Large-scale cluster management at Google with Borg

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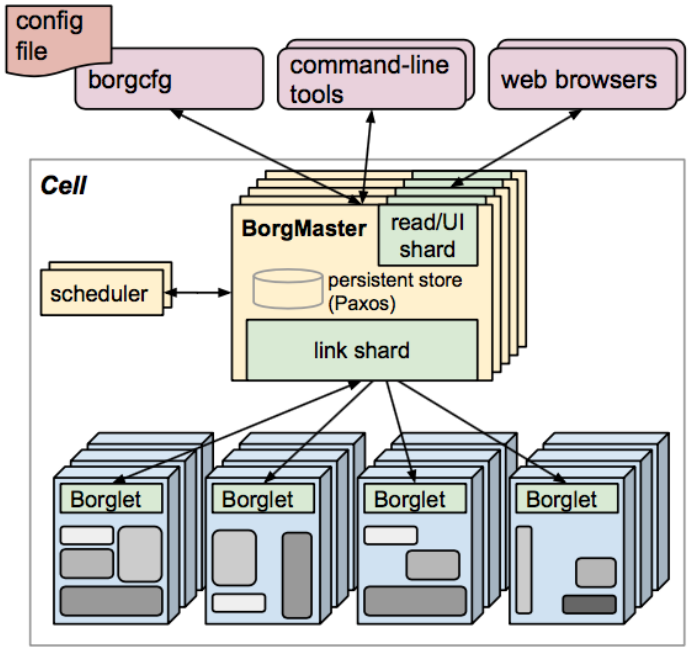
What is Borg?

- A cluster management system developed by Google



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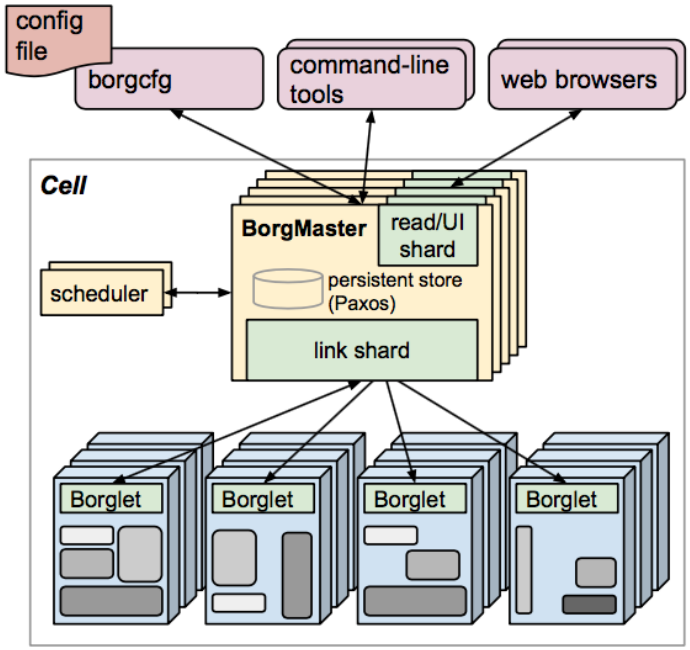

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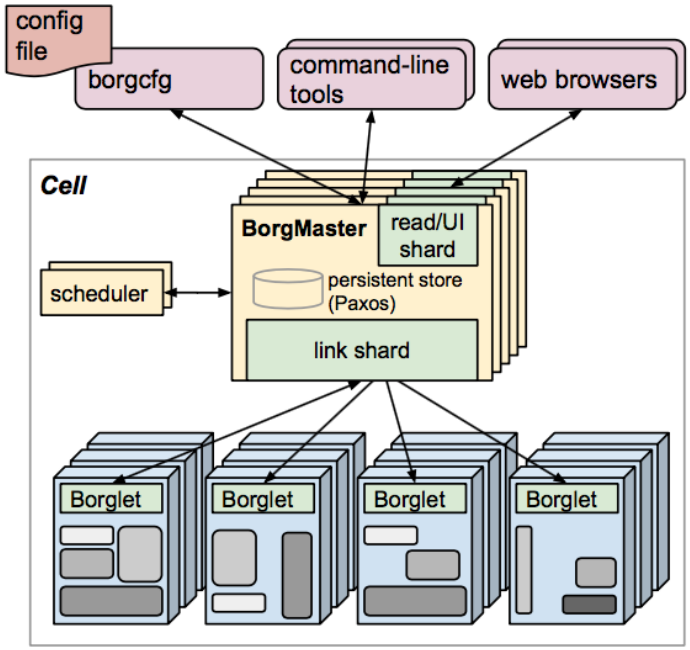

