone = 3;
 uint32 weight = 4;
 string endpoint = 5;
 repeated Shard shards = 6;
 ...
}
```

```
message Placement {
 map<string, Instance> instances = 1;
 uint32 replica_factor = 2;
 uint32 num_shards = 3;
 bool is_sharded = 4;
}
```

Prerequisites for Orchestration

- Consistency of operations
  - Many actors in the system
  - Failures can happen, may re-reconcile states
  - Kubernetes & m3cluster leverage etcd

Lessons Learned

- [Lessons learned orchestrating M3DB generally]
- [Learnings specific to Kubernetes]