Large-scale cluster management at Google with Borg

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Slides heavily derived from John Wilkes's presentation at EuroSys, this year

Borg at Google

- Cluster management system at Google that achieves high utilization by:
  - Admission control
  - Efficient task-packing
  - Over-commitment
  - Machine sharing

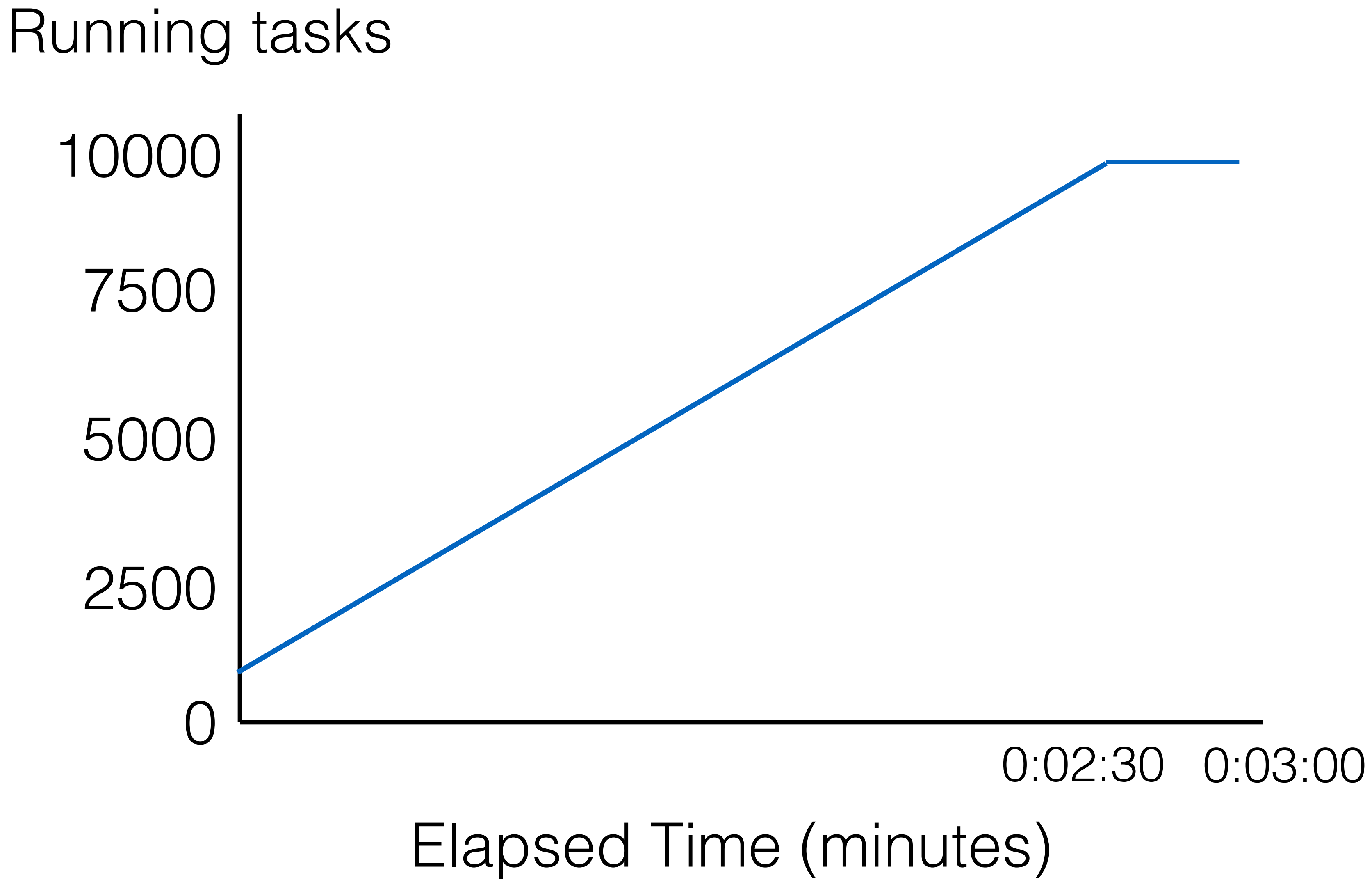
The User Perspective

- Users: Google developers and system administrators mainly
- The workload: Production and batch, mainly
- Cells
- Jobs and tasks
- Allocs and Alloc sets
- Priority, quota and admission control
- Naming and monitoring

The User Perspective

-
  ```
  job hello_world = {
      runtime = { cell = “ic” } //what cell should run it in?
      binary = ‘../hello_world_webserver’ //what program to run?
      args = { port = ‘%port%’ }
      requirements = {
          RAM = 100M
          disk = 100M
          CPU = 0.1
      }
      replicas = 10000
  }
  ```