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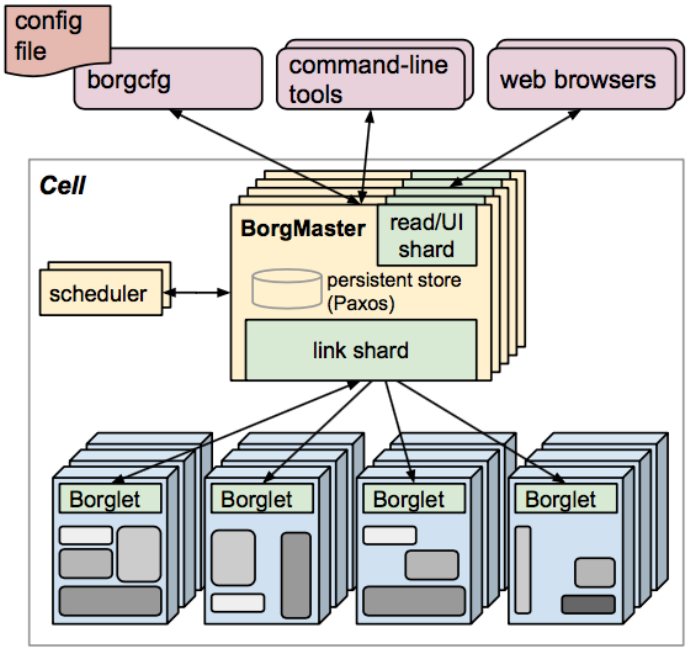

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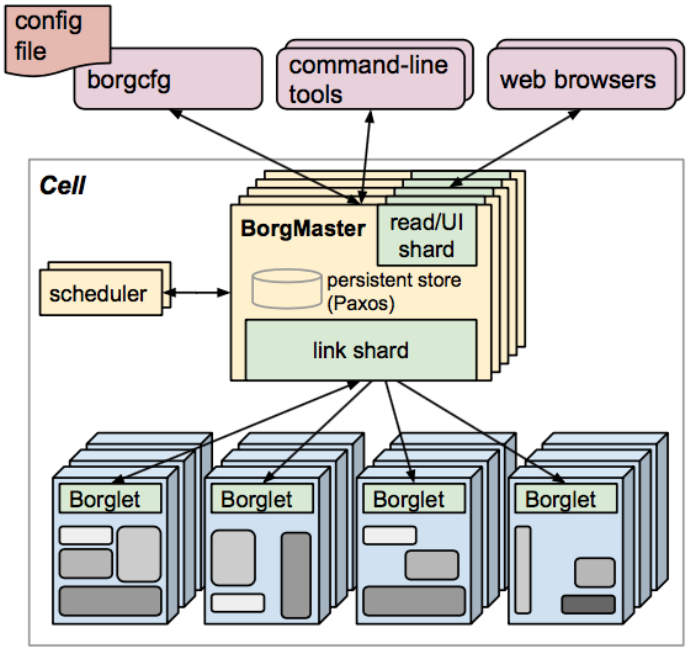
  2. provide high reliability and availability environment for the applications
  3. improve resource sharing



