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Next-Generation Apache Hadoop

Open problems in distributed storage and resource management

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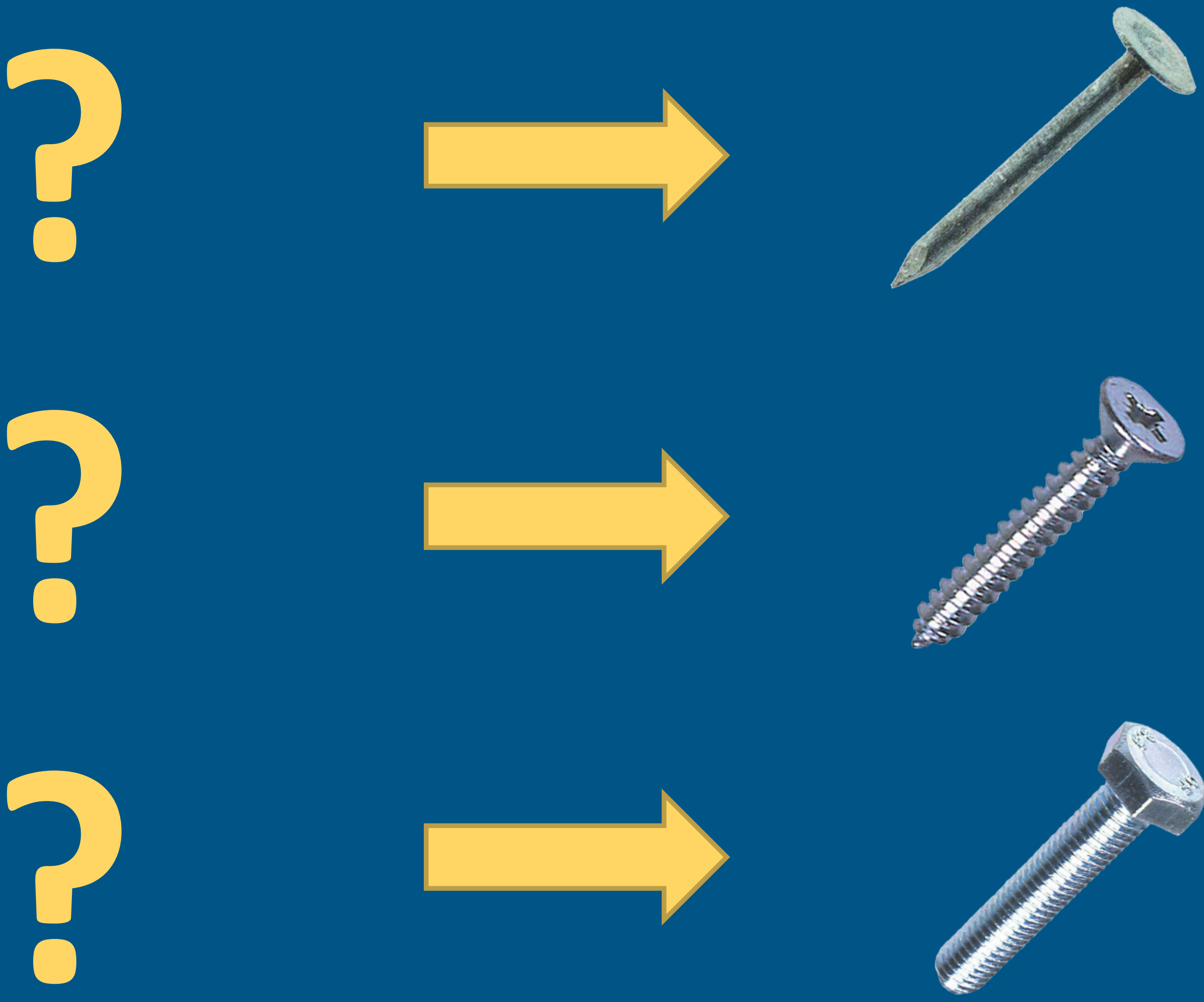

