Google Cloud

Borg: the Next Generation

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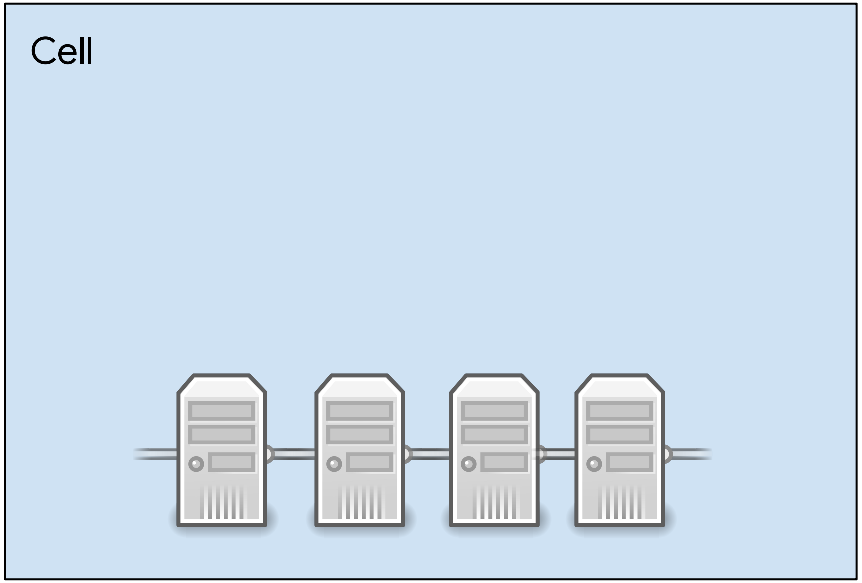
Borg

Google's internal cluster manager.

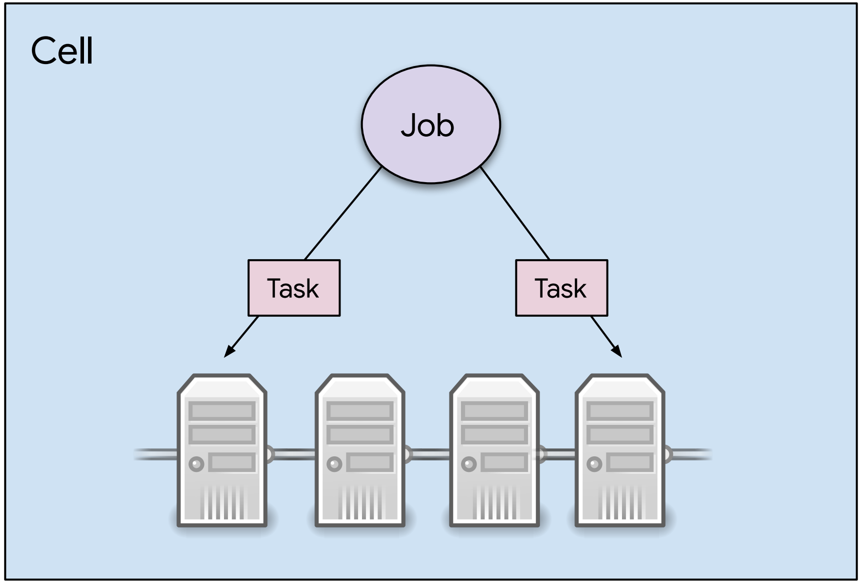
Cell: a set of machines managed by Borg as one unit.



Borg

Users submit work in the form of **jobs**

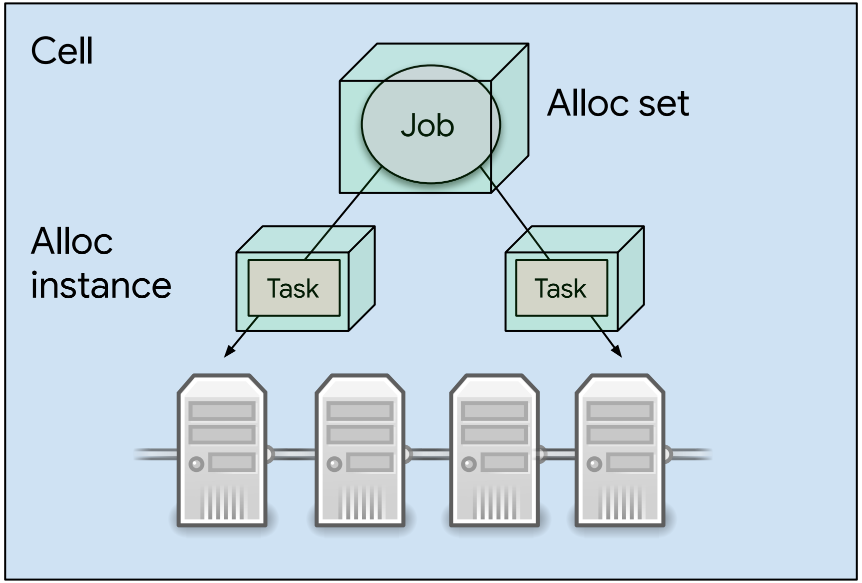
each of which contains one or more **tasks**.



