Apache Hadoop YARN: Yet Another Resource Negotiator

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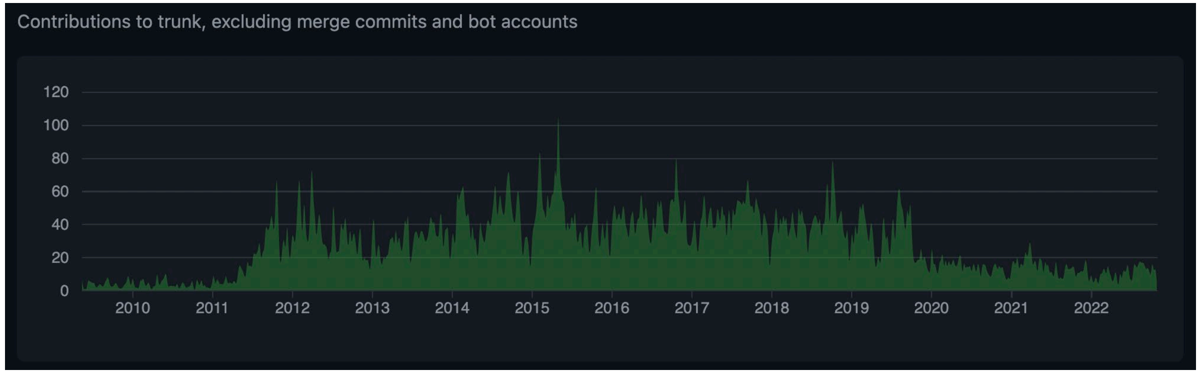
shared and accessed. This broad adoption and ubiquitous usage has stretched the initial design well beyond its intended target, exposing two key shortcomings: 1) tight coupling of a specific programming model with the resource management infrastructure, forcing developers to abuse the MapReduce programming model, and 2) centralized handling of jobs' control flow, which resulted in endless scalability concerns for the scheduler.

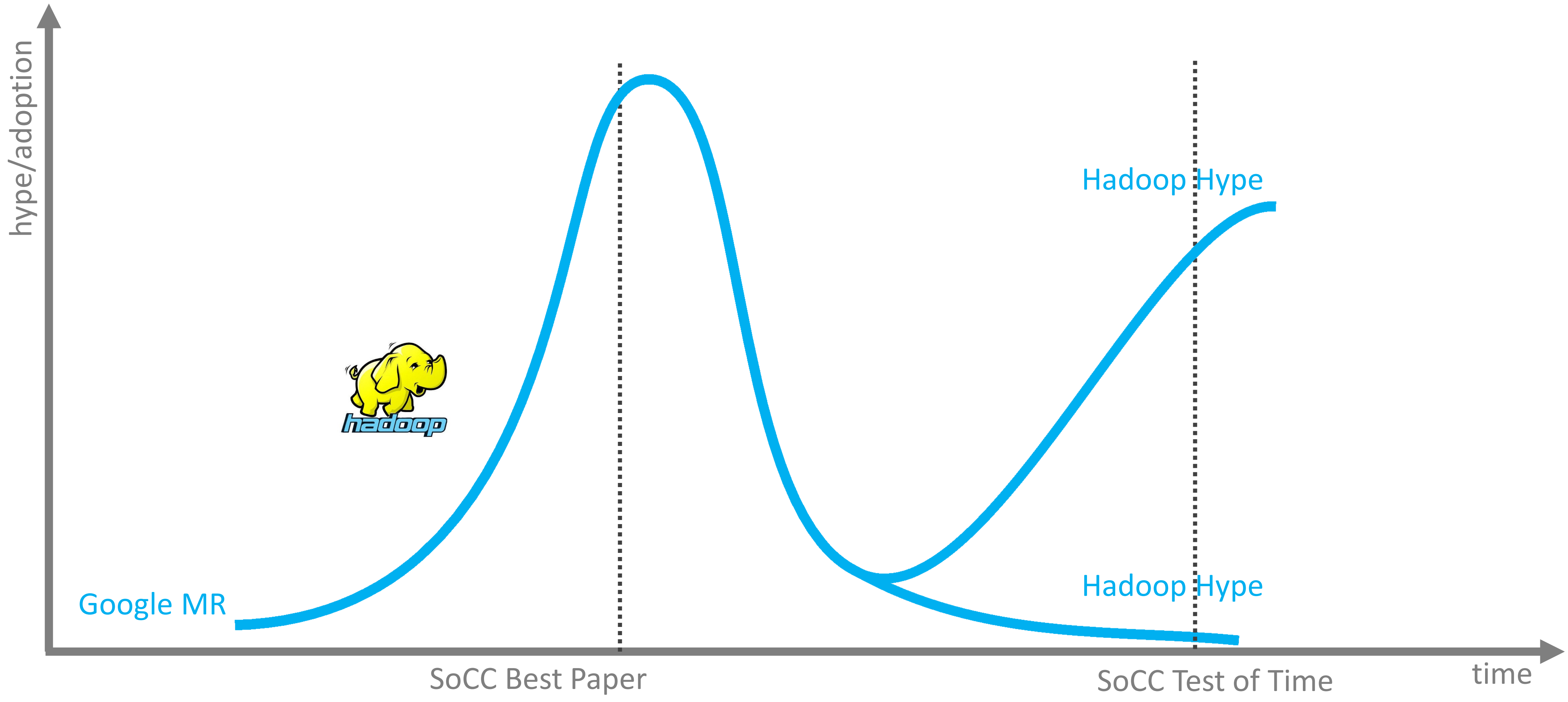
In this paper, we summarize the design, development, and current state of deployment of the next generation of Hadoop's compute platform: *YARN*. The new architecture we introduced decouples the programming model from the resource management infrastructure, and delegates many scheduling functions (e.g., task fault-tolerance) to per-application components. We provide experimental evidence demonstrating the improvements we made, confirm improved efficiency by reporting the experience of running YARN on production environments (including 100% of Yahoo! grids), and confirm the flexibility claims by discussing the porting of several

Apache Hadoop began as one of many open-source implementations of MapReduce [12], focused on tackling the unprecedented scale required to index web crawls. Its execution architecture was tuned for this use case, focusing on strong fault tolerance for massive, data-intensive computations. In many large web companies and startups, Hadoop clusters are the common place where operational data are stored and processed.

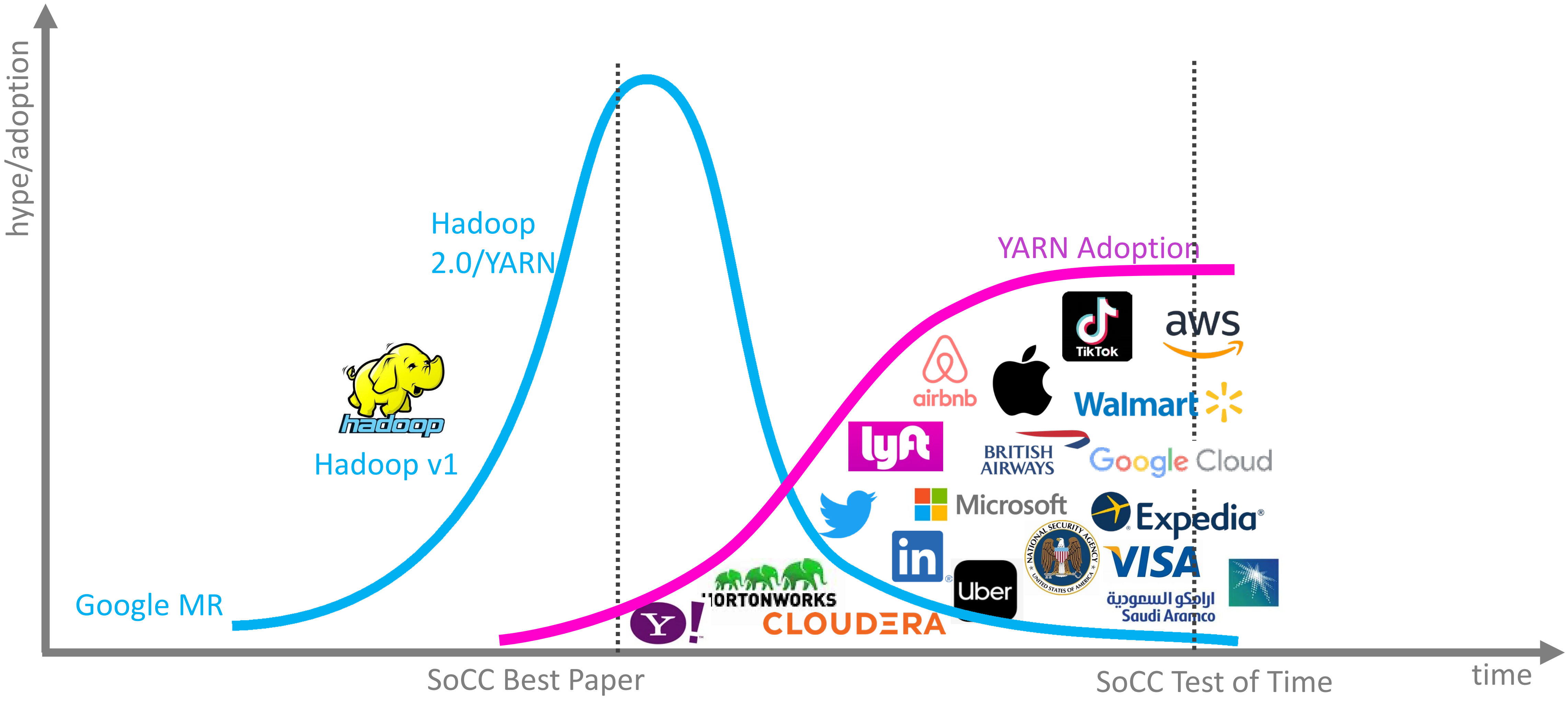
More importantly, it became *the* place within an organization where engineers and researchers have instantaneous and almost unrestricted access to vast amounts of computational resources and troves of company data. This is both a cause of Hadoop's success and also its biggest curse, as the public of developers extended the MapReduce programming model beyond the capabilities of the cluster management substrate. A common pattern submits "map-only" jobs to spawn arbitrary processes in the cluster. Examples of (ab)uses include forking web servers and gang-scheduled computation of iterative workloads. Developers, in order to leverage the