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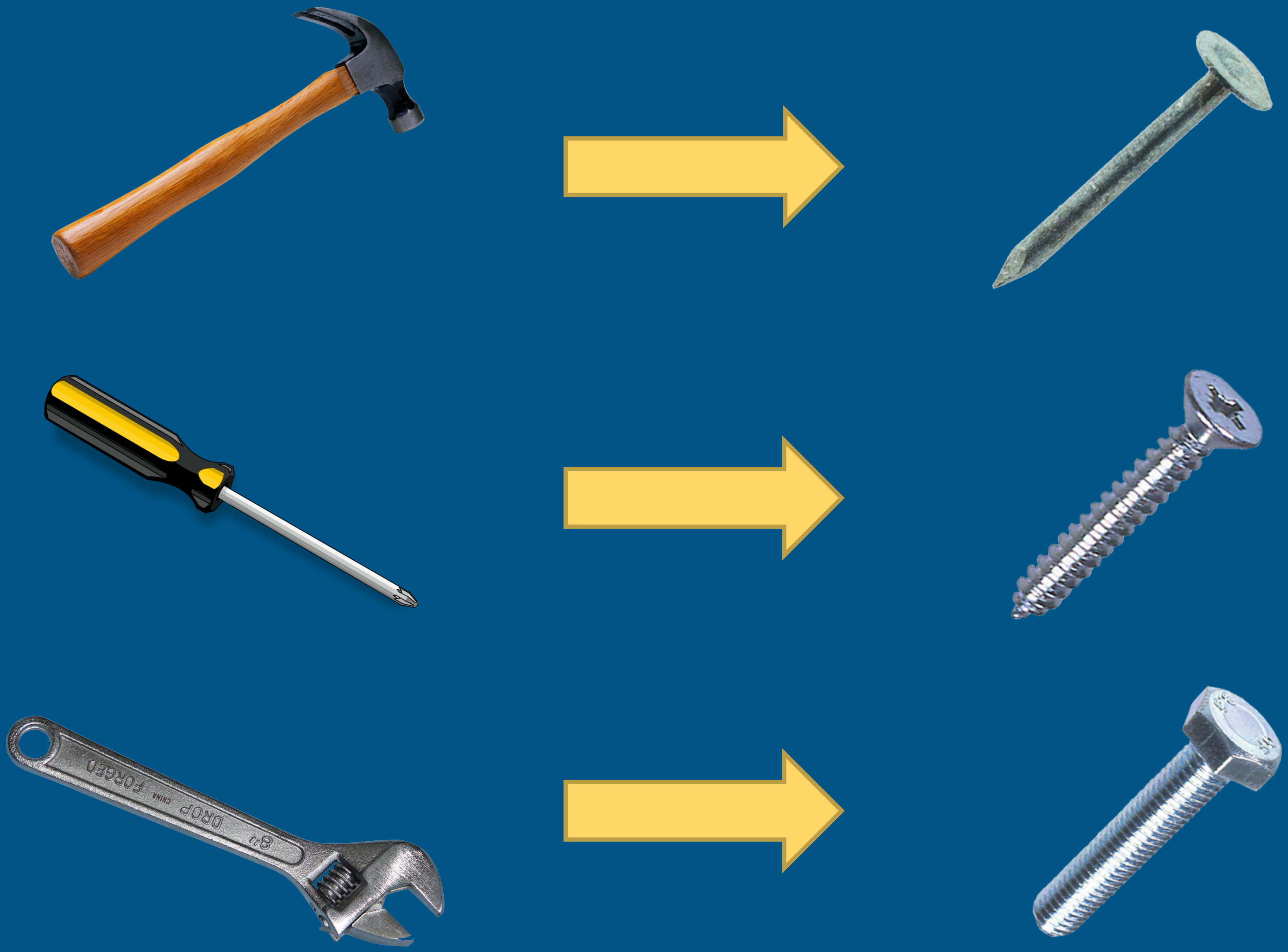
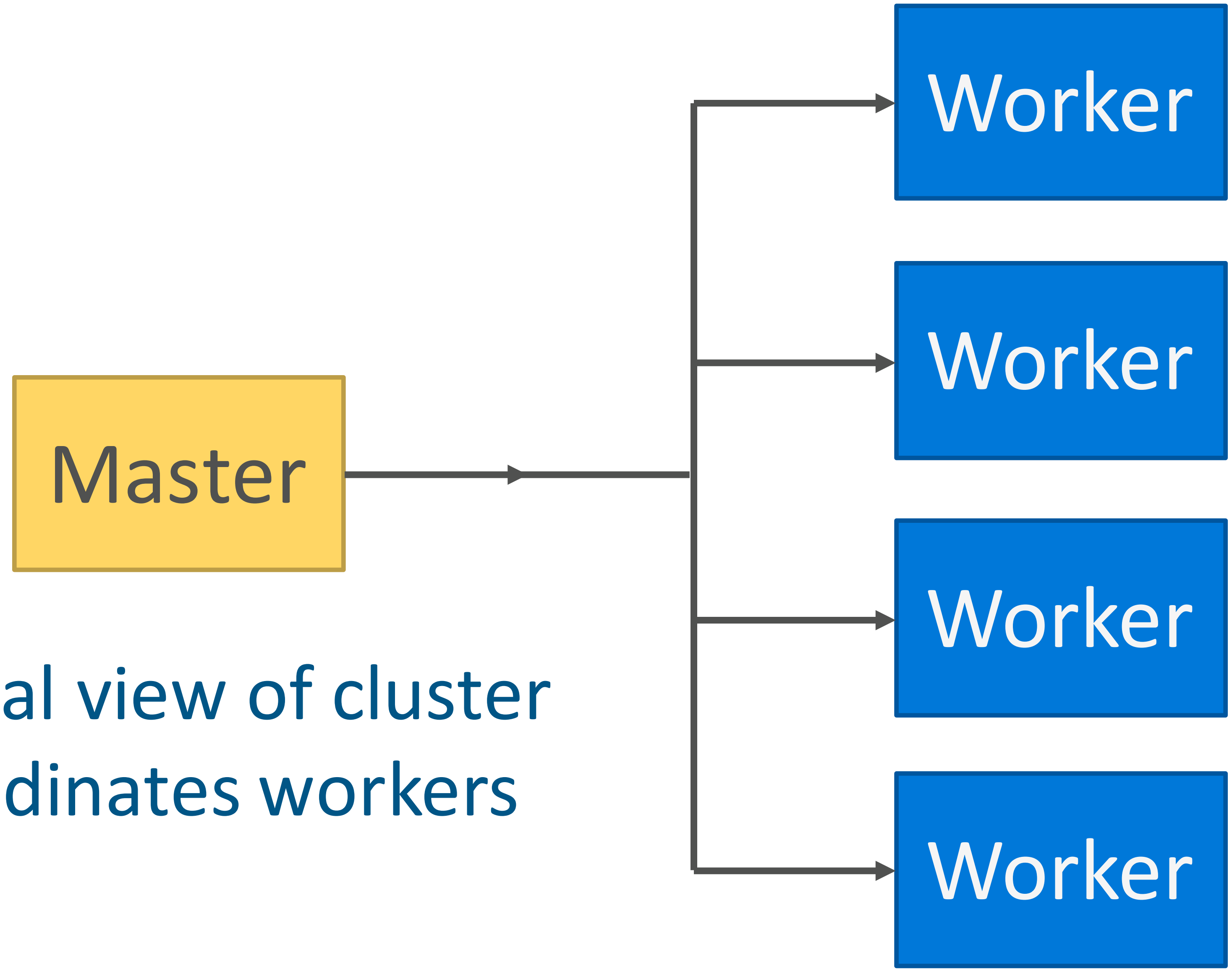

DROP FORGED
CHINA

Cloudera perspective

- Hadoop software stack is relatively mature
- Seen broad uptake in many industries
  - Wider variety of workloads
  - Larger and larger amounts of data
- New datacenter hardware trends on the horizon

- Good time to revisit original design assumptions
- Collaborate with academics on these problems

