Rearchitecting Kubernetes for the Edge

And the DC too!

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About Me

- First year PhD student under Prof. Mortier
- BA in Computer Science from University of Cambridge
- Previously worked at The Hut Group

Work in Progress

Currently under submission to EdgeSys '21

One thing to take away

Orchestration should not require strong consistency!

What we'll cover

The problem of strong consistency in orchestration

Some edge case studies

How does strong consistency impact Kubernetes

Analysing etcd at scale

Using CRDTs for eventual consistency

Implications on deployment architectures

Looking back at the cloud, have we missed something?

Key Takeaway

Orchestration should not require strong consistency

Where are we up to?

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What is the problem?

Our services running at the edge should be:

- Performant
- Available
- Scalable

But they aren't there yet...

Why is it important?

Removes our ability to react!

- To failures
- To changes in demand
- To reconfigurations

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What do we mean by the edge?

Compared to a datacenter the edge has:

- Lots more sites, each being closer to end users
- Higher network latencies between sites and internally
- Lower bandwidth between sites and internally
- Less reliable components

Actual deployment case studies

Scale of communication is always increasing. Technology enables faster communication with more devices and more dynamic content:

- Next generation(s) of connectivity: 5G
- More devices: IoT
- Dynamic content: Elastic CDNs

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What is Kubernetes?

Production-Grade Container Orchestration[1]

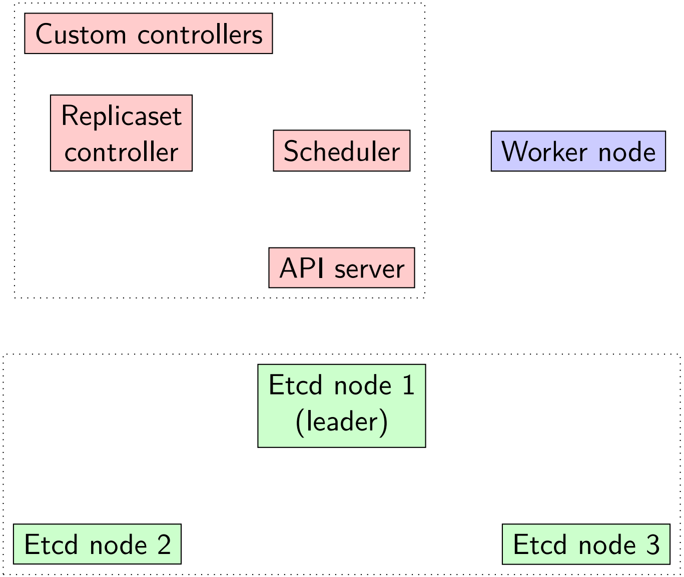
- Scaling
- Healing
- Routing
- Extensibility

59 percent of large organizations use Kubernetes in production[2]

[1] https://kubernetes.io/

[2] https://tanzu.vmware.com/content/blog/why-large-organizations-trust-kubernetes

Kubernetes Architecture



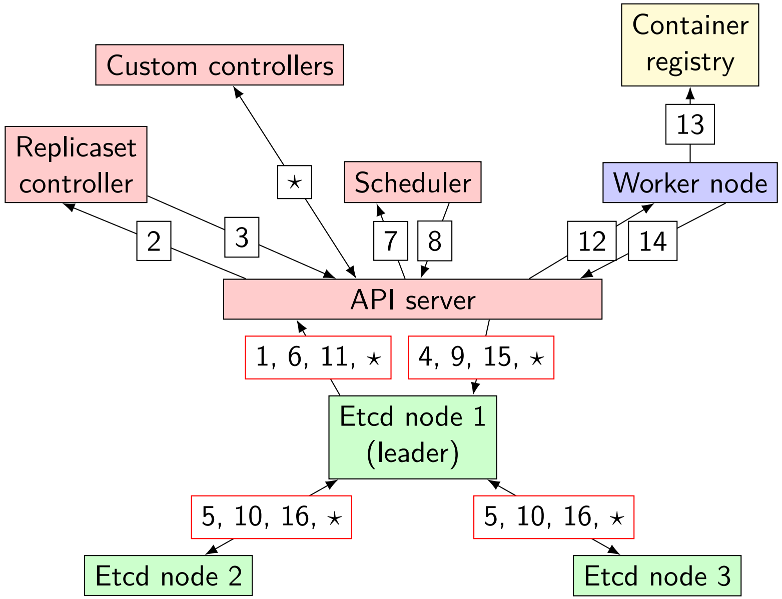
Etcd

A distributed, reliable key-value store for the most critical data of a distributed system[3]

