EC/CS 528: Cloud Computing

Resource Management and Sprint Demos

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BU Department of Electrical & Computer Engineering

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Announcements

- Talk about OpenShift/Kubernetes from Daniel McPherson: Wednesday, Nov. 16, 2022

- Reaching out for mid-term

Framework Isolation

- Mesos uses OS isolation mechanisms, such as Linux containers and Solaris projects
- Containers currently support CPU, memory, IO and network bandwidth isolation
- Not perfect, but much better than no isolation

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Analysis

- Resource offers work well when:
  - Frameworks can scale up and down elastically
  - Task durations are homogeneous
  - Frameworks have many preferred nodes
- These conditions hold in current data analytics frameworks (MapReduce, Dryad, …)
  - Work divided into short tasks to facilitate load balancing and fault recovery
  - Data replicated across multiple nodes

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Large-scale cluster management at Google with Borg

By: Abhishek Verma, Luis Pedrosa, Madhukar Korupolu, David Oppenheimer, Eric Tune, John Wilkes

Google Inc

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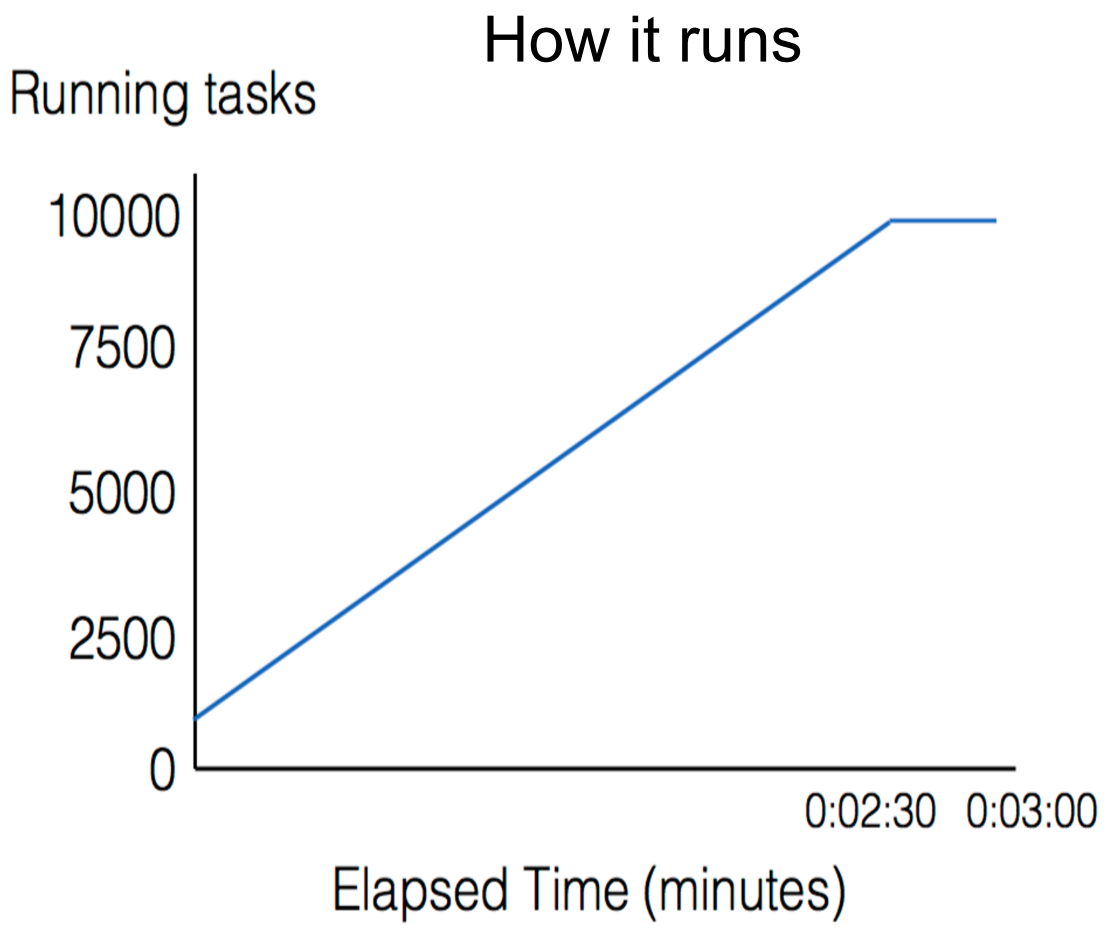
Example

```
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
}
```

Example



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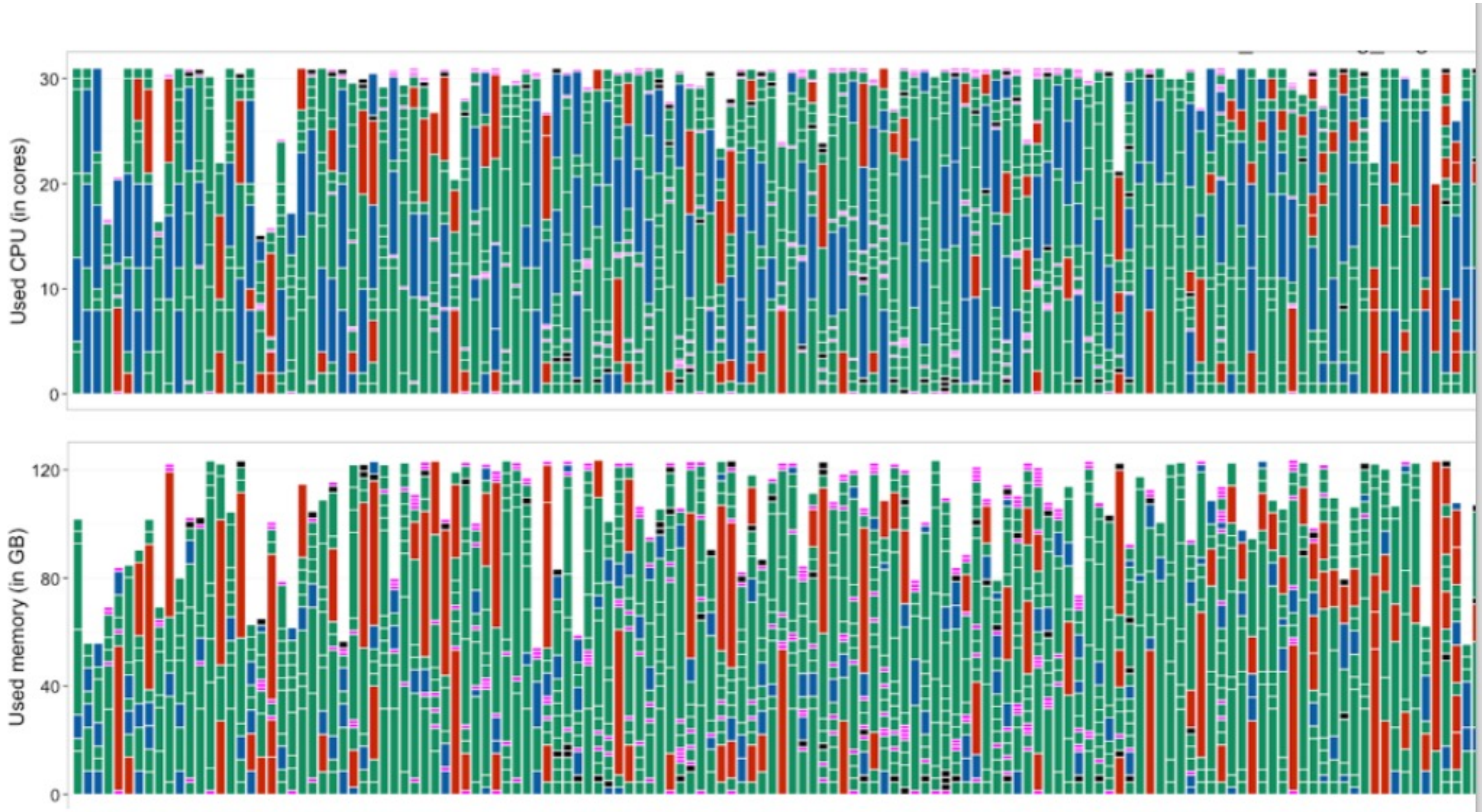
Main Benefits

