Cluster management at Google with Borg - coping with scale

2015-11

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Principal Software Engineer

Derived from EuroSys'15 paper (http://goo.gl/1C4nuo)

Google Cloud Platform

Cluster management

at Google with coping with scale Borg -

the system we internally call

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http://www.google.com/about/datacenters/inside/locations/index.html

http://googleasiapacific.blogspot.se/2015/06/growing-our-data-center-in-singapore.html

Image by Connie Zhou

User view

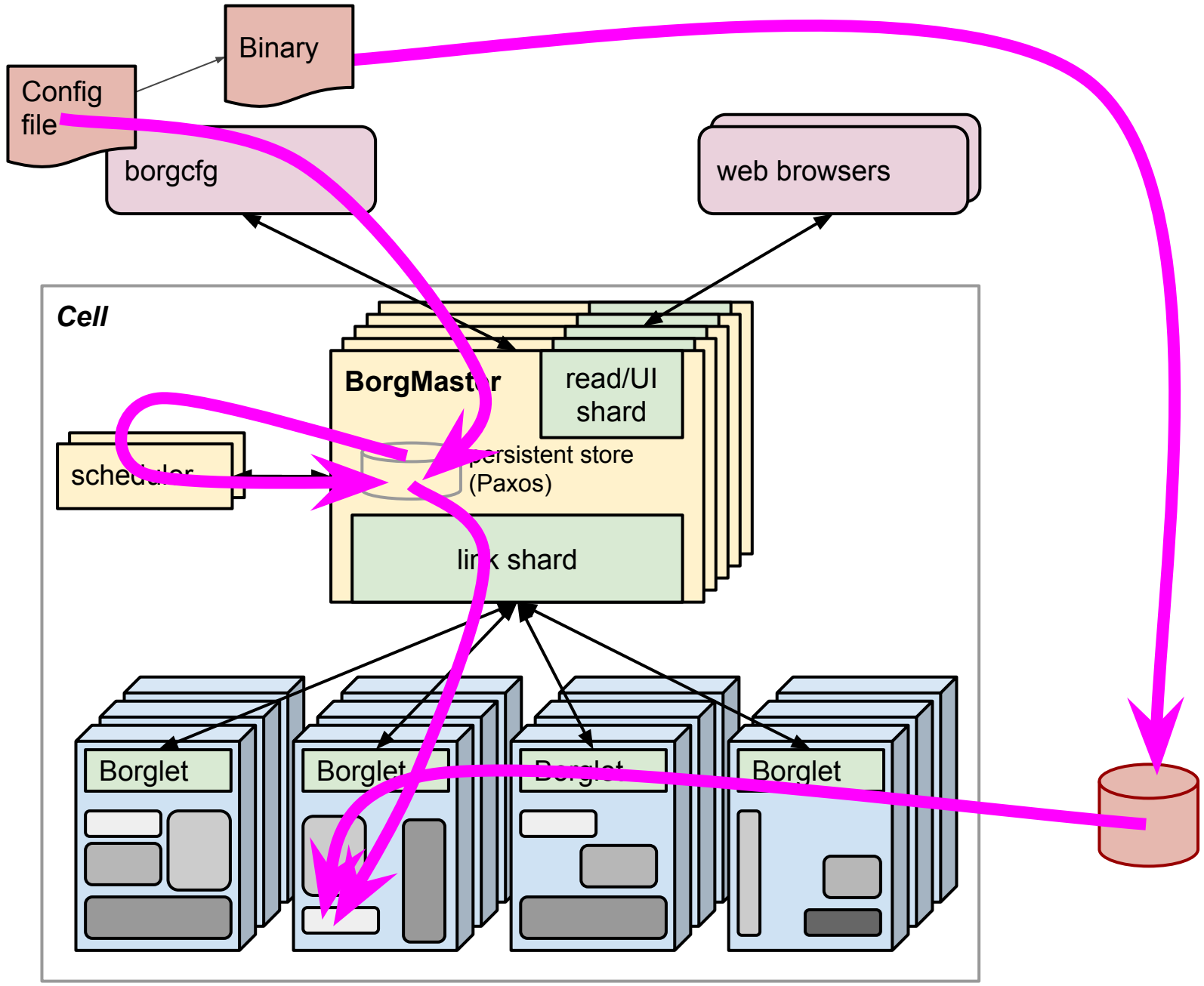
```
job hello_world = {
   runtime = { cell = 'ic' }                  // Cell (cluster) to run in
   binary = '.../hello_world_webserver'       // Program to run
   args = { port = '%port%' }                 // Command line parameters
   requirements = {      // Resource requirements (optional)
     ram = 100M
     disk = 100M
     cpu = 0.1
   }
   replicas = 10000      // Number of tasks
}
```

User view


Running tasks
10000
7500
5000
2500
0
0:00:30
0:01:00
0:01:30
0:02:00
0:02:30
0:03:00
Elapsed time

User view

What just happened?



User view

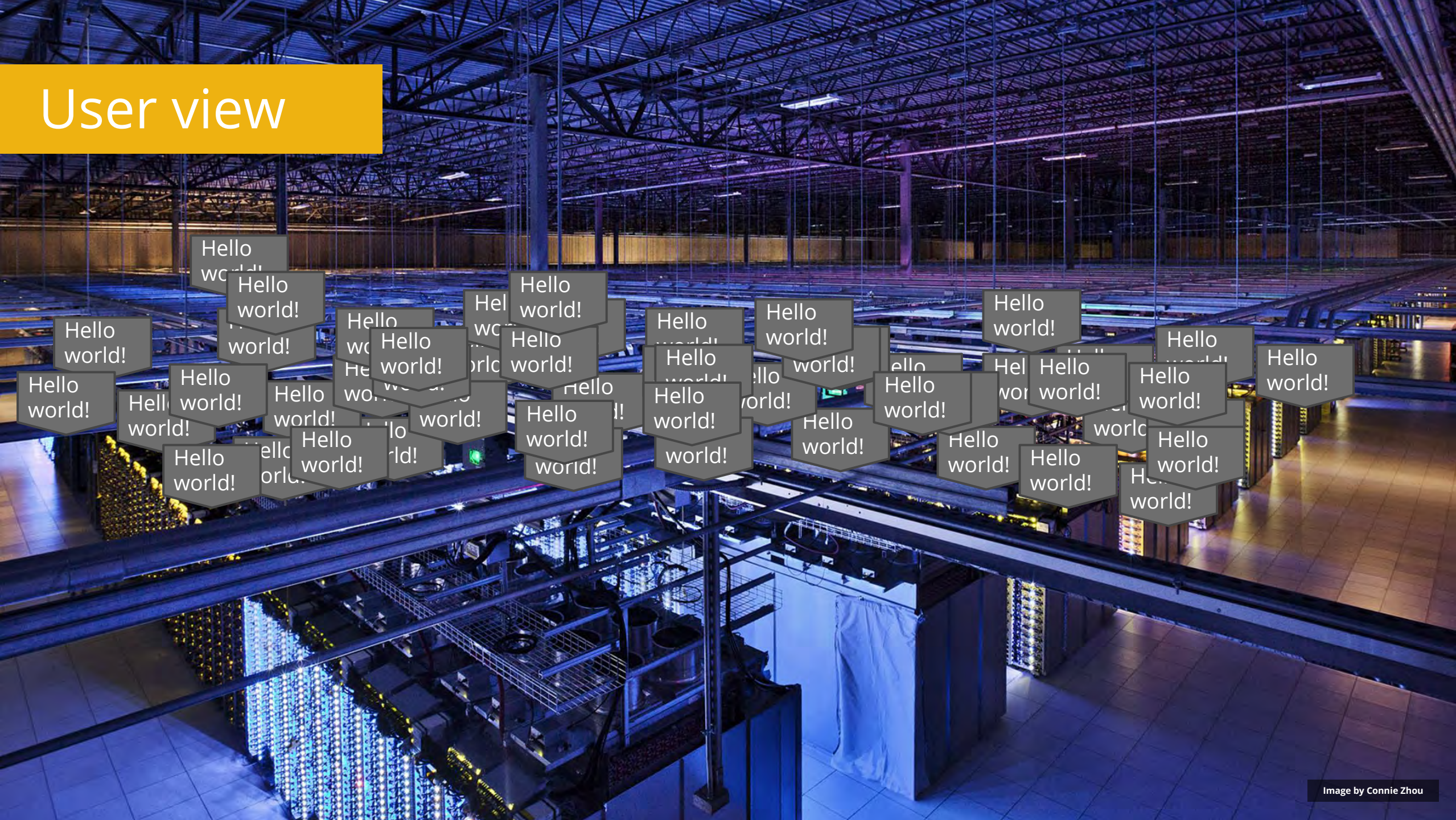
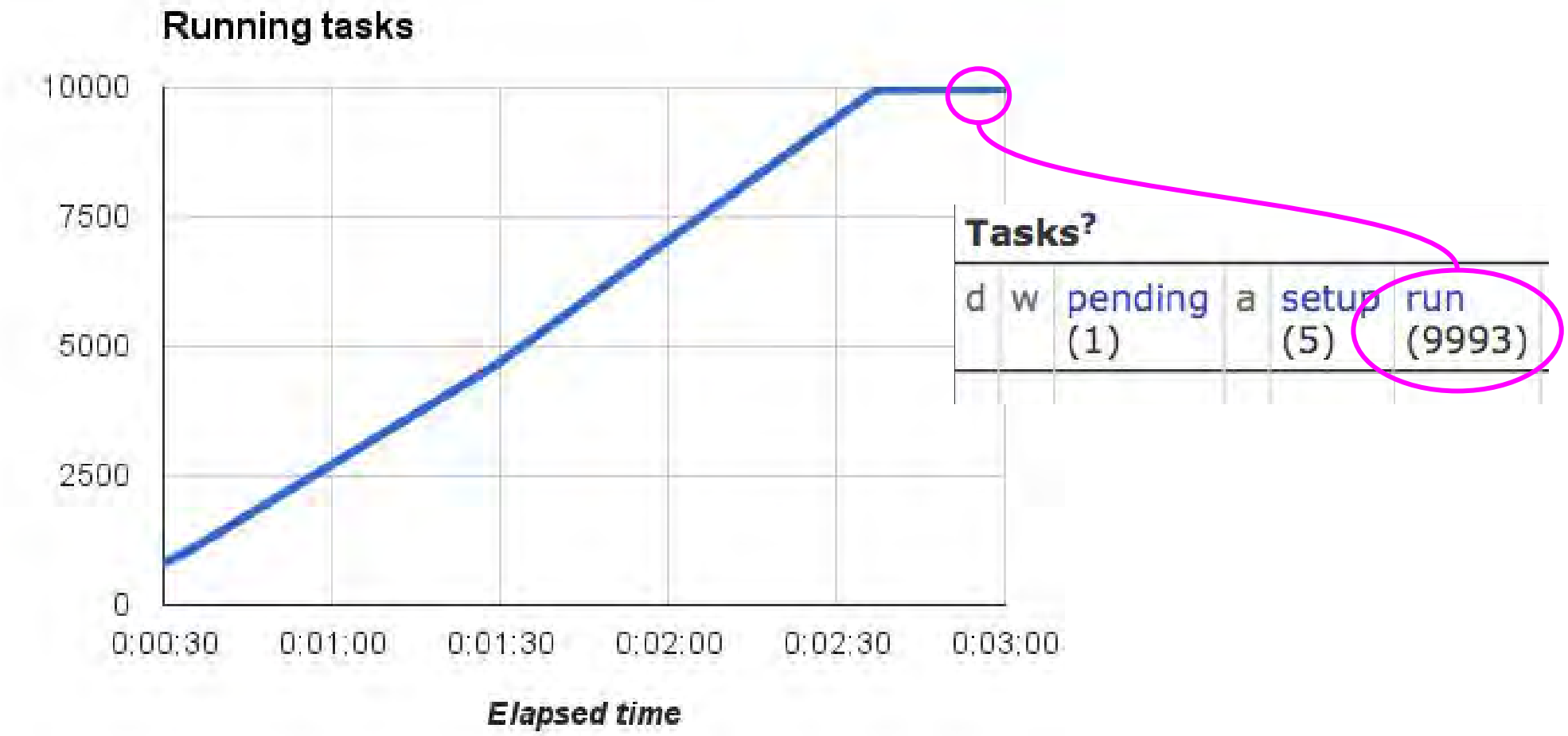
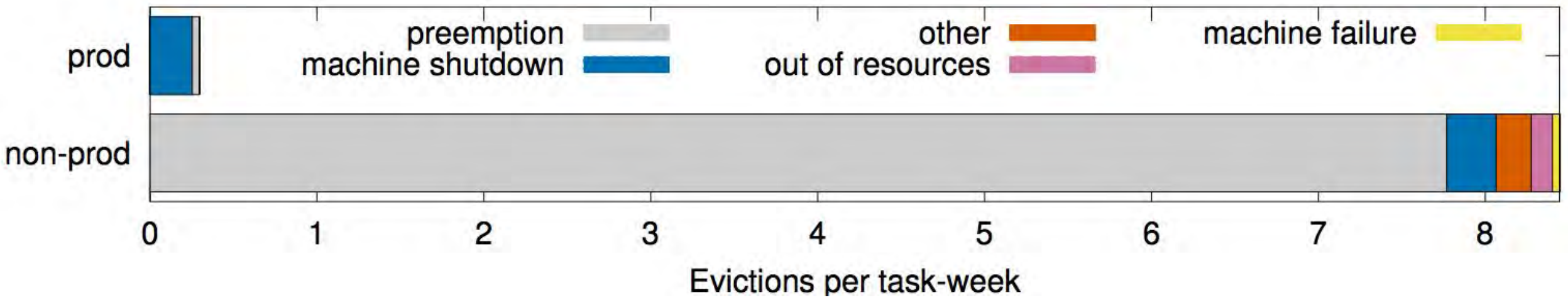