Test of ~~Time~~ Timing Award



Apache Hadoop YARN Hype/Adoption Cycle



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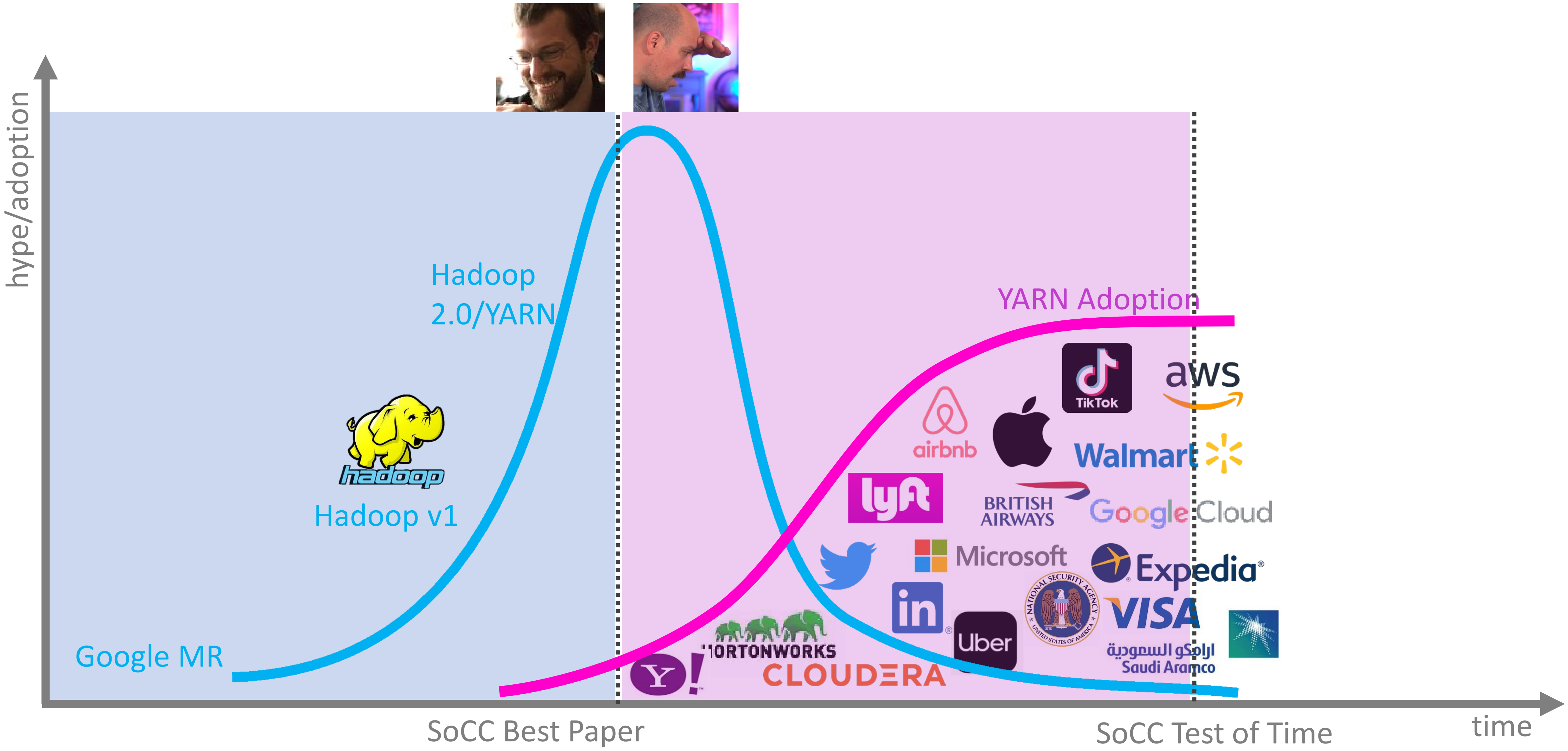
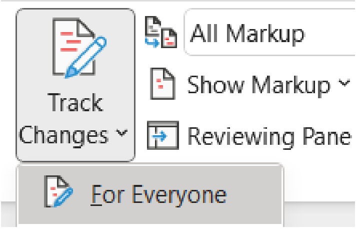


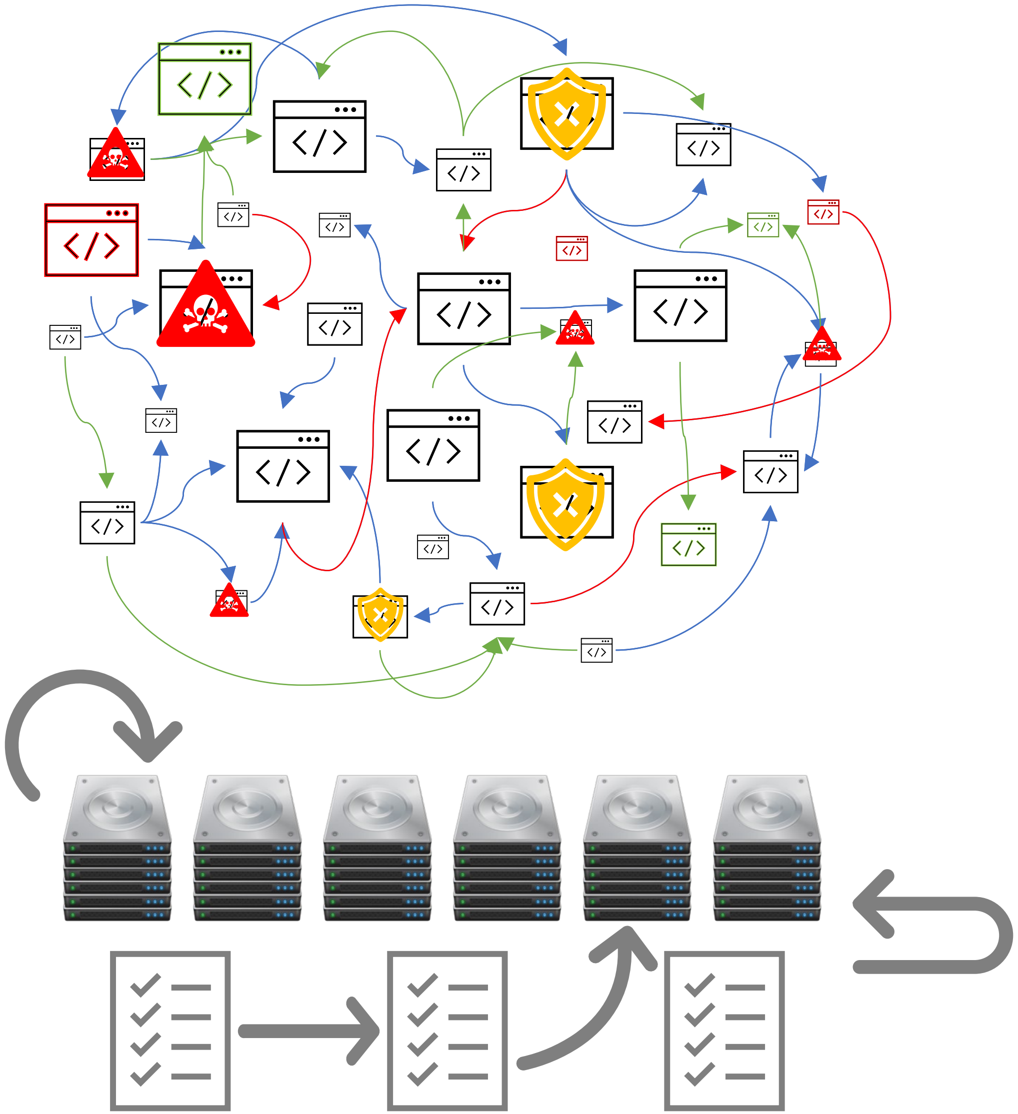
Scaling with the Web (2000s)