- Scalability to thousands of machines, efficiently shares the machines
- Abstracts away details of resource management, monitoring, fault handling from users
- Operates with high reliability and availability

Borg comparison to other resource managers

- Infrastructure for scale, packaging…
- Containers
- Master that distributes work

Efficiency: multiple resources



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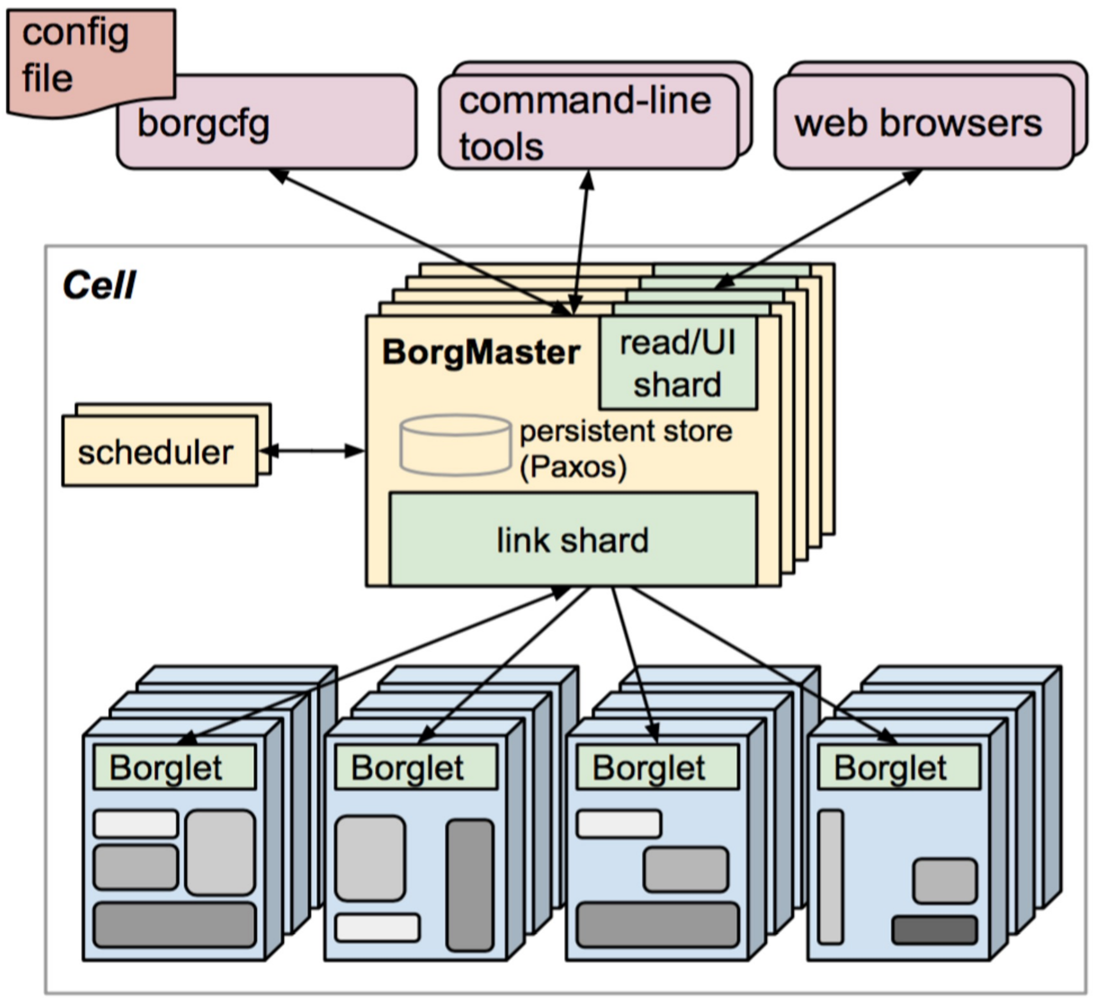
Architecture



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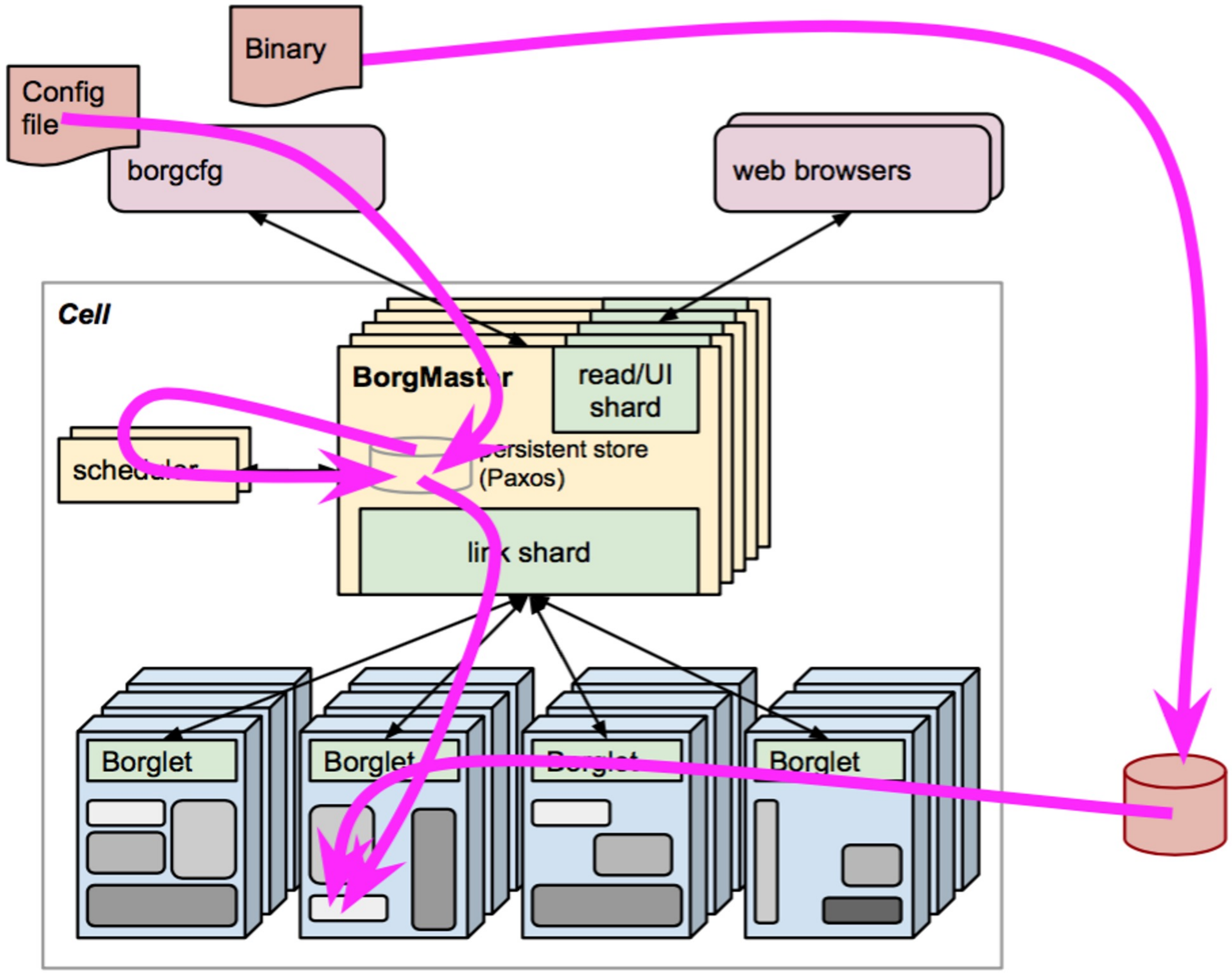
Control Flow