Image by Connie Zhou

User view

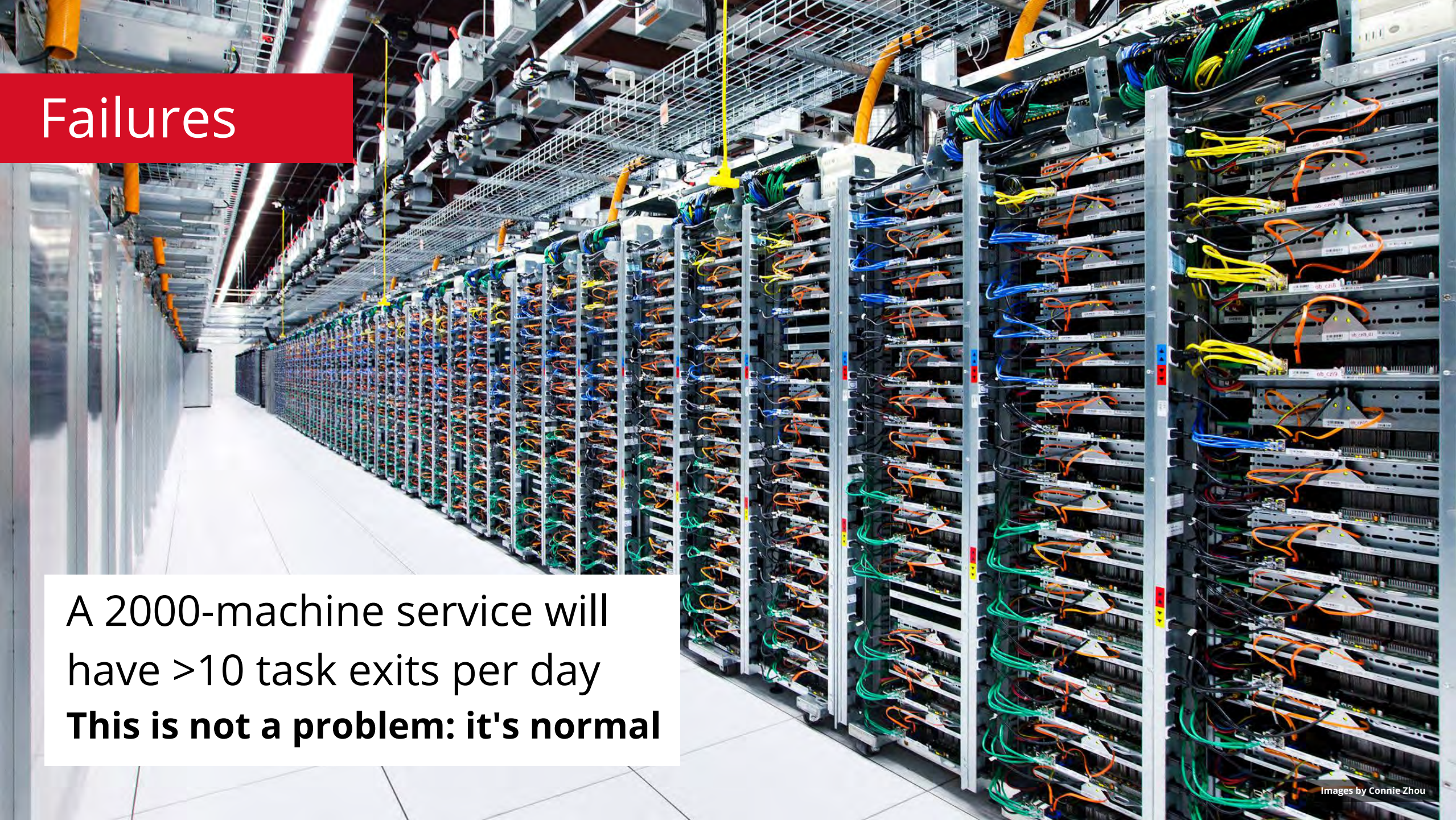

Running tasks
10000
7500
5000
2500
0
0:00:30
0:01:00
0:01:30
0:02:00
0:02:30
0:03:00
Elapsed time
Tasks?
d
w
pending (1)
a
setup (5)
run (9993)