Borg

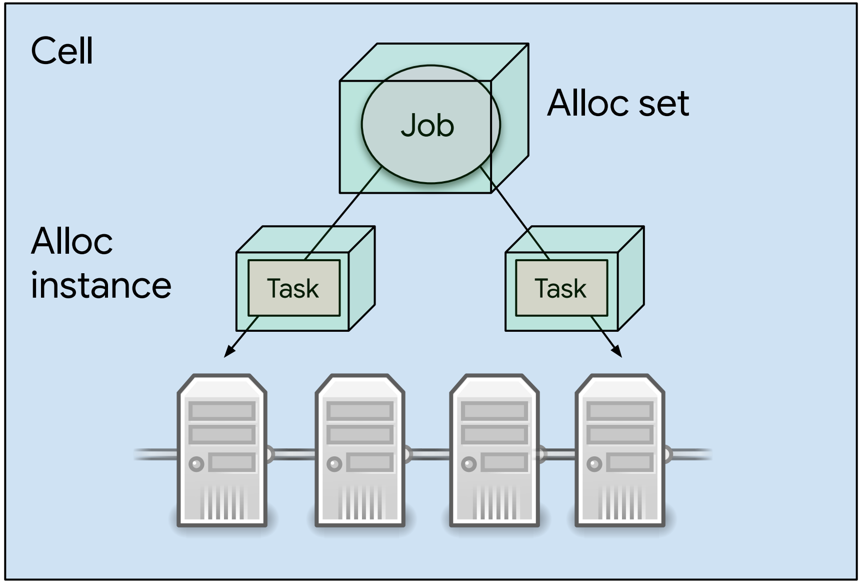
A job may run in an **alloc set**

making each of its tasks run in an **alloc instance**



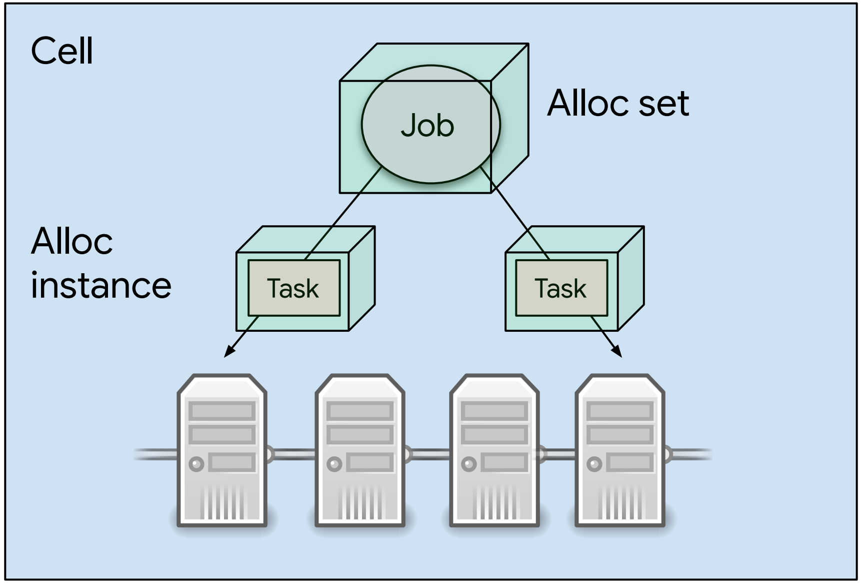
Borg

Jobs have **tiers**: production, mid, best-effort batch, free.



Borg

More info: "Large scale cluster management at Google with Borg" (EuroSys '15)



Borg **traces**

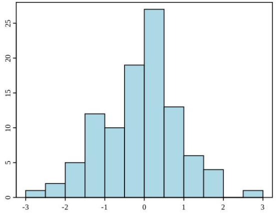
A single Borg trace describes the **workload** in a Borg cell:

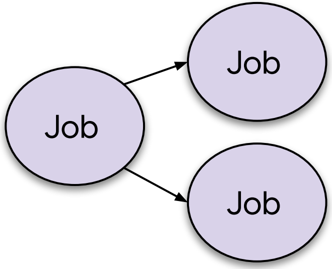
- {Jobs, tasks}, {alloc sets, alloc instances}
  - arrivals and departures: submit, update, finish
  - scheduling decisions: place, evict

- Resource allocations and usage

2011 trace: 1 cell from May, 2011

Borg traces: what's **new**




Job

Job

Job

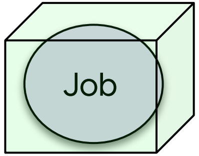
2019 trace: 8 cells for May 2019

- ~96k machines in 3 continents
- CPU usage histograms
- Job-parent information
- Autopilot (see companion paper in session 5)