- Largest, most dynamic dataset ever assembled

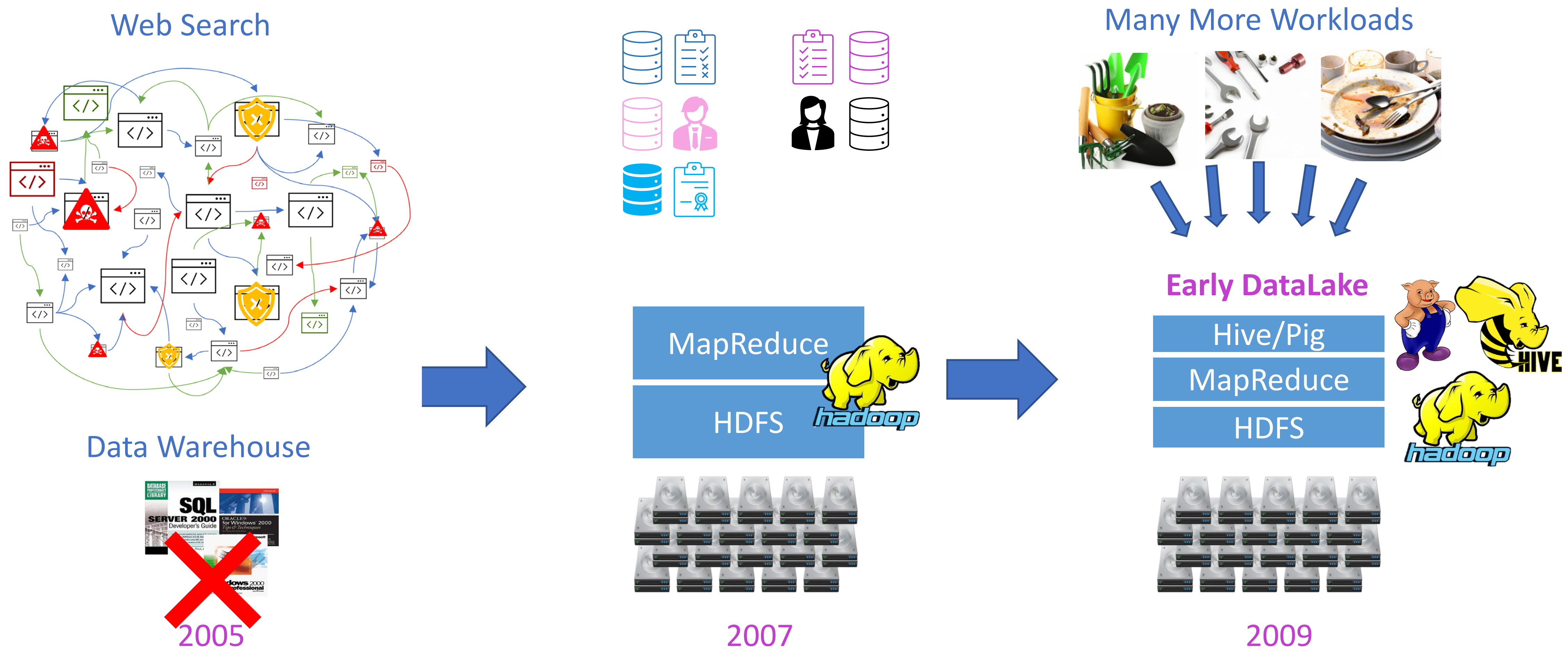
- 

- Annotation dimensions

- Metadata expand with base data



Data Silos to Data Lake



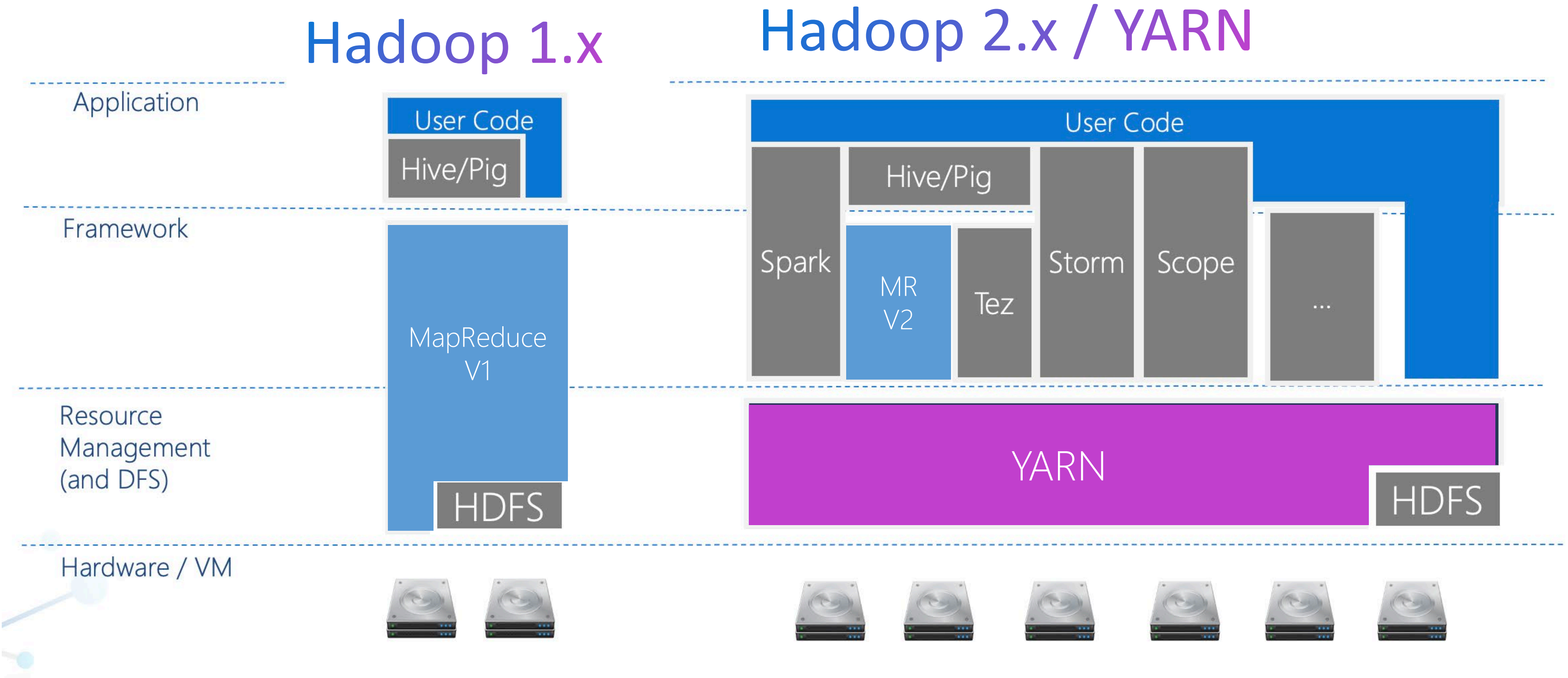
YARN+HDFS → Cluster Operating System

MapReduce was not enough

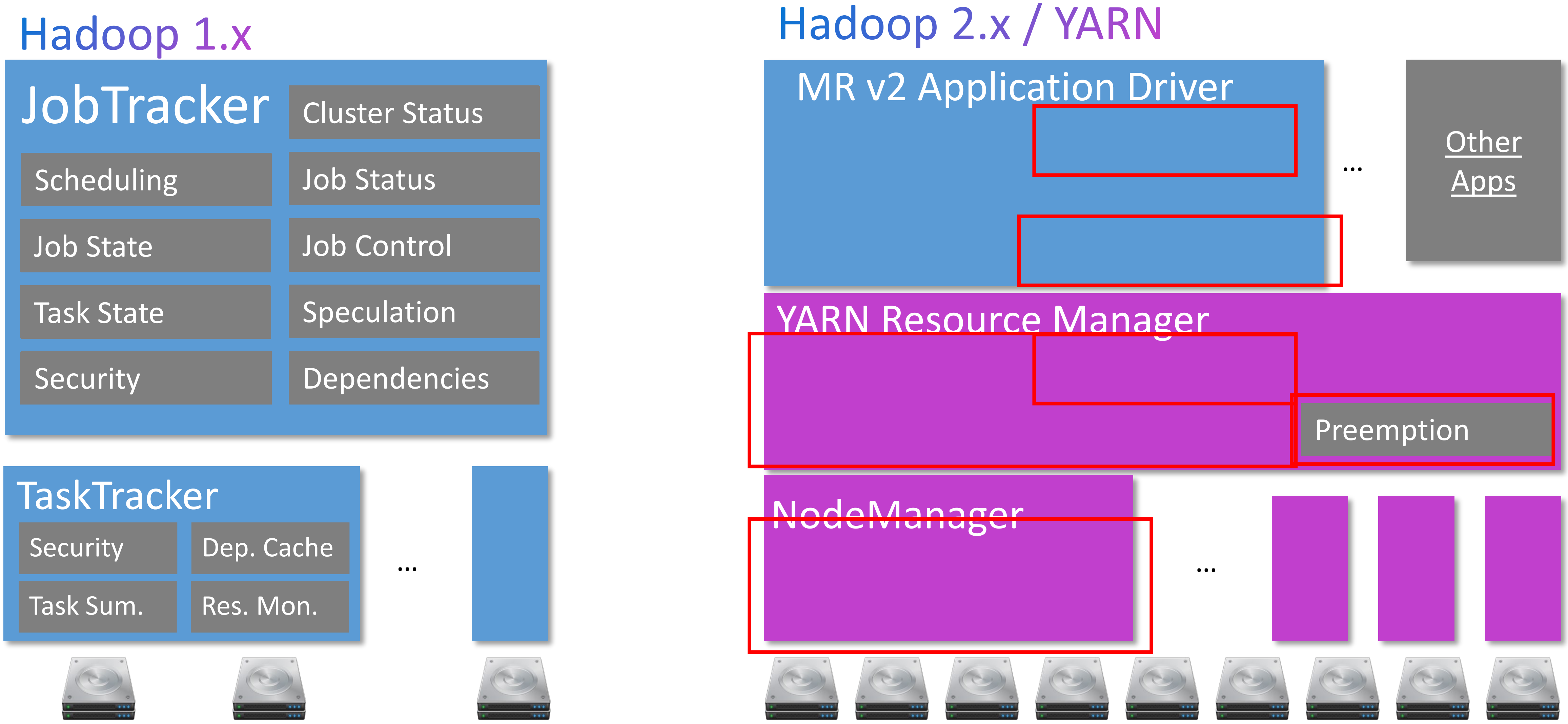
Rigid Programming model,
batch-oriented, low utilization

Decouple Resource Management from App

YARN handles Resource Management
MRv2, Spark, Scope,... are "apps" sharing a cluster



MapReduce to a Cluster OS (YARN)