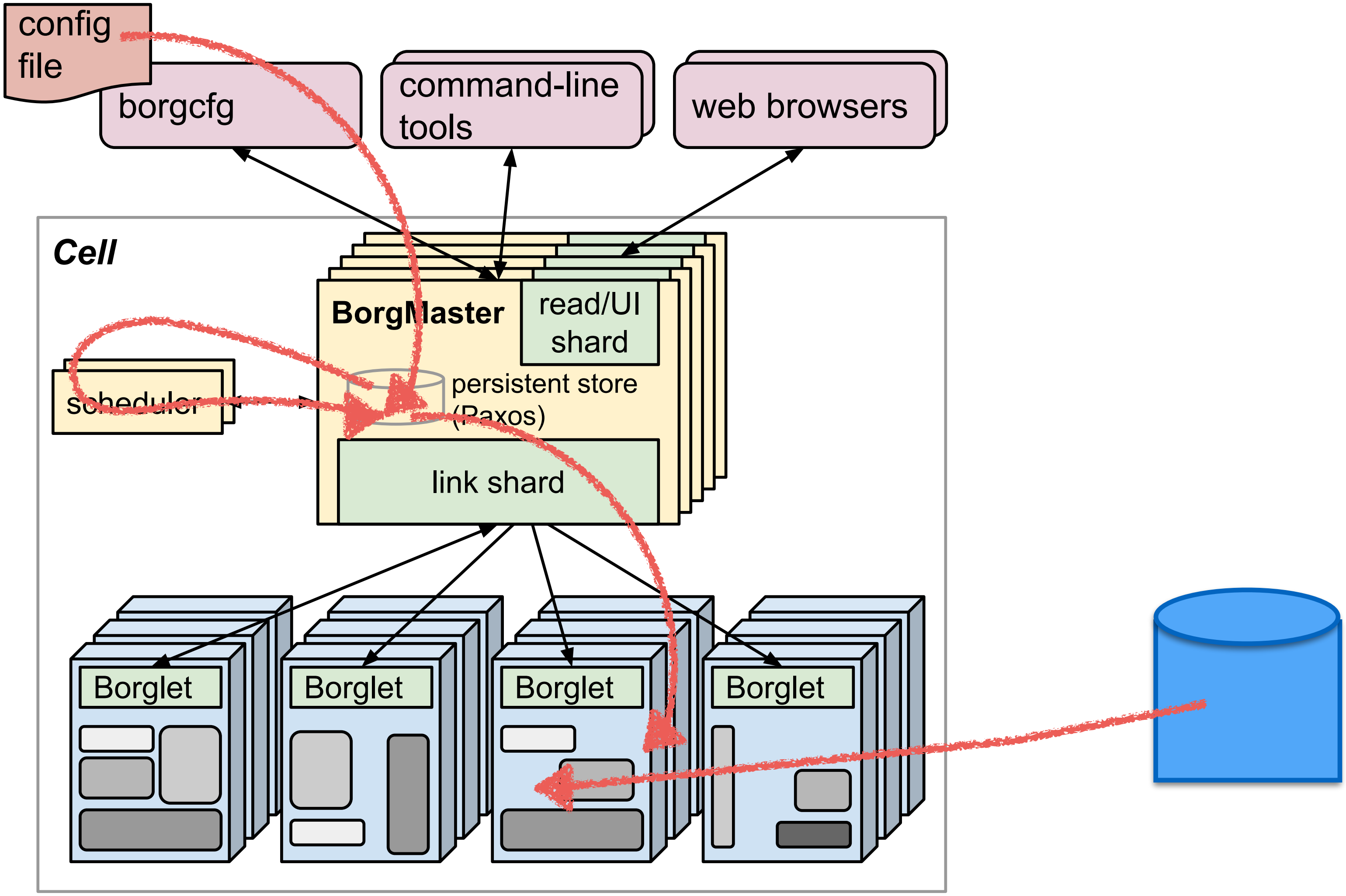
The User Perspective

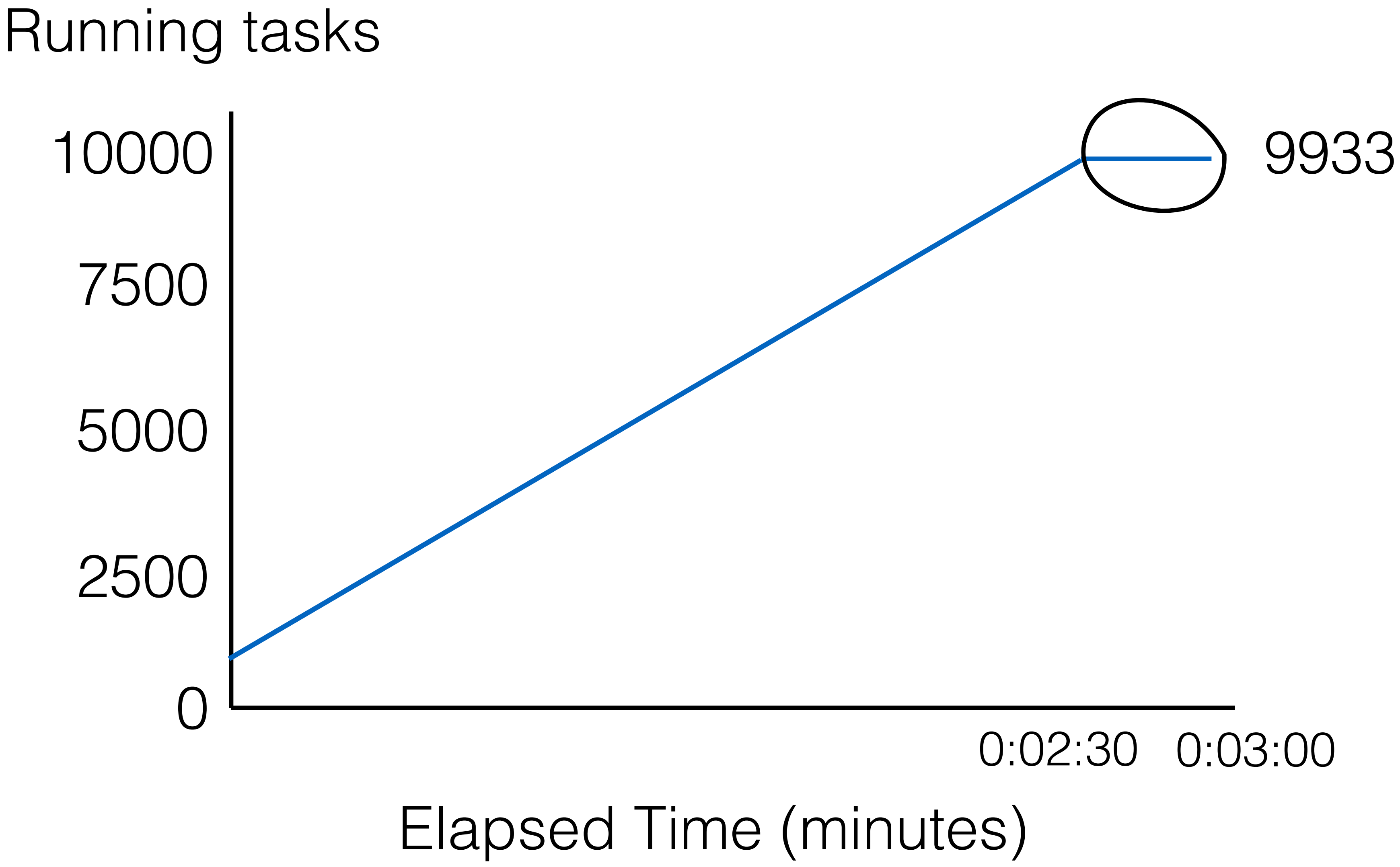


Main Benefits

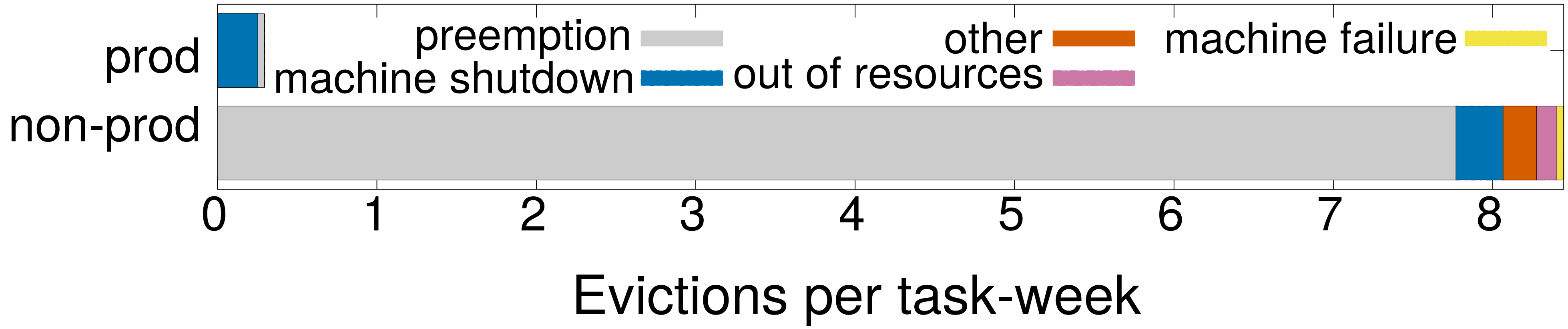
- Provides scalability to run workloads across thousands of machines
- Abstracts away the details of resource management and fault handling from users
- Operates with high reliability and availability

High-level Architecture




Running tasks
10000
7500
5000
2500
0
9933
0:02:30
0:03:00
Elapsed Time (minutes)