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Abstractions

- Cell – group of tightly coupled nodes
- Job – name, owner, collection of identical tasks
- Task – set of linux processes running in a container
- Allocs and Alloc sets - allocation of resources on one machine, or for one job

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Abstractions

- Priority – relative priority of jobs running or waiting to be run
  - Higher will preempt/kill lower
  - Production do not preempt each other
  - Bands: 1) monitoring, 2) production, 3) batch, 4) best effort
- Quota – used to decide which jobs to admit for scheduling; max resources job can ask for
  - Users tend to buy more than they need
  - System sells more lower-priority than it has
  - Systems tends to be oversubscribed

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Characteristics of infrastructure

- Medium cell size around 10K machines
- Heterogenous in resources (core, memory, storage) & capabilities, e.g., external IP

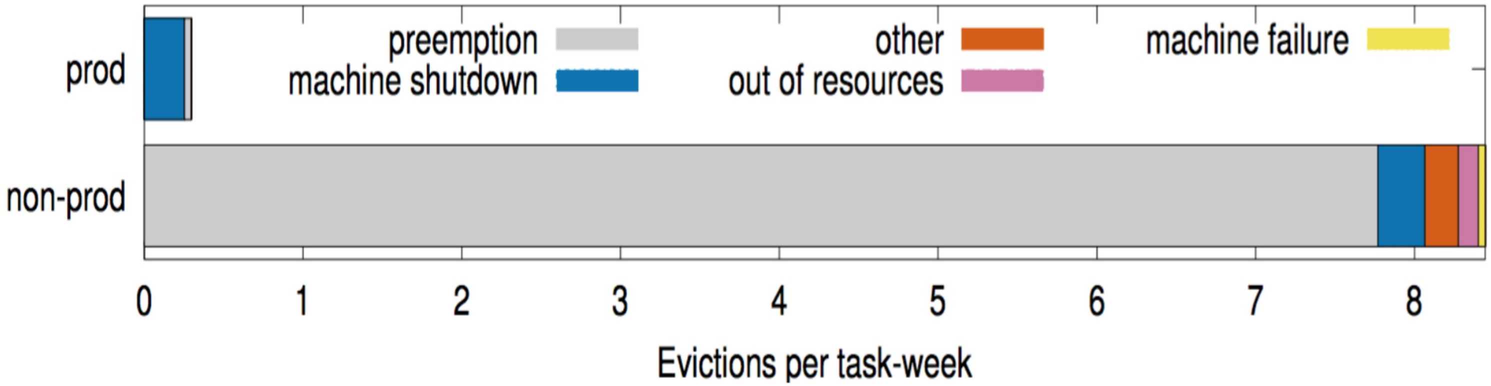
Characteristics of workload

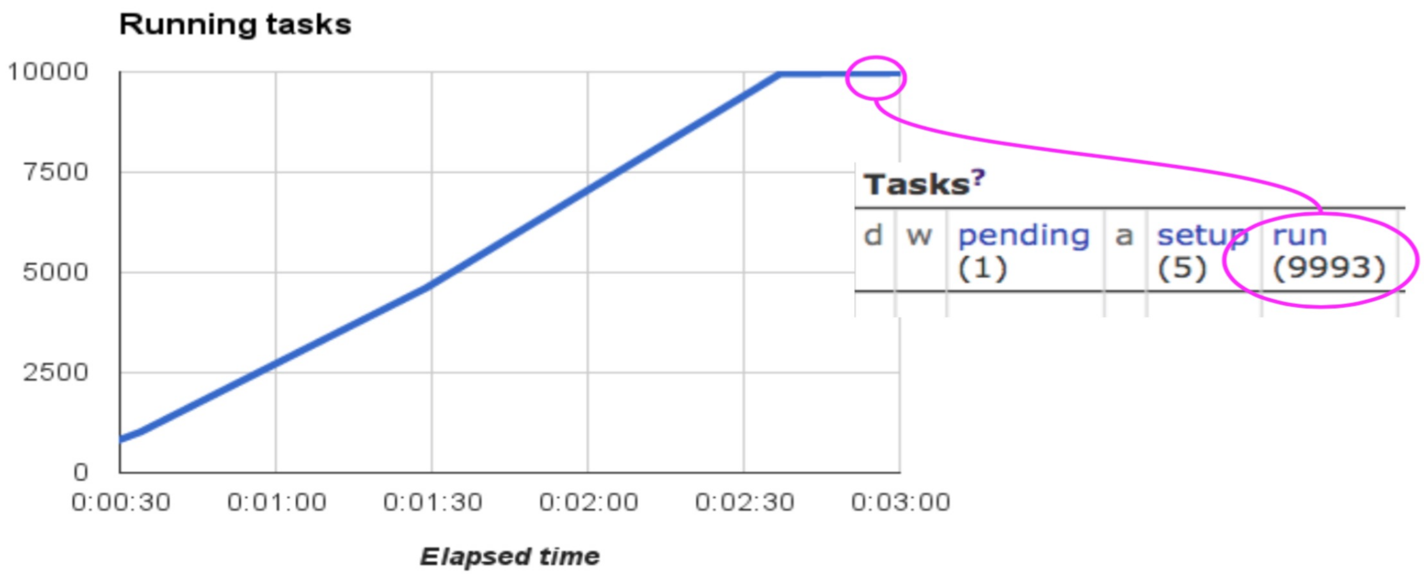
- Long running services
  - Latency sensitive, e.g., Gmail, Google docs, search, BigTable
  - Many frameworks (MapReduce, Pregal…)
  - Diurnal usage pattern
  - Usually controller with master job, one or more worker job
  - Runs as Prod
- Batch jobs
  - Take from seconds to days
  - Insensitive to performance fluctuations

Characteristics of app execution environment

- Everything run in container
- Binaries are statically compiled: dependencies
- Tasks have built in HTTP server
  - Health, and thousands of performance metrics
  - Borg can monitor, and restart tasks don’t respond
- Tasks assumed to handle failures

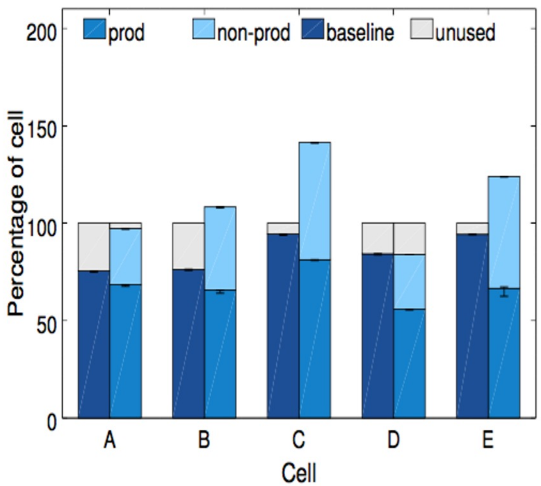
Availability



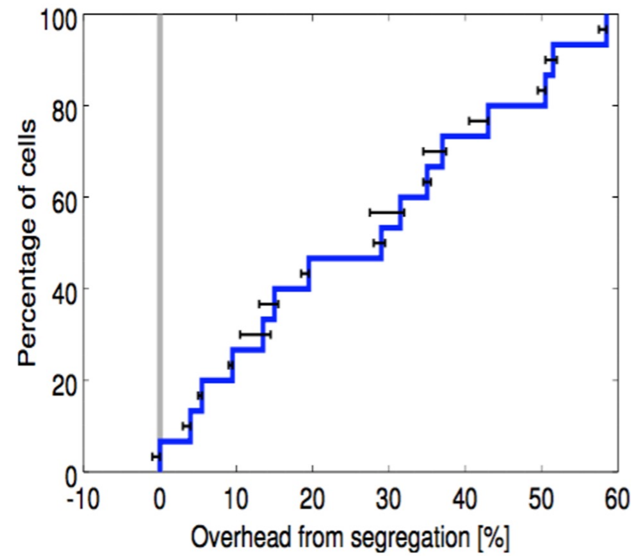


Utilization

Cell sharing: Segregating prod and non-prod work into different cells would need more machines