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```
job hello_world = {
   runtime = { cell = 'ic' }                // What cluster should we run in?
   binary = '.../hello_world_webserver'     // What program are we to run?
   args = { port = '%port%' }               // Command line parameters
   requirements = {     // Resource requirements
     ram = 100M
     disk = 100M
     cpu = 0.1
   }
   replicas = 10000   // Number of tasks
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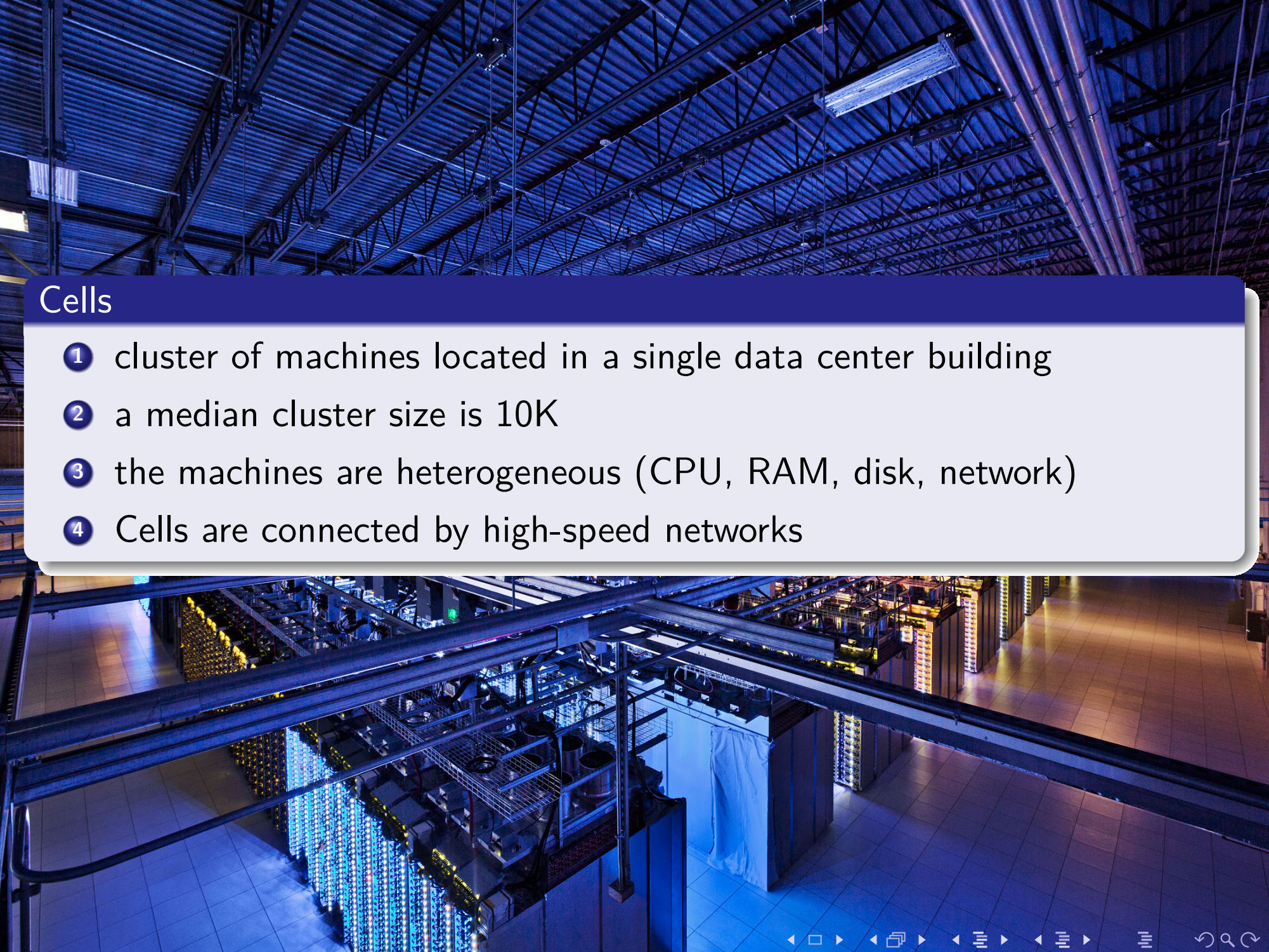
- Likewise, the jobs are classified as production (i.e., higher-priority) and non-production



Cells

1. cluster of machines located in a single data center building
2. a median cluster size is 10K
3. the machines are heterogeneous (CPU, RAM, disk, network)
4. Cells are connected by high-speed networks

1. **Allocs**
   - Reserved set of resources
2. **Priority, quota, and admission control**
   - job has a priority
   - Quota is used to decide which jobs to admit for scheduling
3. **Naming and Monitoring**
   - 50.jfoo.ubar.cc.borg.google.com
   - Monitoring health of the task and thousands of performance metrics

Borg follows a master/slave architecture

1. Borgmaster
   - Borgmaster process and scheduler
   - Replicated
2. Borglet
   - Manage and monitor tasks and resource
   - Borgmaster polls Borglet every few seconds

