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Ask Bigger Questions

Resource Management with YARN and Impala

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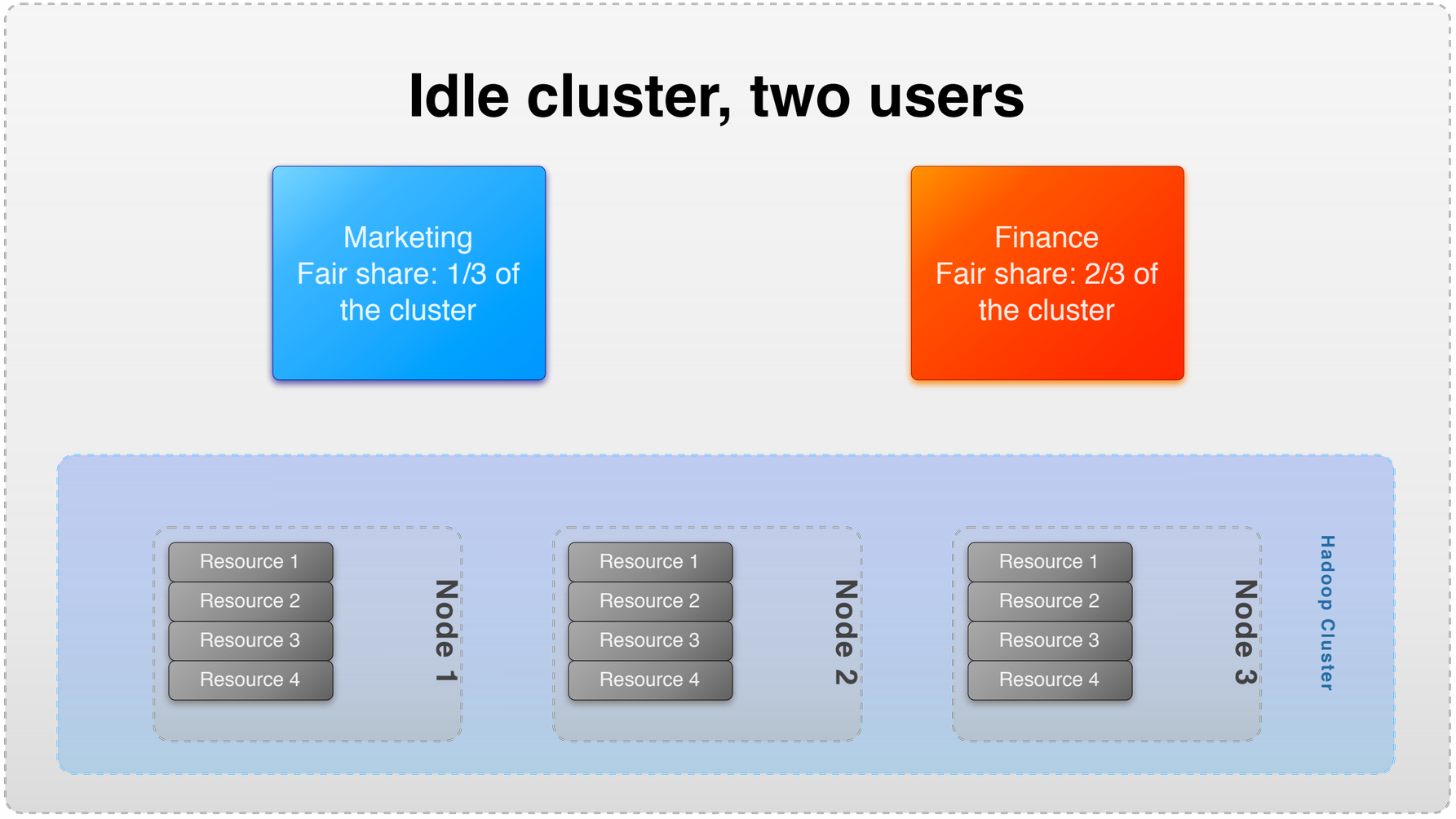
Resource management?

Can’t we all just get along?