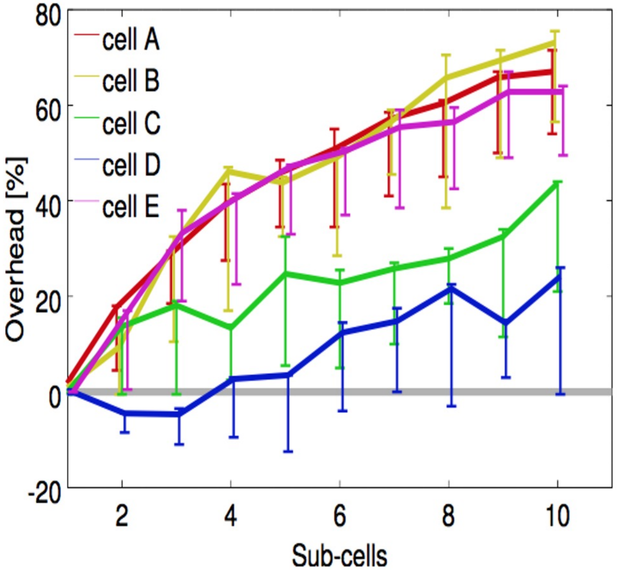
(a) *The left column for each cell shows the original size and the combined workload; the right one shows the segregated case.*



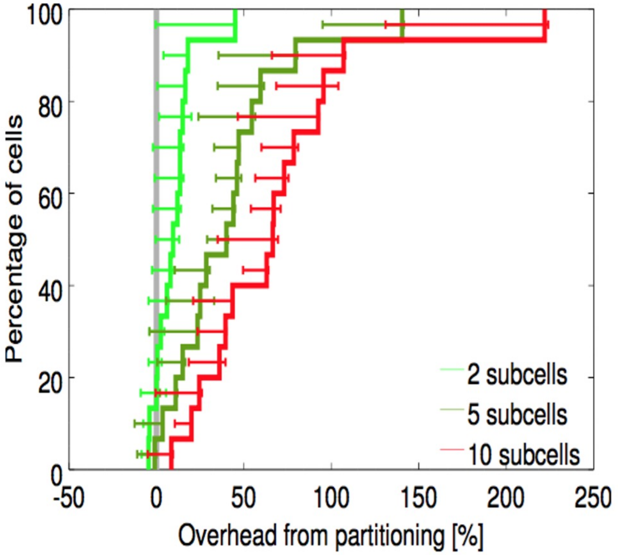
(b) *CDF of additional machines that would be needed if we segregated the workload of 15 representative cells.*

Utilization

Cell size: subdividing cells into smaller ones would require more machines



(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 to divide each of 15 different cells into 2, 5 or 10 cells.*

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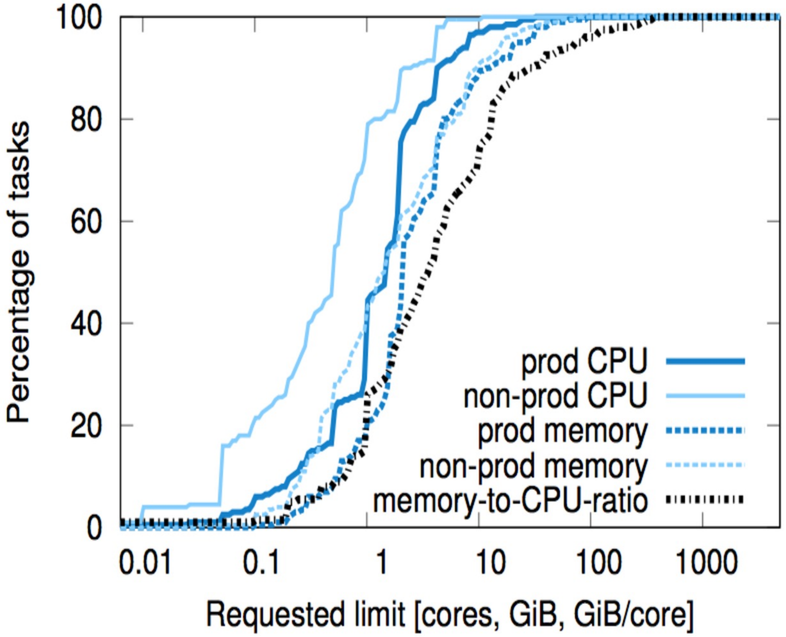
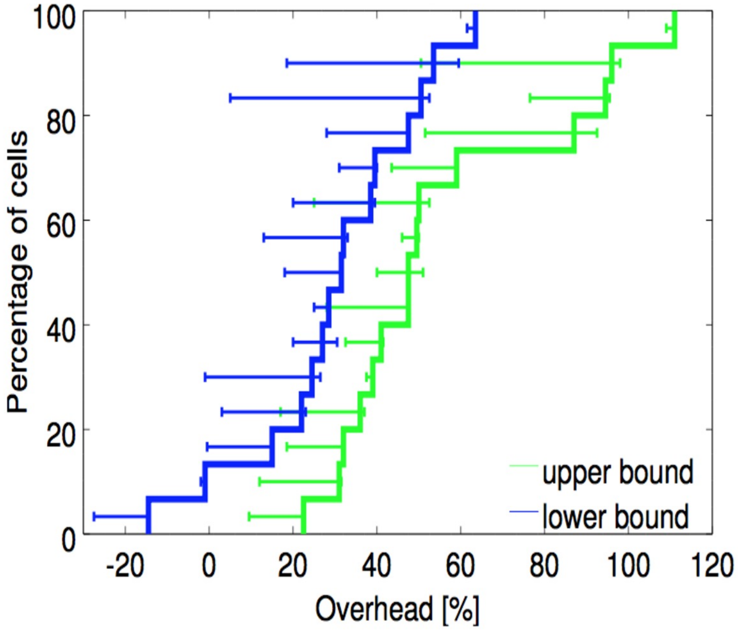
Task use/Bucket size





Lessons

- Bad
  - 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 – hard to use
- Good
  - Allocs are useful
  - Cluster management is more than task management
  - Introspection is vital – expose everything
  - The master is the kernel of a distributed system

Comparison to Mesos

- Infrastructure for scale, packaging…
- Containers
- Master that distributes work

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Differences

- Borg/Kubernetes
  - more prescriptive monitoring…
  - Scheduler that looks at all constraints, more efficient
  - Can schedule arbitrary jobs
- Mesos
  - exokernel like model, exploits/works with frameworks; not arbitrary jobs
  - Doesn’t talk about jobs that require more resources than available
  - Much much simpler
  - Arguably more general
  - Probably more scalable

More thoughts

- Borg wasn't published, and Kubernetes was not created, until after Mesos was published