Failures



task-eviction rates
and causes

Failures



A 2000-machine service will have >10 task exits per day

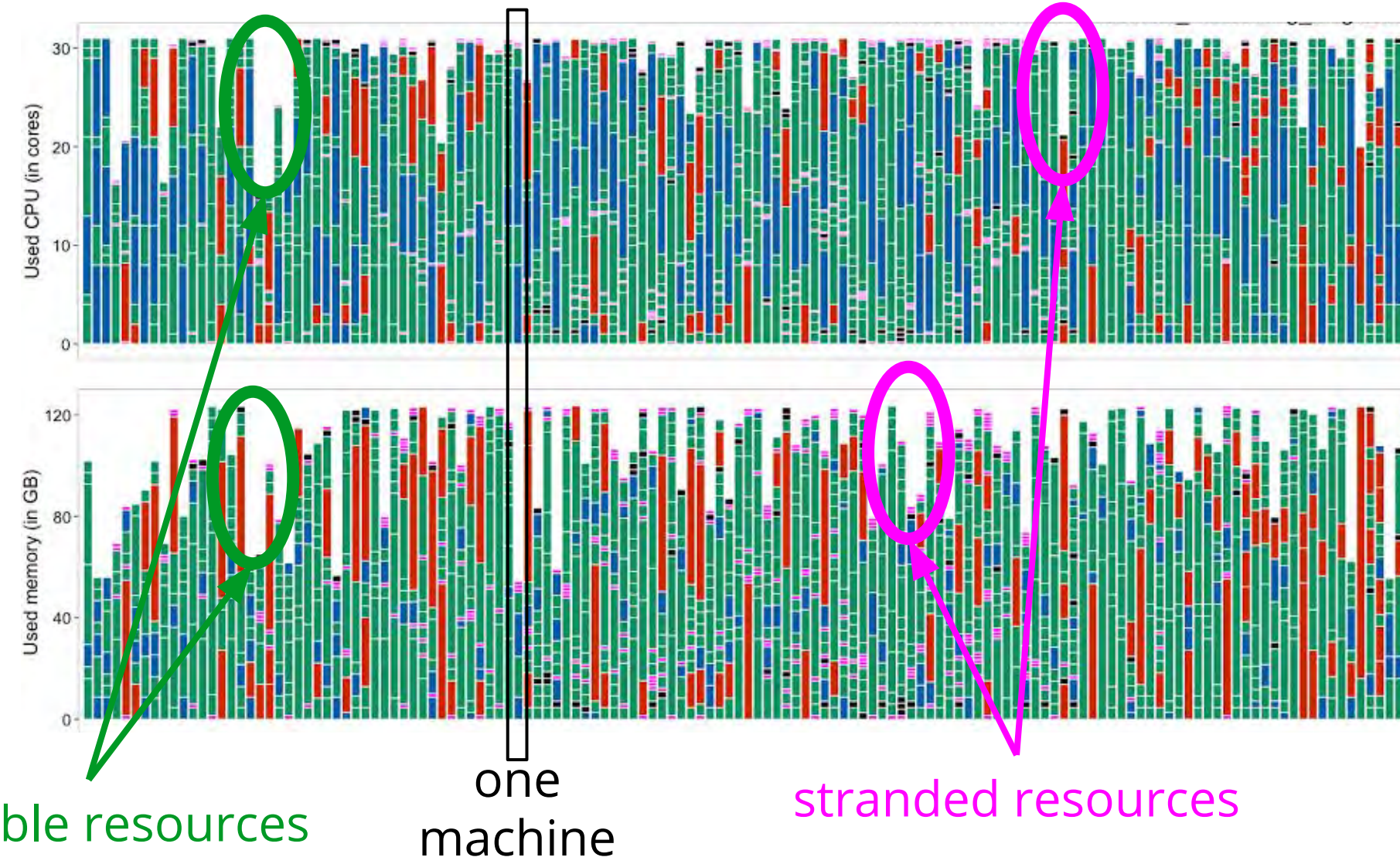
This is not a problem: it's normal

Images by Connie Zhou

Efficiency

Advanced bin-packing algorithms

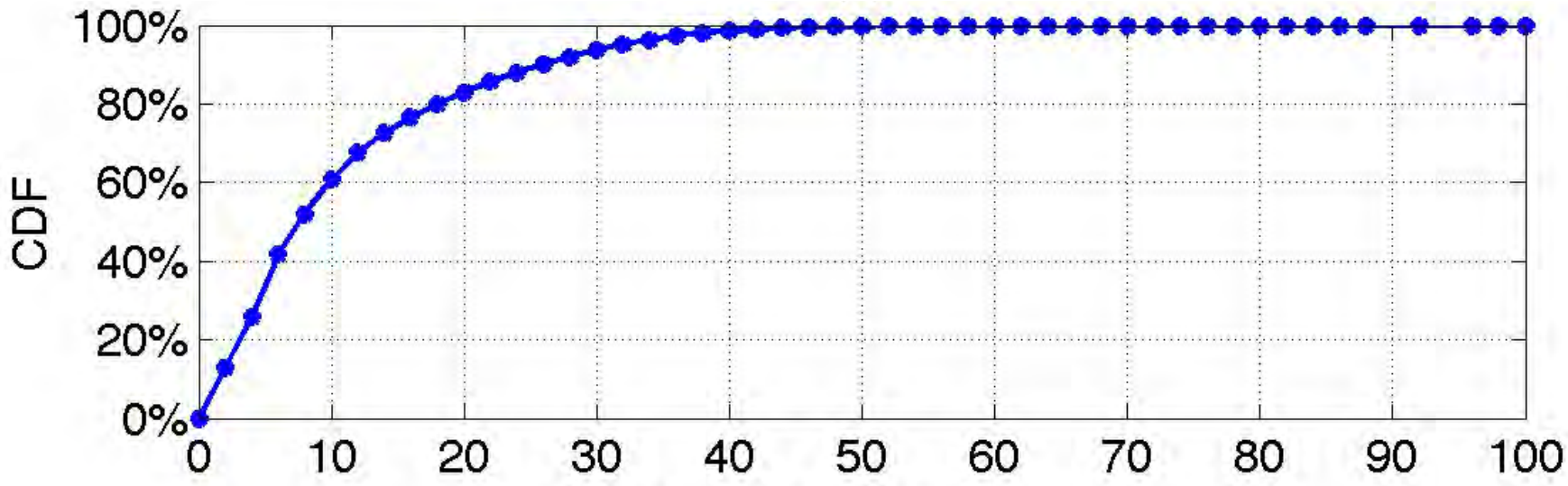
Experimental placement of production VM workload, July 2014



Efficiency

Multiple applications per machine

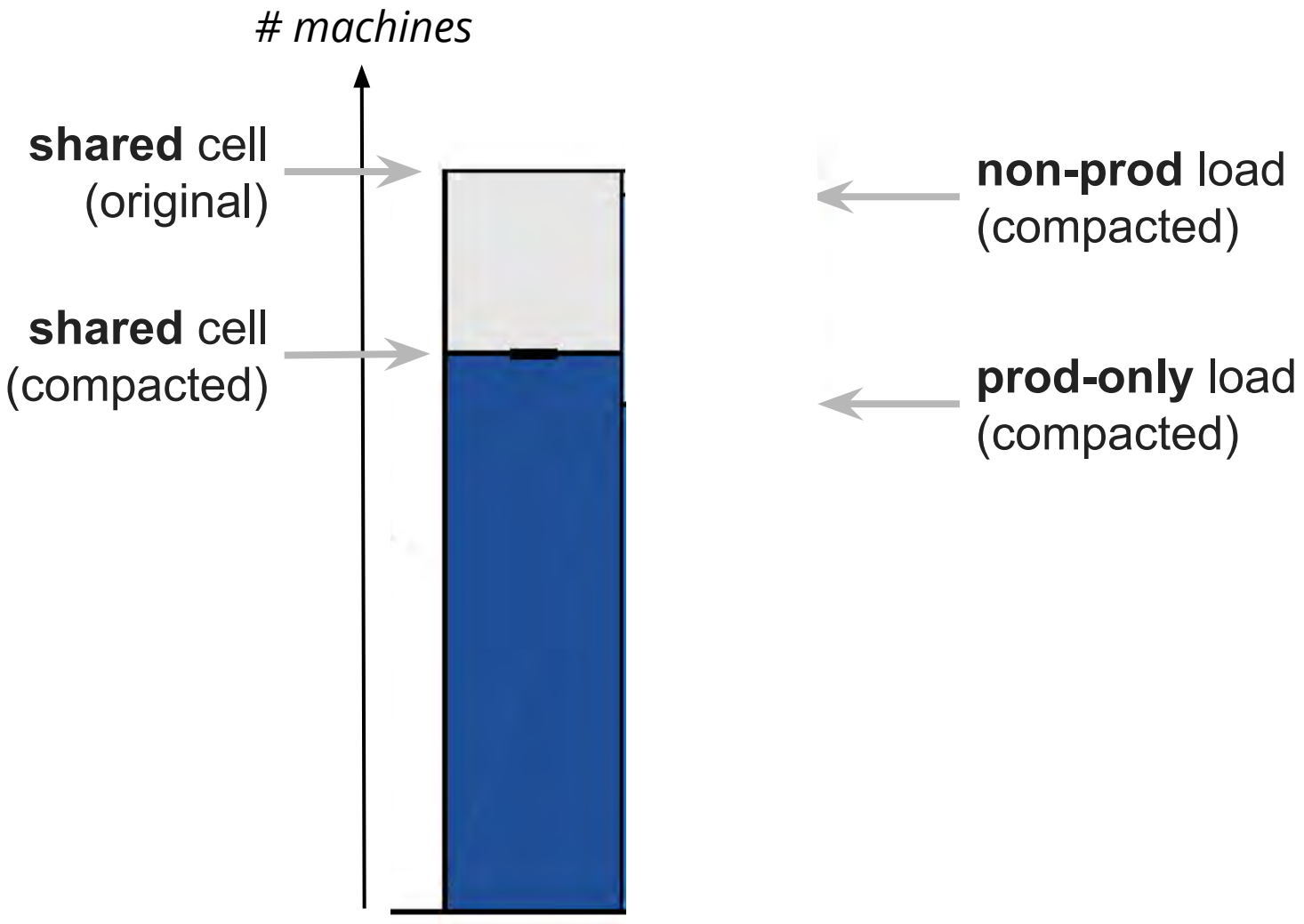
CPI^2 paper,
EuroSys 2013



Efficiency

Sharing clusters between prod/batch helps

Segregating them would need more machines



Efficiency

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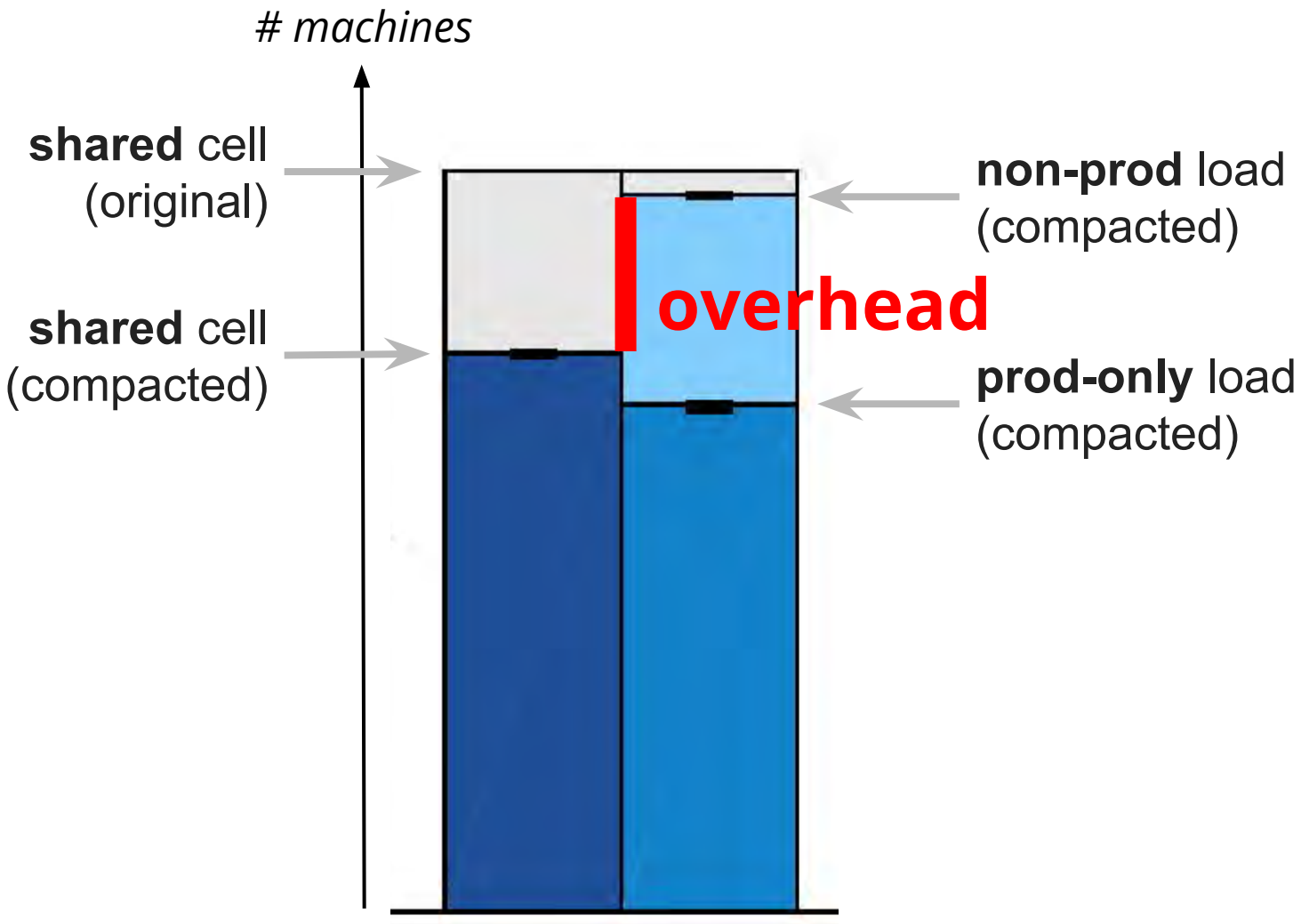
Segregating them would need more machines