github.com/google/cluster-data

Resources used by jobs

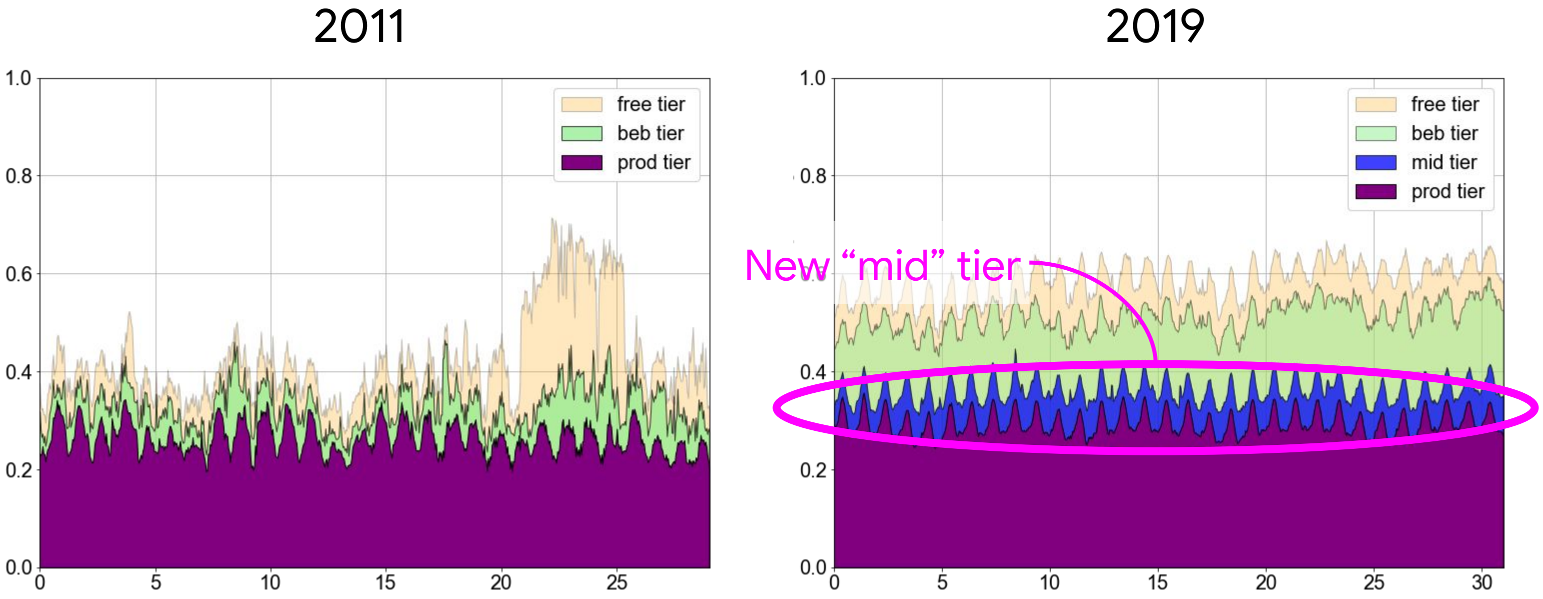
Two metrics:



- Resource used by job
- Resource allocated to job

Compute **used** by jobs

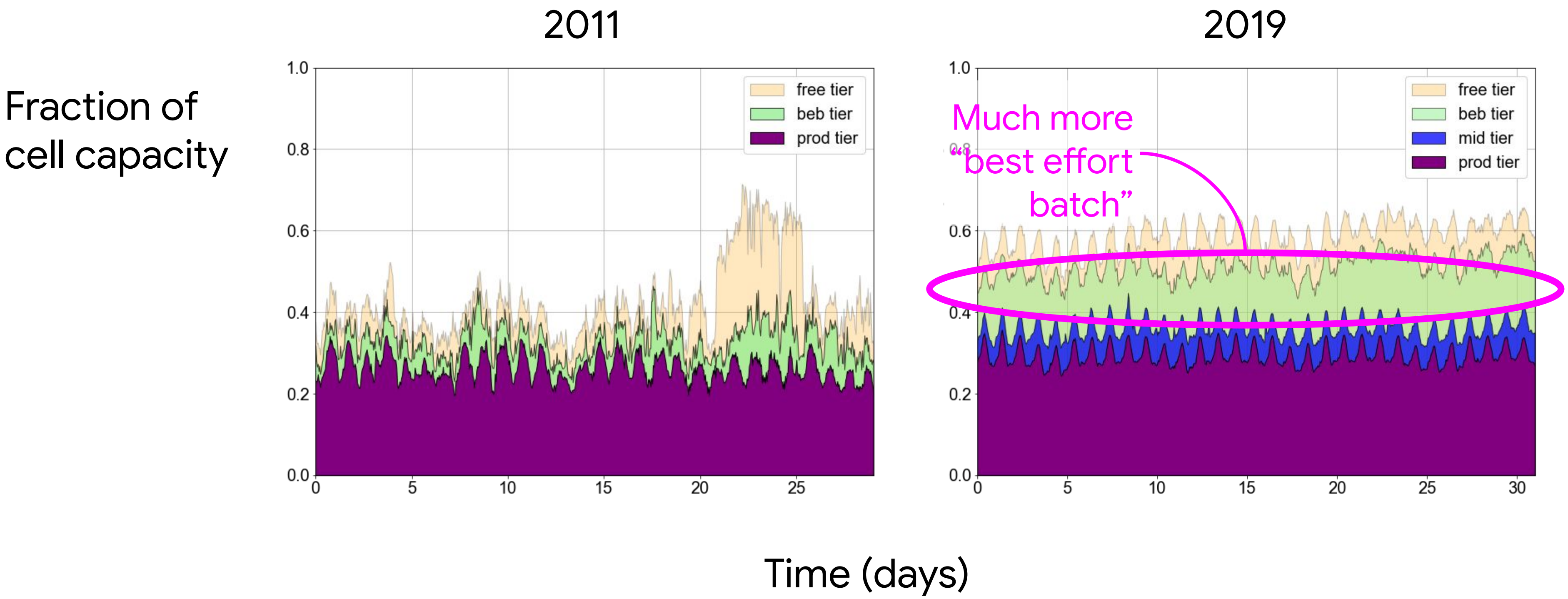
Fraction of cell capacity



New “mid” tier

Time (days)