Building warehouse-scale computers

or … what's it like to supply *exponential growth*

john wilkes 2017-03

Google Cloud Platform

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$29.4B

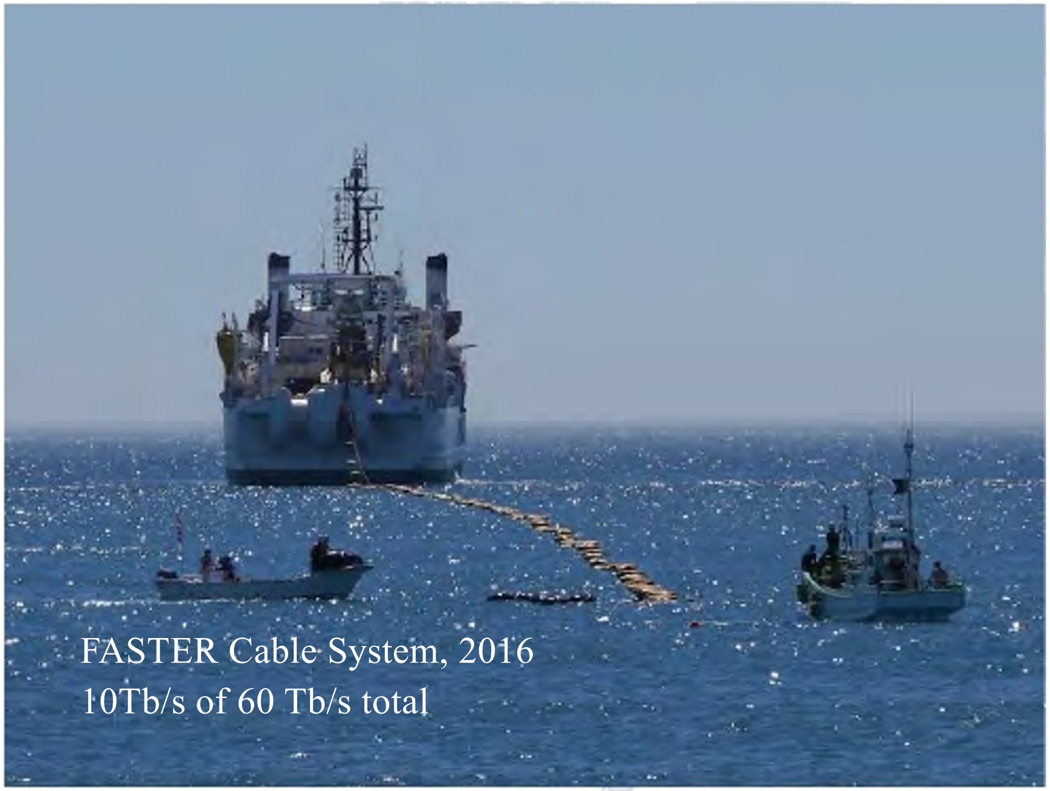
3-year trailing CapEx, as of March 2017

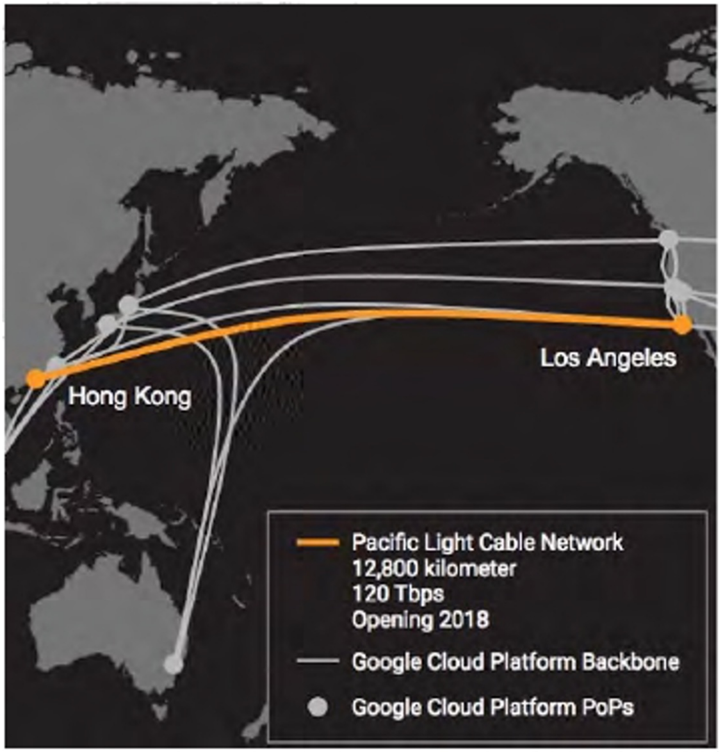
GCP infrastructure

2016-12: 6 regions, 18 zones, over 100 points of presence, and a well-provisioned global network comprised
of hundreds of thousands of miles of fiber optic cable.

Planning for network

Google network: 12 years to build and still growing





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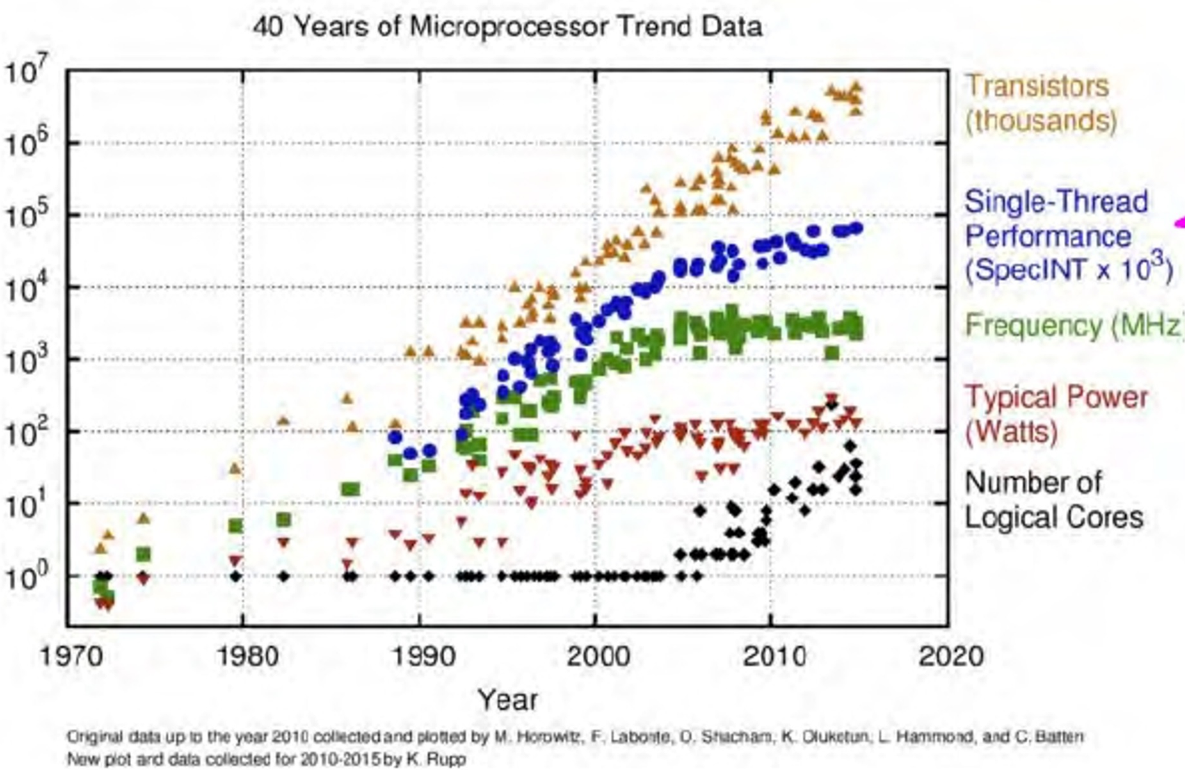
Meanwhile – what’s up with Moore’s law?



Single-core performance plateauing after decades of exponential growth

Google Cloud Platform

Graph from [40 Years of Microprocessor Trend Data](), Karl Rupp,

Meanwhile – what's up with Moore's law?

