Ωmega

Cluster management at Google

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Google

Cluster management: what is it?

- A fleet of *machines* live in *datacenters* placed in different *regions & countries*

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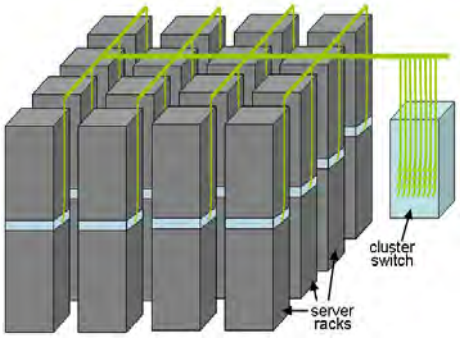
Cluster management: what is it?

- A datacenter contains 1 or more *clusters*

machine

rack: 40-80 machines
+ Ethernet switch



cluster

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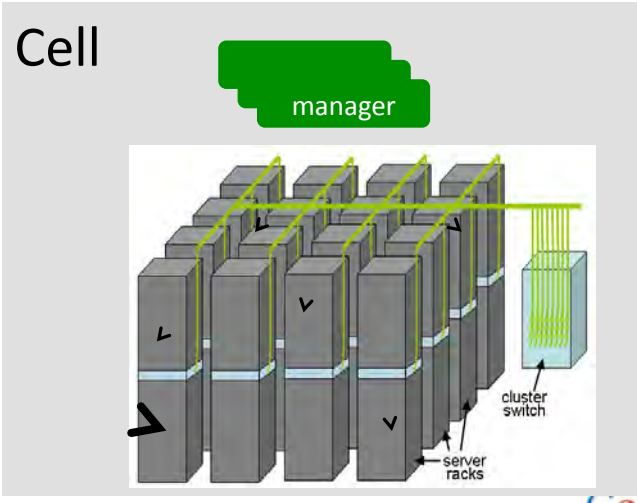
Cluster management: what is it?

- Clusters are managed as 1 or more *cells*



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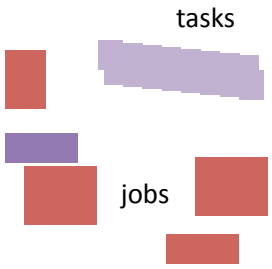
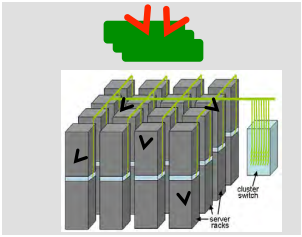
Cluster management: jobs

- Users submit *jobs* to a cell
- A job has up to a few thousand *tasks*



- Jobs & tasks have *requirements* (sizes, constraints)



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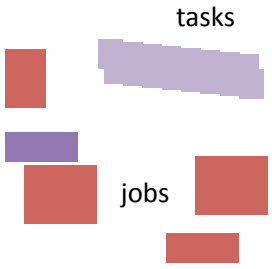
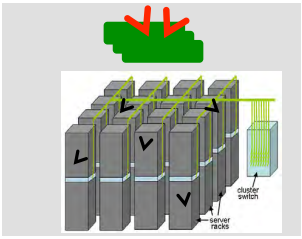
Cluster management: jobs

- Jobs & tasks have *requirements*
  - resource *shape* (e.g., how much CPU, RAM, …)
  - constraints (e.g., machine type, external IP)
  - software to run (“package”)
  - preferences





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Cluster management: jobs

Job types:

- *services*; e.g., user-facing (latency-sensitive)
- *batch*; e.g., MapReduce (throughput sensitive)

  – important or not
  – one-off or periodic
  – standalone or coprocessor (e.g., BigTable)
  – inter-job dependencies

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Cluster management: other stuff

- Machine lifecycles
  – provisioning; testing; repairs; upgrades
- Software lifecycle
  – e.g., OS install + upgrades + downgrades
- Cluster maintenance
  – Planned Change Requests (PCRs)
  – scheduling; draining; restoring
- Monitoring (stats, events, usage, …)

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Cluster management: storage

- **Persistent storage** is distributed (GFS, Colossus/CFS, BigTable)
  - spread across machines in cluster
- **Local storage** is volatile
  - cache for data being served
  - logging: (1) write locally; (2) async copy to persistent store

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Cluster management: scale

- Big: the storage system **holds a Petabyte**
- Google: the storage system pages you when there's **only a few Petabytes of space left**

-- Luiz Barroso

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Cluster management: faults ☹