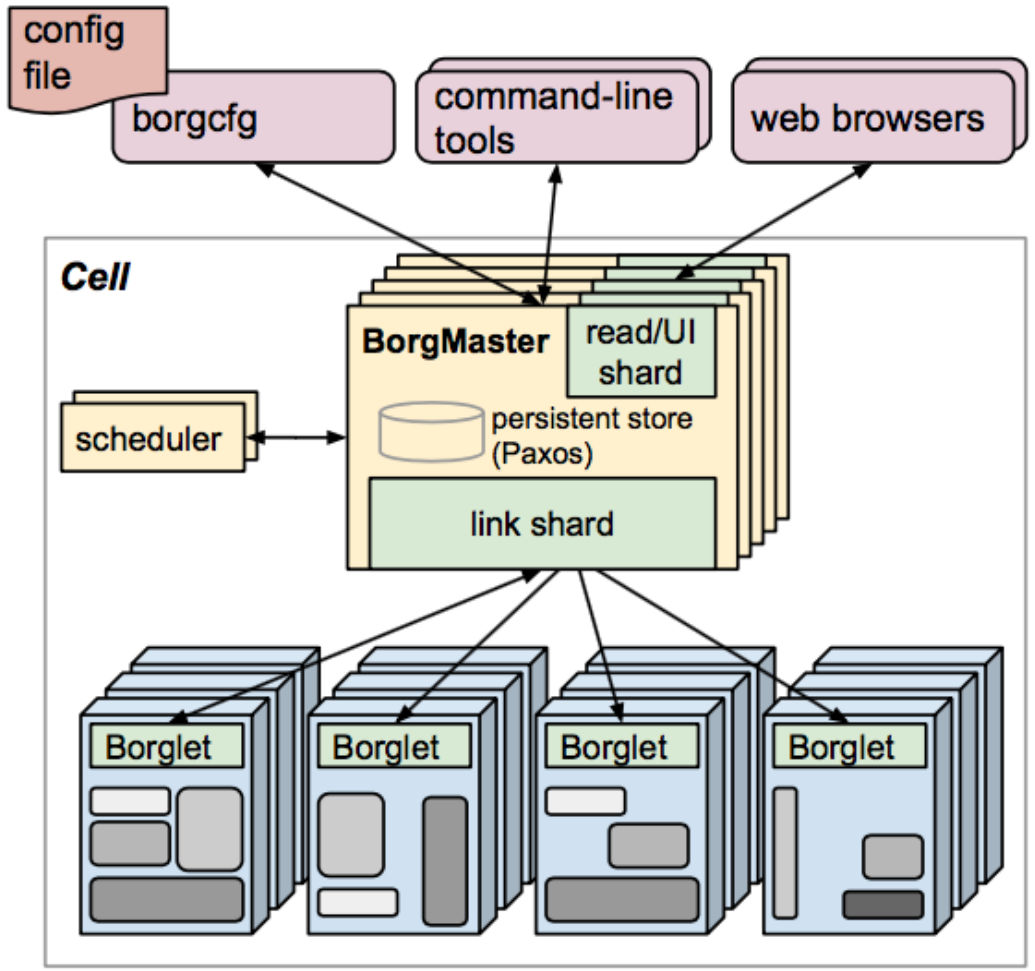


Figure 2: Borg's high-level architecture

A scoring system combines user-specified preferences & build-in criteria

1. Scheduling
   - **feasibility checking**: find machines on which the task could run
   - **scoring**: pick a machine considering different criteria