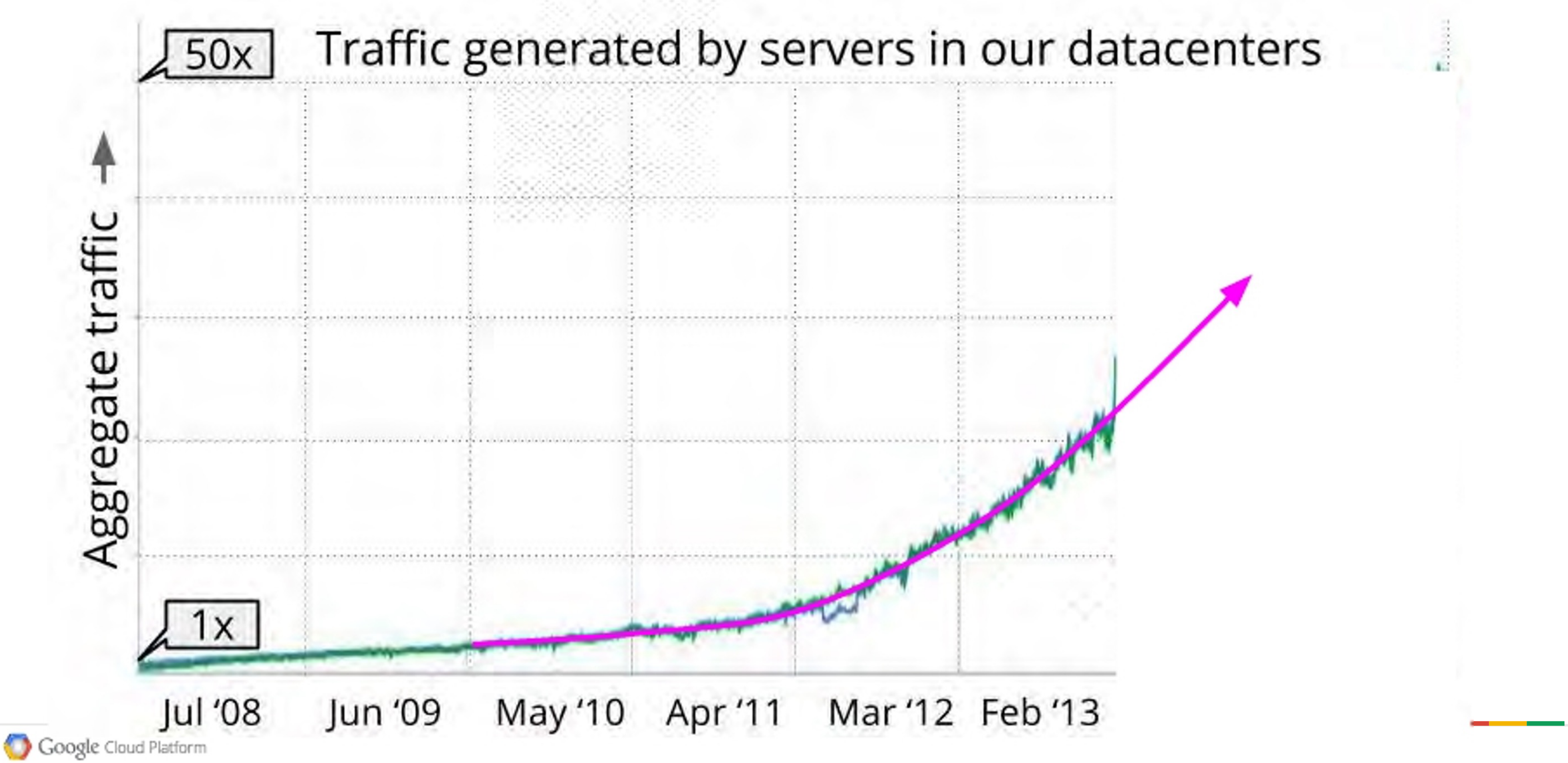
Accelerators to the rescue!

	Intel®Xeon® ProcessorE7-8890 v4CPU	NVIDIAK80GPU (perGPU)	AMDS9300x2GPU (perGPU)	NVIDIAP100GPU
Cores	24 (48threads)	2496 streamprocessors	4096 streamprocessors	3584 streamprocessors
Memory Bandwidth	85GBps	240GBps	512GBps	732GBps
Frequency (boost)	2.2(3.4)GHz	562MHz(875MHz)	850MHz	1.13(1.30)GHz

20% per year: CPU processing power
40% per year: data growth
50% per year: GPU processing power

Jupiter Rising: A Decade of Clos Topologies and Centralized Control in Google's Datacenter Network. SIGCOMM 2015.

How much capacity do we need?



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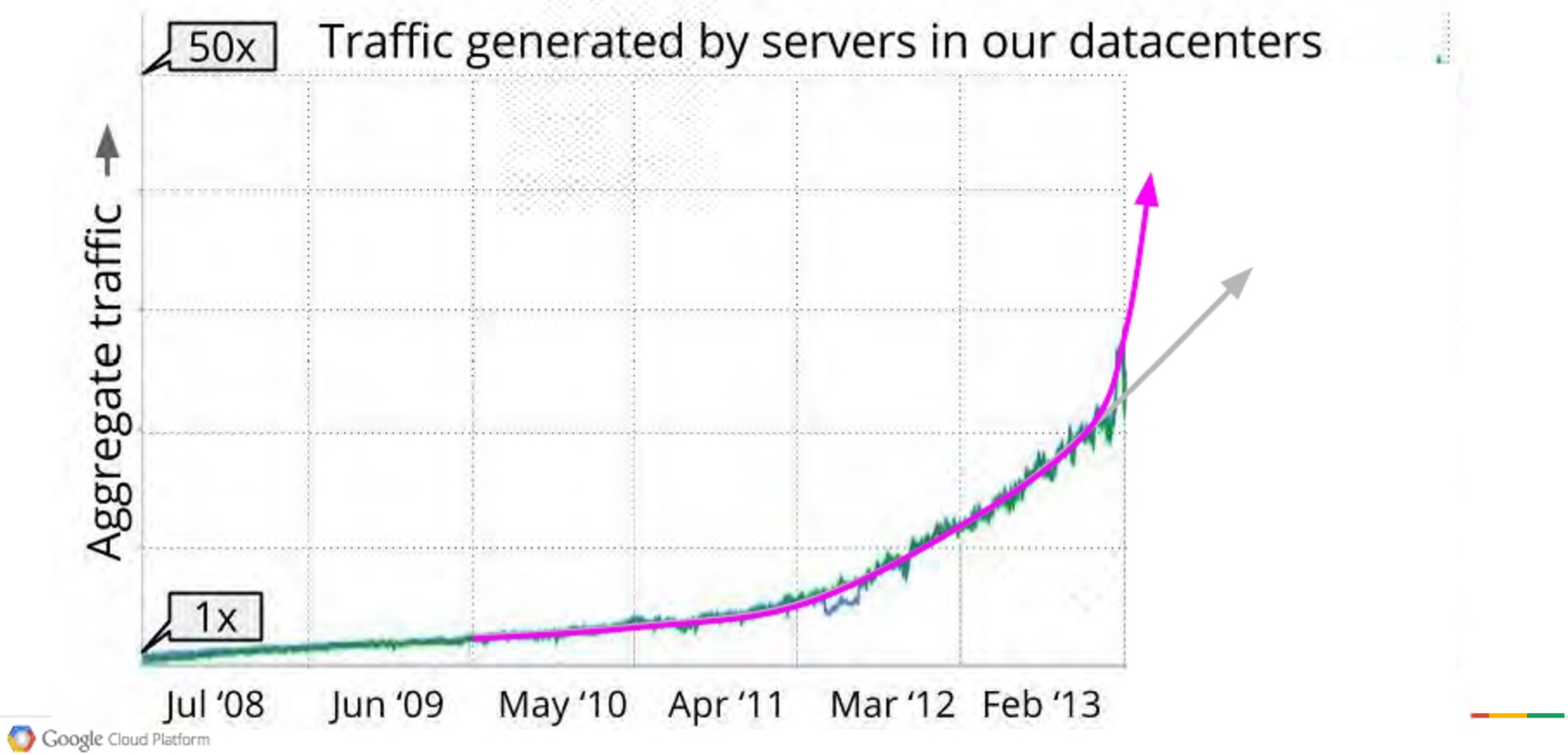