Scalability



Master

Worker

Worker

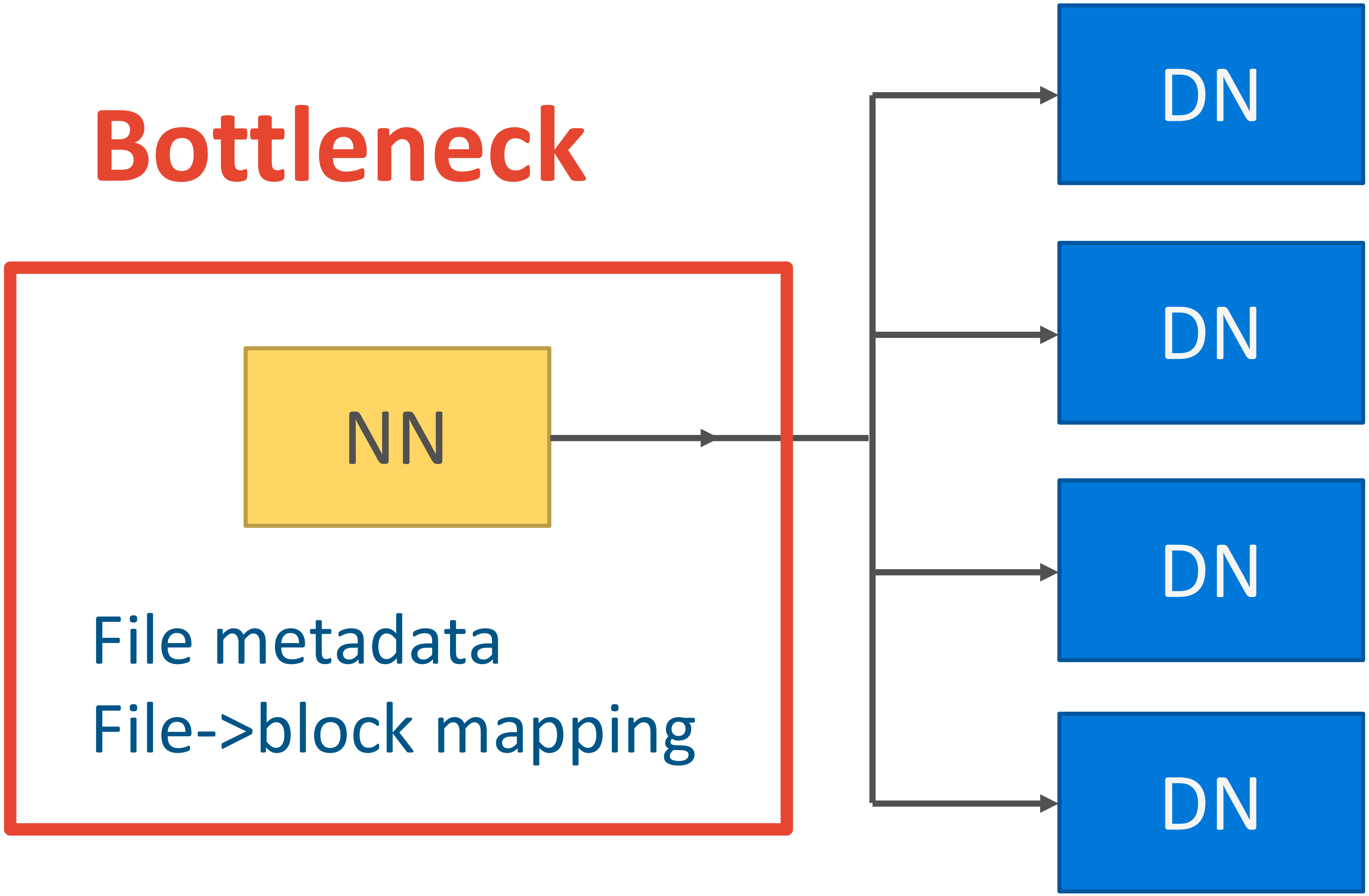
Worker

Worker

Global view of cluster
Coordinates workers

Simple
Do work
Scale-out

Bottleneck



NN

File metadata
File->block mapping

DN

DN

DN

DN

Store blocks
Serve data reads/writes

Vertically scaling HDFS

Project	Improvement	Cost (months)
Multiple volumes per NN	Operational	6
Split namespace and block management locking	2x RPC	12
Fine-grained locking of namespace	2x RPC	6
Pageable namespace	2x object count	6
Persistent block space	Operational	6
Block management as a service	2x object count	12+
Volume migration	Operational	12

Scary changes

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Incremental

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Years of work

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Hardware trends on the horizon

	2006	2016	2021
HDD capacity (TB)	0.2	2	20
HDD speed (MB/s)	90	110	140
Network speed (Gb/s)	0.1	10	40

Fewer IOPS/GB

HDD locality irrelevant

A fresh look

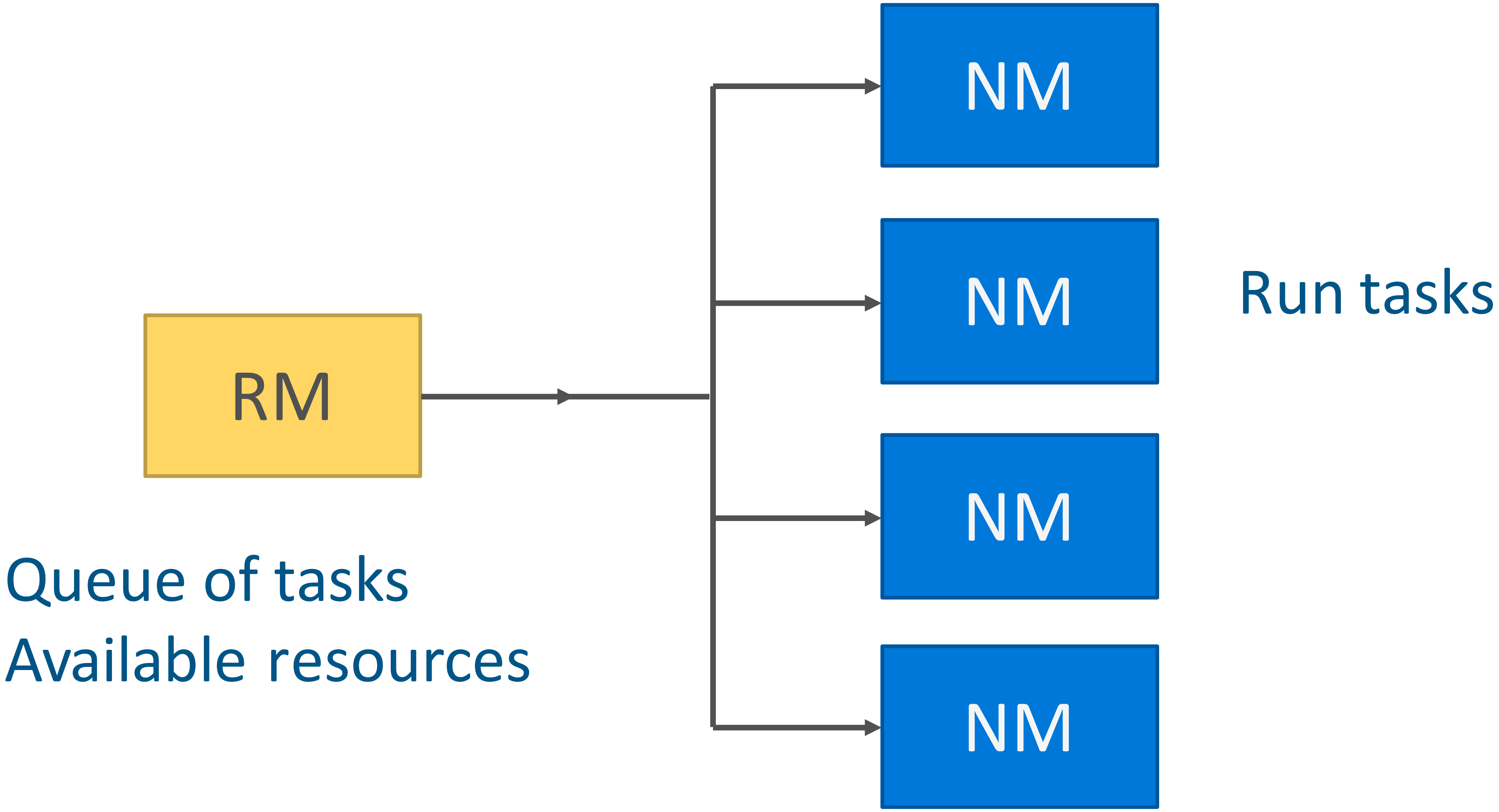
- Designed for analytic workloads
- Scales horizontally (exabyte scale)
- Operationally robust
- Designed for future hardware trends

Blobstore

- Users think in datasets, not directories and files
- Spectrum of blobstore vs. filesystem functionality
- What is the equivalent of the POSIX API for a scalable storage system?
  - What set of operations are required?
  - What are their semantics?
  - What can and cannot be supported scalably?