Compute used by jobs

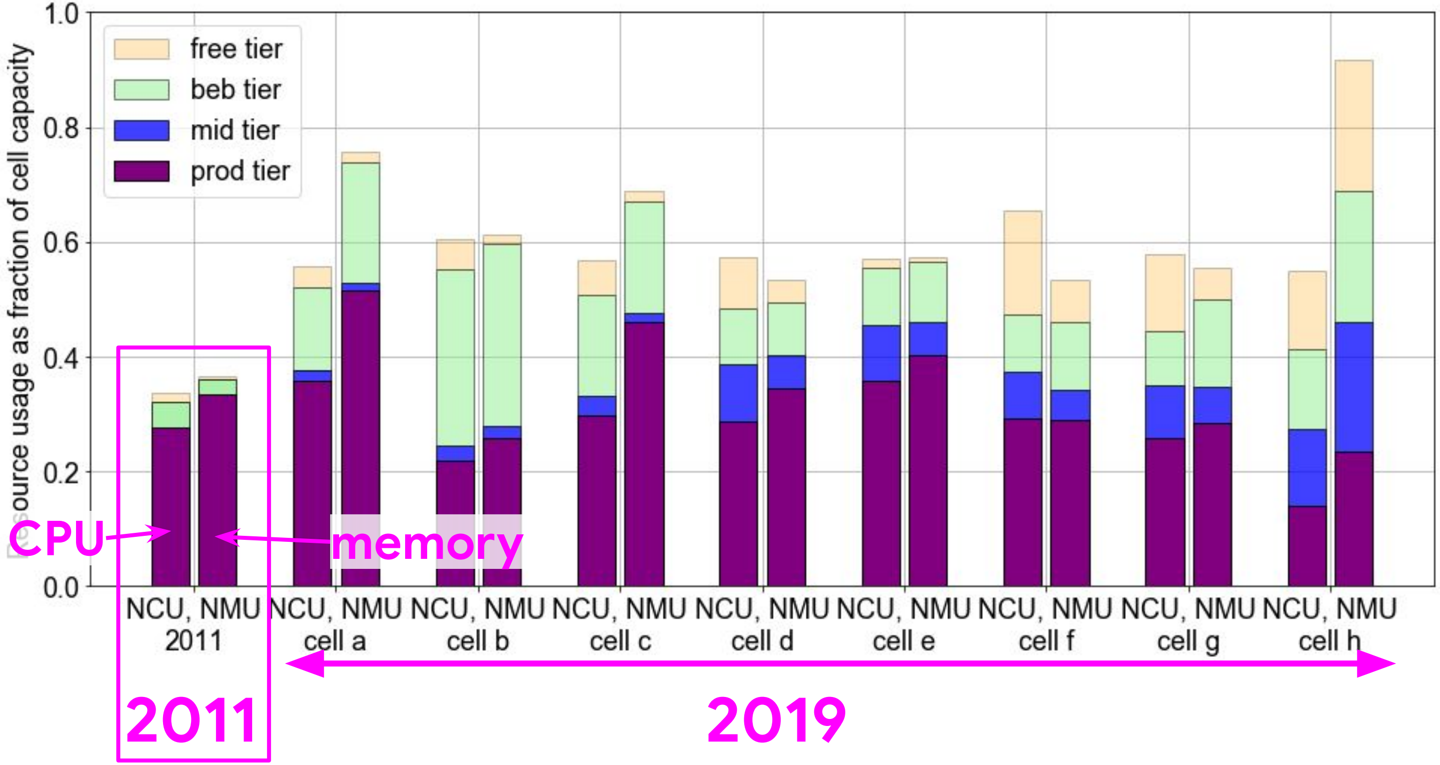


2011

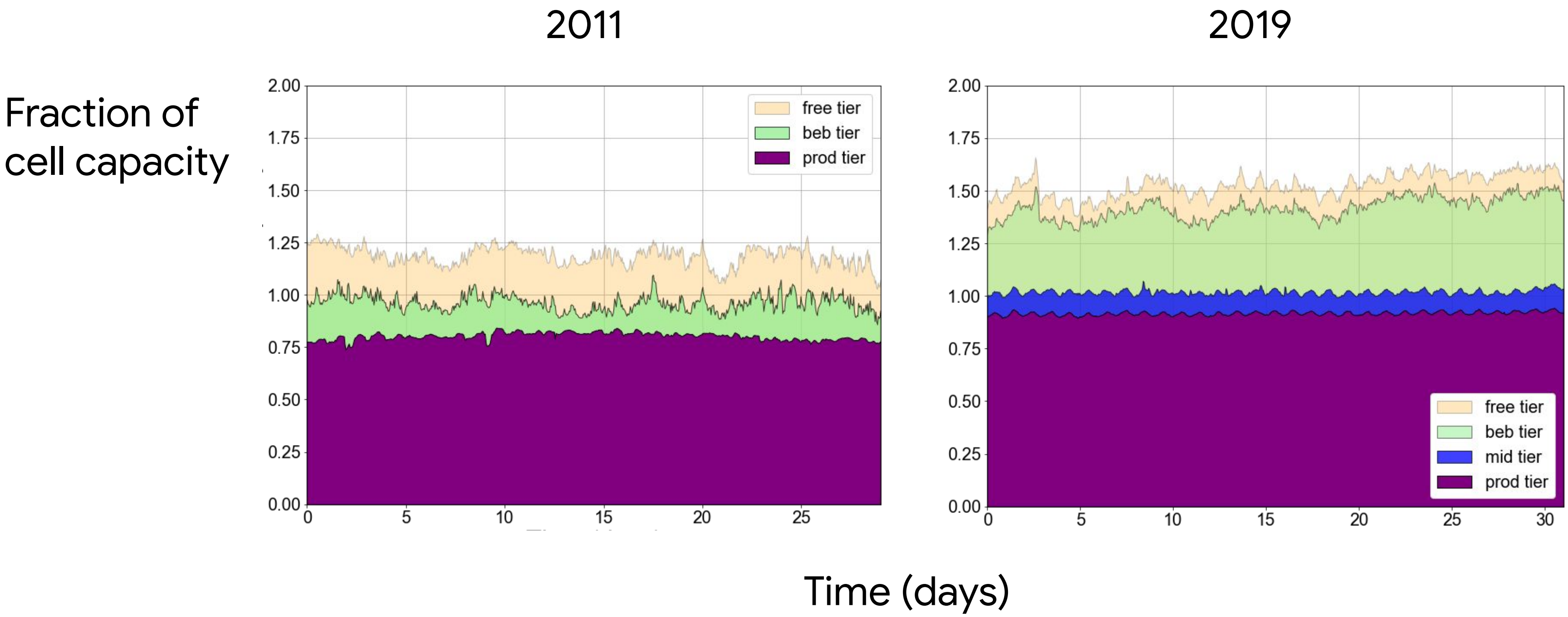
2019

Much more "best effort batch"