Failures

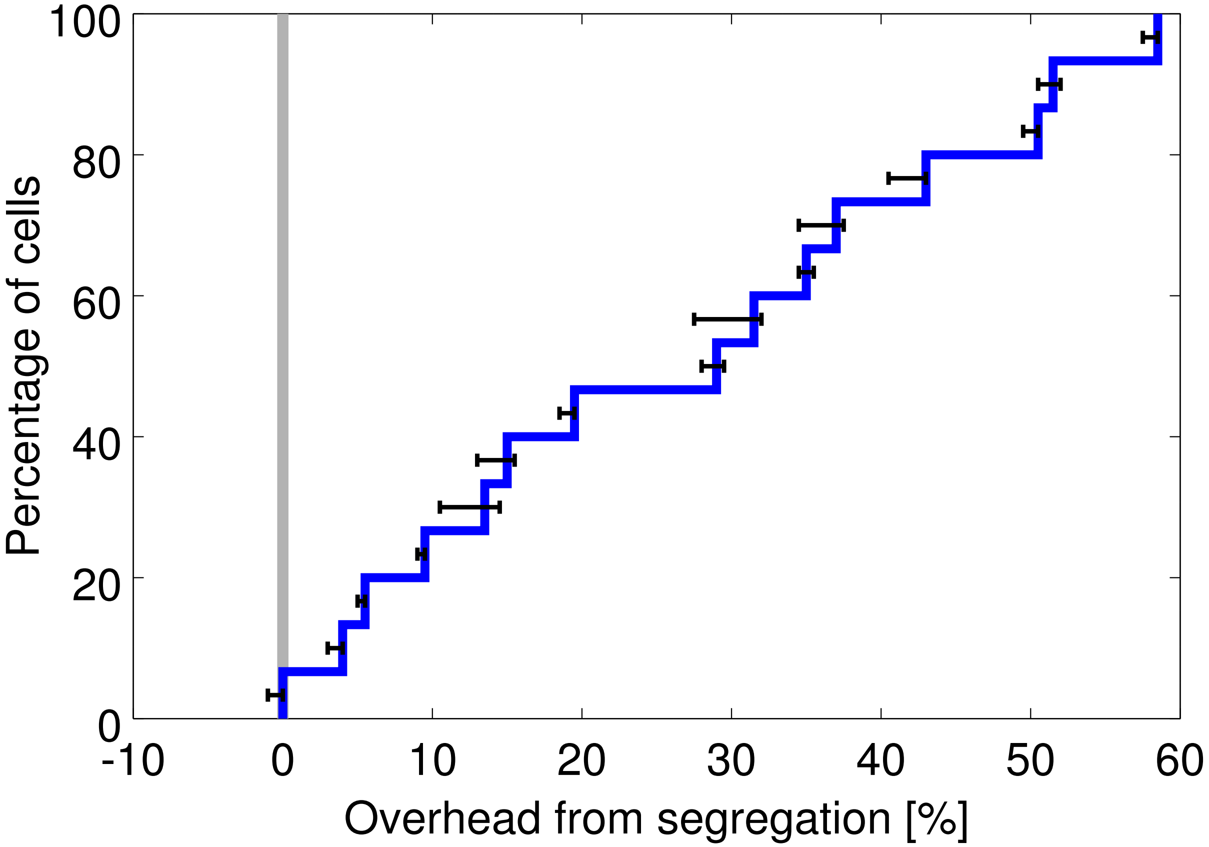

prod
non-prod
preemption
machine shutdown
other
out of resources
machine failure
0
1
2
3
4
5
6
7
8
Evictions per task-week

Efficiency: Is Borg’s policy the best for utilizing clusters?

- Advanced Bin-Packing algorithms:
  - Avoid stranding of resources
- Evaluation metric: Cell-compaction
  - Find the smallest cell that we can pack the workload into…
  - Remove machines randomly from a cell to maintain cell heterogeneity
- Evaluated various policies to understand the cost, in terms of extra machines needed for packing the same workload

Should we share cluster?

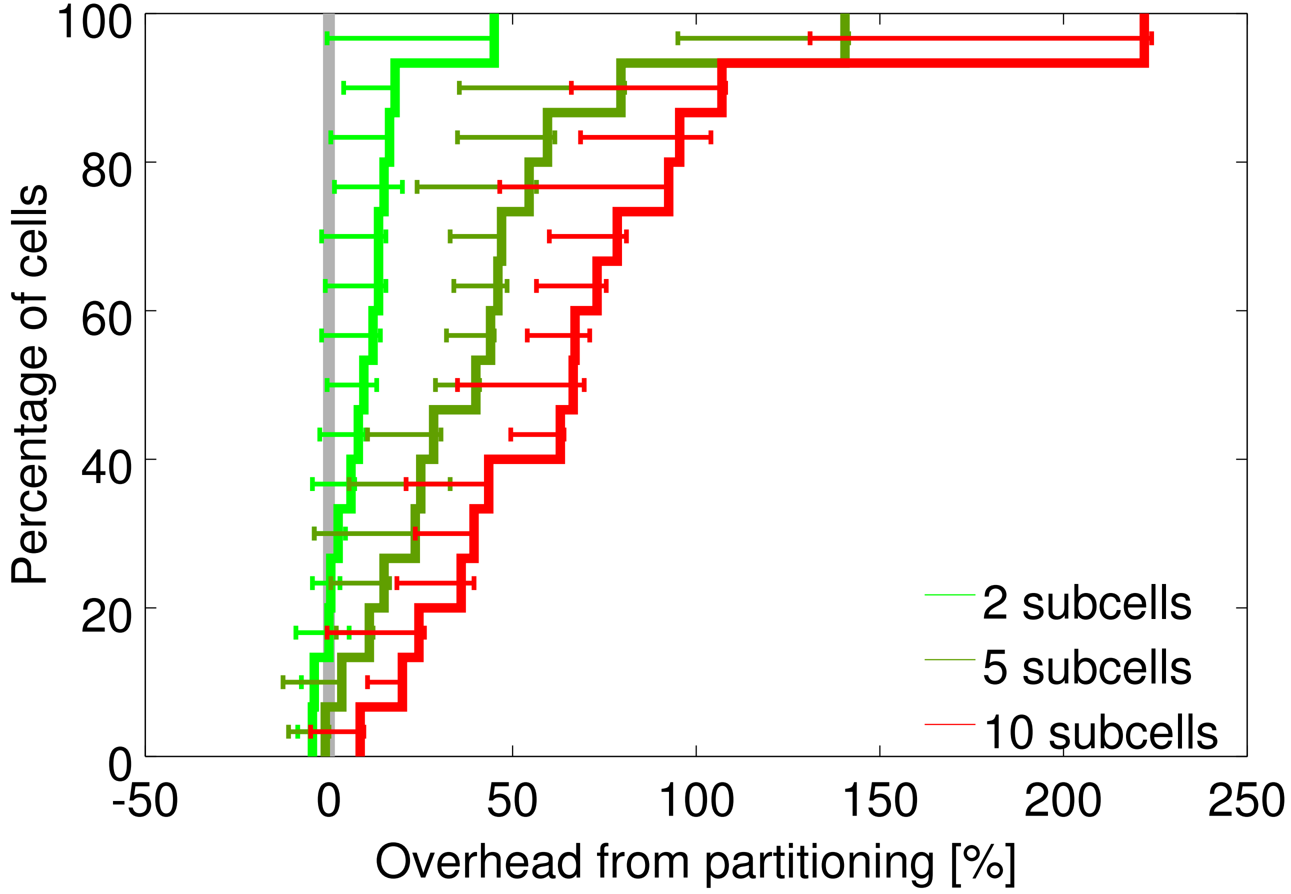
- …between production and non-production workloads?