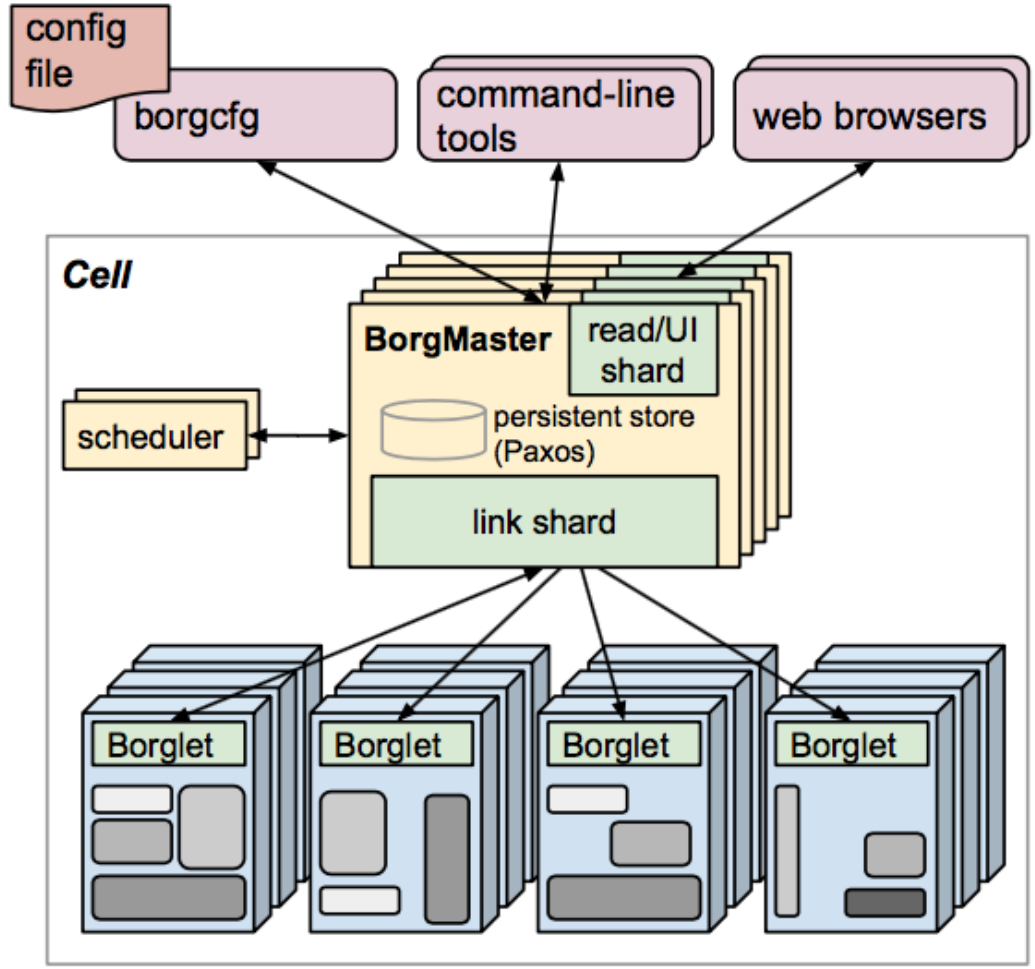


Figure 3: Borg's high-level architecture

Borg employs a modular approach to run its functions across different processes

1. Separate scheduler
2. Separate threads to poll the Borglets
3. Partition functions across the five replicas
4. Score caching: Cache score, ignore small changes
5. Equivalence classes: scoring for one task per equivalence class
6. Relaxed randomization: don't scores all machines, choose random number of machines