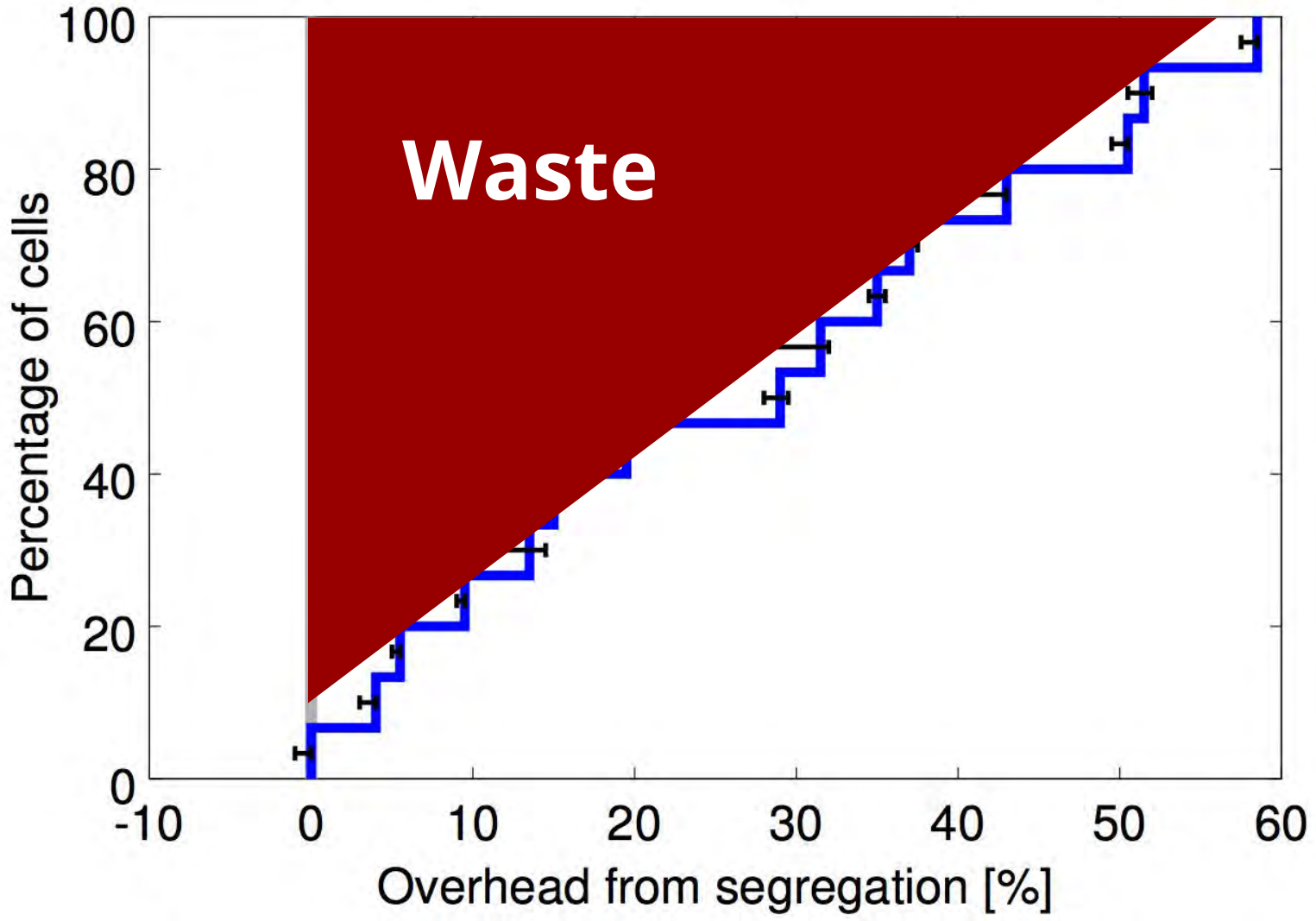


Efficiency

Sharing clusters between prod/batch helps

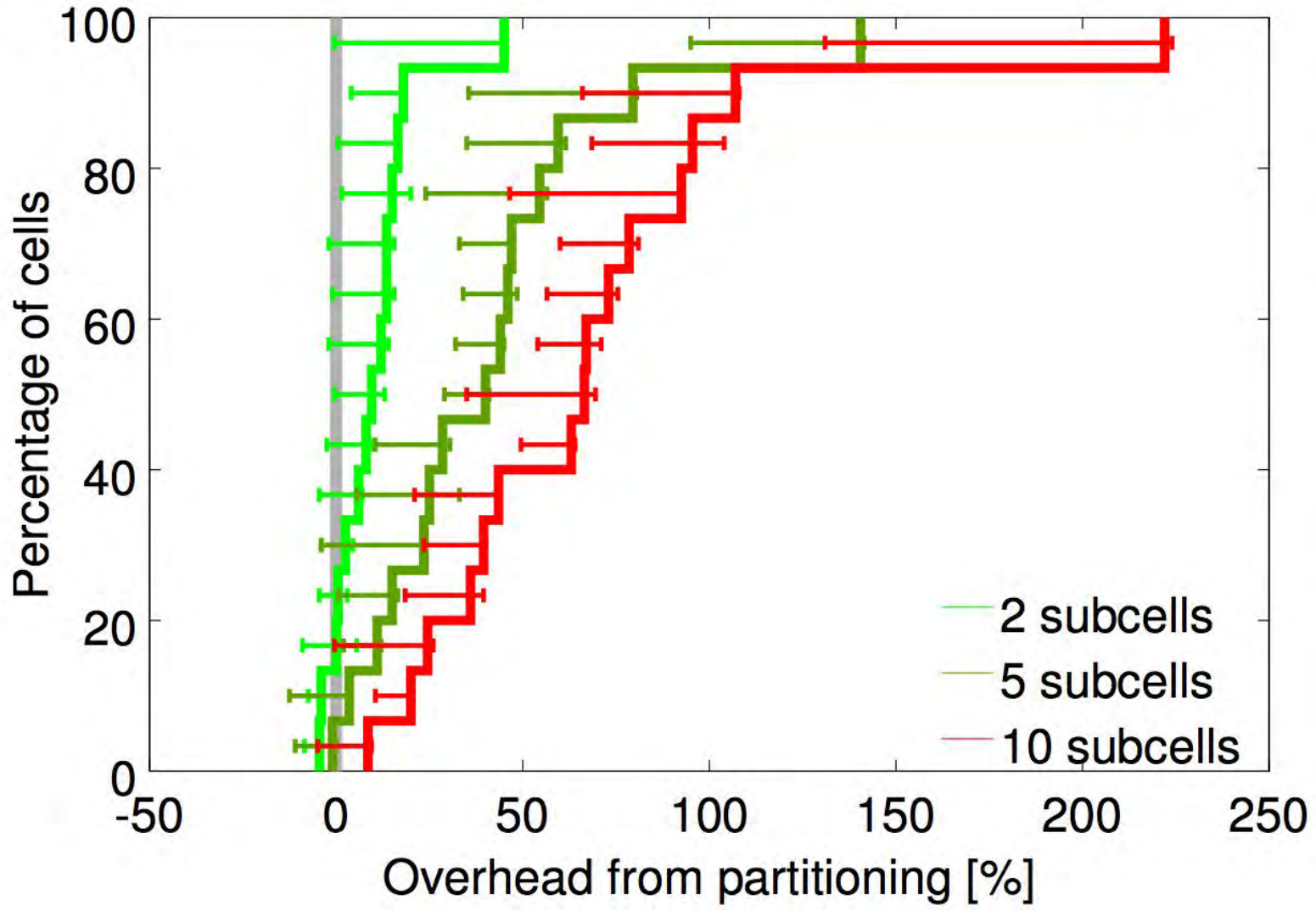
Segregating them would need more machines

15 production cells from a larger pool, omitting small ones (<5000 machines)