Real-world resource management

- Hadoop brings generalised computation to big data
- Workloads are becoming more and more diverse
  - From frameworks including MR, **Impala**, Spark, Search
- Some workloads are more important than others
- A cluster is only a finite resource
  - Limited CPU, memory, disk and network bandwidth
- **How do we make sure each workload gets the resources it deserves?**

Example: Finance vs Marketing



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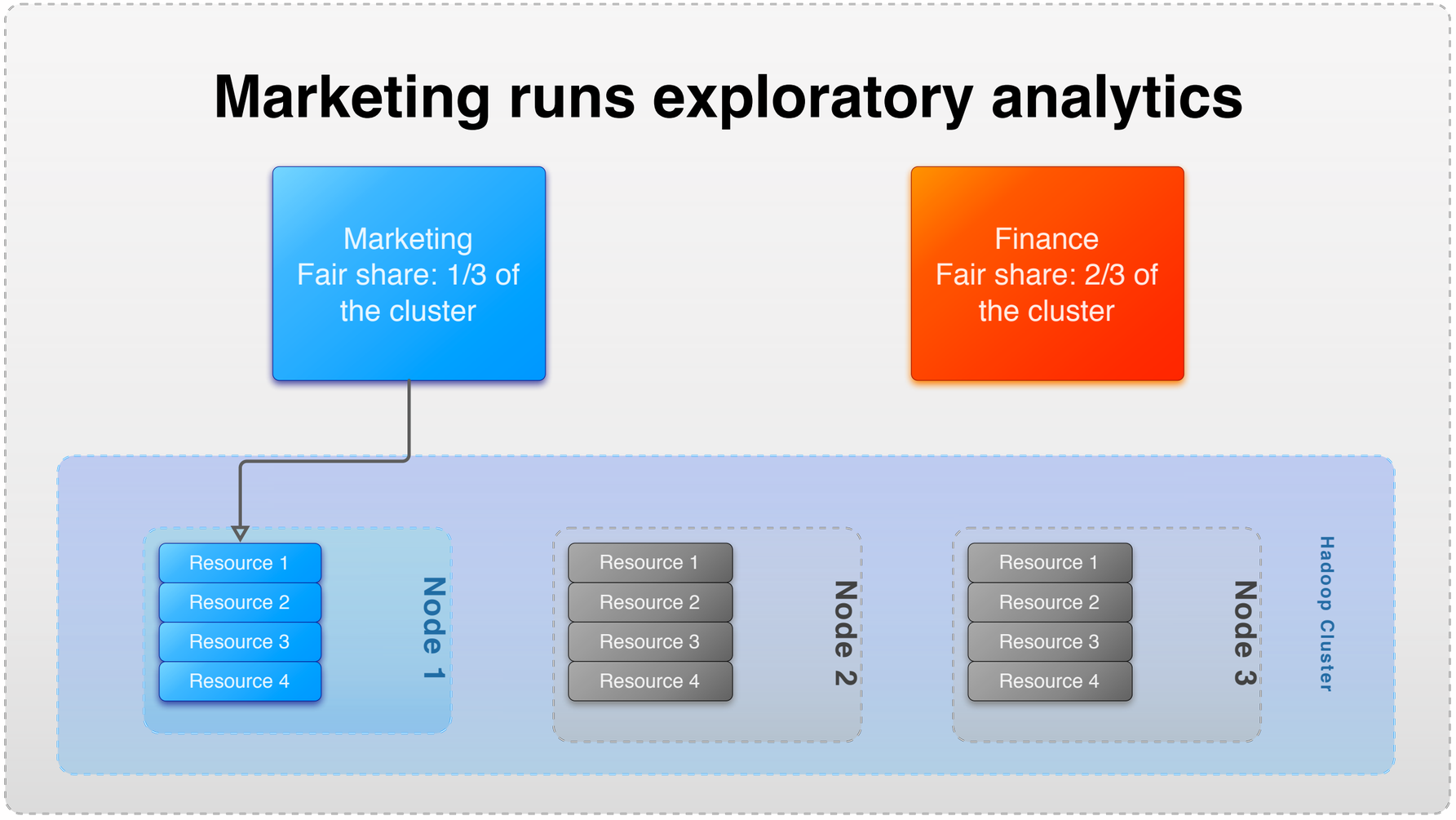
Example: Finance vs Marketing