CPU + memory used by jobs



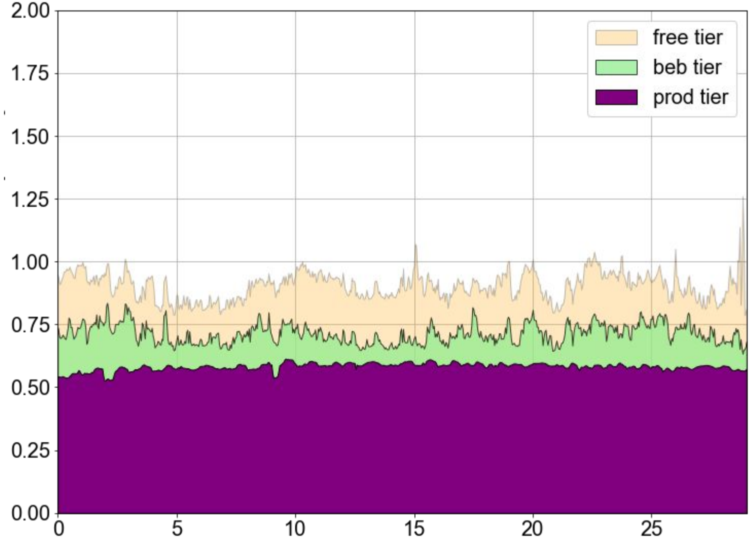
Compute allocated to jobs



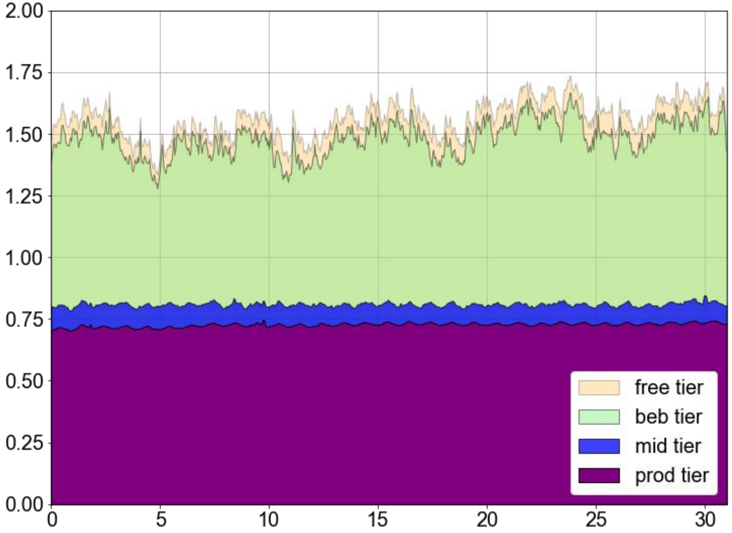
Memory allocated to jobs

Fraction of cell capacity

2011

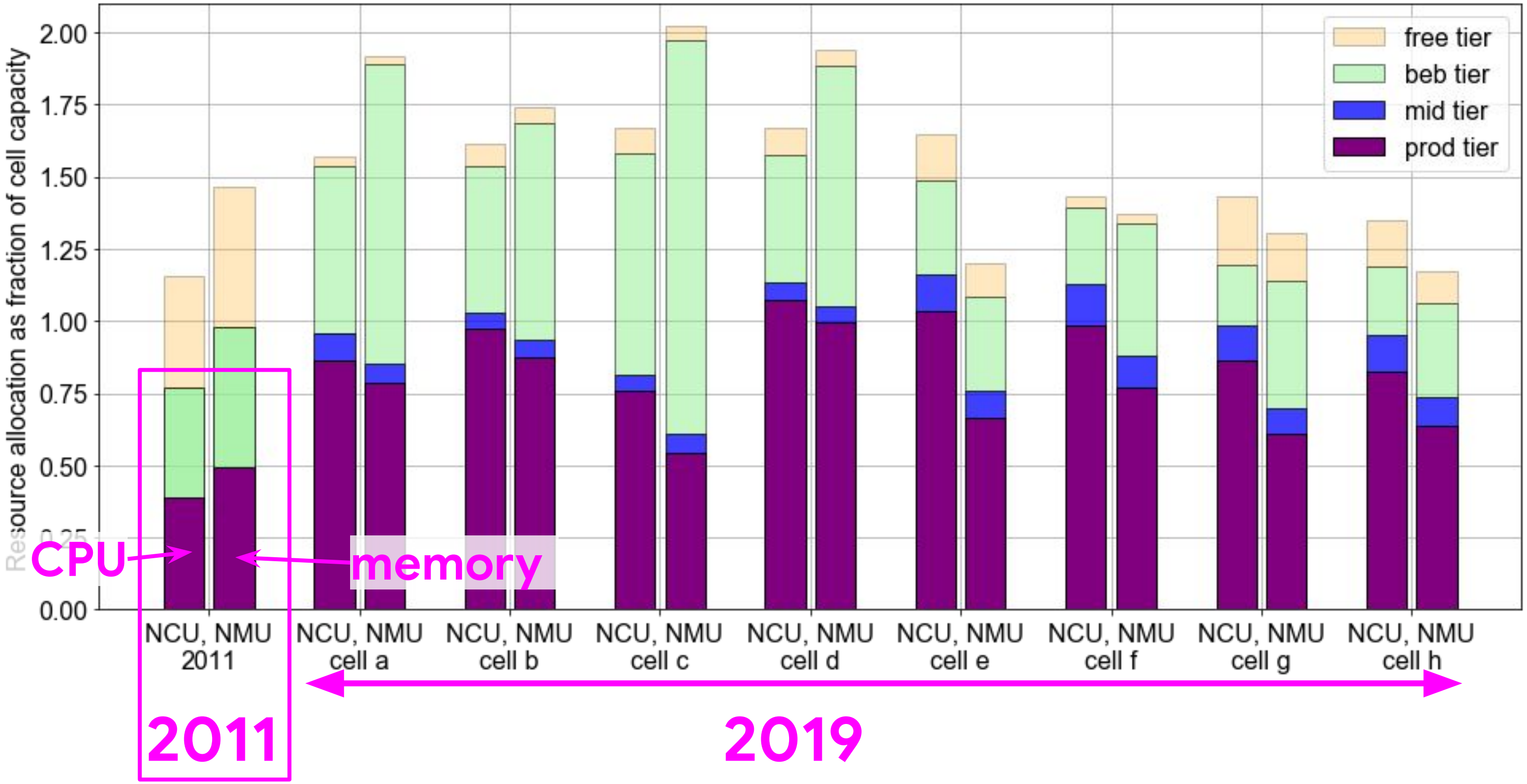


2019



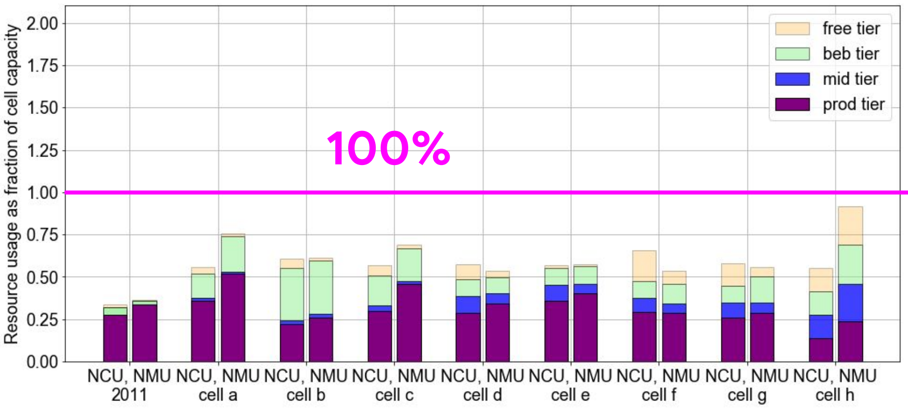
Time (days)