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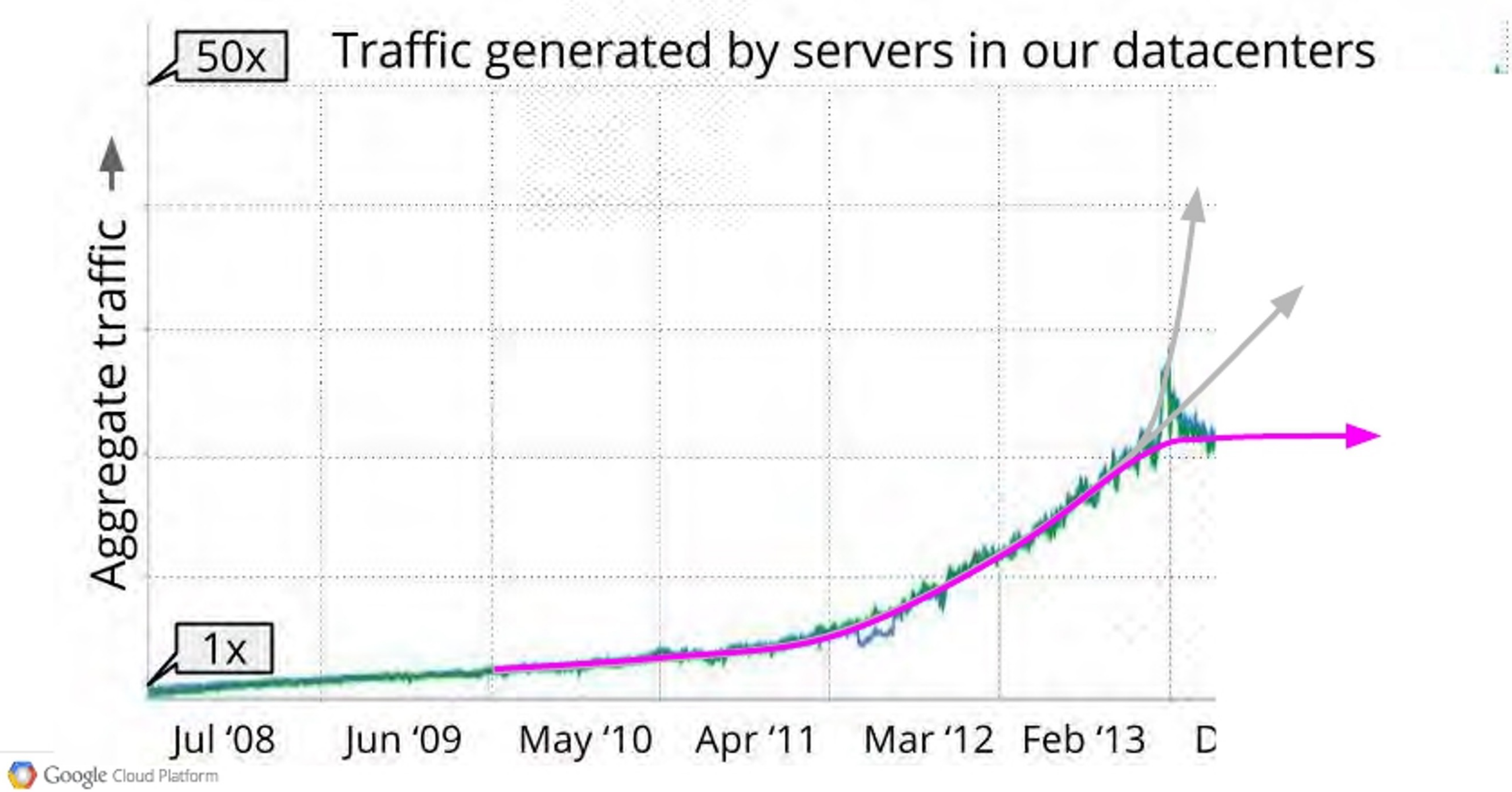