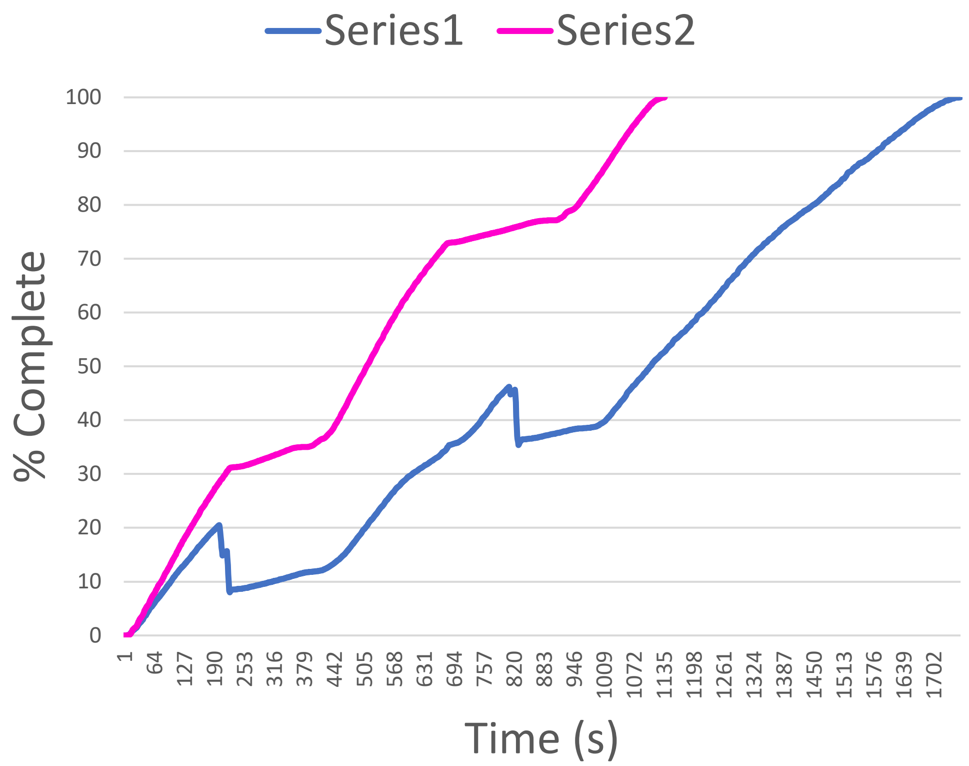
YARN Preemption: Why

OS Scheduling: bin packing over time

- Workload changes affect allocations
- Preemption to evict process from resources
- Fallow resources to absorb changes

Cluster scheduling: dynamic bin packing

- (Temporarily) Failures cause reconfiguration
- Killing tasks loses progress



YARN Preemption: How

Diverse applications

Dependencies, costs opaque to RM

Announce need for resource revocation

Symmetric protocol for requests

Specific nodes, filter expression

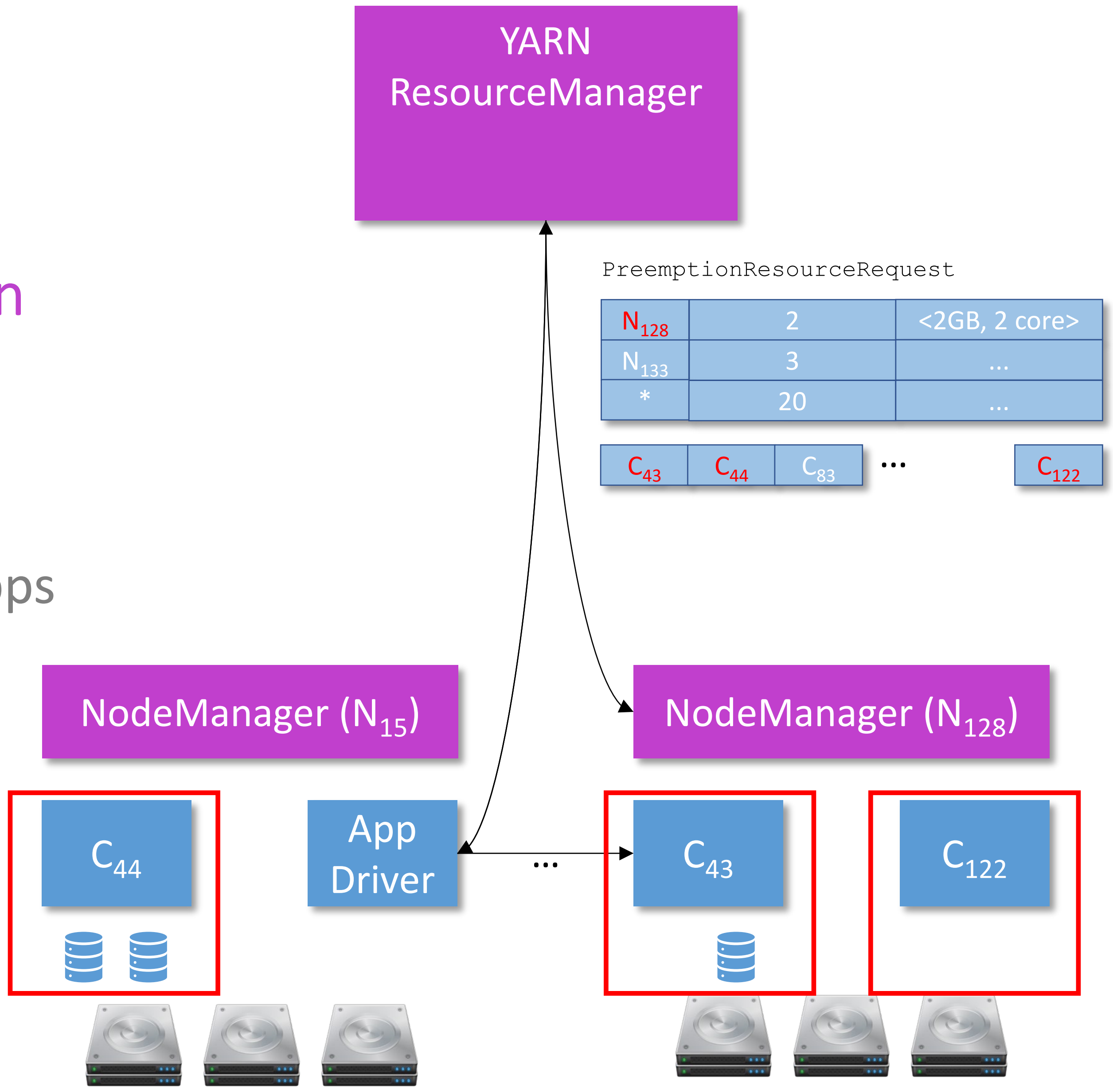
Apps select satisfying set of resources

System-enforced for non-cooperating apps

New capability in YARN

Agent to negotiate

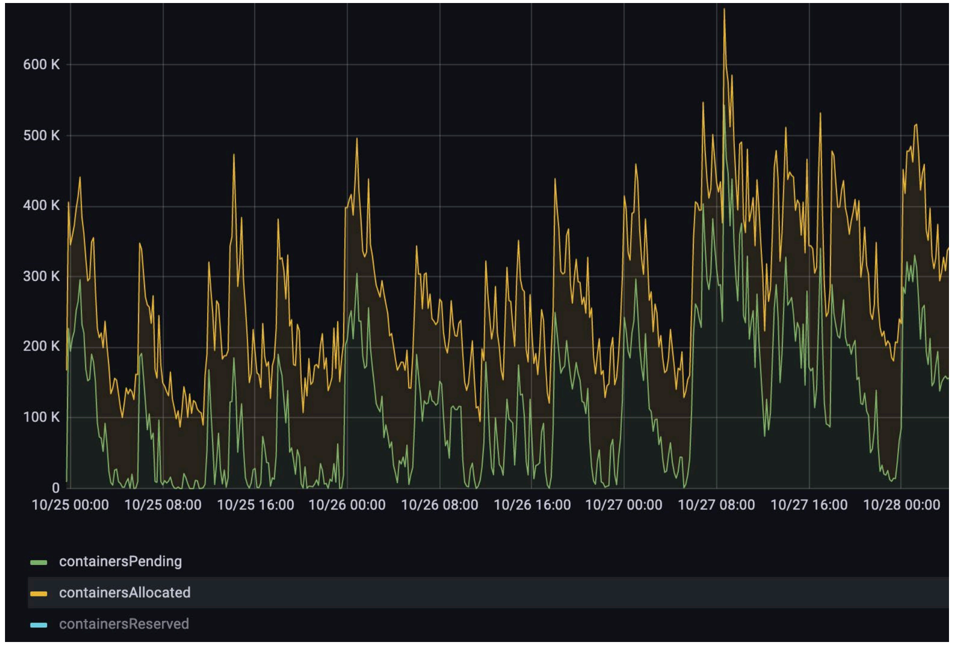
Capacity for application logic



YARN@in: Container Utilization (two weeks ago)

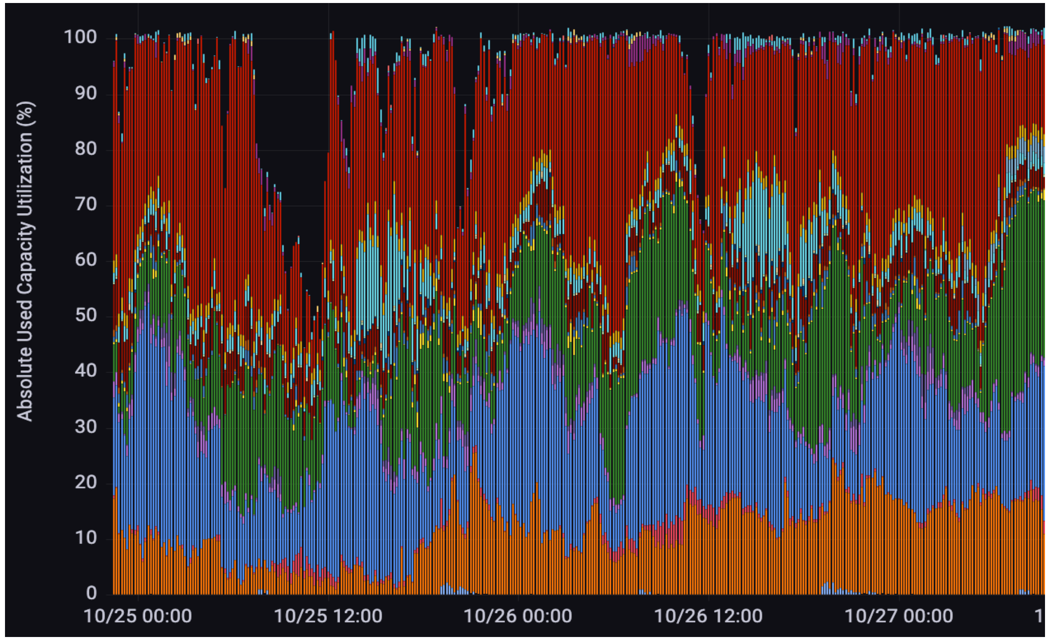
Very Diverse Workload

- Multiple frameworks
- Spark has most resources
- MR has most containers



Preemption -> High Utilization

- Many queues (per organization/user)
- 80-90% container utilization
- Clusters of 7-10k nodes