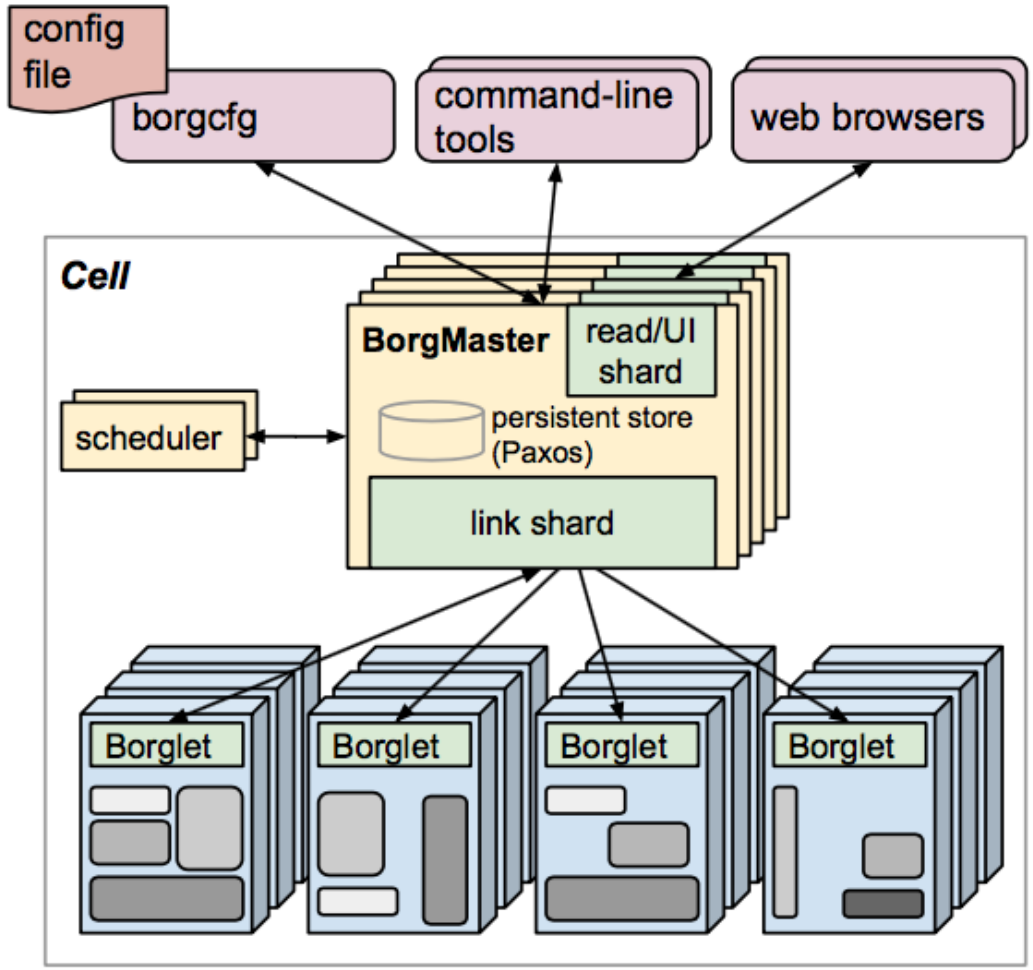
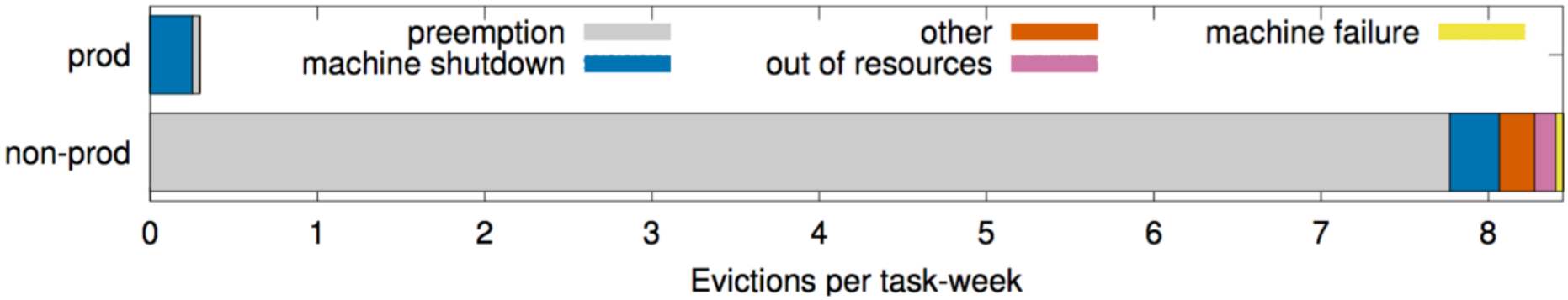
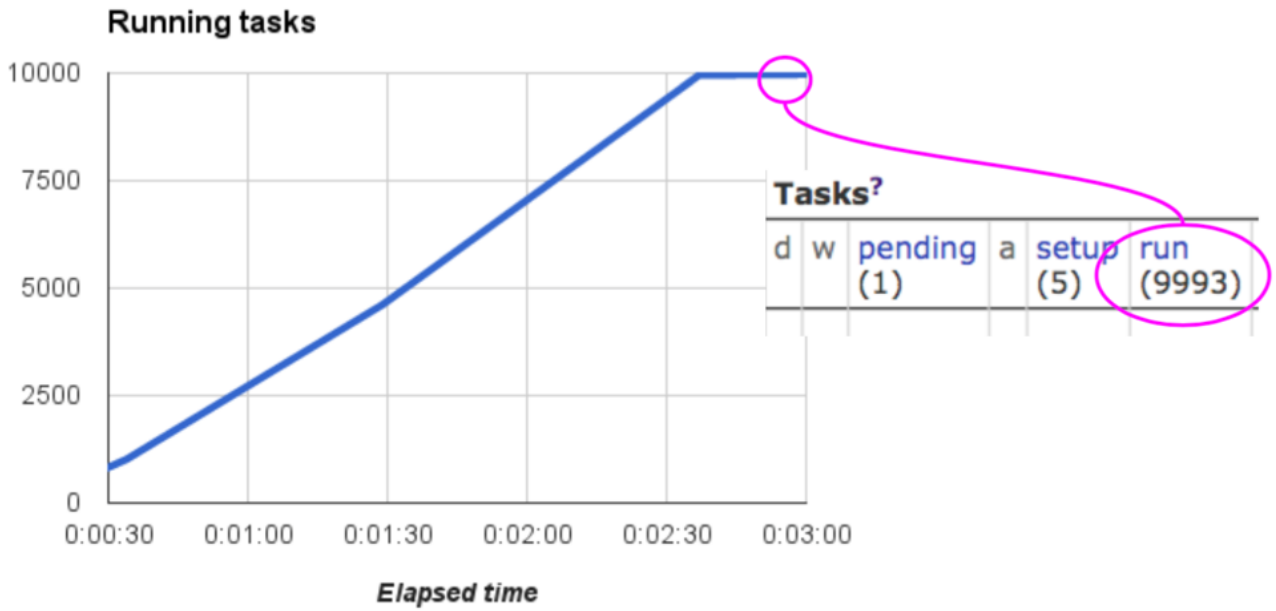