CPU + memory allocated to jobs

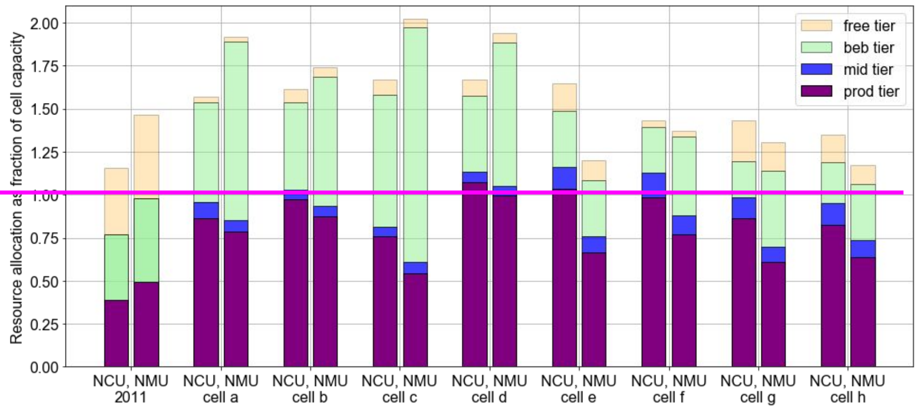


CPU + memory used vs allocation

Resources used by jobs

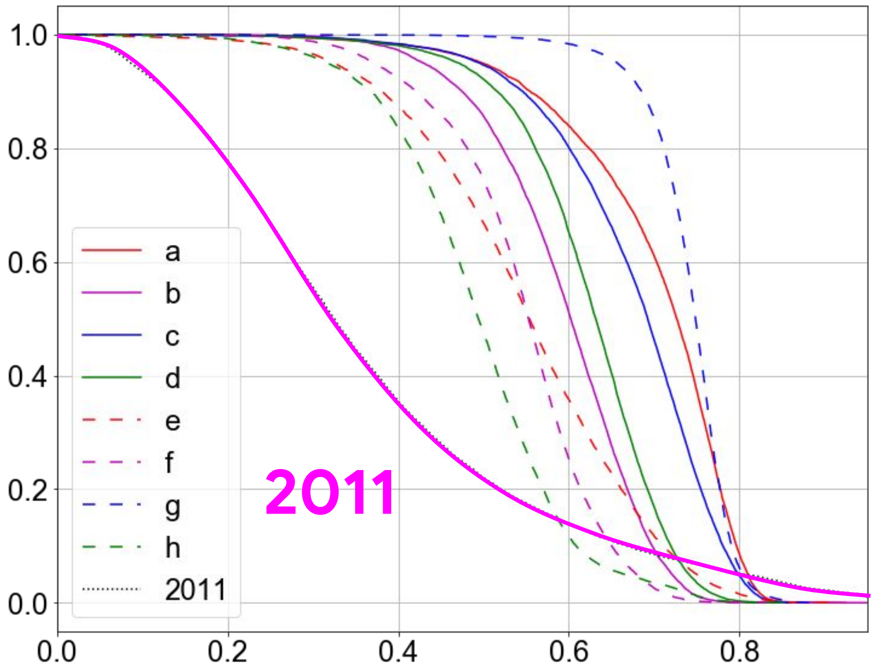


Resources allocated to jobs



Machines used by jobs

P(utilization > x)



x - utilization

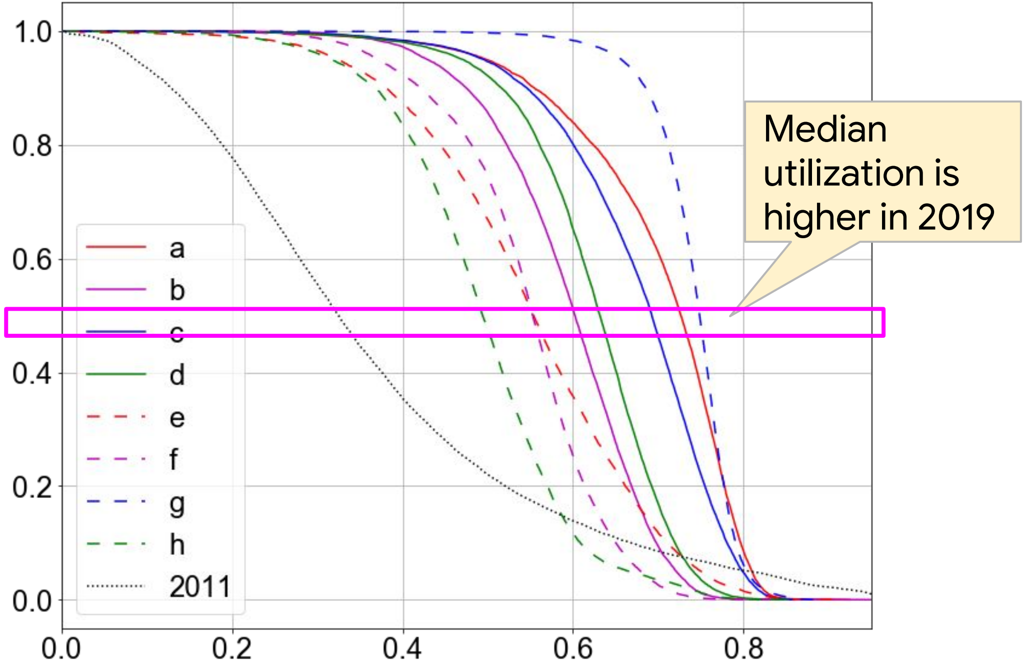
Machines used by jobs

P(utilization > x)

Median machine **in 2011:**
~ 30% utilized

Median machine **in 2019:**

50 - 77% utilized

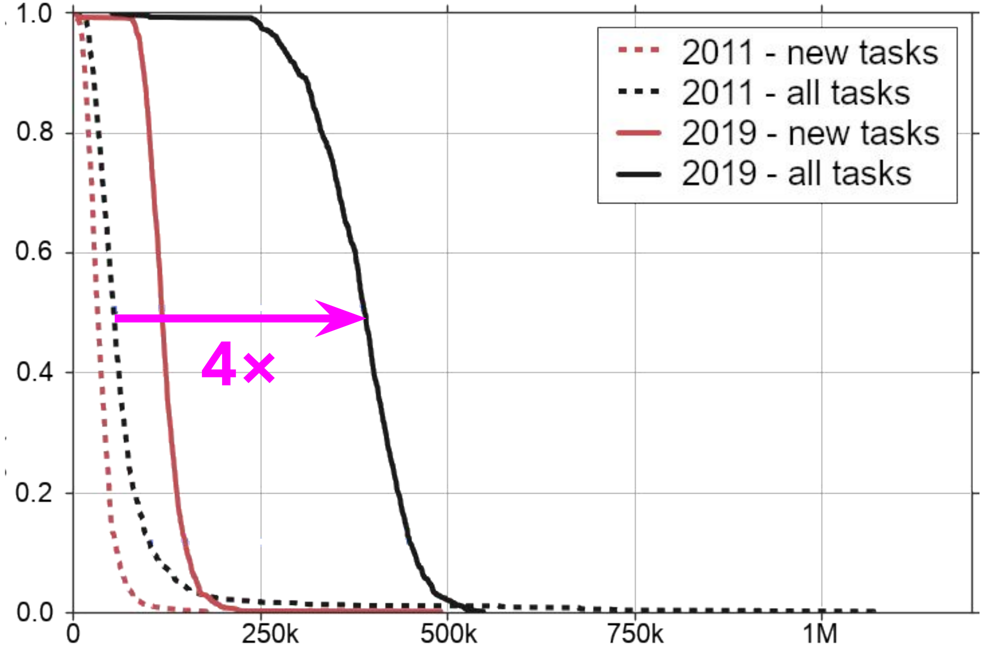


Median utilization is higher in 2019

x - utilization

Scheduler load is evolving

Scheduler load today:
~ **4 times** higher



Job usage has VERY high variability

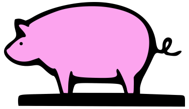
C^2 = variance / mean^2

for CPU-hours and memory-hours

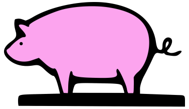
- CPU-hours of UNIX jobs (1996): C^2≈**50**
- CPU-hours of supercomputing jobs (2005): C^2≈**250**
- CPU-hours of Google Borg jobs (2011): C^2≈**8400**