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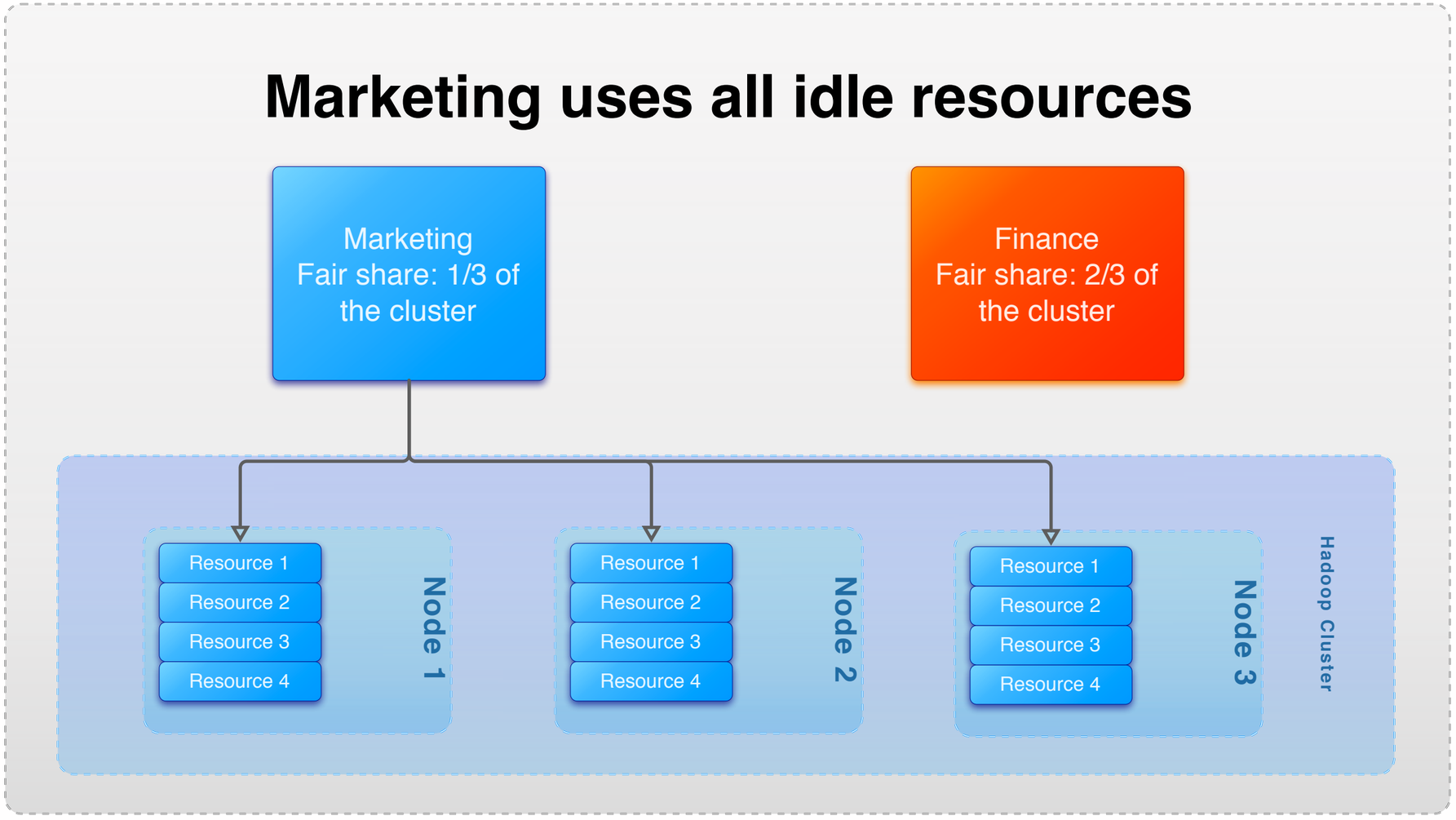