- Critical data here is Kubernetes state
- Supports transactions on data
- Also has concept of watches: notifications of changes

[3]https://etcd.io/

Scheduling with centralised state



Key limitation

Centralised, strongly consistent state

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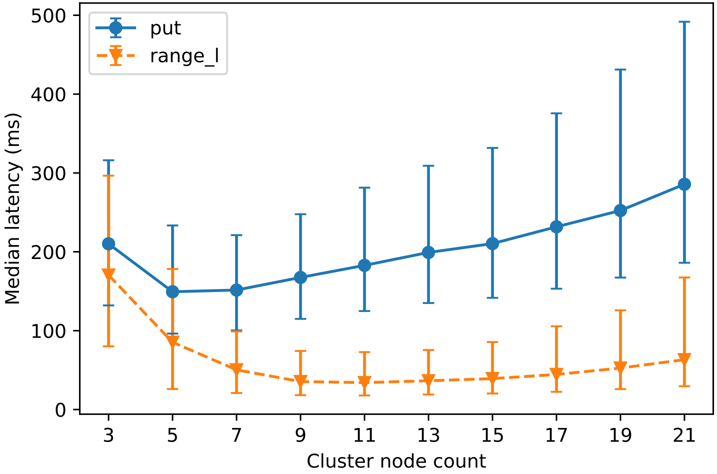
Results of Etcd: Request breakdown

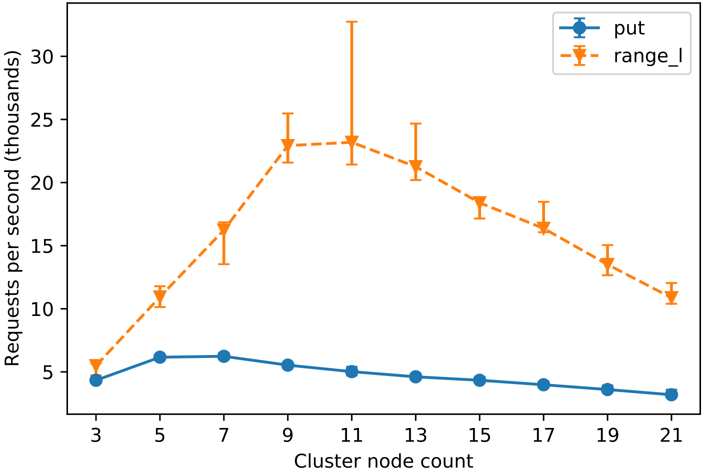
Request type	**Count**	**Percentage**
Range	1542	52.3
Txn Range	476	16.1
Txn Put	866	29.3
Watch create	67	2.3
Total	2951	100

Table: *Etcd* request counts averaged over 10 runs. Series of creating a deployment of 3 containers, scaling to 10, scaling to 5 and then deleting. Range requests are all linearisable. Requests with negligible count are omitted.

Results of Etcd: Latency



Results of Etcd: Throughput



Key limitation - Etcd

Centralised, strongly consistent state
This is all etcd

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Key limitations revisited

Decentralised, **eventually** consistent state

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Changing the datastore

- We don’t want to change all of Kubernetes, that would be too much work
- We also want to use a strong mechanism for eventual consistency: Conflict-Free Replicated Datatypes (CRDTs)

What gets stored?

JSON-like Data!

```
apiVersion: apps/v1
kind: ReplicaSet
metadata:
  name: frontend
spec:
  replicas: 3
  selector:
    matchLabels:
      tier: frontend
  template:
    metadata:
      labels:
        tier: frontend
    spec:
      containers:
      - name: nginx
        image: nginx
```

How out of date will this get?

Assuming we don't want our state to be stale...

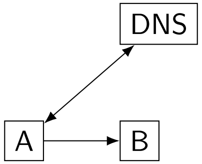
But maybe we can use staleness to our advantage?

Can Kubernetes even handle stale state?

Distributed systems are dynamic environments and at best we can only model them.