Other considerations

- Erasure coding
  - Required to be cost competitive
- Multi-datacenter replication
  - Important for business-critical analytics
- 3D Xpoint
  - New addition to storage hierarchy
  - Could change how we write software and think about persistence



Queue of tasks

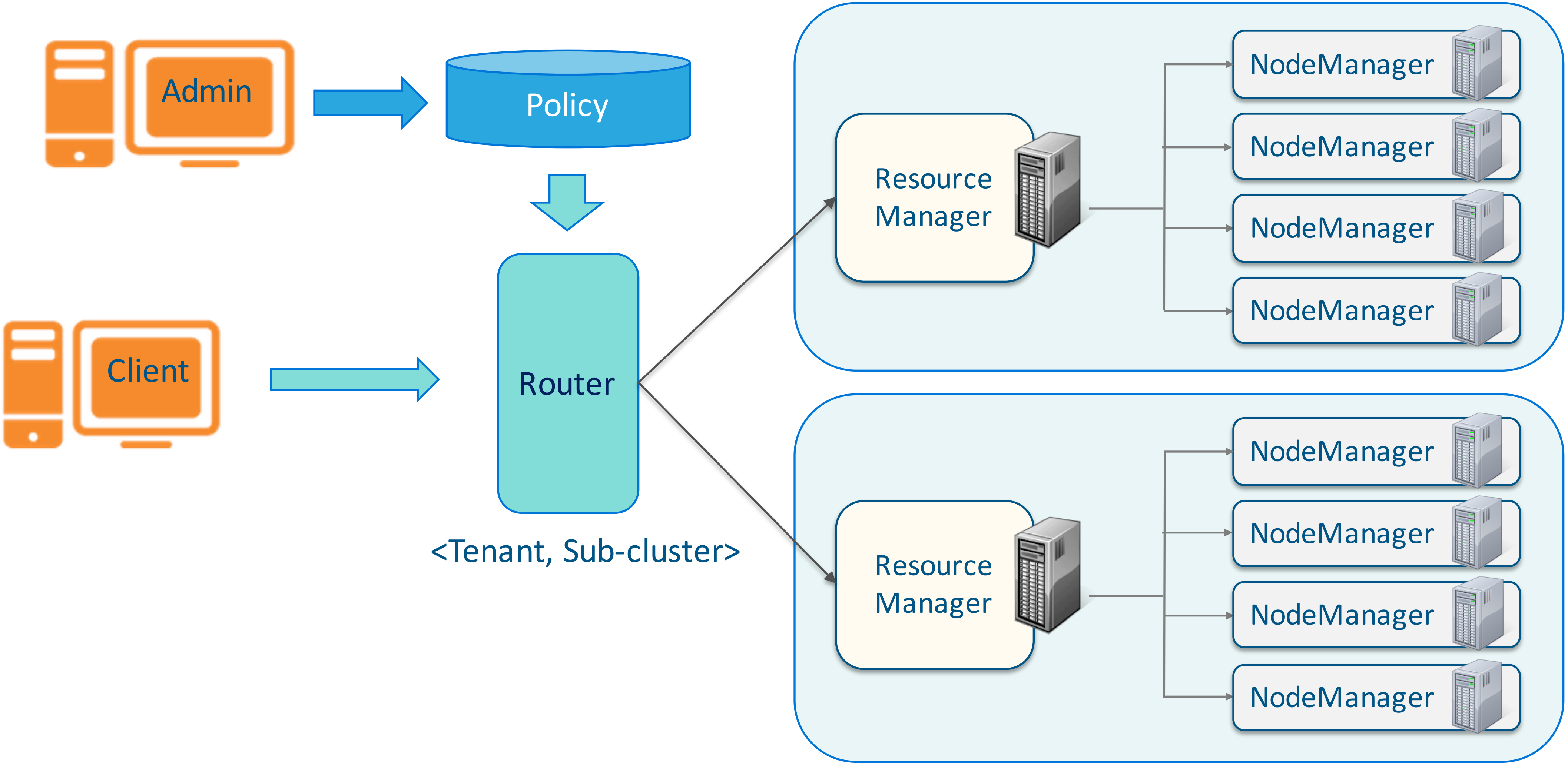
Available resources

Run tasks

One cluster to rule them all

- Exabyte-scale storage means exabyte-scale processing
- Current: 10,000 node YARN clusters
- Goal: 1,000,000 nodes
    - One cluster for all compute at an internet-scale company
    - Think Microsoft or Twitter