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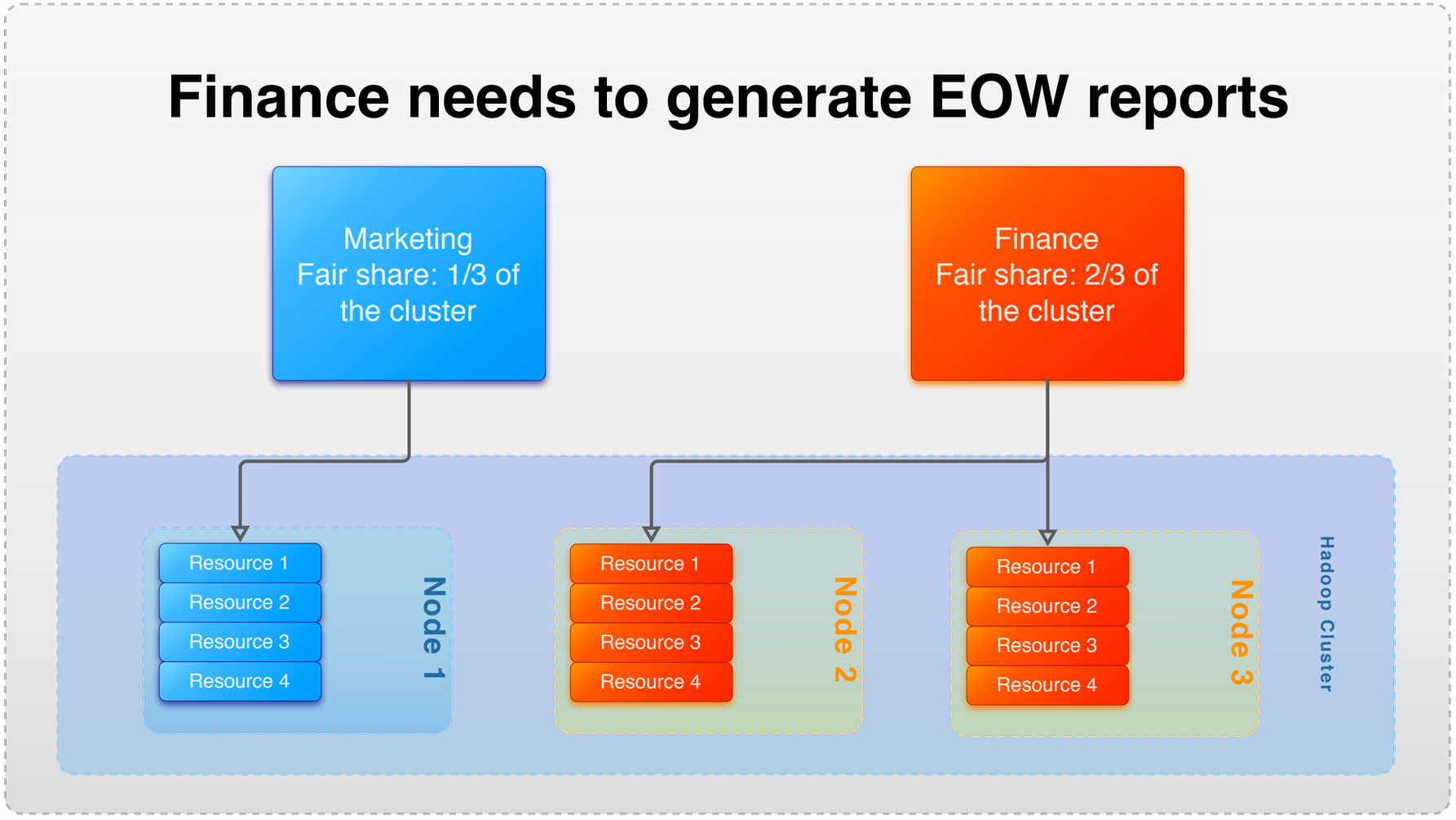