Efficiency

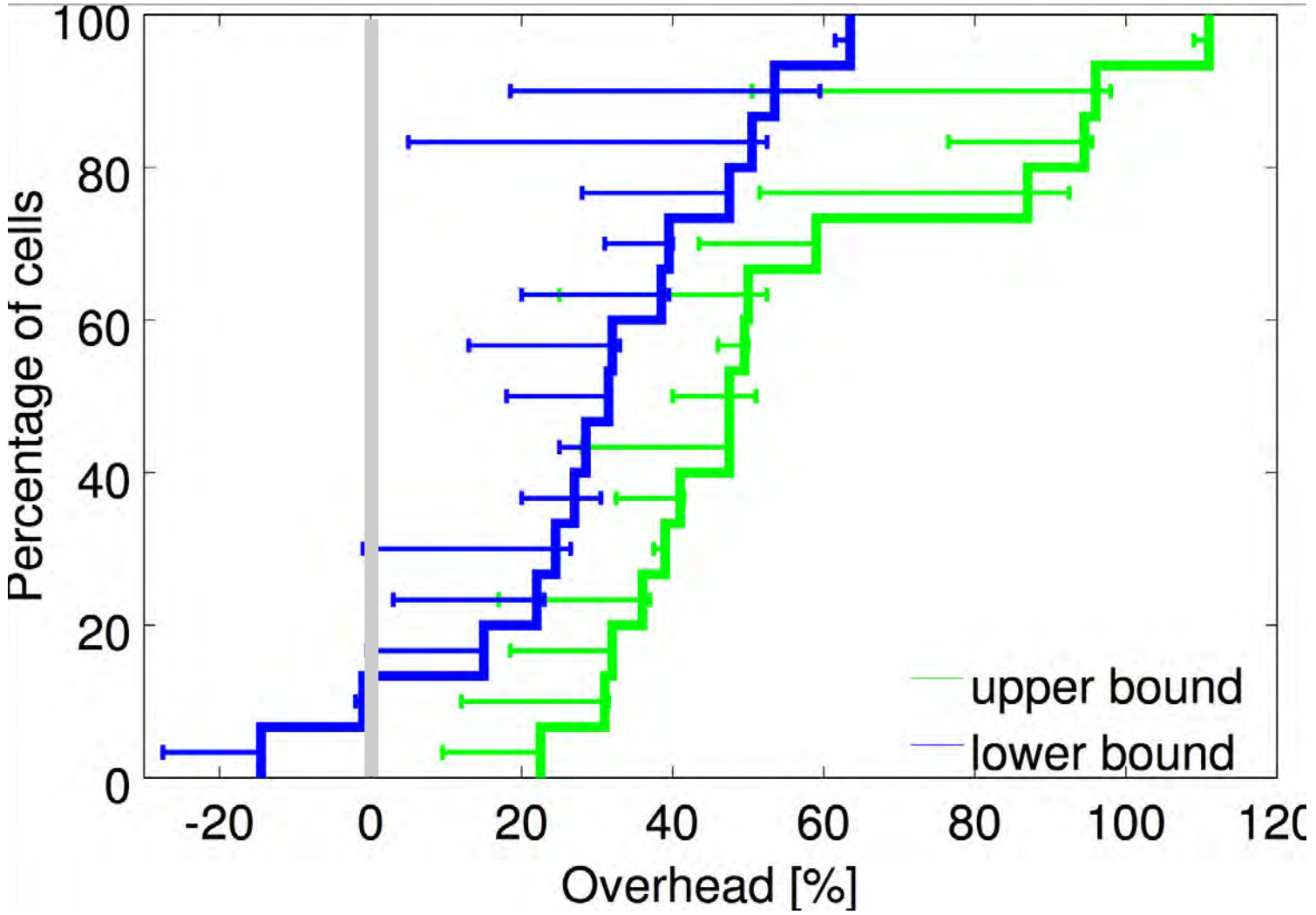
Smaller cells would need more machines



Efficiency

Bucketing to next-largest power of 2 would need more machines

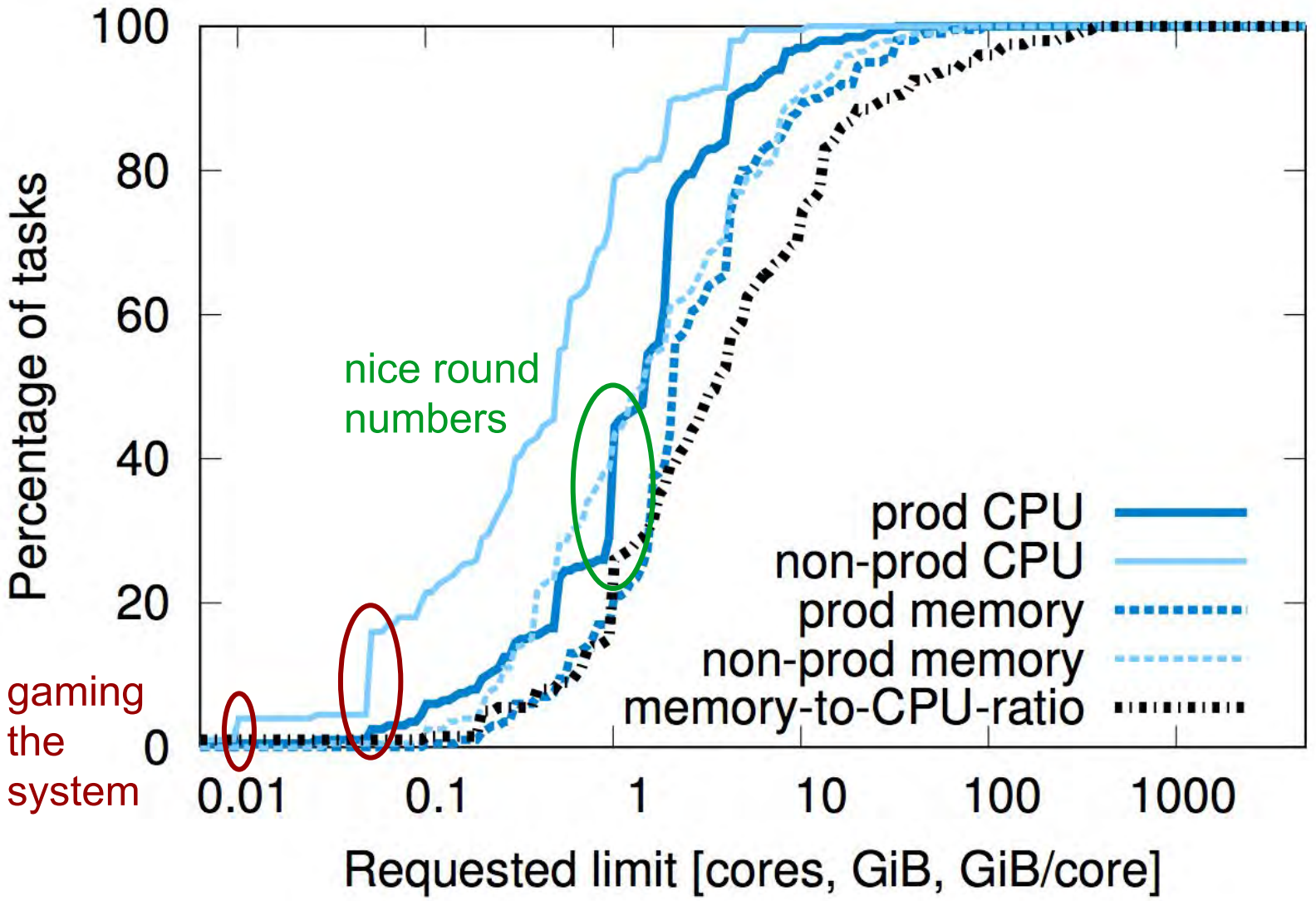
prod only,
starting from 0.5 cores, 0.5GiB



Efficiency

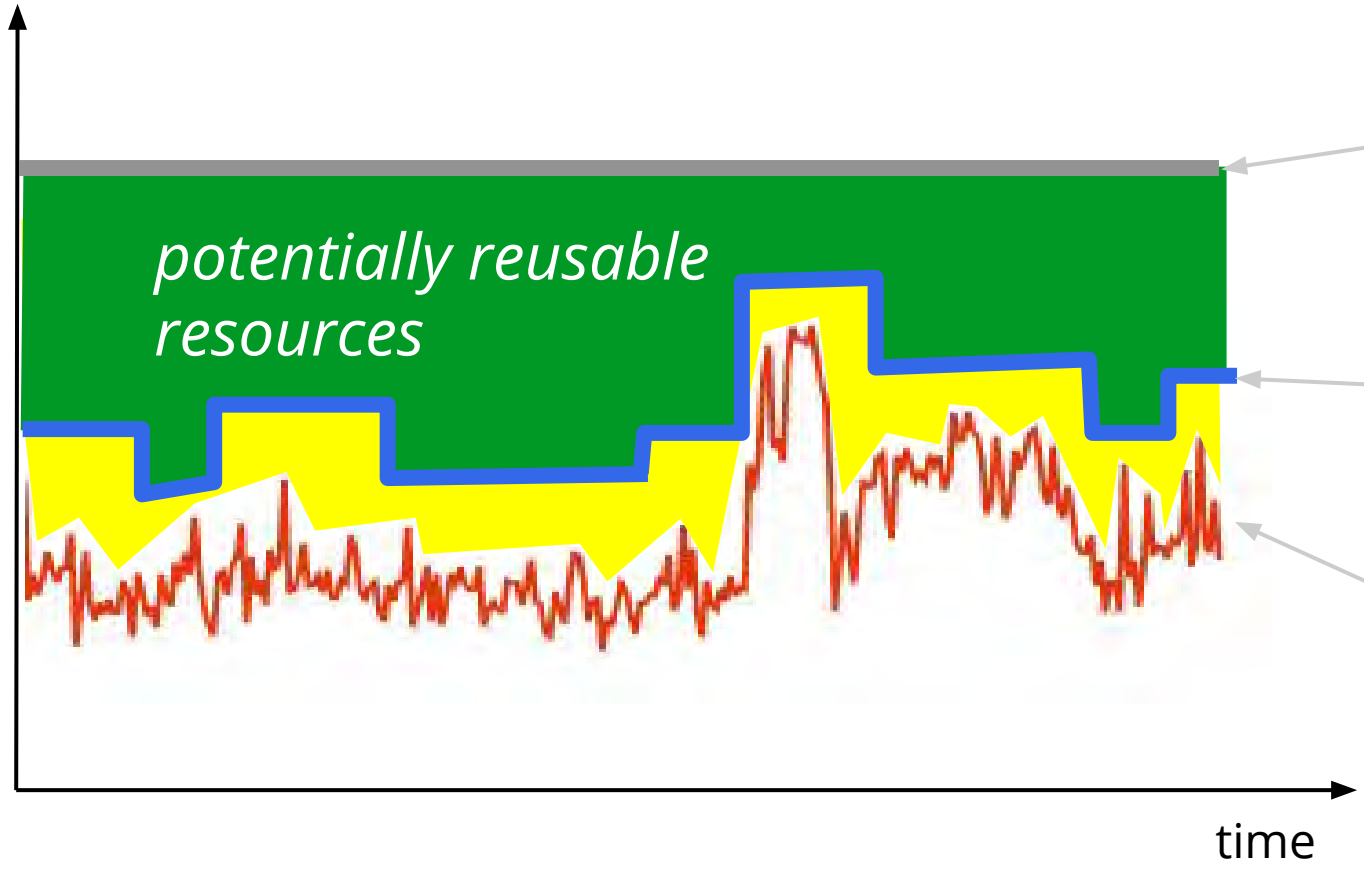
There are no obvious resource bucket sizes

cf. cloud VMs



Efficiency

Resource reclamation



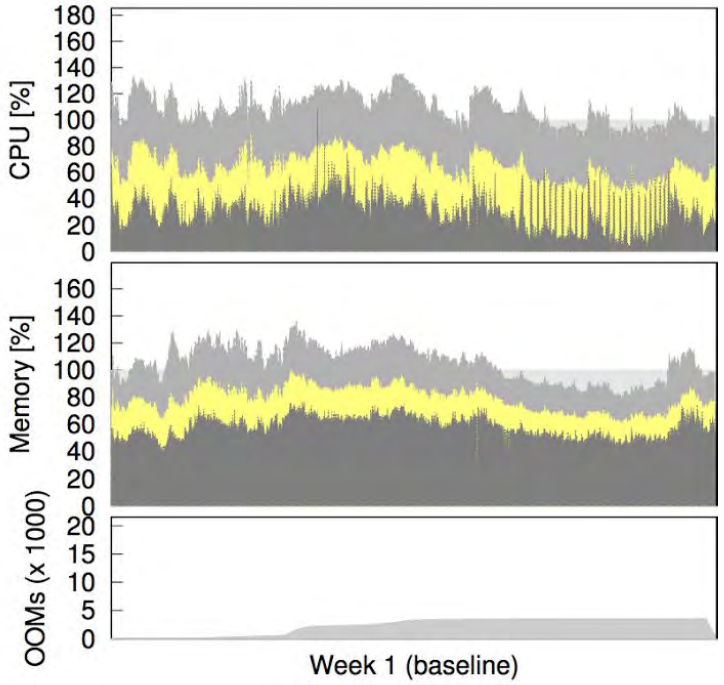
limit: amount of resource requested

reservation: estimate of future usage

usage: actual resource consumption

Efficiency

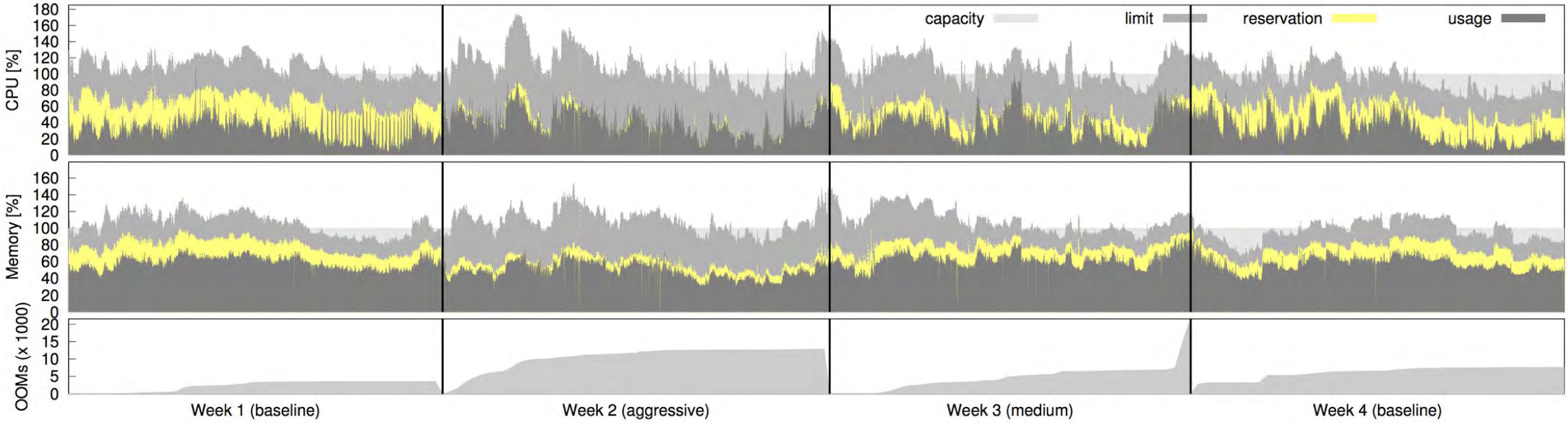
Resource reclamation could be more aggressive