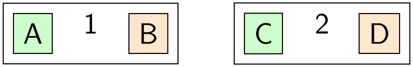
So does Kubernetes already act on stale information?

Stale state: Services



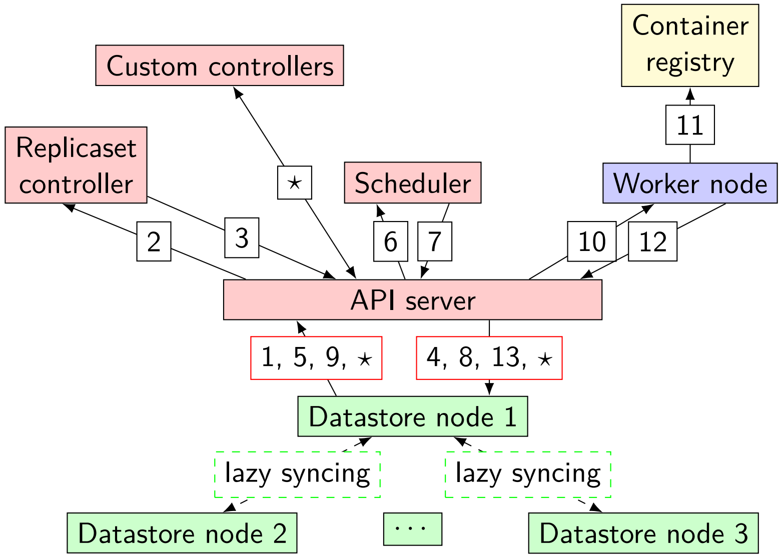
- DNS could resolve to IP address which matches a dead container
- So, this could already be an issue

Stale state: ReplicaSets



- Under failures we could schedule more, as well as less
- So, again, this could already be an issue in our distributed system
- With CRDTs we can control over-replication rather than under-replication on merge

Scheduling with the decentralised state



Saved at least 3 critical path network hops!

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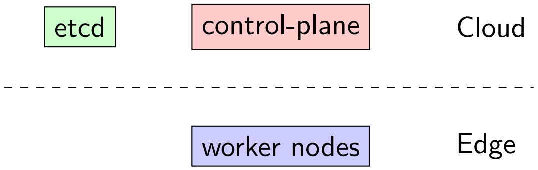
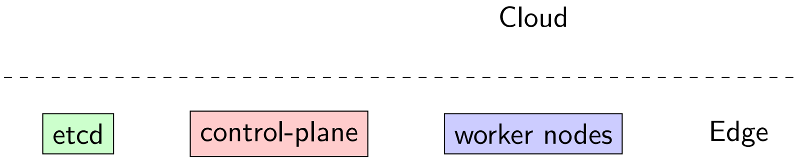
Current edge architectures: Split DC and Edge



Current edge architectures: All Edge



Rearchitect with eventual consistency?

Our new datastore gives us more flexibility

- We can now scale across multiple edge sites
- We can run on slower links and still be efficient
- We can use fewer resources and maintain the same fault tolerance

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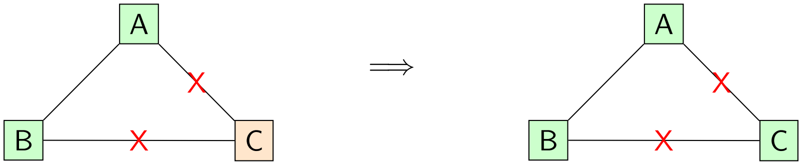
What if we look back to the cloud?

Not everything will be running at the edge so maybe we can influence cloud deployments too?

Spreading out for availability



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Conclusion

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By adhering to this we can

- Improve performance of our clusters and make them more reactive
- Make them more tolerant to failure
- Scale them across more sites without fear

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Bonus: Federation

- Rather than looking inside a cluster we can look between
- No room, run jobs in other cluster instead
- Kubernetes still wants strong consistency on this!
- Some researchers have a similar idea of using eventual consistency instead

Bonus: New system

- We could just create a new system from scratch
- But why waste the effort, adoption is hard enough for production systems
- Kubernetes is the industry standard now, easier to try things out and then maybe we can build afresh

Bonus: Adaptive consistency

- A useful option if some parts of state require more consistency
- Could also use etcd for less critical state and eventual consistency for high traffic items