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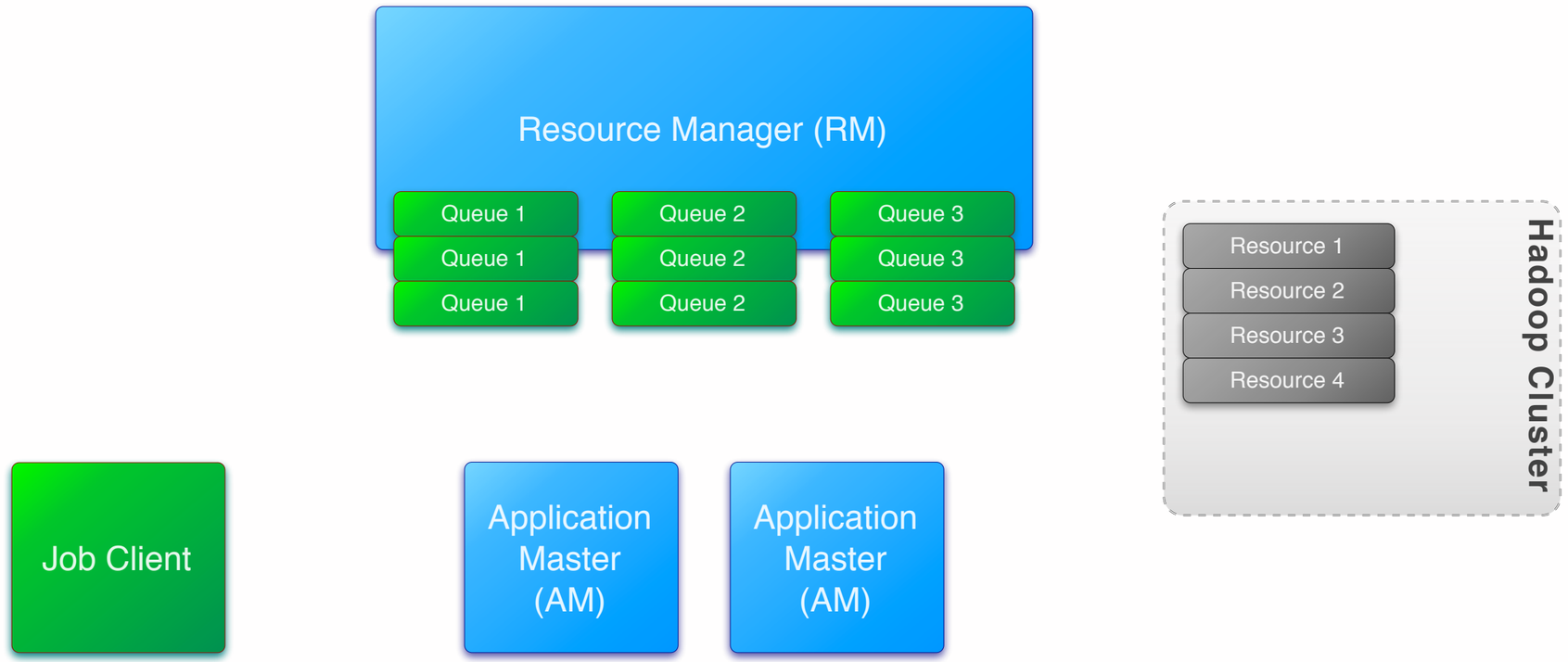
State-of-the-art: Apache Yarn

- YARN brings resource management to Hadoop
  - Via a centralised **resource manager** which satisfies resource allocation requests in turn
- Resources are shared between **queues**, each of which is entitled to a share of the cluster
  - e.g. Finance gets 2/3, marketing gets 1/3
- Each **job** registers as an **application master** with YARN
  - YARN manages the resource lifecycle on behalf of that job

Jobs and resources

Job creation and resource acquisition



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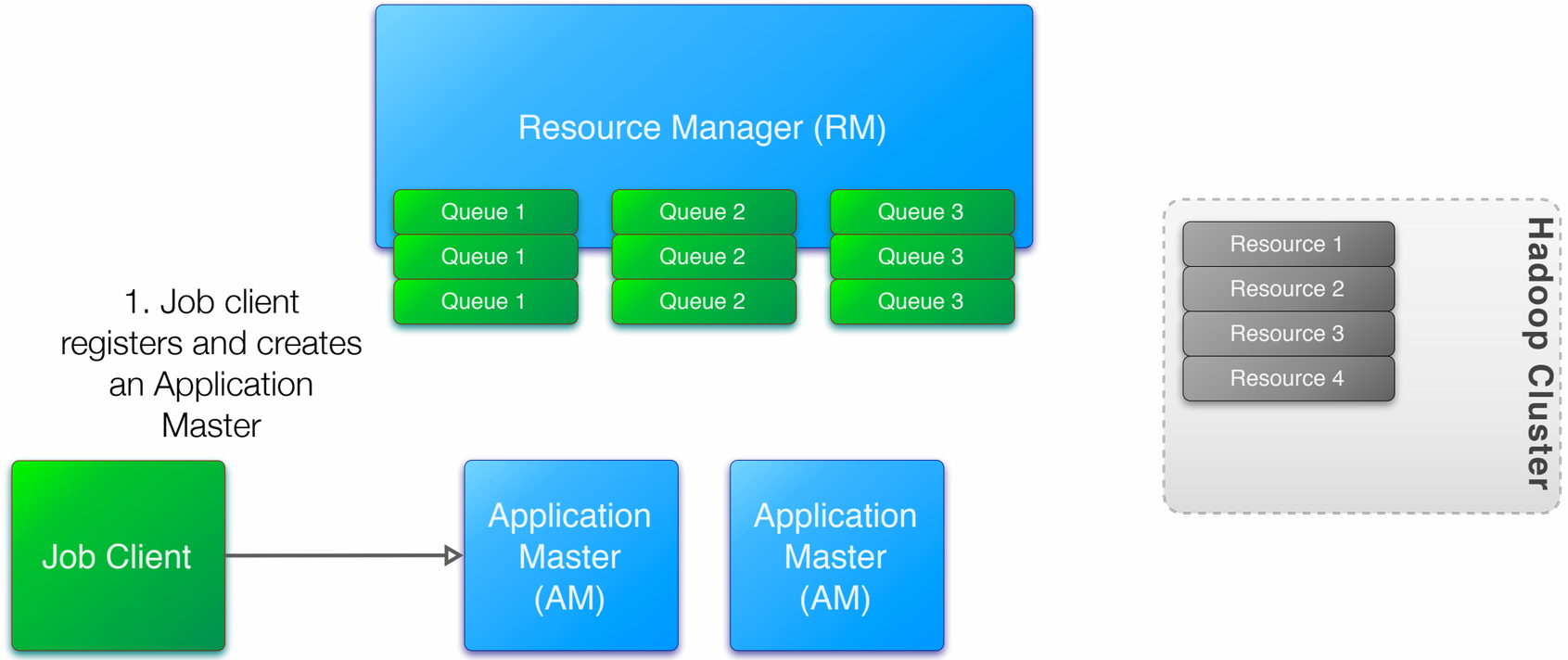