Screenshots courtesy of: Varun Saxena (LinkedIn)

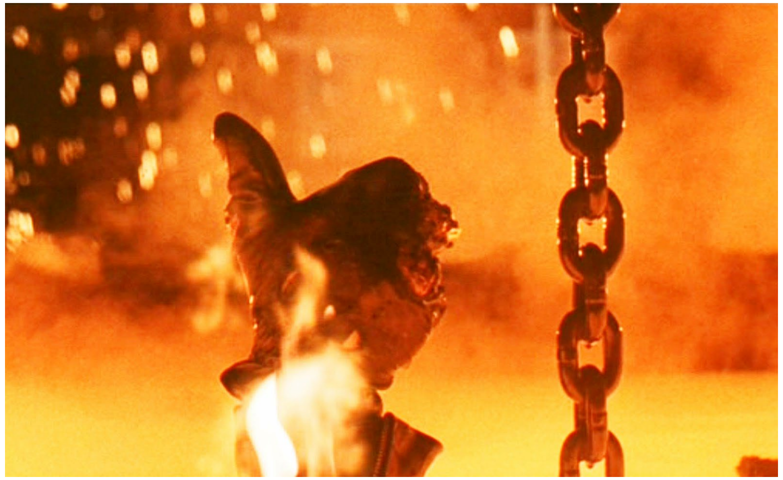
Second System: Lessons Learned

Existing system is your fiercest competitor

- Share its defaults to share its strength
- Same >> Improved: **until you're deployed**

Software is easier to change than people

- Change harms adoption
- Start structural, not functional



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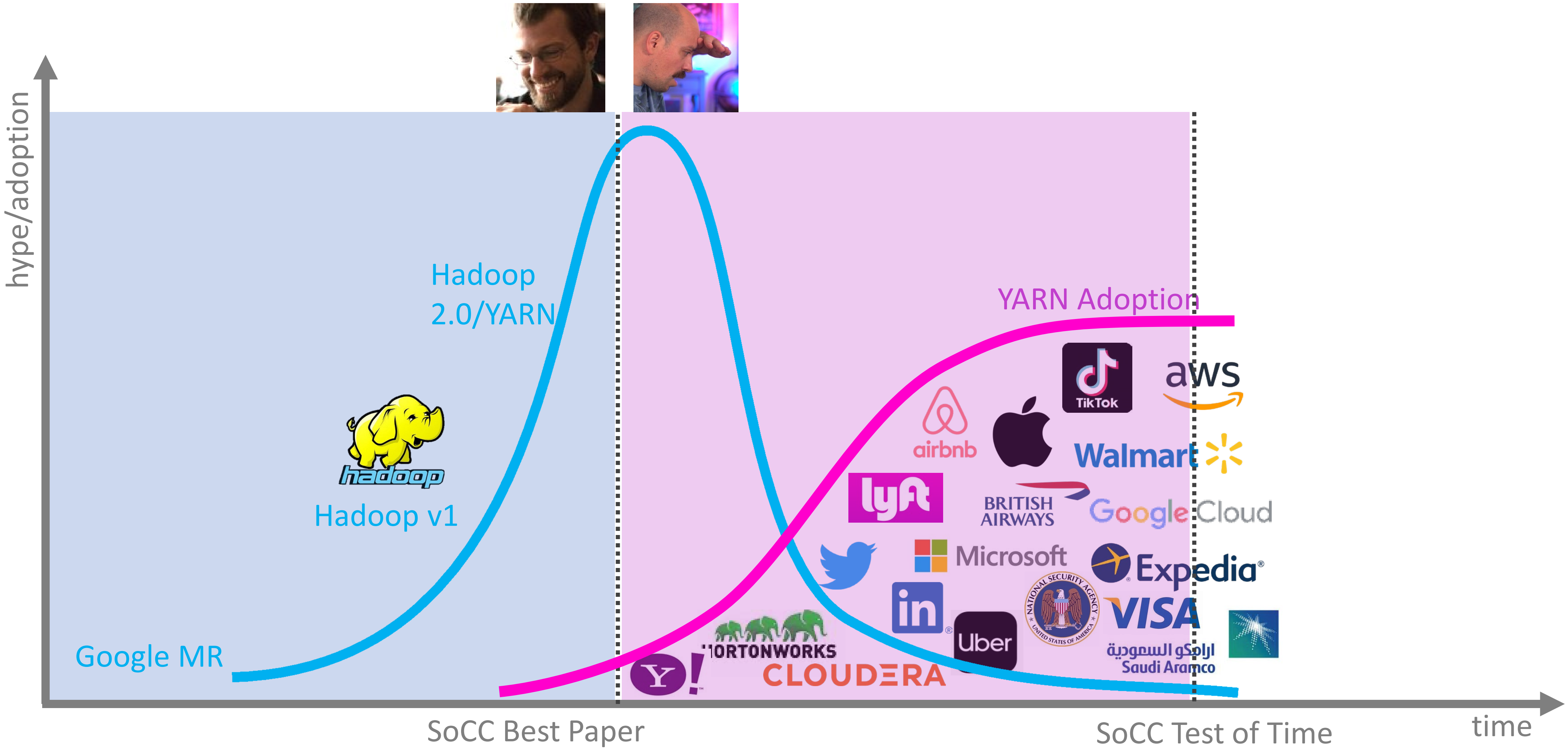
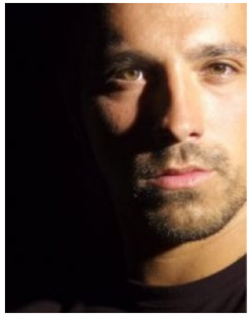


My Vantage Point..



Carlo at CSAIL MIT (2009):
Stonebraker: "[MapReduce] is a giant step backward."

DBs are the best, SQL is the way!

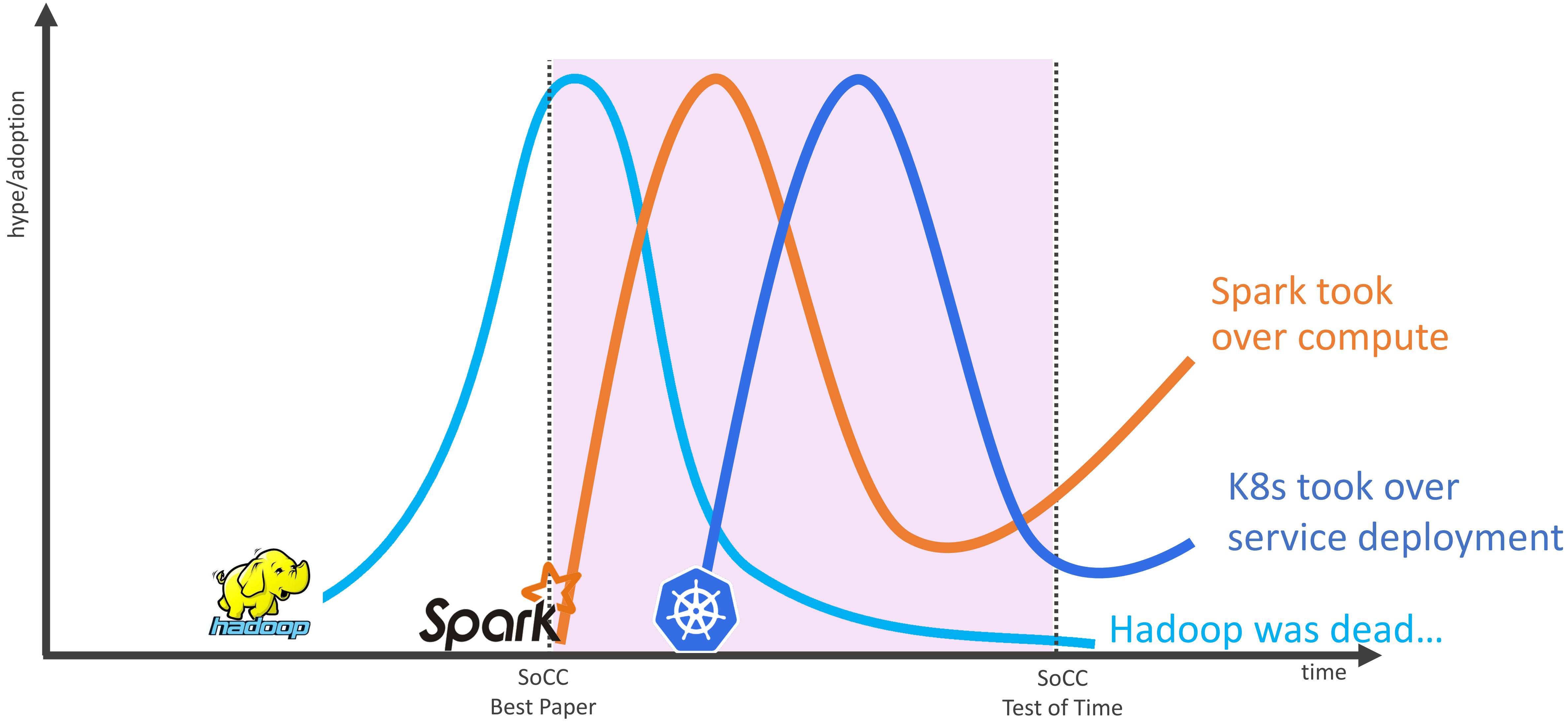
Carlo at Yahoo experience (2011):
Need to process some logs, two options:
*a) **Use MySQL:** Weeks of red-tape*
*b) **Learn Hadoop:** Thousands of servers with data preloaded*

The "DataLake" experience is Exhilarating!