- Segregating them would need more machines!

Why such large cells?

- Should we split them into smaller cells?



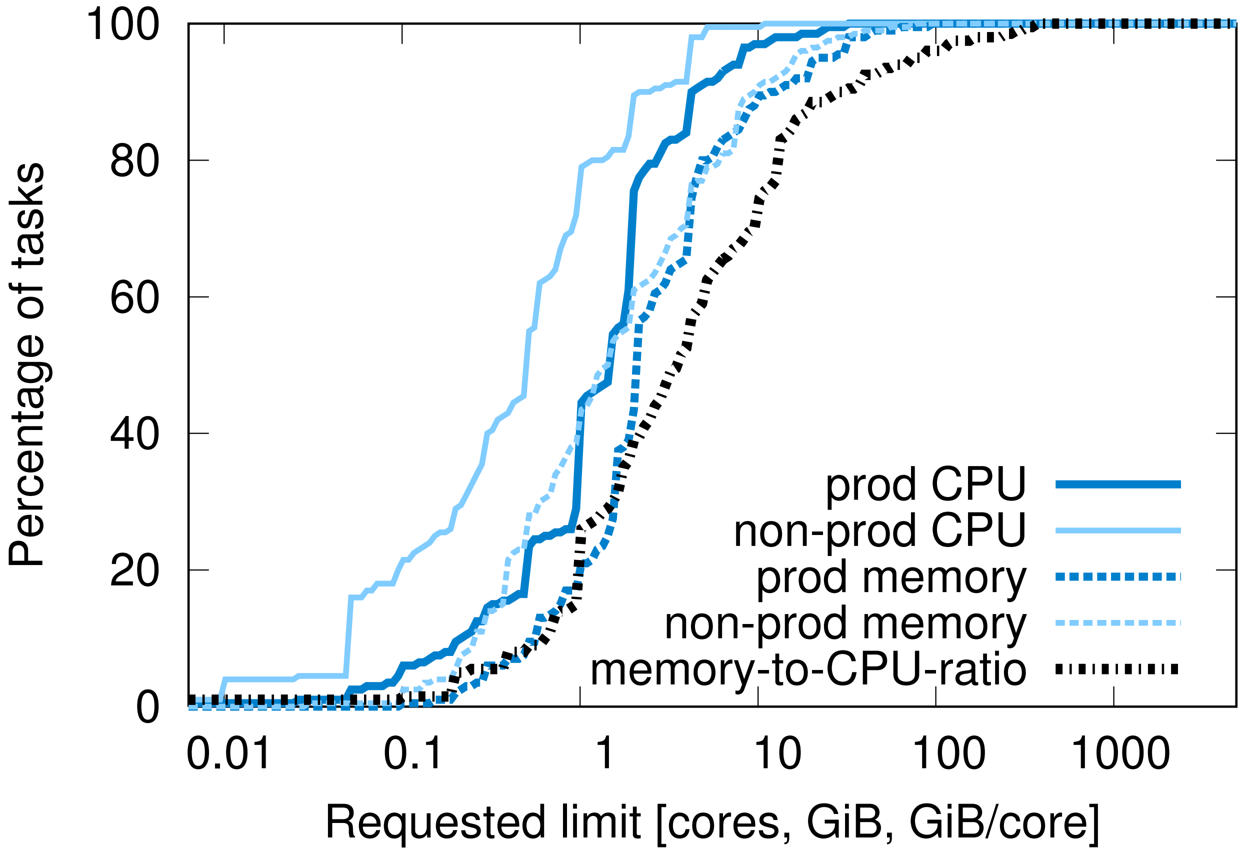
- …might end up having to partition workload across multiple sub-clusters
- would need more machines
- …might be useful to share a cell between users

Should we make cells even larger?