> 1%	Rate of uncorrectable DRAM errors/ machine/year
2-10%	Annual failure rate of disk drives
~2	Crashes/machine/year
2-6	OS upgrades/machine/year
> 1	Power utility events per year

-- Luiz Barroso Google

Cluster management: faults ☹

A 2000-machine service sees
>10 machine crashes per day

Main causes of service outages:
networking, power, "oops"

Rarer events:
wild dogs, sharks, dead horses,
copper thieves, drunken hunters, …

-- Luiz Barroso/Jeff Dean
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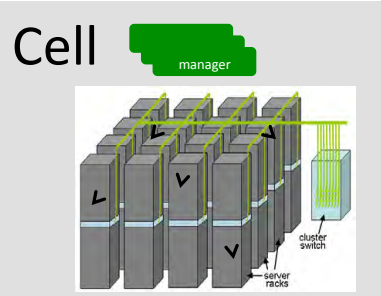
Cluster management: goals

1. Run everything :-)
2. High utilization
3. Predictable, understandable behavior



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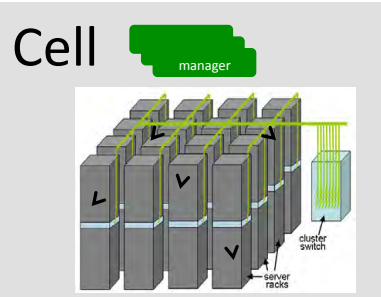
Cluster management: goals

4. Fine control for the big guys (resource efficiency)
5. Ease of use for others (innovation efficiency)
6. Keep going (failure tolerance)



7. At large scale
8. With few people

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Cluster management: goals

- Q: why not energy/power?
- A: we *do* care about energy/power proportionality

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Cluster management: goals

- Q: why not energy/power?
- A: we *do* care about energy/power proportionality

- But …
  - best way to save energy is to write good software
  - Google PUE was 1.13 in Q1'2011 (3-month weighted average)
  - don't buy idle machines!

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Cluster management: pre-Omega

- Current system was built 2003-4
- Works pretty well ☺

- Beginning to run out of steam …
  - scale (largest clusters)
  - inflexibility (ease of adding new features)
  - internal complexity (ease of adding new people)

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Ωmega

- The "second system" …
- Main *user* goals: predictability & ease of use
- Main *team* goal: flexibility

- Caveat: Omega is currently being prototyped
  - not in production!
  - many things will change!
  - it may never be deployed!

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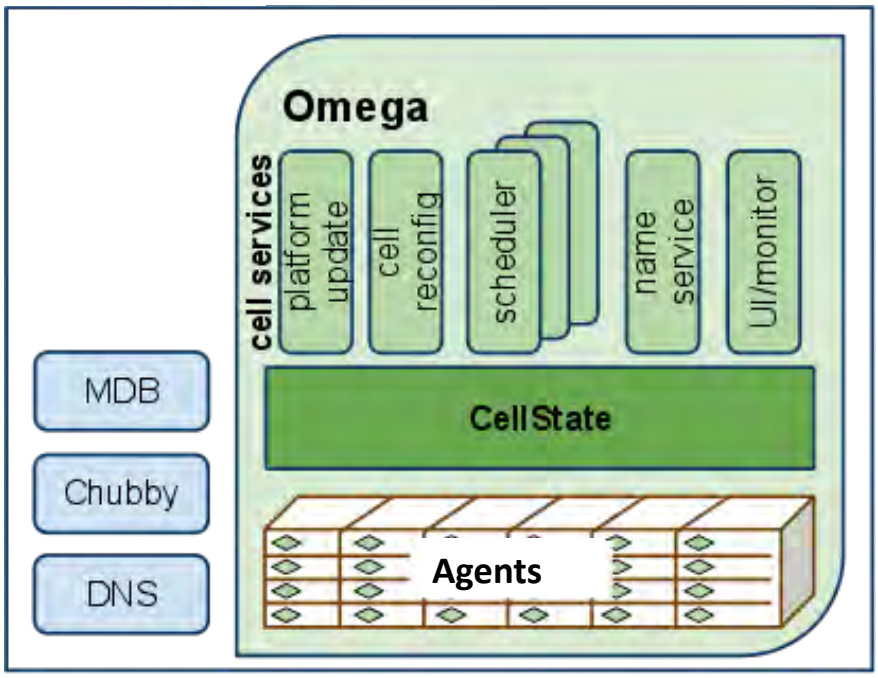
Ωmega the general approach