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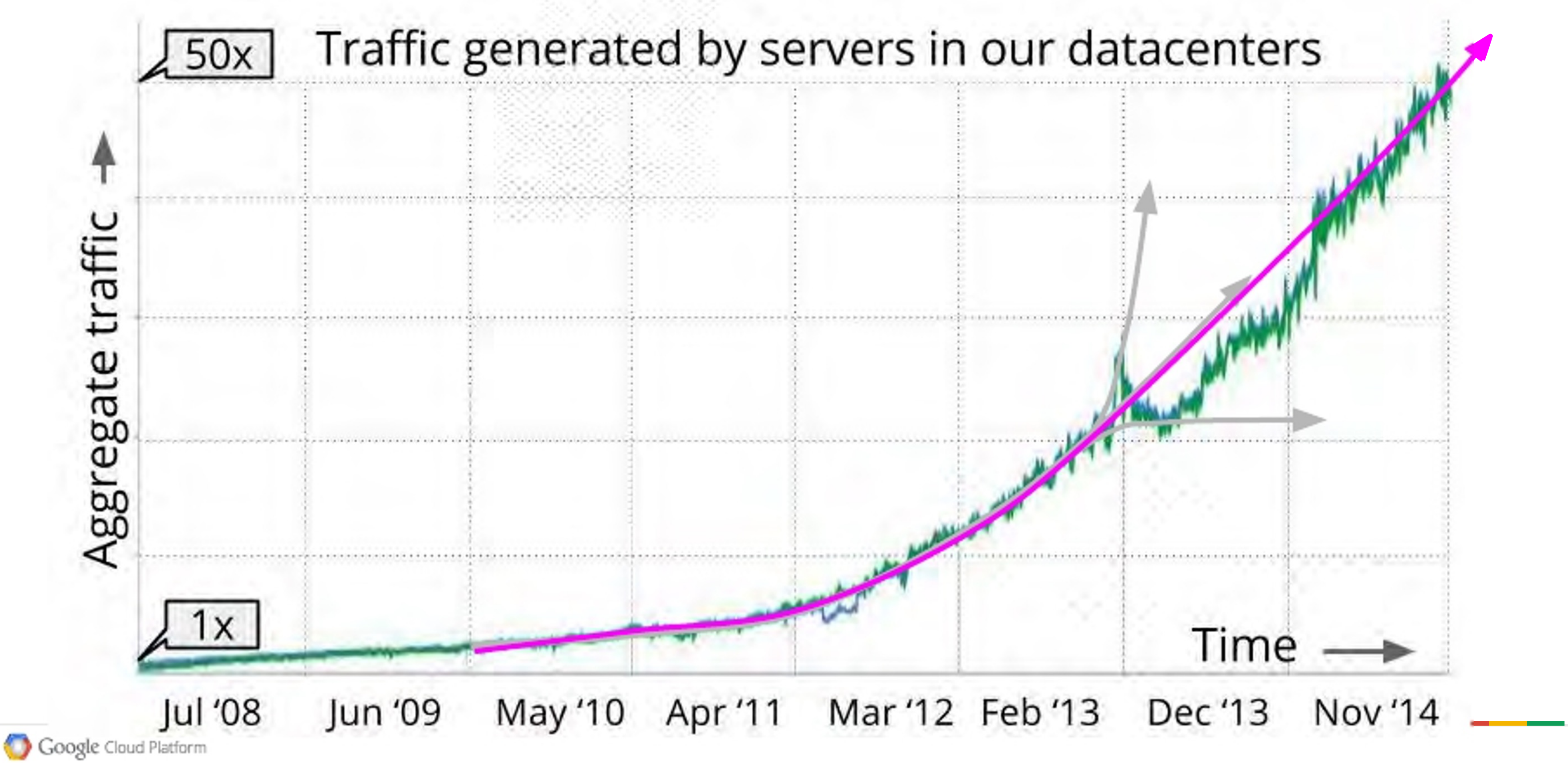
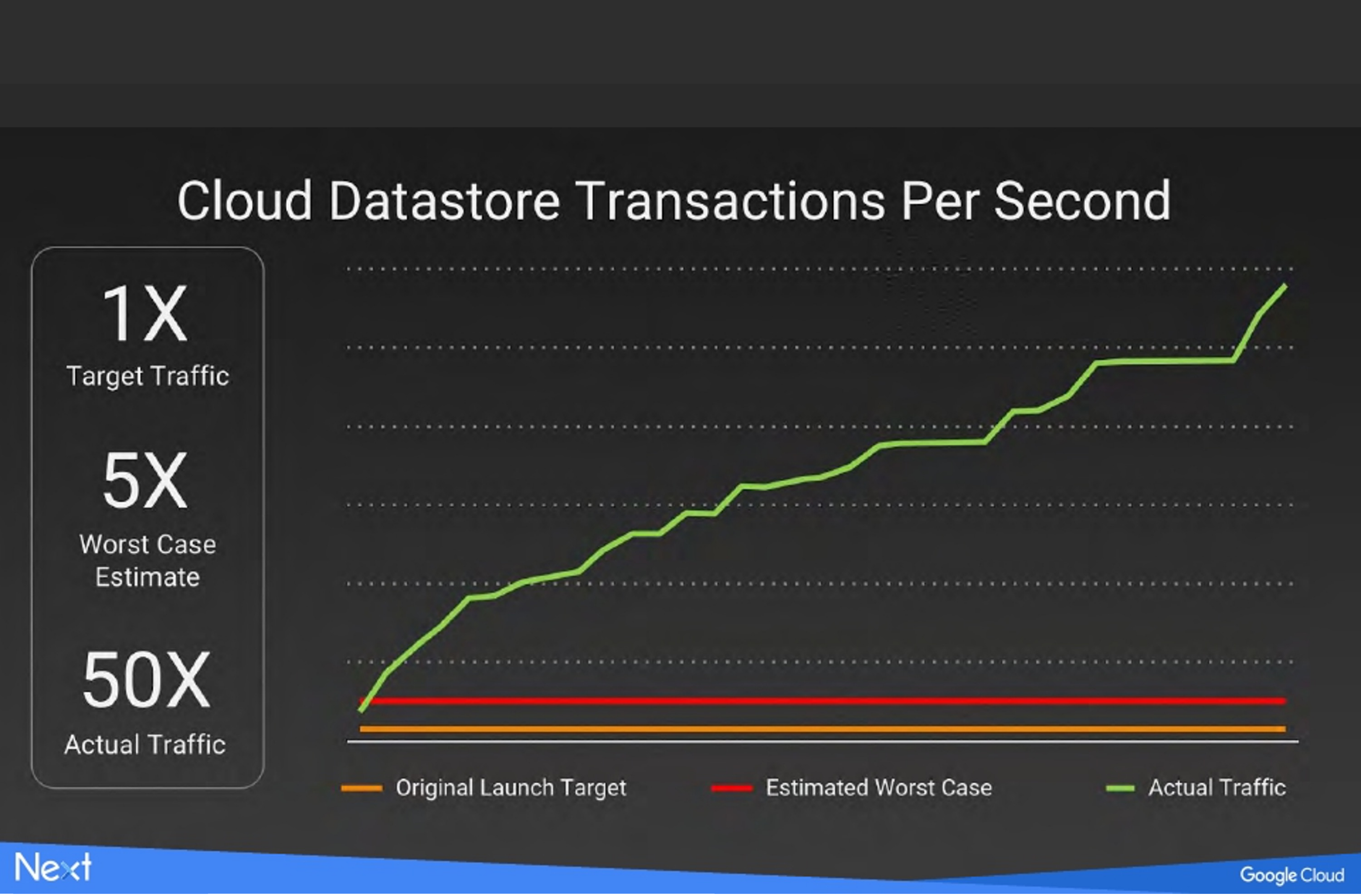
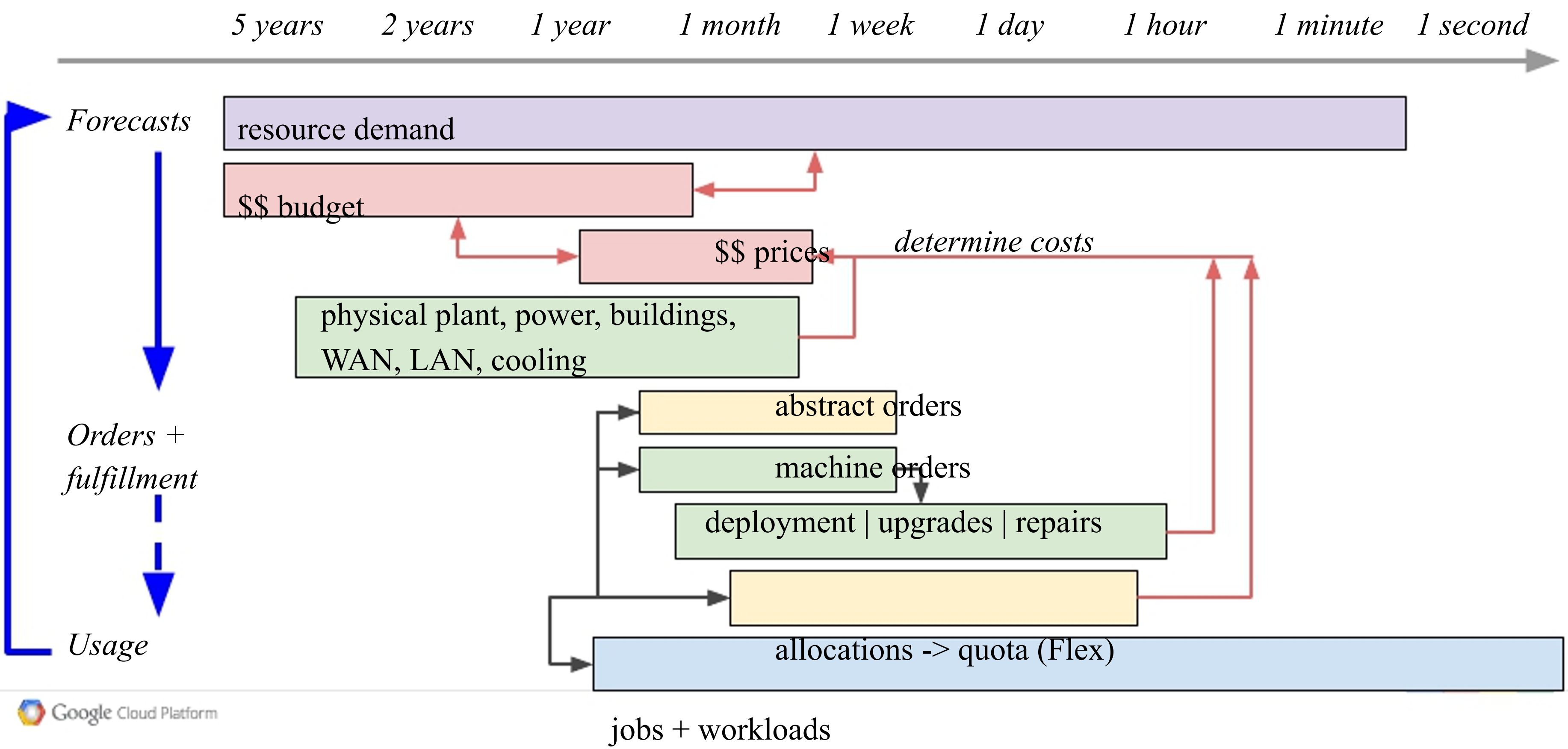



Cloud Datastore Transactions Per Second
1X
Target Traffic
5X
Worst Case
Estimate
50X
Actual Traffic
Original Launch Target
Estimated Worst Case
Actual Traffic
Next
Google Cloud

Putting it all together



Q&A