Figure 4: Borg's high-level architecture

Availability

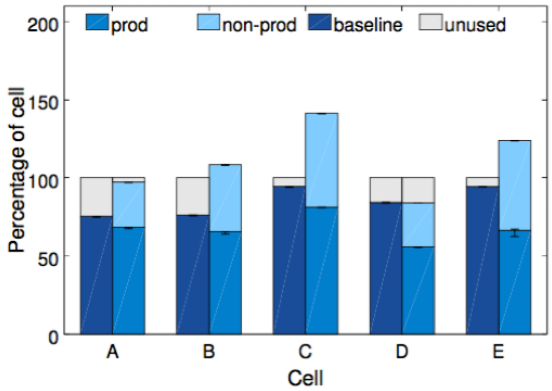


1. Implements checkpoint
2. Reschedules evicted tasks
3. Spreads tasks across failure domain

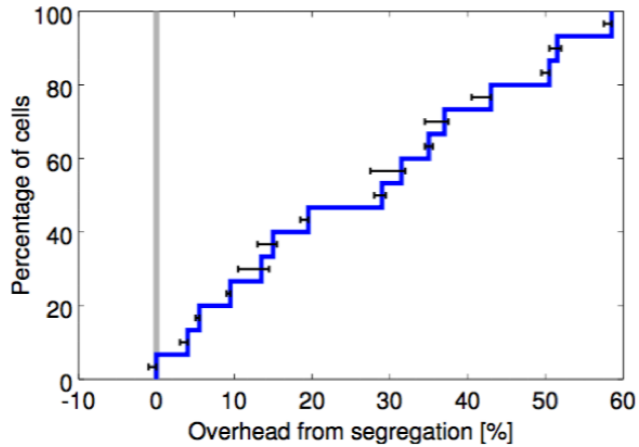


Utilization I

1. **Cell sharing**: segregating prod and non-prod works into different cells would need more machines



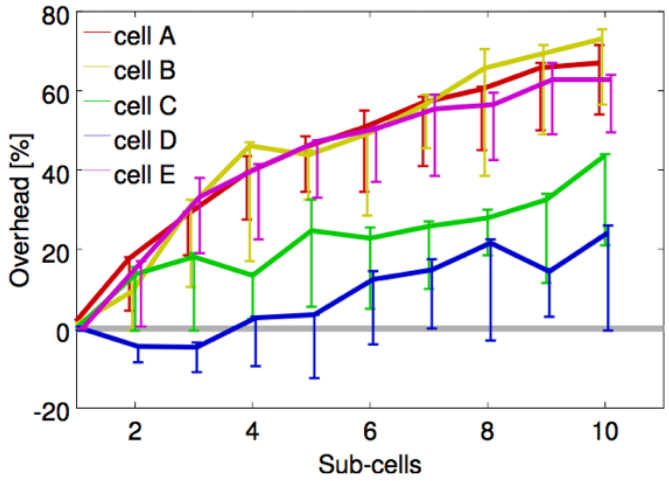
(a) *The left column for each cell shows the original size and the combined workload; the right one shows the segregated case.*



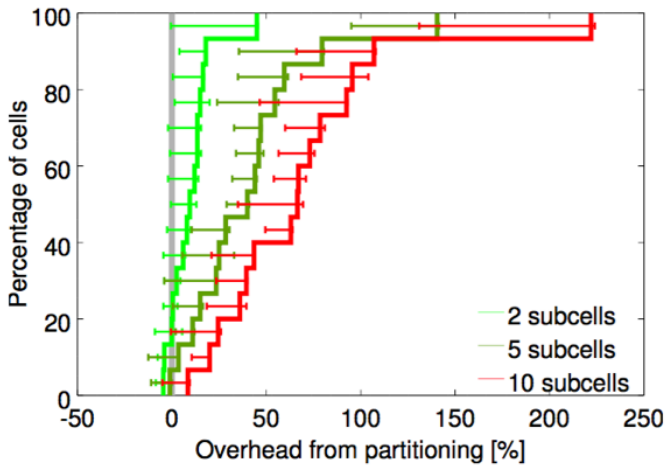
(b) *CDF of additional machines that would be needed if we segregated the workload of 15 representative cells.*

2. **Cell size**: subdividing cells into smaller ones would also require more resources