Carlo at Microsoft (hindsight 2020):
*Through OSS and careful API design. We **can** have it all (scale, efficiency, flexibility)!*

Make your sandbox open(-source) and friendly. Academics and other companies will come!

Apache Hadoop YARN Hype/Adoption Cycle



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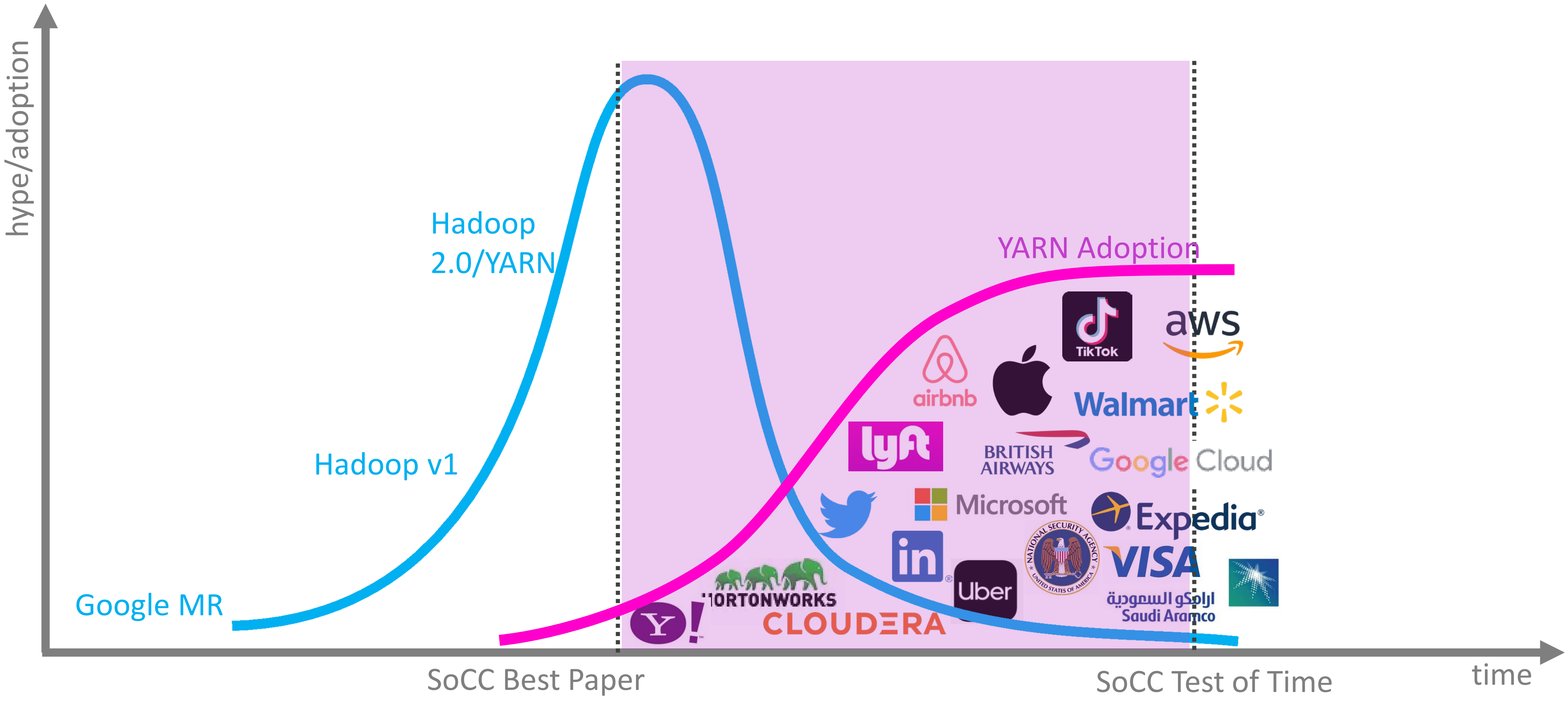
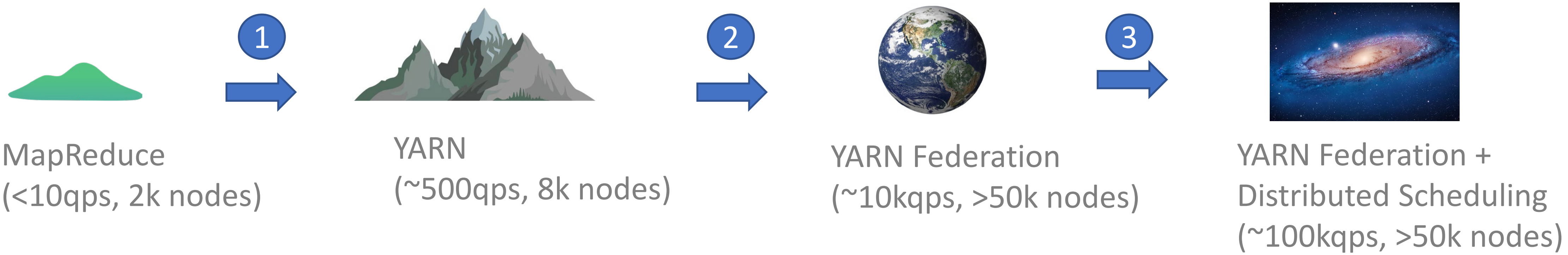


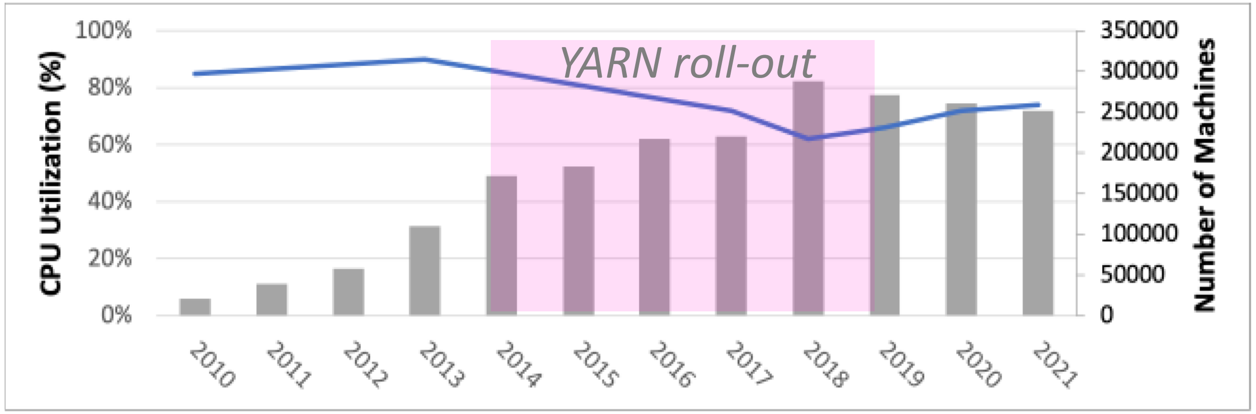
Why YARN adoption among Hyperscalers?



Scale and High Utilization

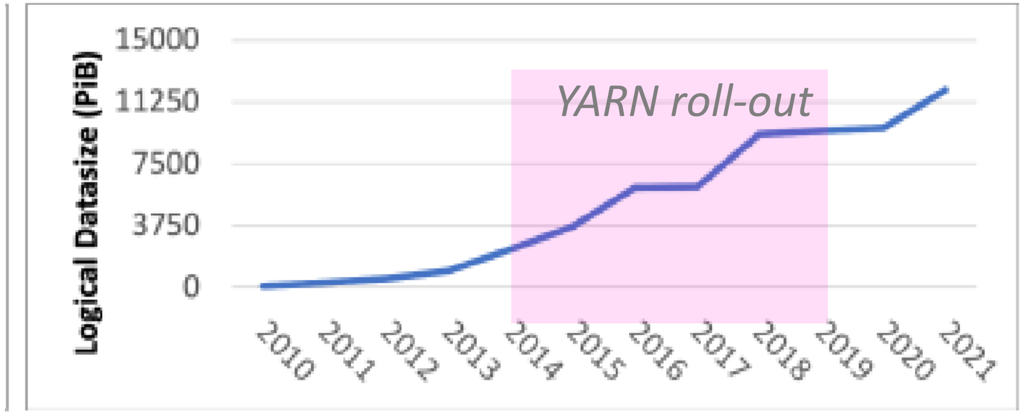
Many of the largest/busiest BigData clusters are YARN-based
How? We progressively “removed” responsibilities from central components

BigData at Microsoft

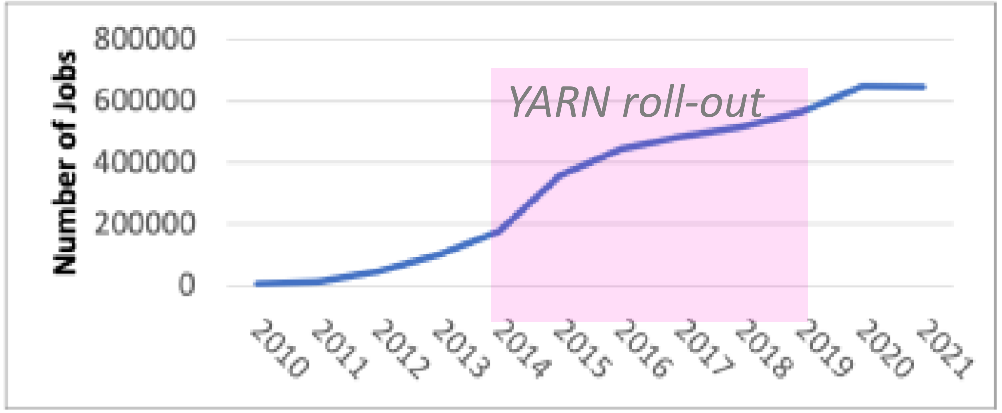


User: ~15k
Queue: >5k
Job: 600k / day
Task: 5 Billions / day
Cluster: >50K nodes
Data: >10Exabyte

Figure 5: CPU utilization over the years in Cosmos.