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Ωmega the general approach

- Dedicated "**vertical***s*" for different needs
  - services, batch, machine management
- Central shared **state**
  - calendar of allocation decisions
  - minimal necessary data
  - no policies; just enforces invariants
- **Failures** are a first-class property
  - the resource model

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Omega issues: *intentions*

Avoid detailed specifications of *how*

- **not**: "place 40 tasks on that rack, 20 on this one"
- **not**: "I need 4.6 CPUs of processor type *p1*"

Use *goals* (SLOs/SLAs)

- "<=2 tasks down at a time (99.9%ile)"
- "<25ms request latency (95%ile)"

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Omega issues: *failure tolerance*

- Goal: limit the number of concurrent outages
  - topology-aware scheduling
  - surety: likelihood of resources being available
- Fault detection
  - real fault, or just lost touch?
  - time to detect *vs.* false positives
  - correlated failures

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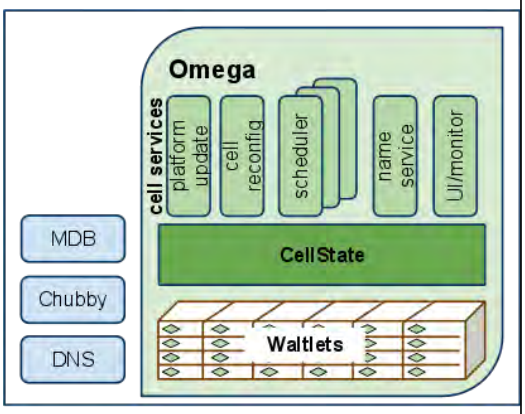
Omega issues: *master scalability*

- Calendaring
  - super-efficient "does it fit?" checks
  - scheduling horizon? edge effects?



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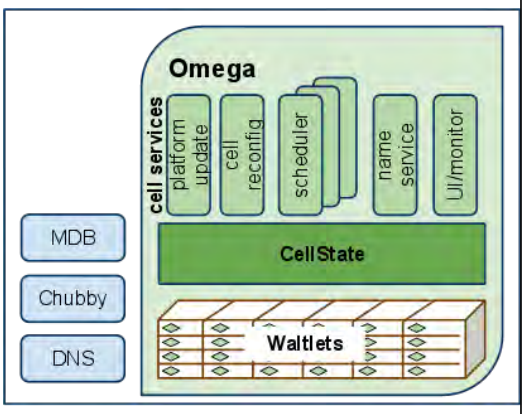
Omega issues: *master scalability*

- Multiple scheduler verticals
  - livelock / mutual interference
  - optimistic concurrency?
  - what needs to be communicated?



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Omega issues: *predictable behavior*

In the machine

- normalized performance (CPU, memory/NUMA)
- **performance isolation**
  - low latency **and** high throughput
  - storage?
  - caches?
- security isolation (PII, SOX)

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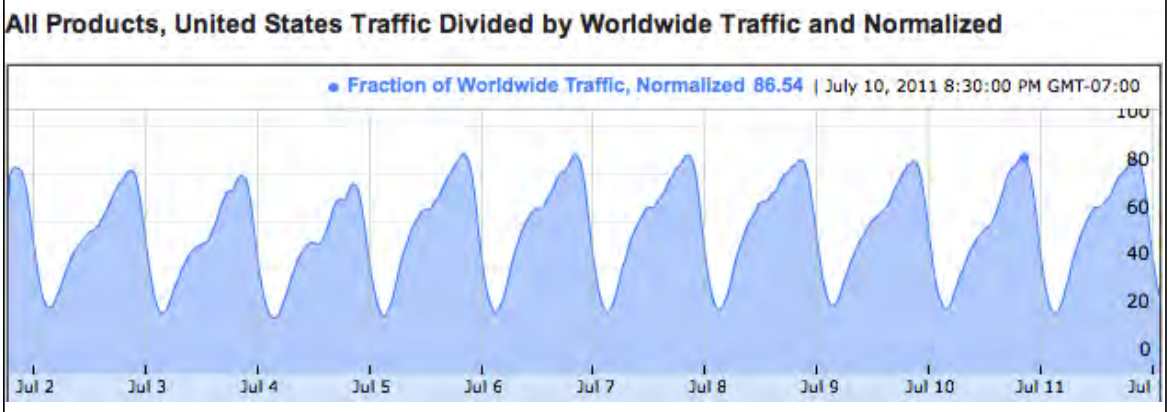
Omega issues: *predictable behavior*

Under load



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Omega issues: *predictable behavior*

Across the cell

- "why was my job not scheduled?"
- "where should I provision a new service?"