Yarn Federation



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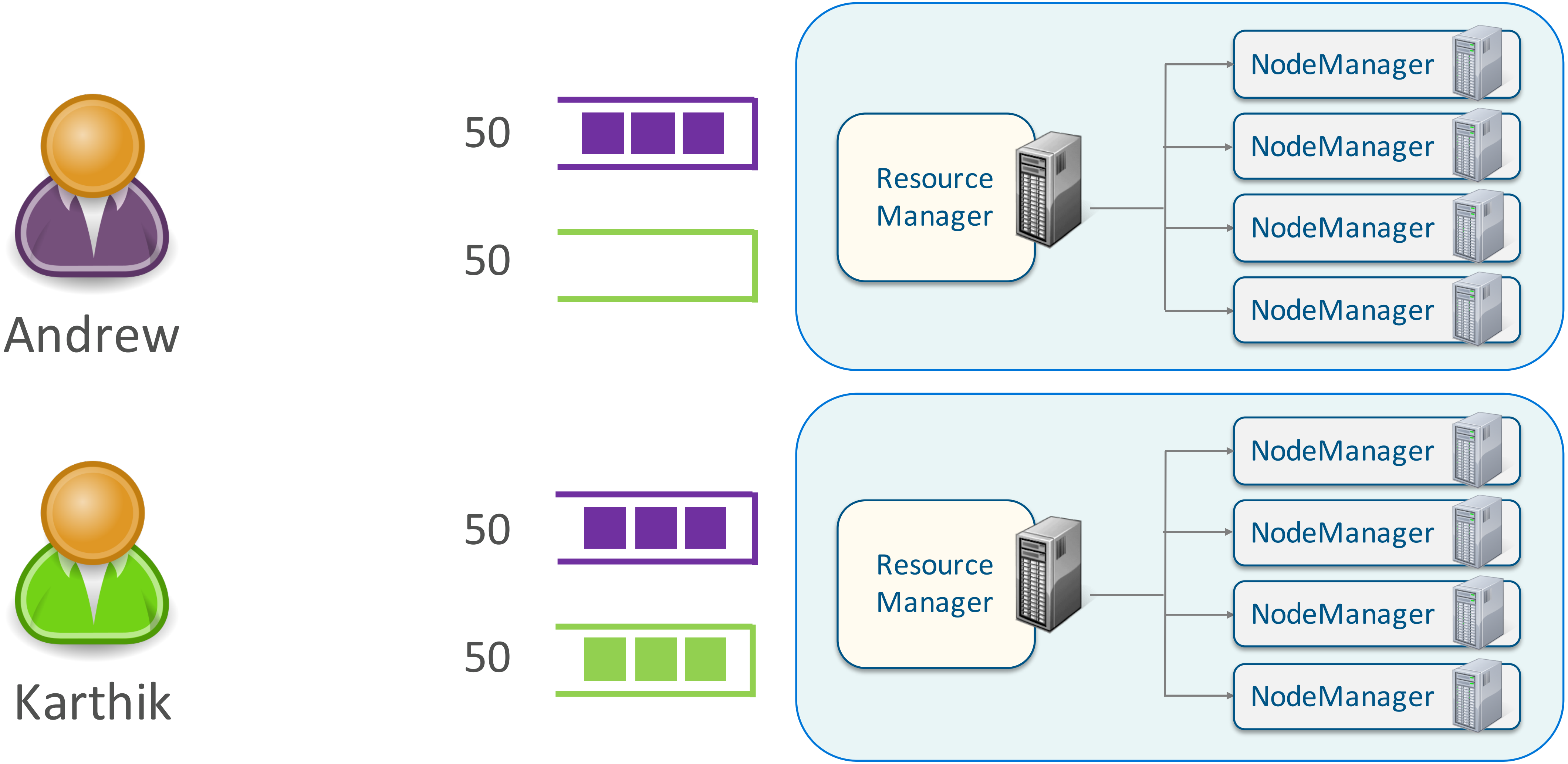
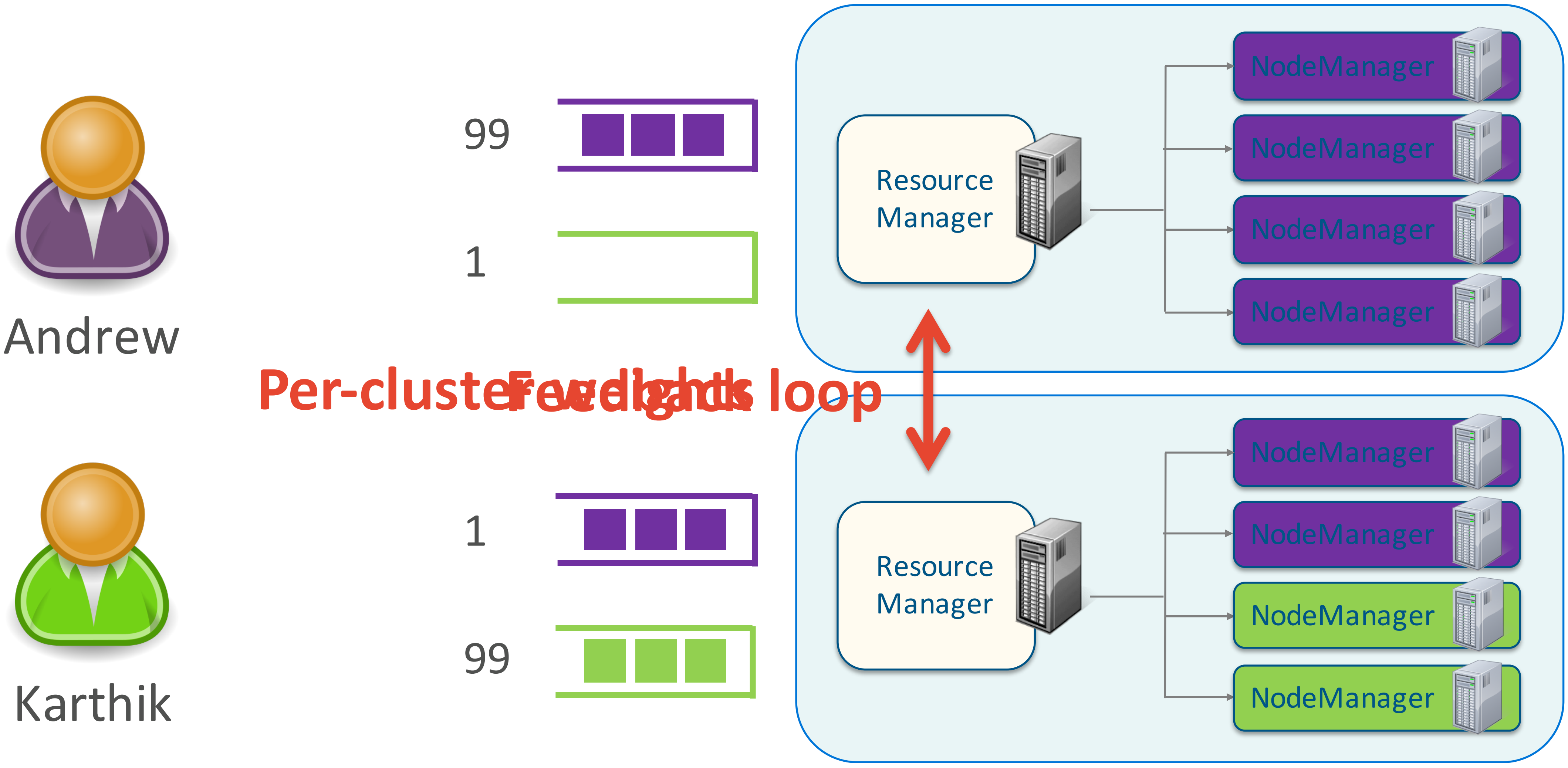
Fair-Sharing and Federation