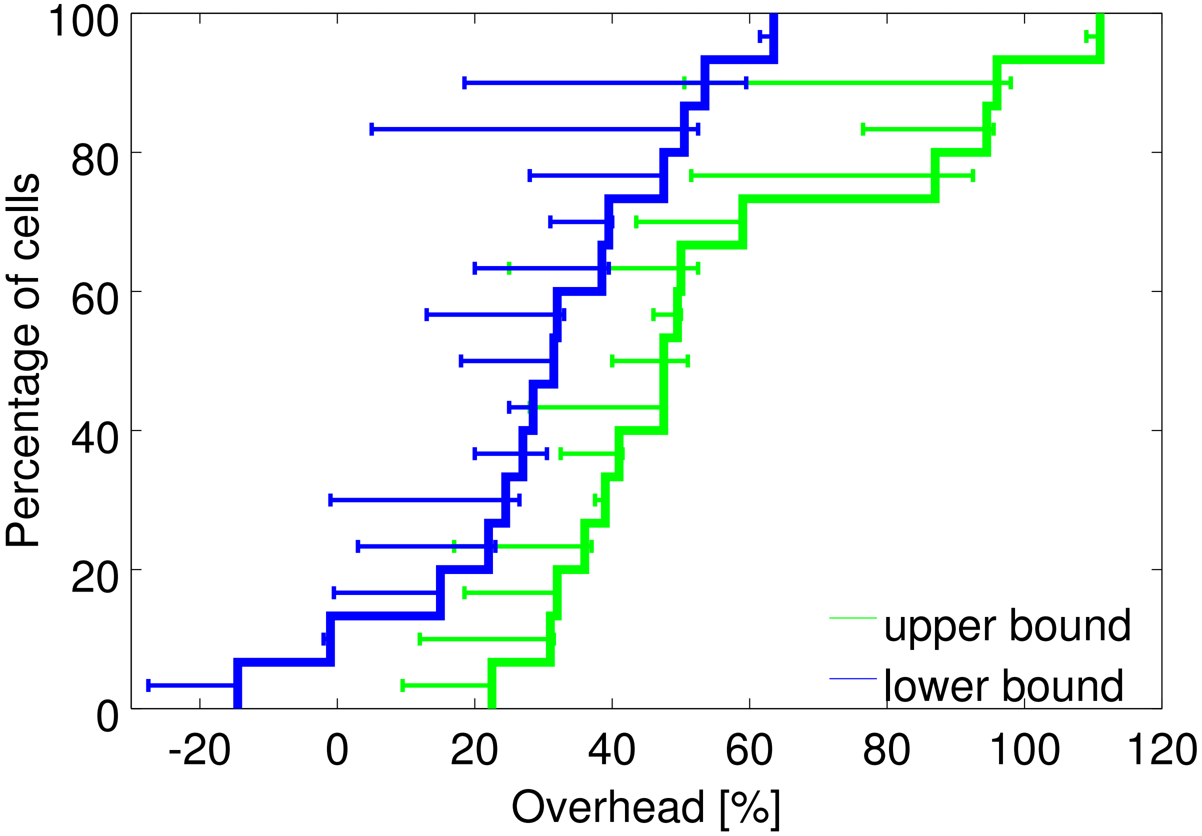
- Failure containment

Would fixed resource bucket sizes be better?