Nov/Dec 2013

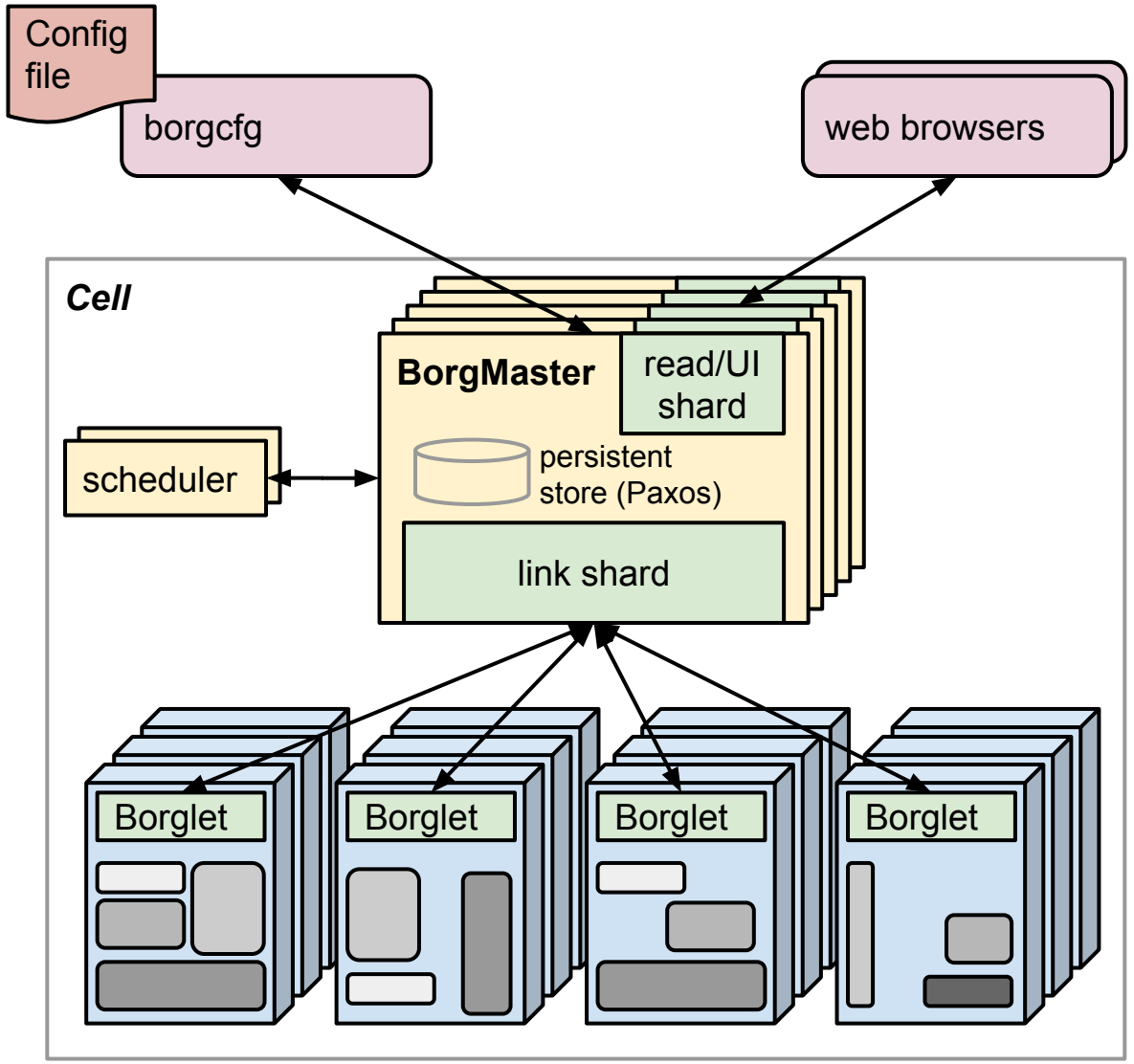
Efficiency

Resource reclamation could be more aggressive



Nov/Dec 2013

A few other moving parts



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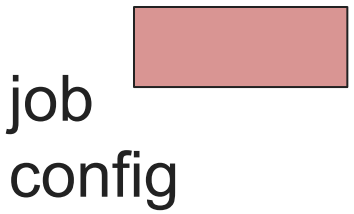

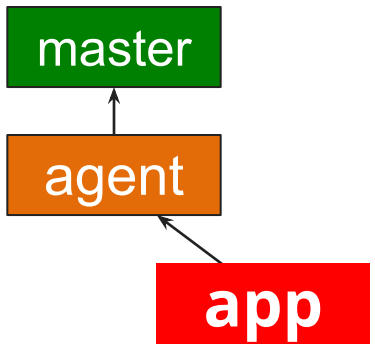

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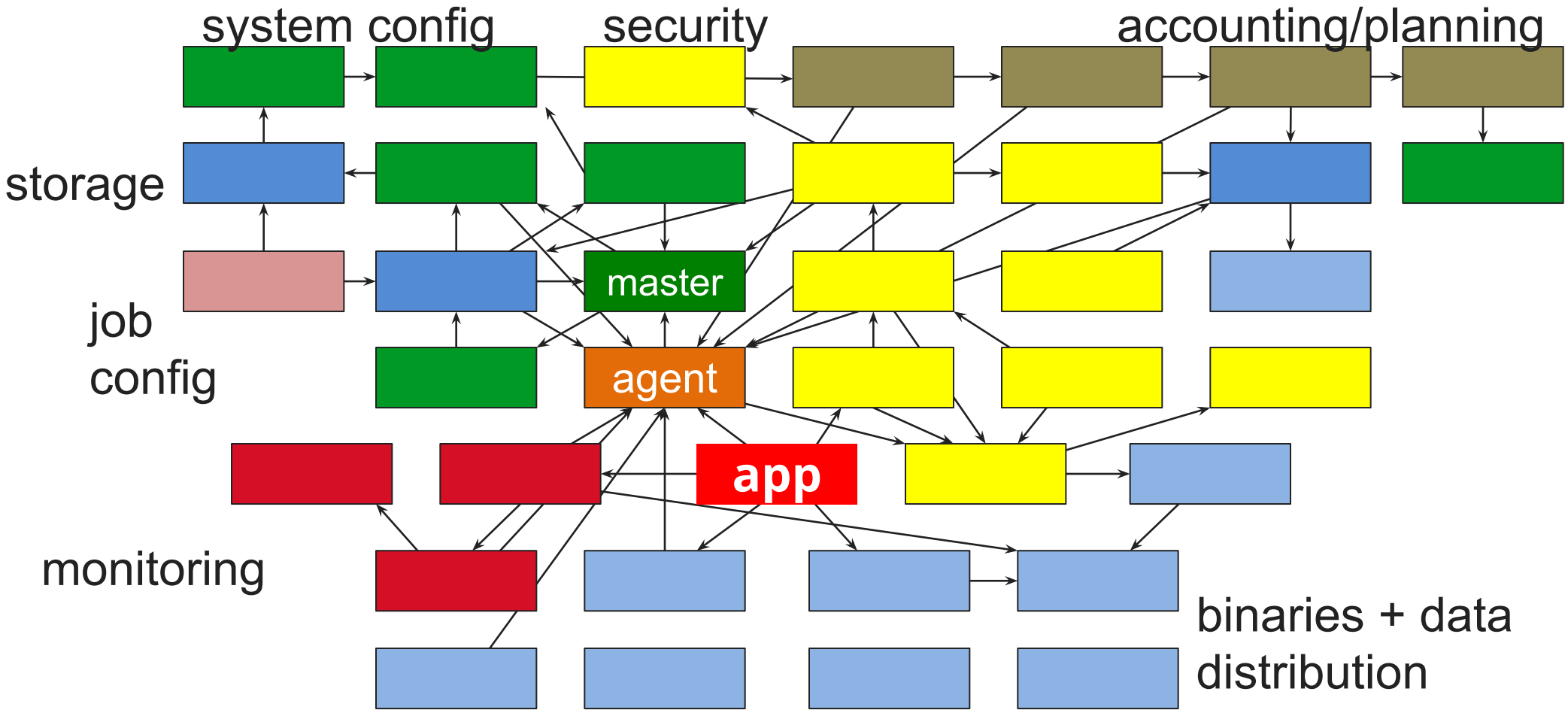


Diagram from an original by Cody Smith.

A few other moving parts

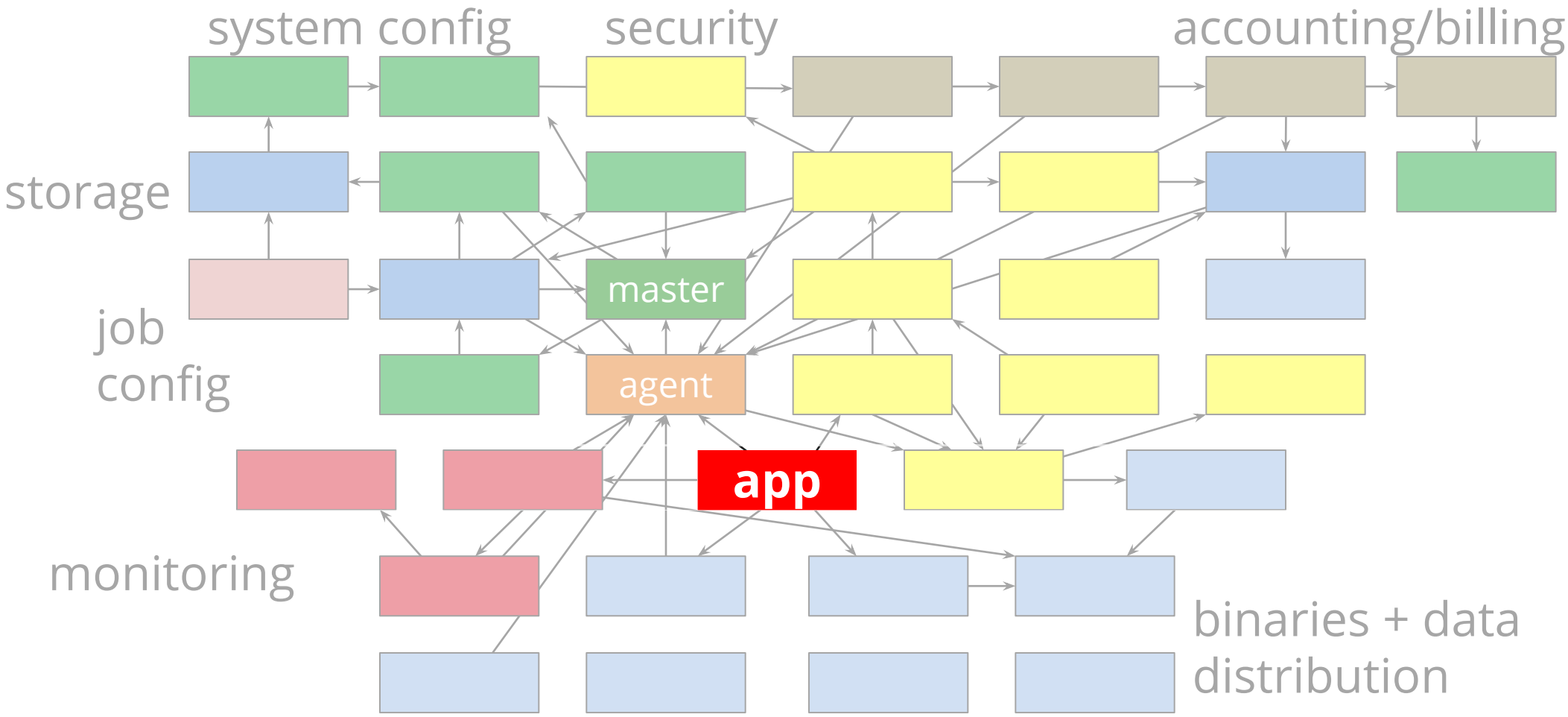


Diagram from an original by Cody Smith.