Approaches

- admission control
- explanations that make sense
- avoid the problem

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Omega issues: *objectives*

SLOs and SLAs

- what can/should be offered?
- how can they be controlled for at runtime?
- handling evolution

"Fair" objective functions

- is fairness useful/important?
  (reality is more complicated)

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Omega issues: *cell management*

It's 3am and your pager goes off

- are we in trouble?
- are we about to get into trouble?

- what should we do about it?

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Omega issues: *ease of use*

How much can we simplify things?

- "here's a binary … run it"
- predictions based on prior history may help
- parameters?

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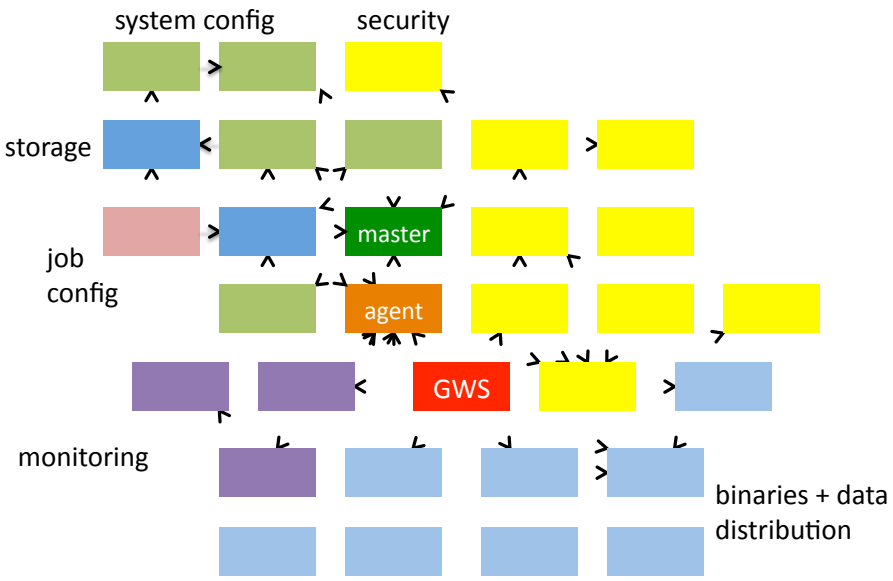
Omega issues: *configuration*



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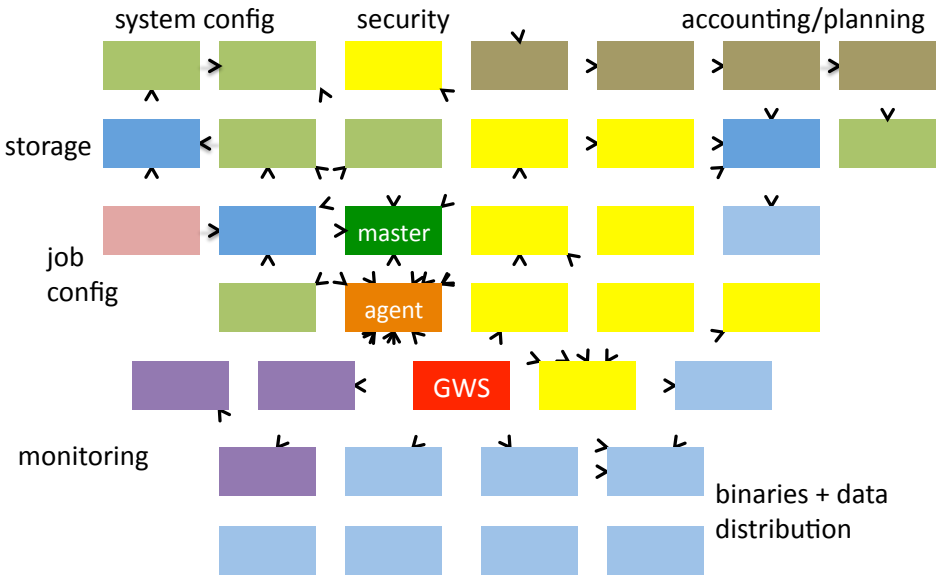
Omega issues: *configuration*



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Issues: *configuration*

- Make an app work right for one instance: *simple*
  - Google Docs uses ~50 systems and services
- Make an app work right in production: ***priceless***
  - run it in half a dozen cells
  - release a new version
  - fix it on the fly in an emergency
  - move one copy to another cell

http://melinathinks.com

Google

Summary

Ωmega

- Large-scale systems have some fun problems
  - driven by scale + failures
  - enormously fruitful ground for CS research
- Configuration may be **the** next big challenge

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