(b) Data size before compression/replication.



(c) Number of batch SCOPE jobs run per day.

* *Pictures from* "[The Cosmos Big Data Platform at Microsoft: Over a Decade of Progress and a Decade to Look Forward]"

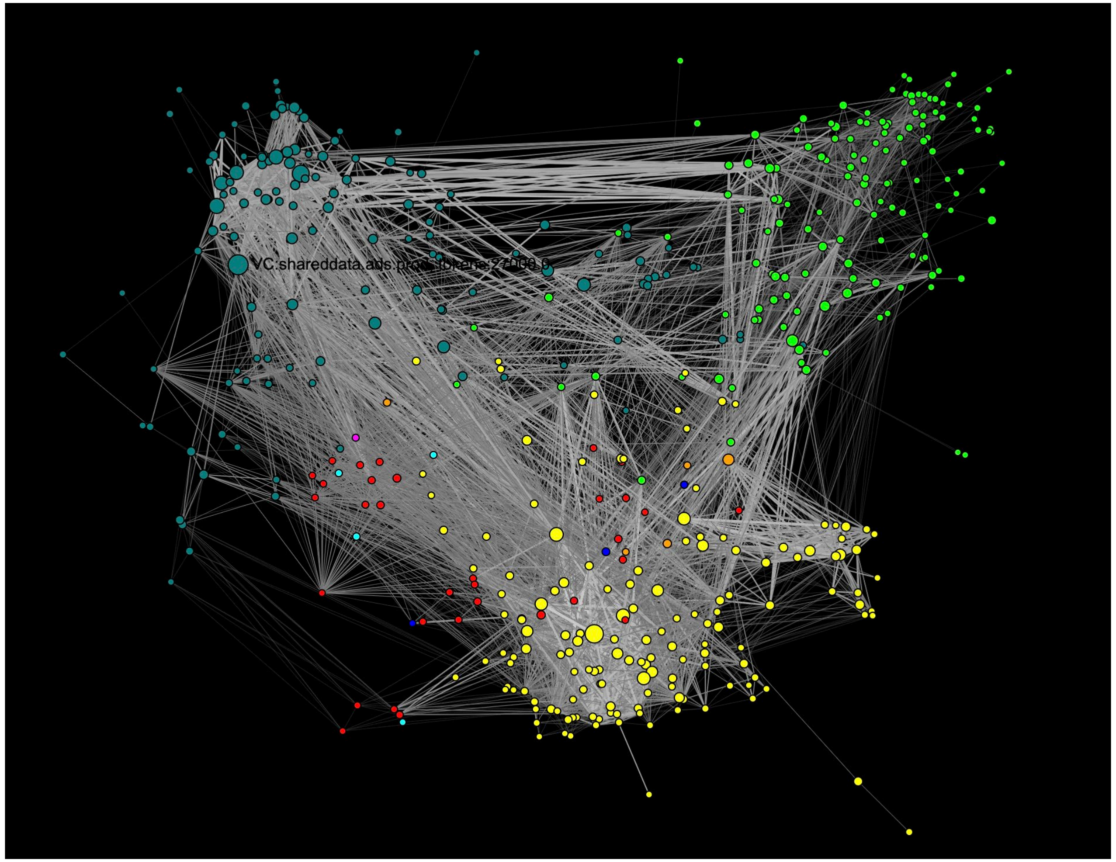
Why not partitioning to smaller clusters?

Individual very-large jobs (~16k servers)

Usability/Fragmentation advantages

DataLake Effect (visualized):

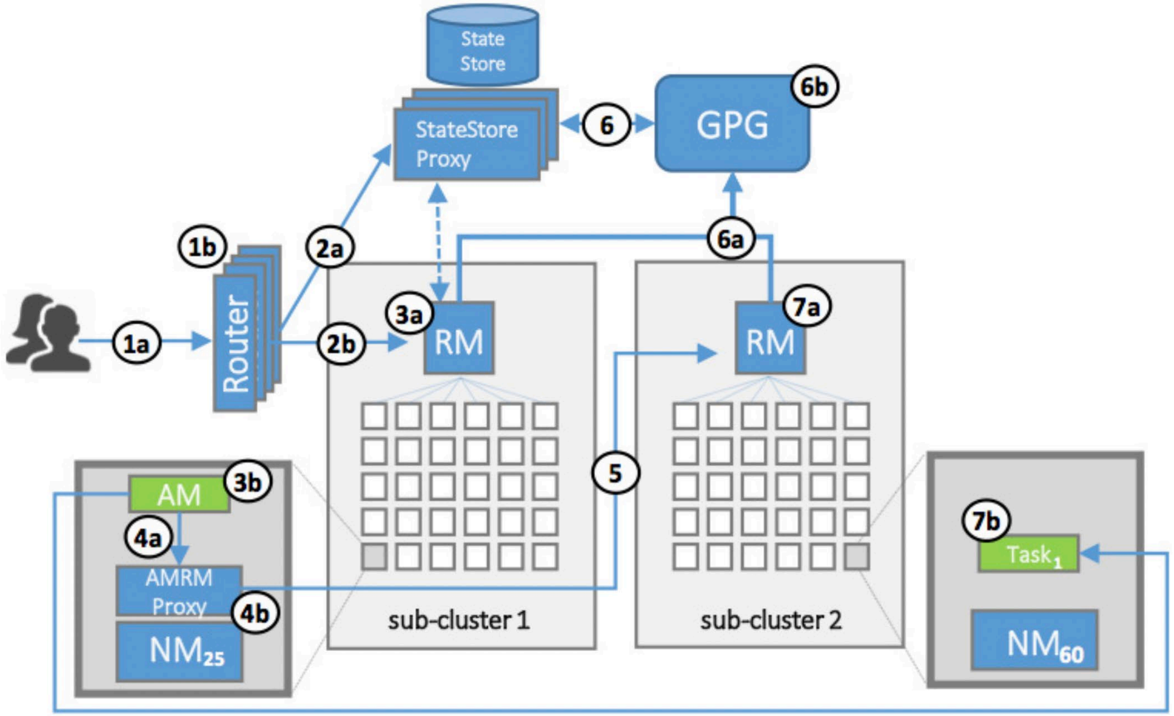
- Nodes represent 2k queues
- Edges represent “data sharing”



YARN Federation*

Illusion of single-cluster

- Proxy all interactions with the system
- Centrally define capacity policies
- Routers/RM/AMRMProxy choreograph enforcement
- AMRMProxy/RM coordinate to handle “placement” decisions



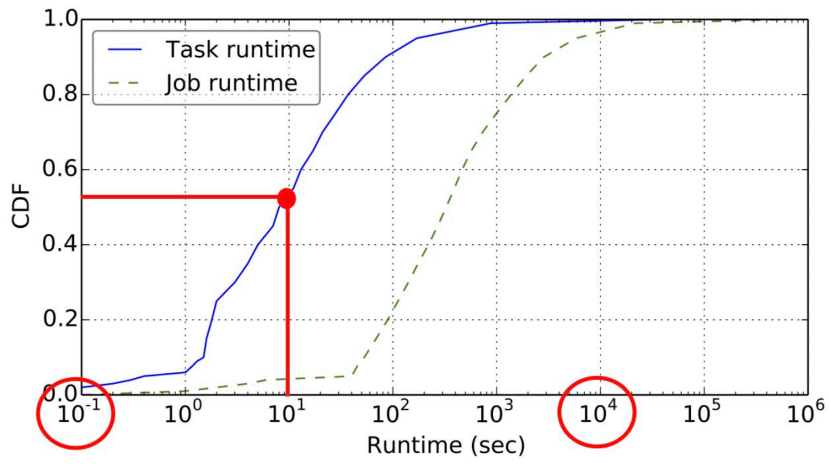
* Hydra: a federated resource manager for data-center scale analytics, NSDI 2019

YARN Distributed Scheduling*

Challenge

Scheduling rates at 50k nodes with short tasks

Heartbeat latencies waste resources (~10sec from free-to-used resources)