Utilization II



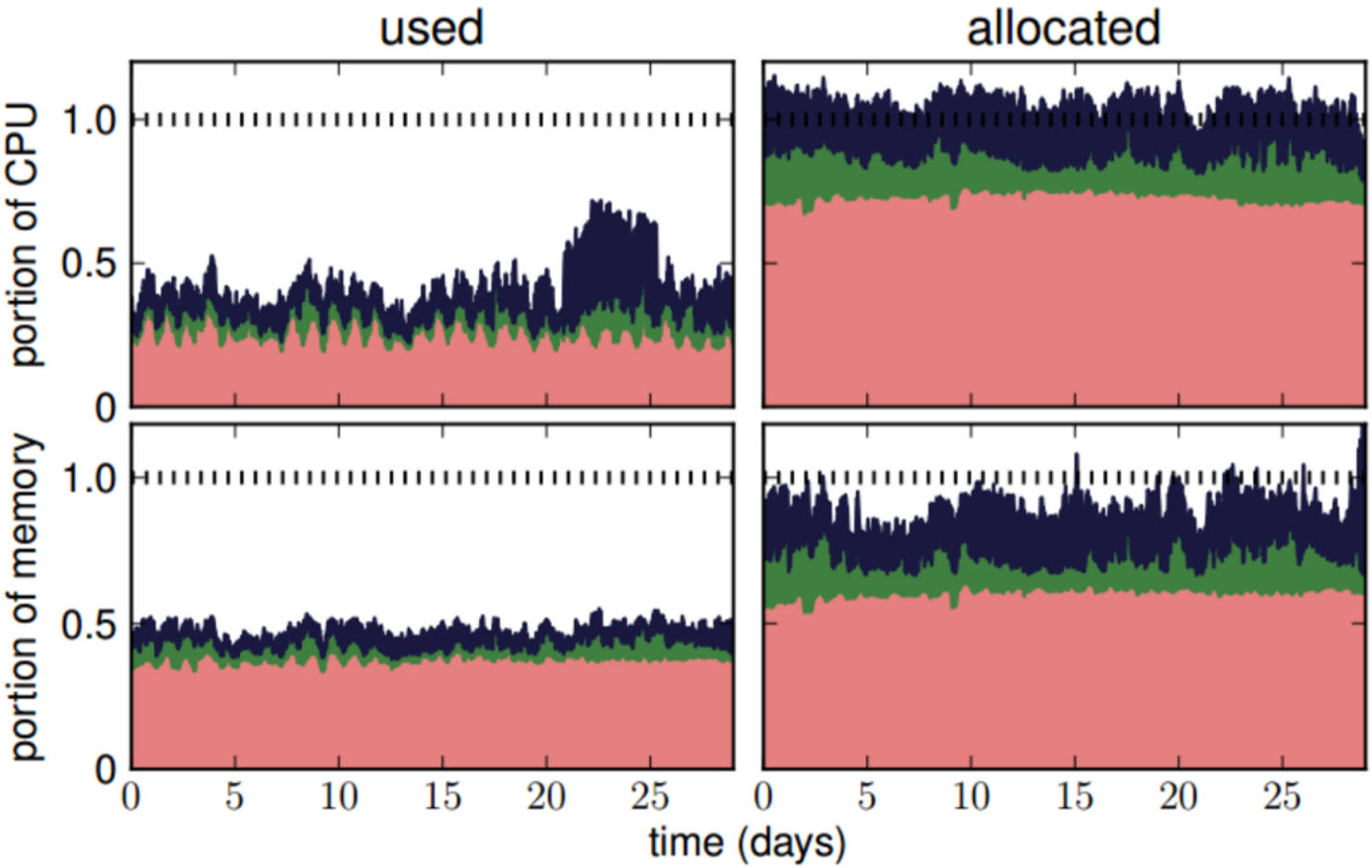
(a) *Additional machines that would be needed as a function of the number of smaller cells for five different original cells.*



(b) *A CDF of additional machines that would be needed divide each of 15 different cells into 2, 5 or 10 cells.*

3. **Resource reclamation**: estimate how many resources a task will use and reclaim the rest for work

Utilization III

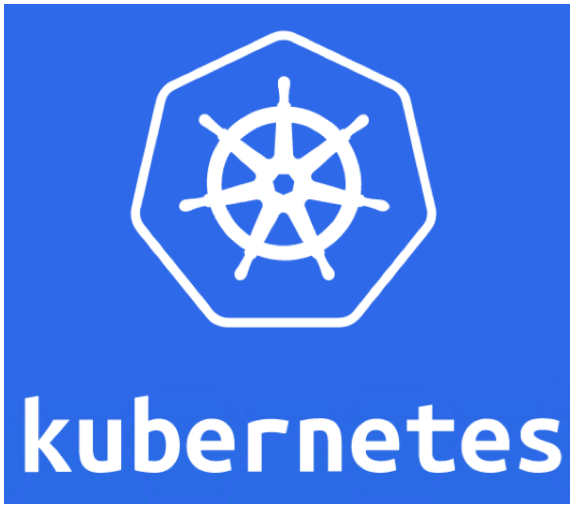


Lessons

1. Bad decisions
   - jobs are restrictive as the only grouping mechanism for tasks
   - one IP address per machine complicates things
   - optimizing for power users at the expense of casual ones
2. Good decisions
   - use of *allocs*
   - cluster management is more than task management
   - introspection is primordial
   - the master is the kernel of a distributed system

Kubernetes evolved from Borg

1. An open-source system for automating deployment, operations, and scaling of containerized applications
2. Pods: groups of containers
3. Labels
4. Replica controller
5. Services



That's all Folks!