Kubernetes

κυβερνήτης: *pilot*
or helmsman of a ship

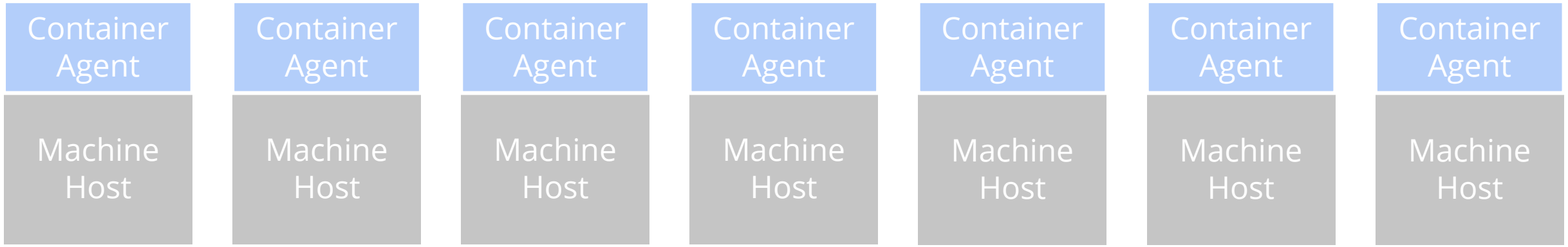
kubernetes by Google

http://kubernetes.io

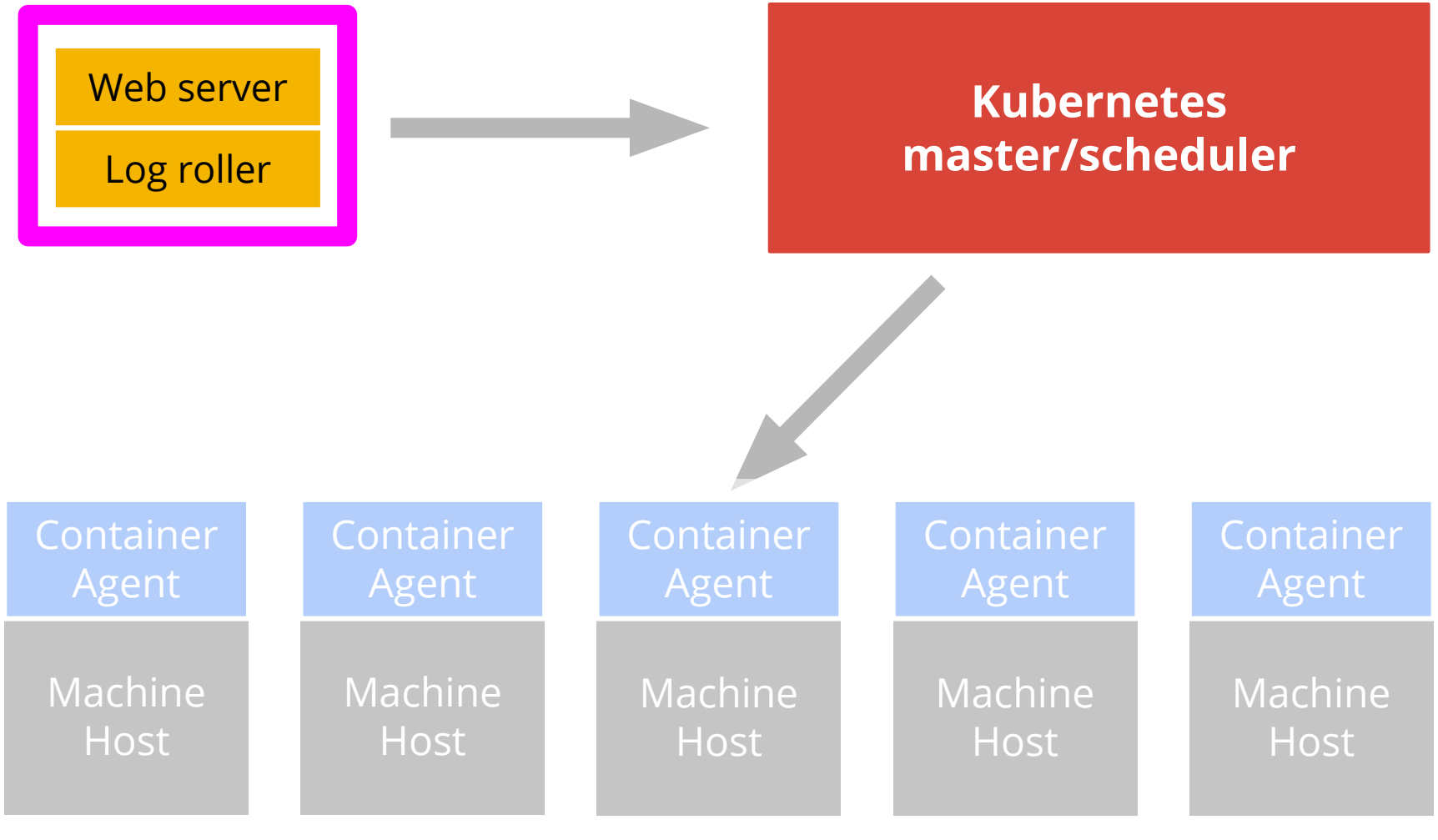
Kubernetes

Web server

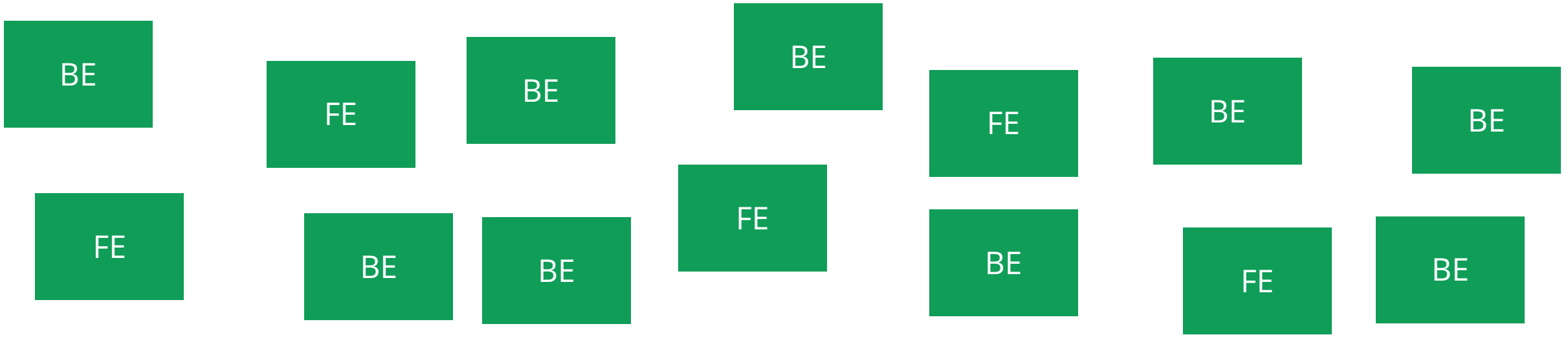
Log roller



Pods


Web server
Log roller
Kubernetes master/scheduler
Container Agent
Machine Host
Container Agent
Machine Host
Container Agent
Machine Host
Container Agent
Machine Host
Container Agent
Machine Host
Container Agent
Machine Host
Container Agent
Machine Host

Labels

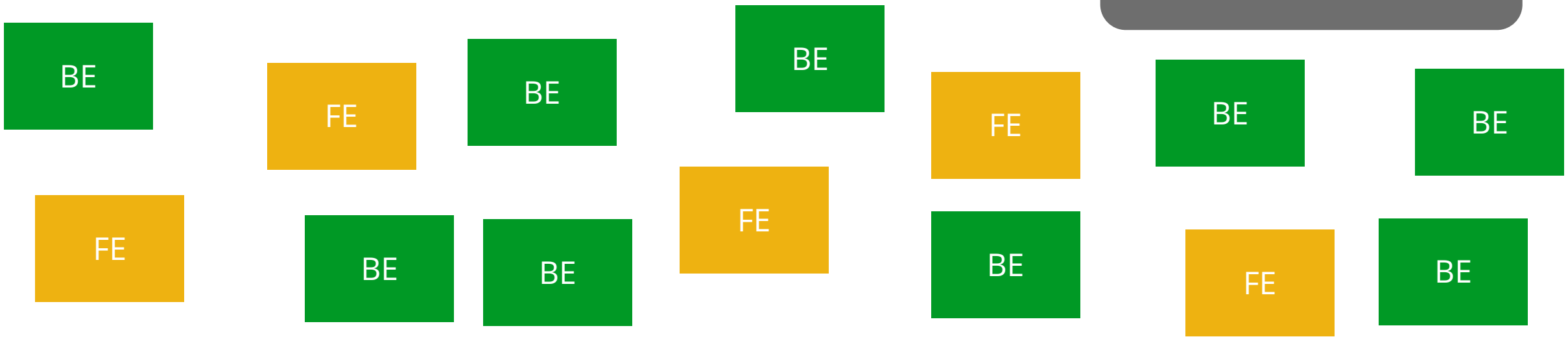


Kubernetes master/scheduler

Container Agent	Container Agent	Container Agent	Container Agent	Container Agent	Container Agent	Container Agent
Machine Host	Machine Host	Machine Host	Machine Host	Machine Host	Machine Host	Machine Host

Label selectors

labels:
role: frontend



Kubernetes master/scheduler

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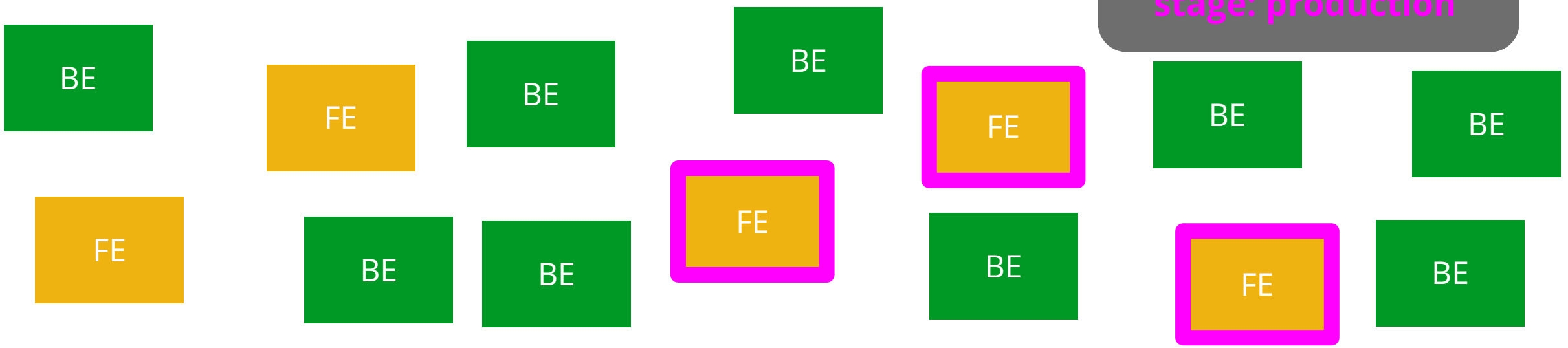
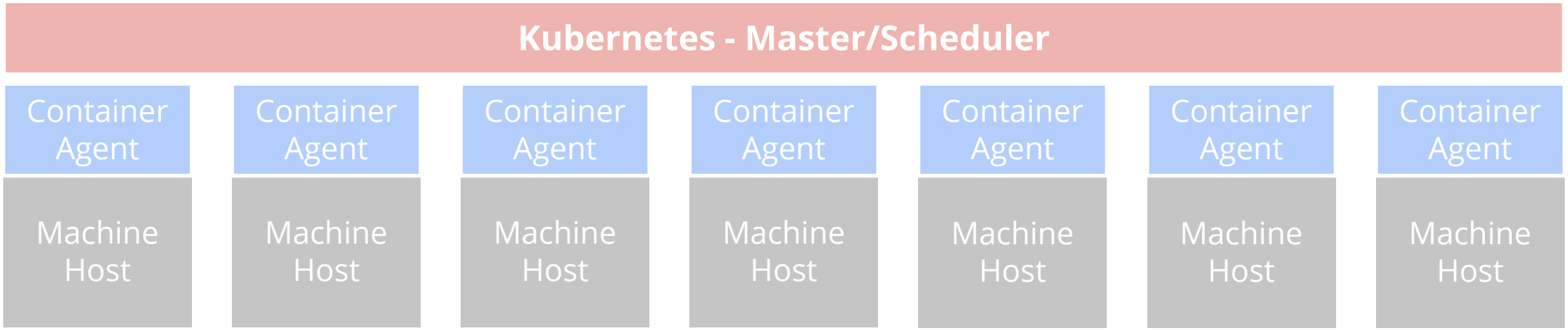
Label selectors