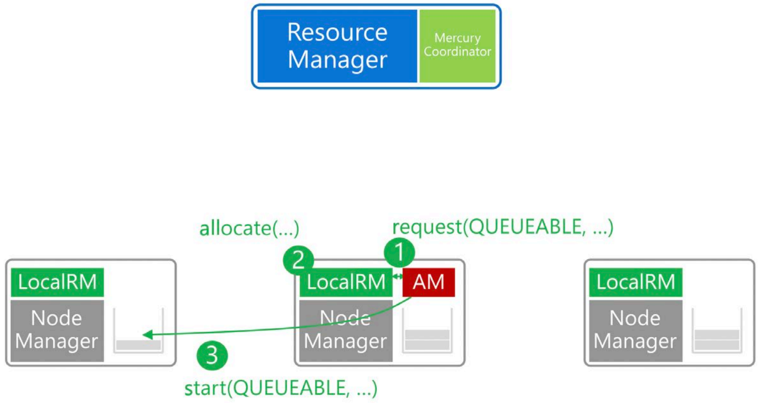
Key idea: Distributed Scheduling

Introduce Opportunistic Containers

Per-node LocalRM makes scheduling decisions

OC queue at NM and are locally preempted

Quotas/Queue priorities/Rebalancing

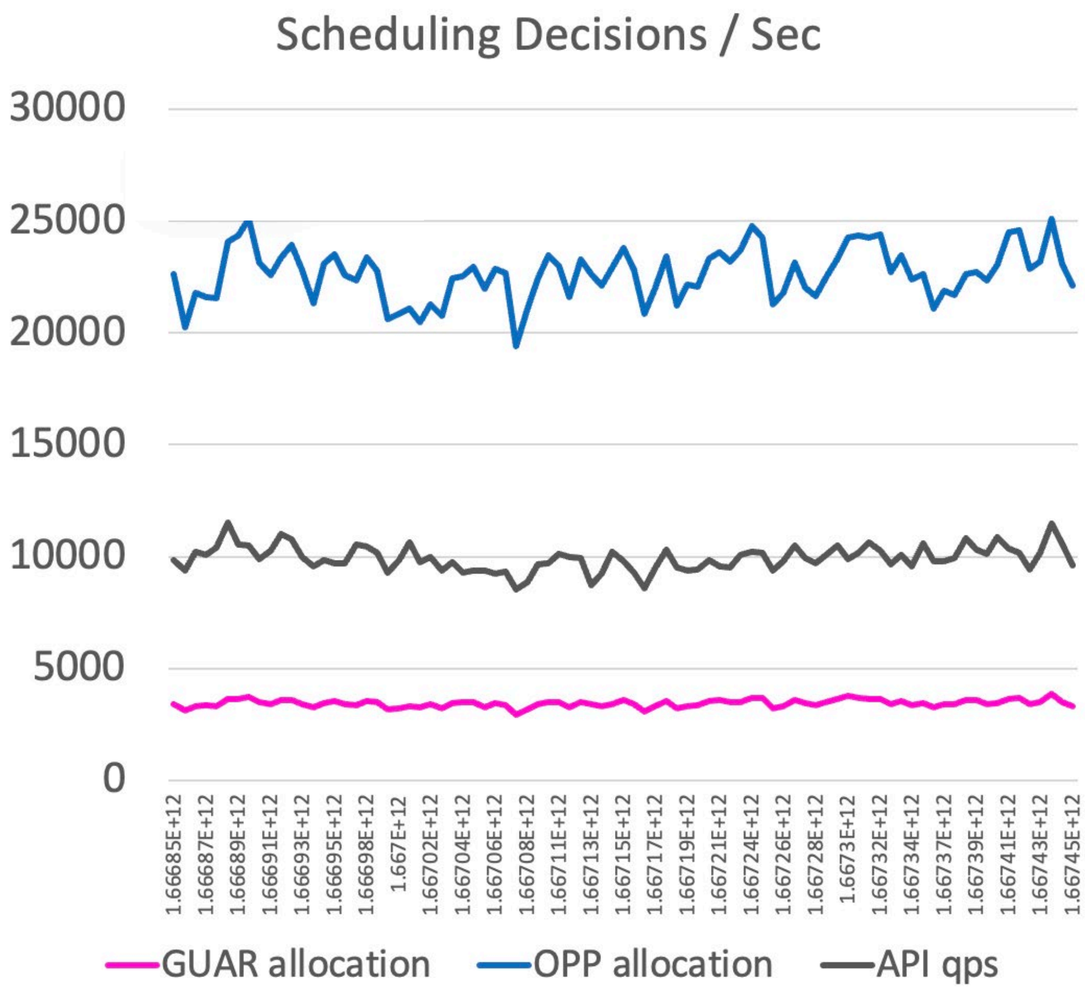


* Mercury: Hybrid Centralized and Distributed Scheduling in Large Shared Clusters, ATC 2015

YARN @ Microsoft (federation+OppCont)

Scheduling Pressure:

~40k qps average
>100k qps at peak
~50k queued OPP



Screenshots courtesy of Cosmos Team (Microsoft)

Why is YARN used for small-scale OnPrem/Cloud?

Battle-tested/non-differentiating functionalities

Scalable Scheduler, fault tolerance, library management, rolling-upgrades, load balancing, log aggregation, metrics gathering, node health, job cleanup, …

Cluster-OS + OSS APIs

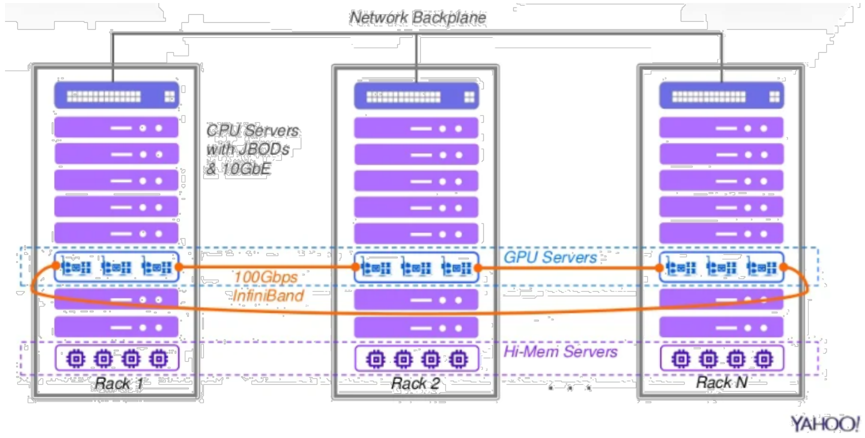
OSS APIs targeted by most “new” frameworks
Customizable deployments

YARN @ yahoo!: Example of Customization

Availability at 99.999%!!

Diverse set of workloads

Diverse HW (node-labels)



Screenshots courtesy of: Eric Badger (Yahoo!)

Conclusions

Origin Story:

Web-Index →BigData → DataLake → YARN

YARN Adoption:

Scalable/High Utilization Cluster OS

OSS APIs and Sturdy Core Features

Next Decade:

New powerful trends towards Cloud and SaaS → ?

THANK YOU

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Zac Zhou
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Zhe Zhang
Zhijie Shen
Zheng Shao
Zhankun Tang
Zhihai Xu

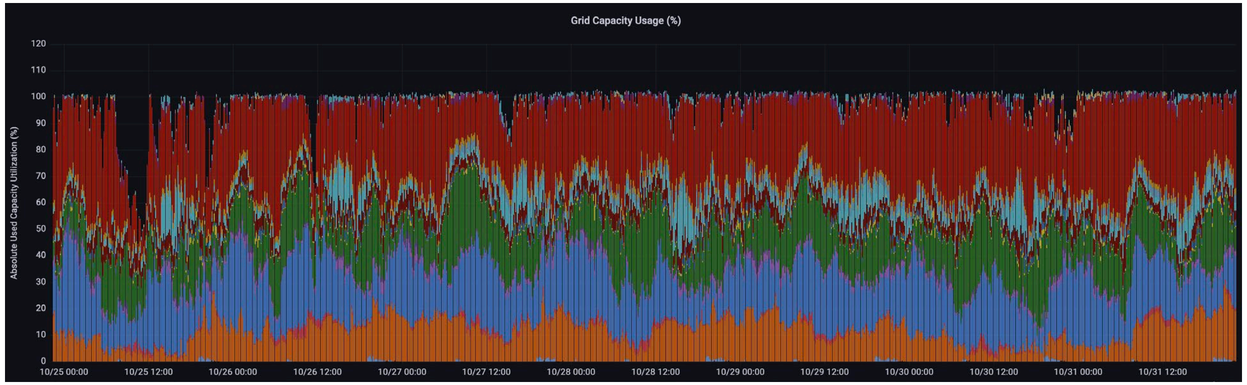
YARN@in: Container Utilization (two weeks ago)

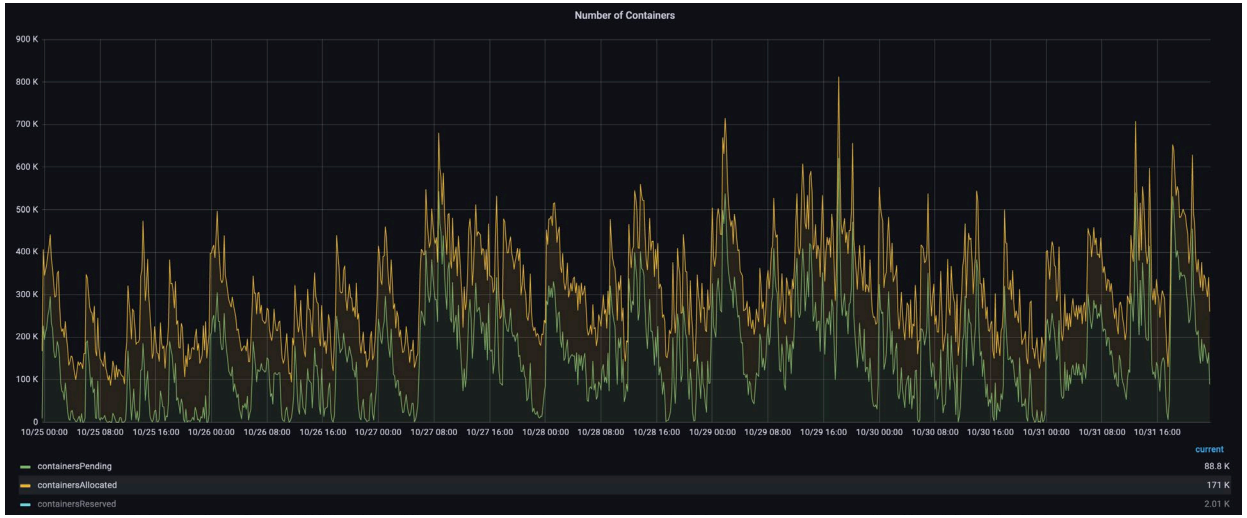
Cluster statistics

- 80-90% container utilization
- Average 20 containers per node (peak ~70)
- 31K nodes in clusters of 7-10.5K nodes
  - Recent, annual growth of 38% GB/Hr
  - Peak 1.1k containers allocated per second

Workload statistics

- Up to 1.1k container allocations per second
- Majority rsrc usage: Spark
- Majority of containers: MapReduce





Screenshots courtesy of: Varun Saxena (LinkedIn)