- Borg offers flexible resource requirement specification

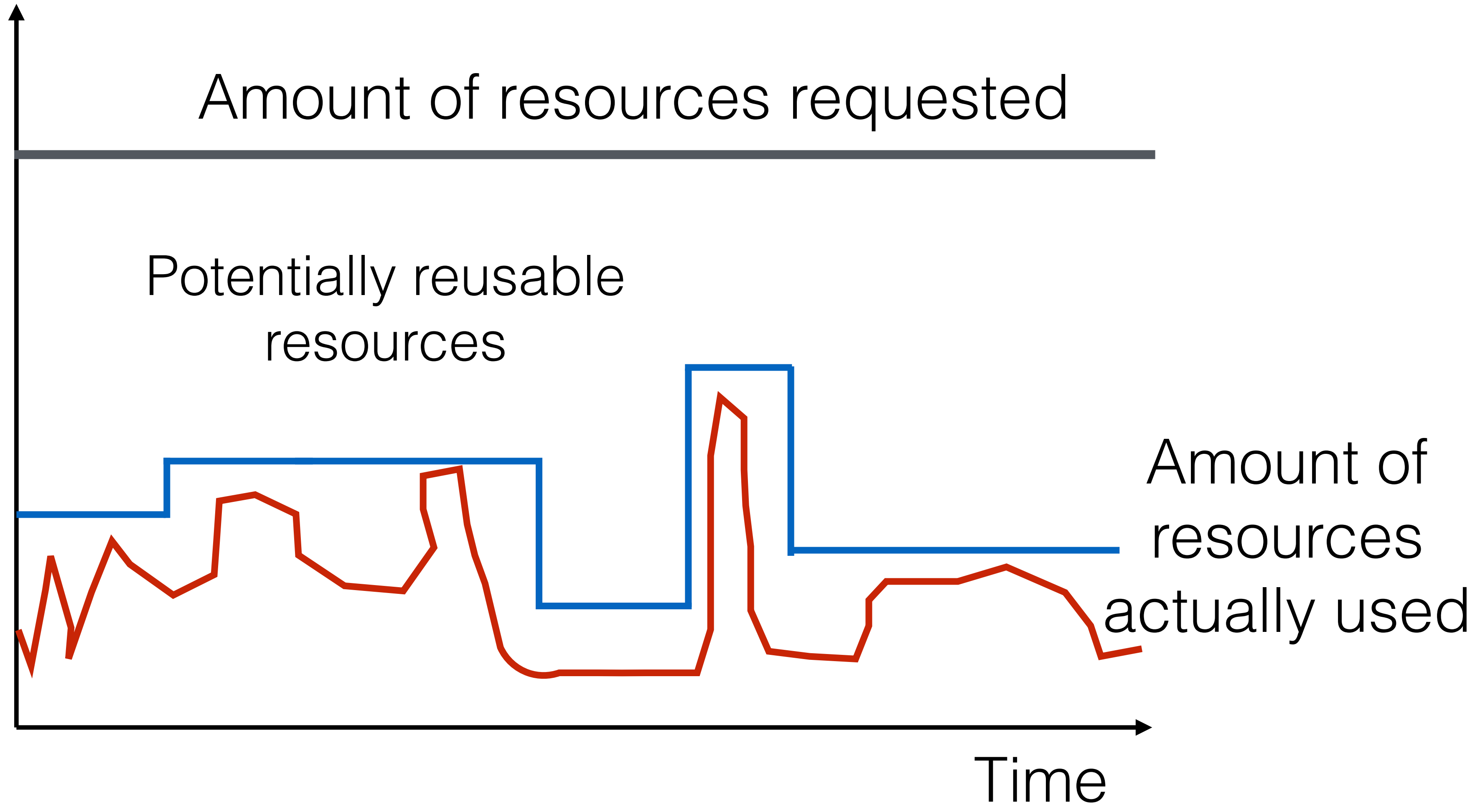


Bucketing resource requirements

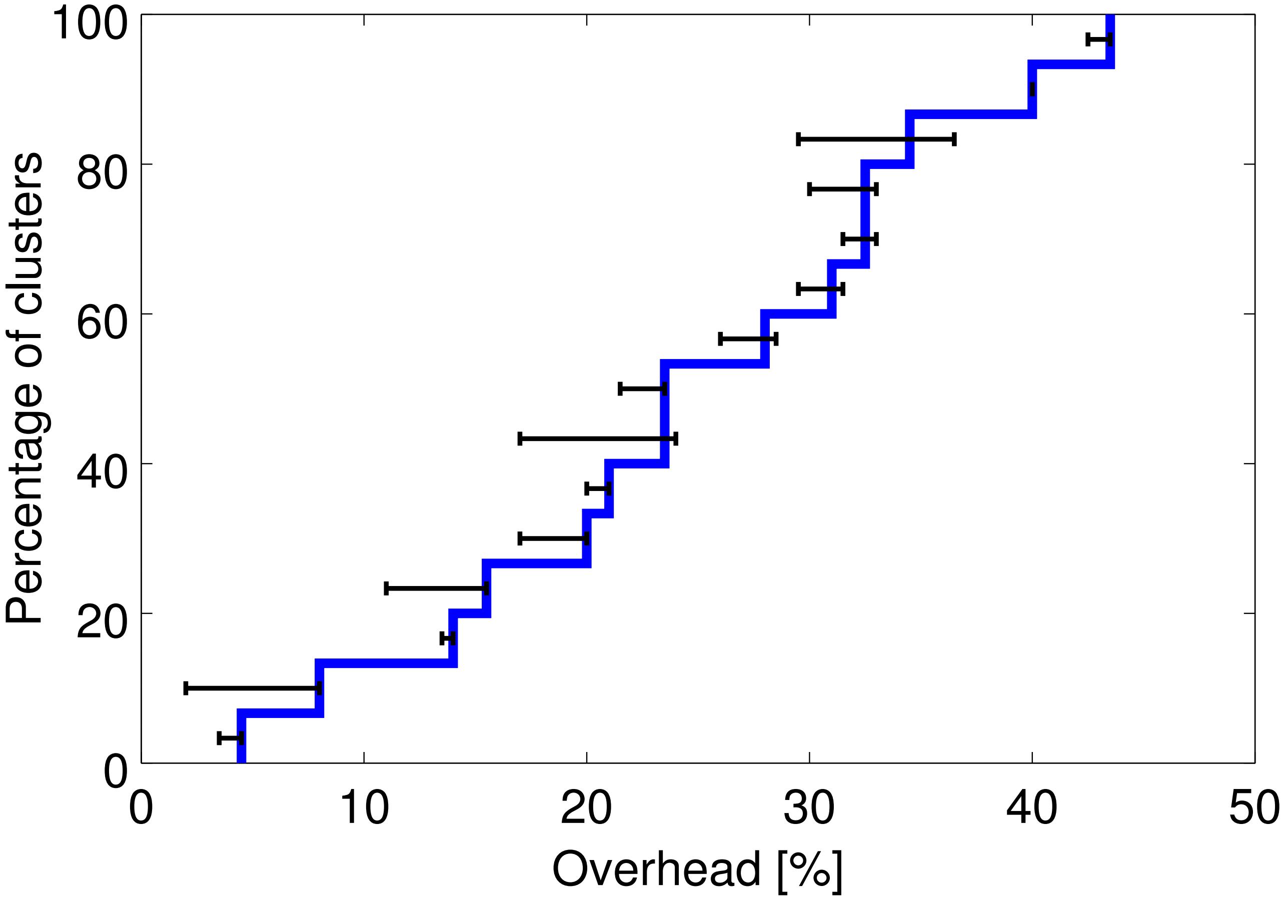


- …would need more machines

Resource Reclamation

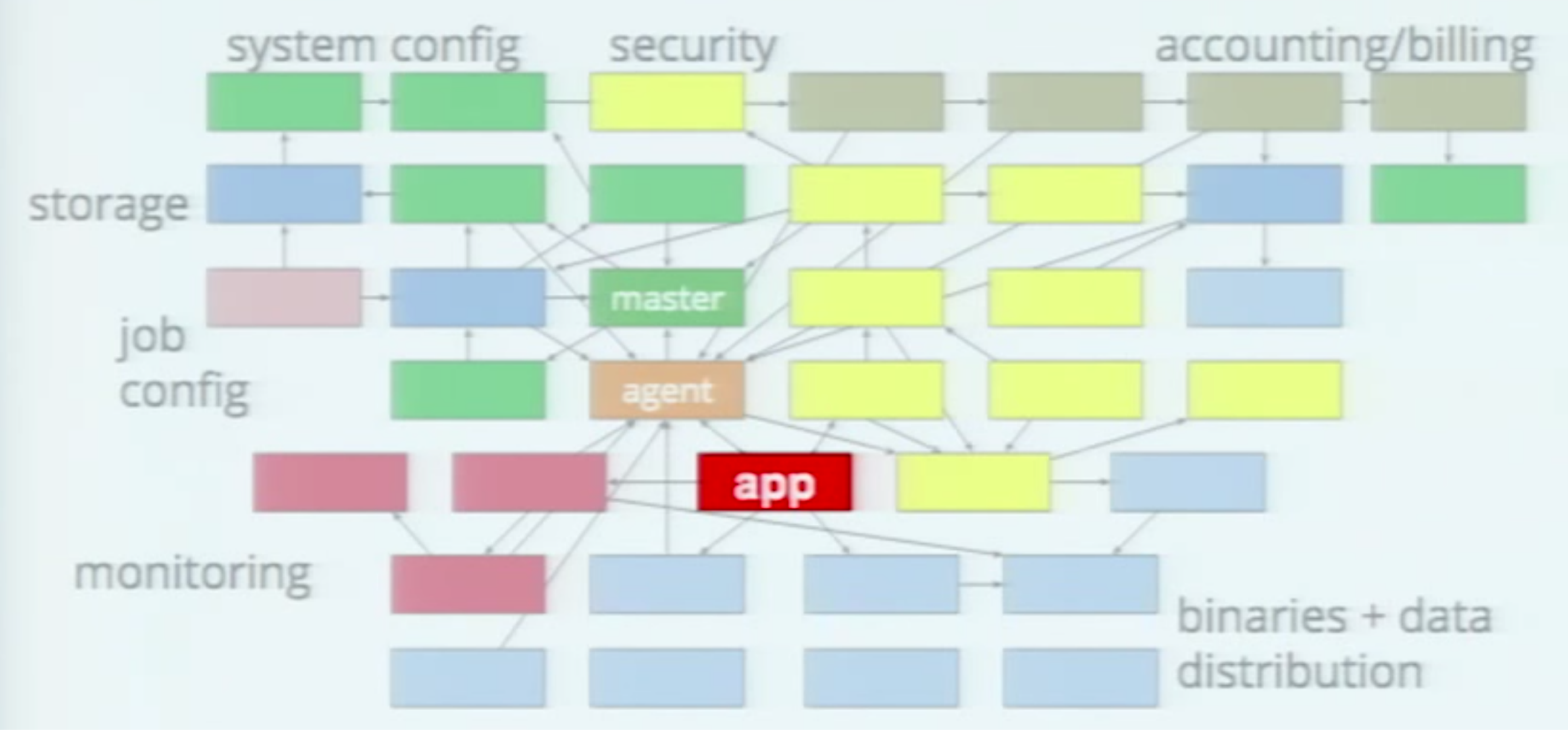


Effectiveness of resource reclamation



- would end up using more machines if resources aren’t reclaimed

Users can focus on their application



Containers

- Google runs everything inside containers, even their VMs
- Containers provide:
    - resource isolation
    - execution isolation

Kubernetes

- An open-source cluster manager derived from Borg
- Also runs on the Google Compute Cloud

- **Directly derived:**
  - Borglet => Kubelet
  - alloc => pod
  - Borg containers => docker
  - Declarative specifications
- **Improved:**
  - Job => labels
  - managed ports => IP per pod
  - Monolithic master => micro-services

Summary

- Resiliency: A lot of attention is given to fault tolerance
- Efficiency: share resources between users, between workloads, reclaim unused resources
- Kubernetes: containers enables users to focus on their applications