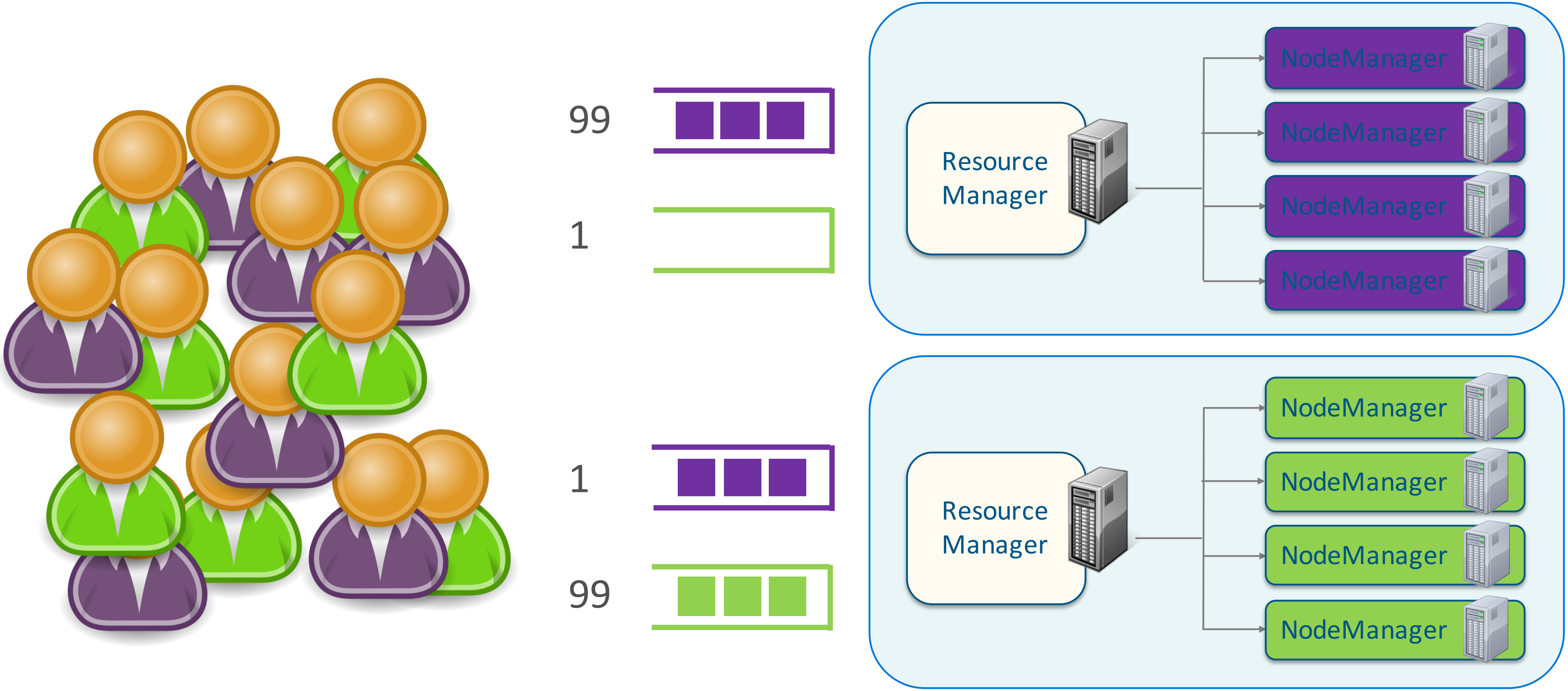
Fair-Sharing and Federation



Per-cluster weights

Feedback loop

Fair-Sharing and Federation



Scheduling

Variety of workloads

	Duration	Scheduling Latency	“Tasks”	Tenant Scale	Placement Quality
Batch processing	Mins - hours	Seconds	**< 400,000**	**Jobs (10Ks)**	Low
Interactive SQL	Seconds	Milliseconds	100s	Users (100s)	Medium
Stream processing	Months	Minutes	10s	Jobs (10s)	High
Long-running services	Months	Minutes	# Nodes	Services (10s)	High

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Scheduling latency

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Low latency scheduling for distributed systems

- State of the art
  - Low-latency scheduling: Sparrow
    - Second-level scheduler that needs pre-allocated resources
  - Operational
    - Static partitioning: set aside resources
    - Semi-static: Maintain a per-user cache of resources
    - Downside: low utilization

Can we design scalable algorithms for low-latency scheduling?

Scheduling latency

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Scalability - Tenants

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Scalability – Tenants vs Nodes

- Scheduling is allocating resources for tenants on cluster nodes
  - Matching/join between two sets
  - Scheduling latency = |Tenants| x |Nodes|

Can we lower the bound on scheduling latency?

Quality of placement

	Duration	Scheduling Latency	“Tasks”	Tenant Scale	Placement Quality
Jobs	Mins - hours	**Seconds**	**< 400,000**	**~ 10,000**	**Low**
Services	Seconds	**Minutes**	**#Nodes**	**< 100**	**High**

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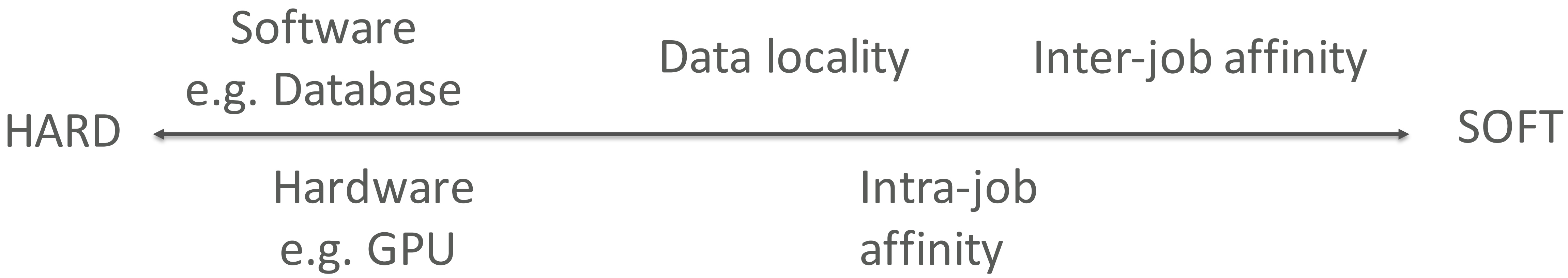
Placement requirements