Replica controller

FE FE FE

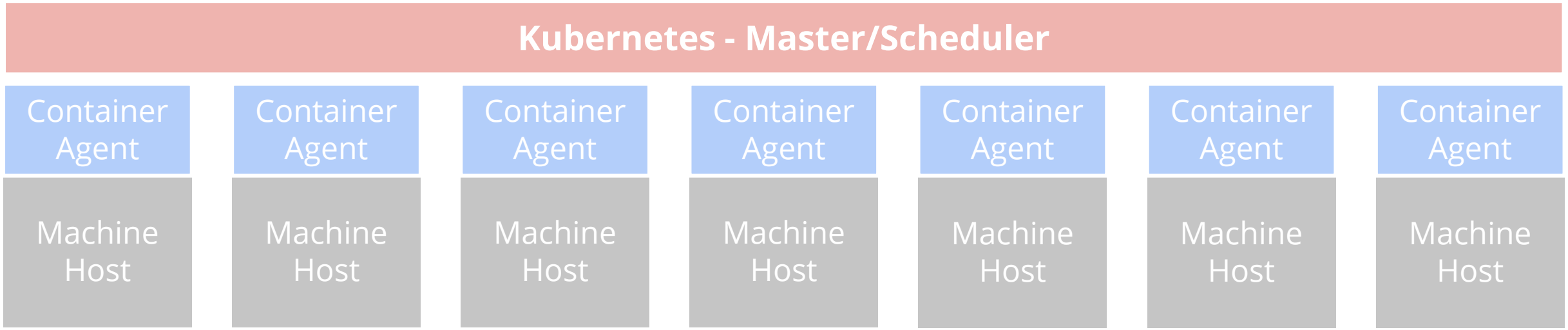
replicas: 3
template:
...
labels:
role: frontend



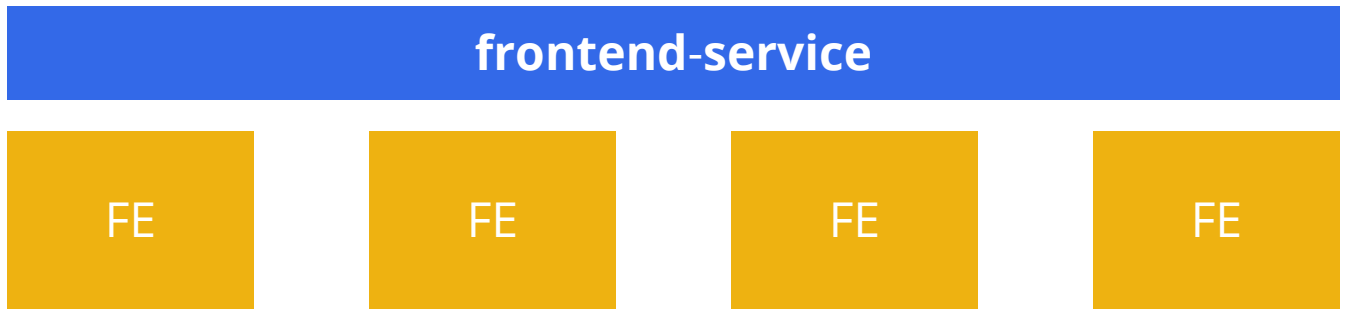
Replica controller

FE FE FE FE

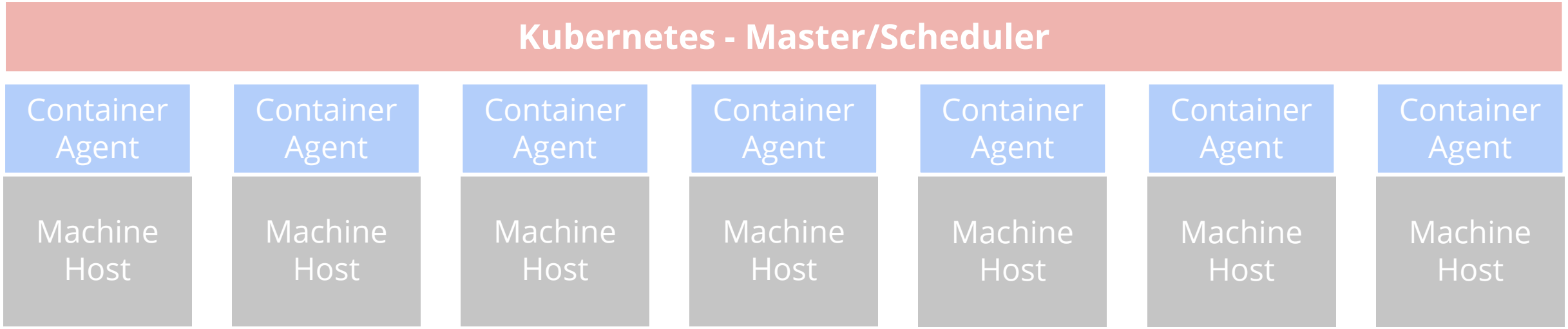
replicas: 4
template:
  ...
labels:
  role: frontend



Service



id: **frontend-service**
port: 9000
labels:
  role: **frontend**



Kubernetes

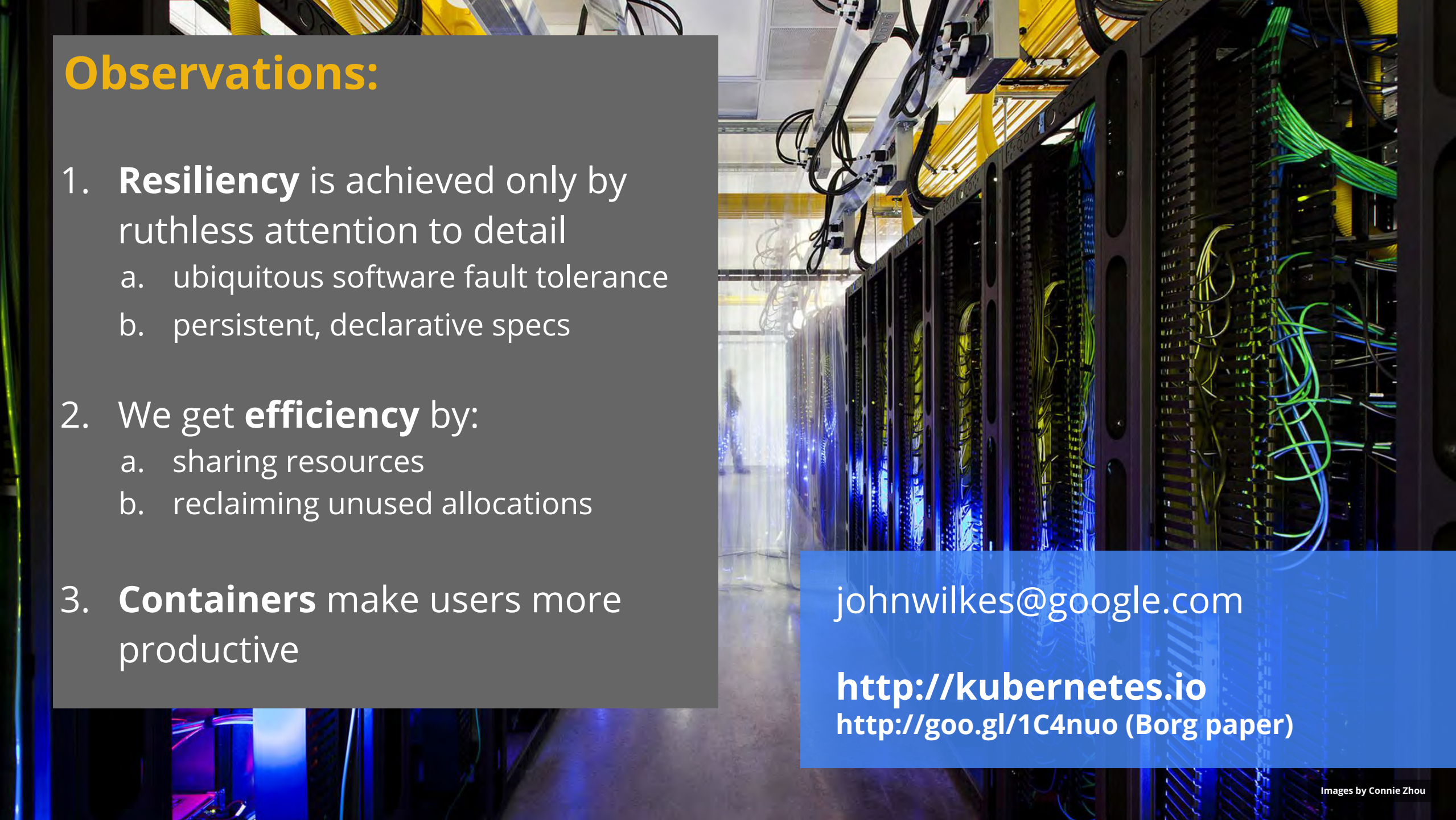
Direct Borg analogues:

- Borg containers => **Docker containers**
- alloc (task group) => **pod (container group)**
- Borglet => **Kubelet**
- **persistent, declarative specs**
- **reconciliation loops**

Kubernetes

New / improved:

- **labels + label queries**
- **service abstraction**
- **composable microservices**
  - replication controller
  - horizontal autoscaler
- IP per pod



Observations:

1. **Resiliency** is achieved only by ruthless attention to detail
   a. ubiquitous software fault tolerance
   b. persistent, declarative specs

2. We get **efficiency** by:
   a. sharing resources
   b. reclaiming unused allocations

3. **Containers** make users more productive

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http://kubernetes.io
http://goo.gl/1C4nuo (Borg paper)

Images by Connie Zhou