2019 Google Borg trace: **23k**

Hogs and mice

Largest 1% of jobs: **hogs** 

Remaining 99%: **mice**

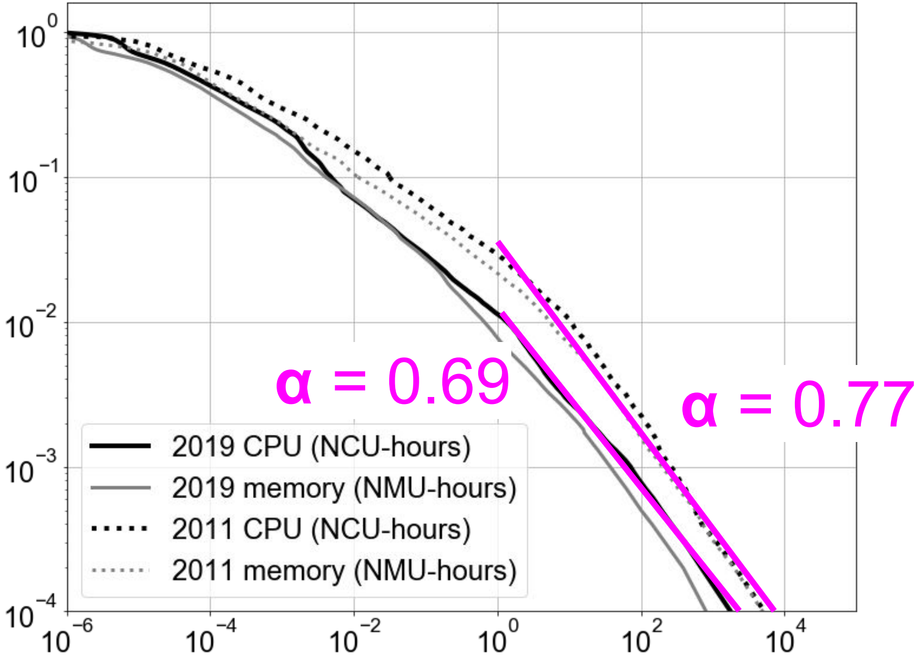
Fraction of resources consumed by 

- Prior work: 50%
- Google, 2011: 97.3%
- Google, 2019: **99.2%**

Job usage is heavy tailed

Fraction of jobs where:
{CPU, RAM}-hours > x

Even more
heavy-tailed!



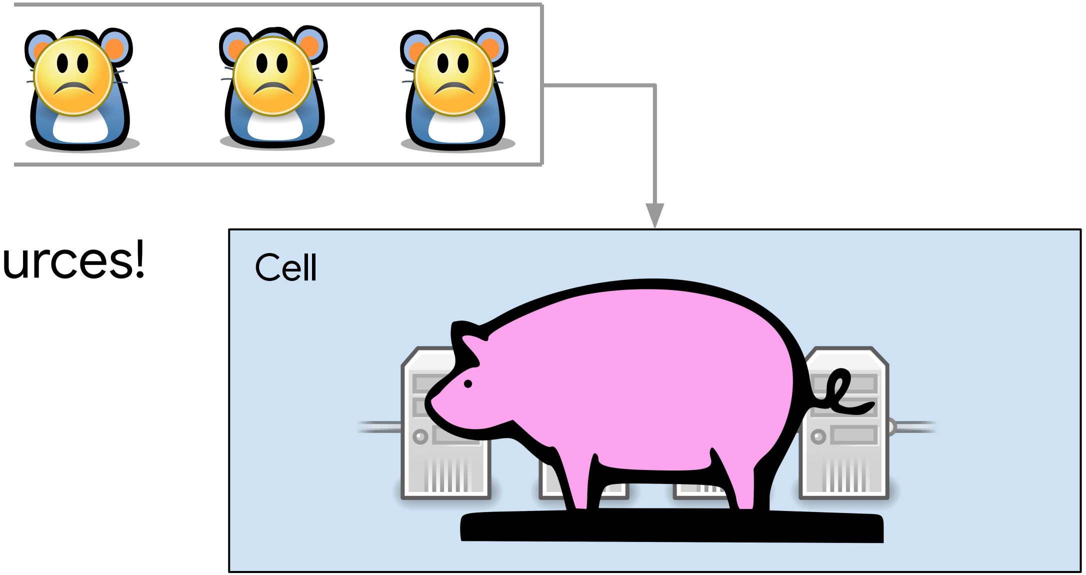
x - {CPU, RAM}-hours

Extremely
heavy tailed

Implications for scheduling

Since Google's workload has high C^2

Hogs can fill all the resources!



Summary

- New Borg workload trace:
  - 8 cells for month of May 2019
  - 2.4TB data accessed via BigQuery
  - **github.com/google/cluster-data**

- Workload and machine utilization have increased

- Disparity between hogs and mice more extreme than any other reported trace
  - largest 1% of jobs consume >99% of resources