HARD

Software
e.g. Database

Hardware
e.g. GPU

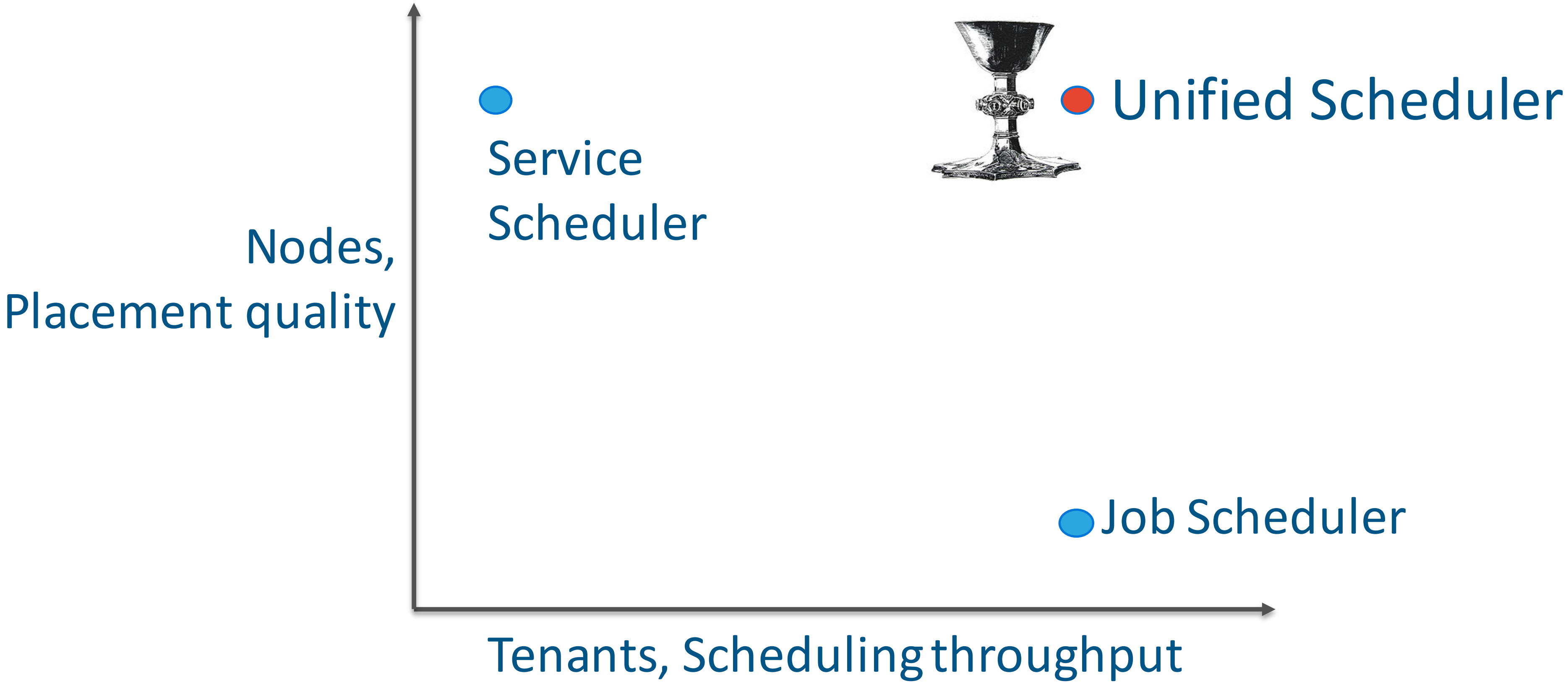
Data locality

Intra-job
affinity

Inter-job affinity

SOFT

Multi-tenancy and scalability



Utilization

Production clusters

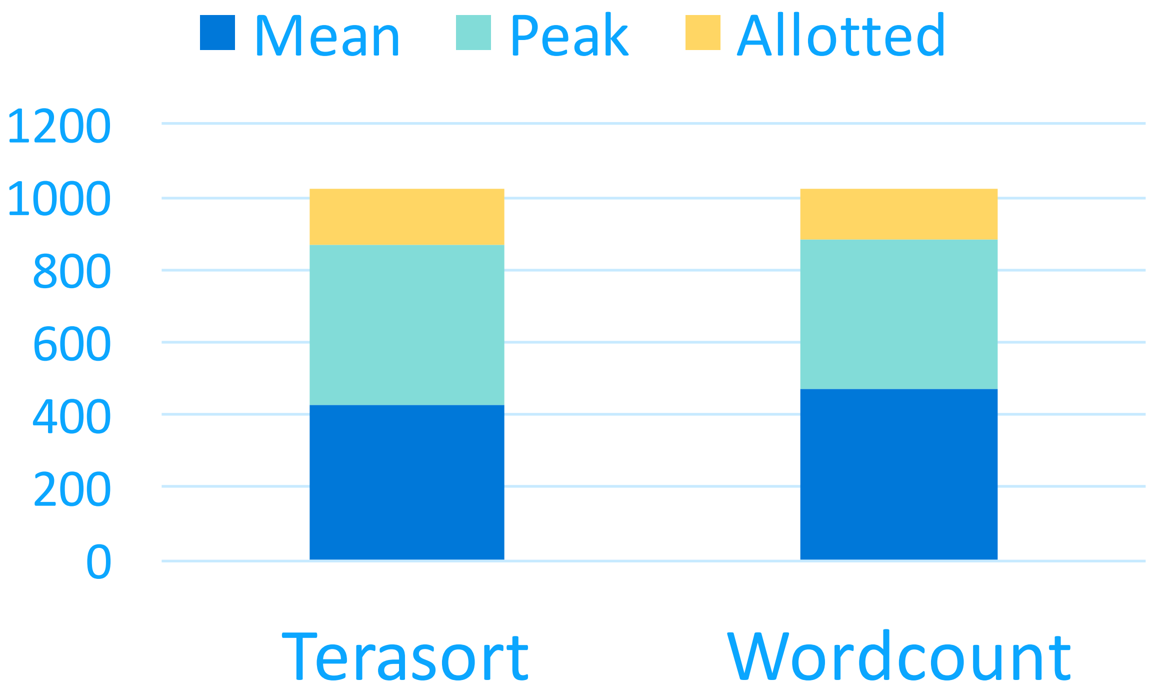
	CPU Utilization %	Memory Utilization %
MapReduce v1	< 20 [1]	< 20 [1]
YARN / MapReduce v2	50 [1]	30 [2]

[1] Apache YARN at SOCC ‘13

[2] Anecdotal from the community

Potential for improvement

- A task's resource usage varies over time.
- Resource usage varies across tasks of the same job



Over-subscribing nodes

- Allocate unused resources to pending tasks
- Challenges
  - Handle sudden spikes in resource usage gracefully
  - Performance of tasks can not deteriorate
    - Contention on non-isolated resources

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Conclusion

Apache Hadoop is mature and very widely deployed.

The underlying assumptions are 10 years old and need revisiting.

Lots of interesting and hard research problems in the space.

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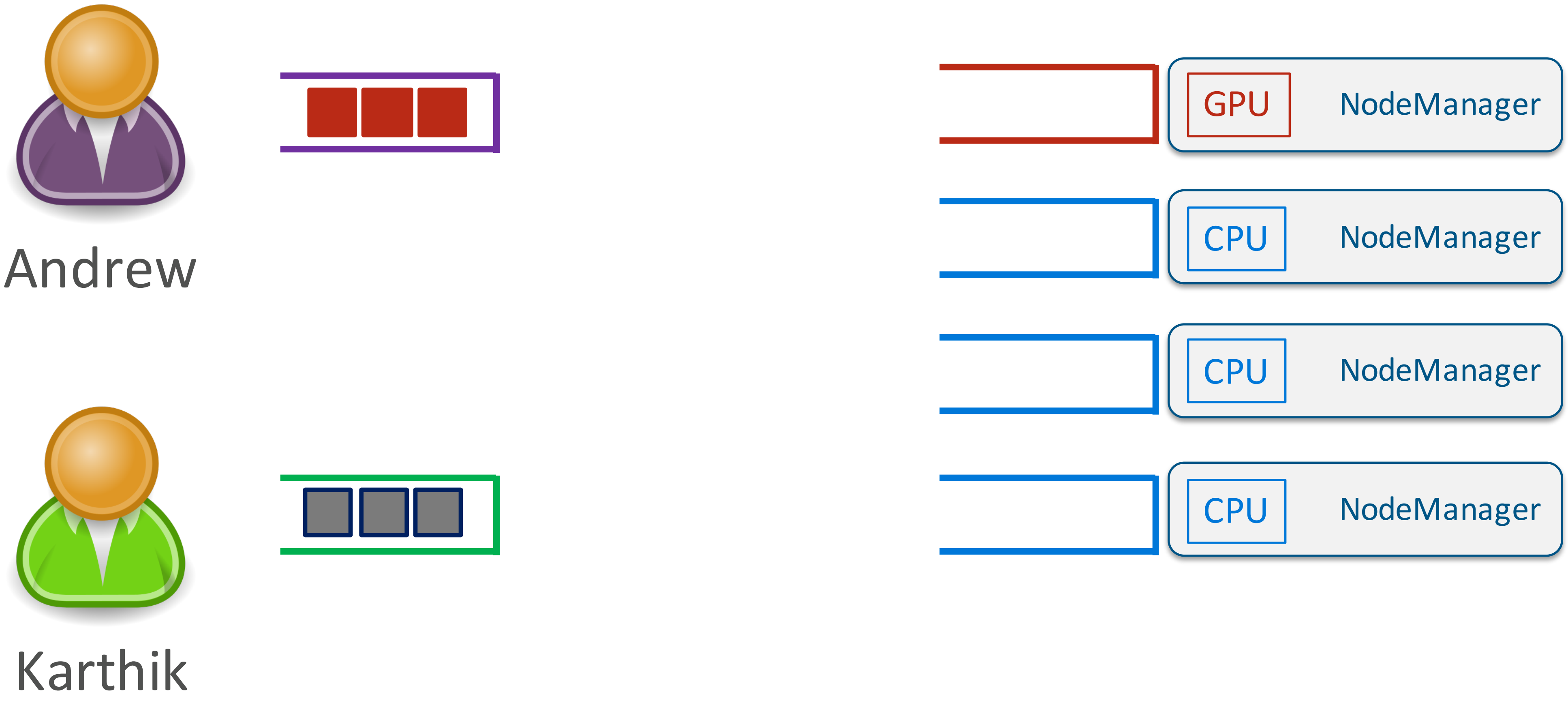
Thank you

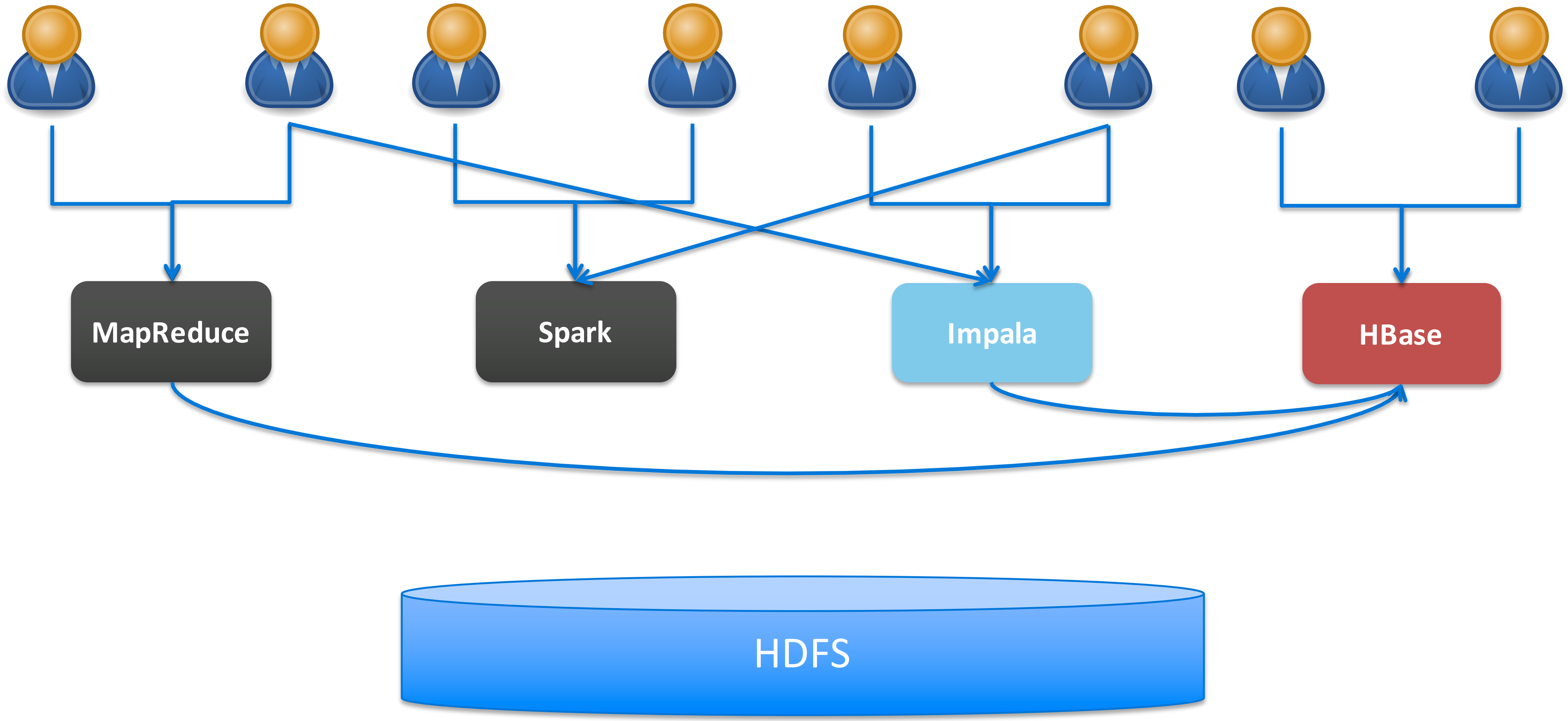
Open Problems

- Storage scalability
- Blobstore API for analytic workloads
- Global fairness in a federated YARN cluster
- Low-latency scheduling
- Jobs and services on the same cluster
    - Scheduler scalability in tenants and nodes
    - Improving quality of placement with a latency upper bound
- Cluster utilization improvements
- I/O scheduling for predictability and QoS

Greedy placement is not optimal



Multi-tenancy


MapReduce
Spark
Impala
HBase
HDFS