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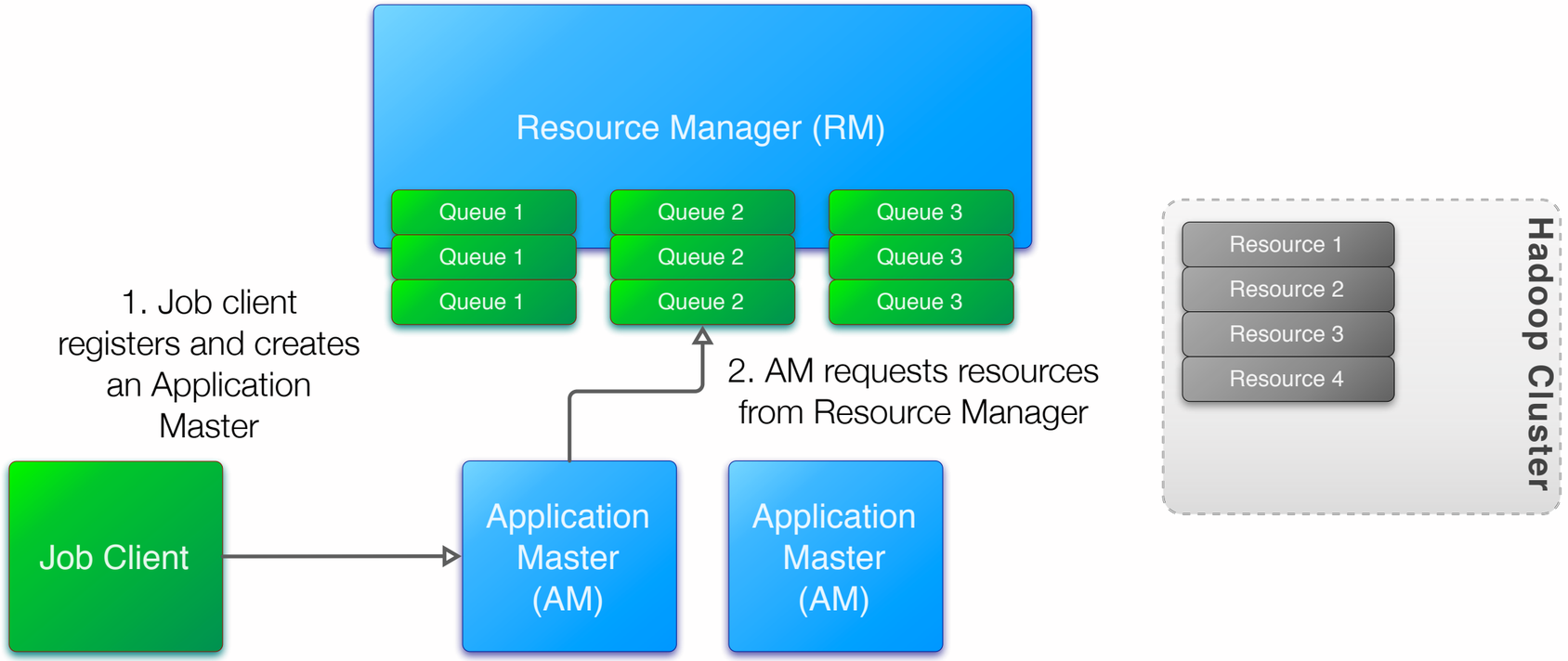

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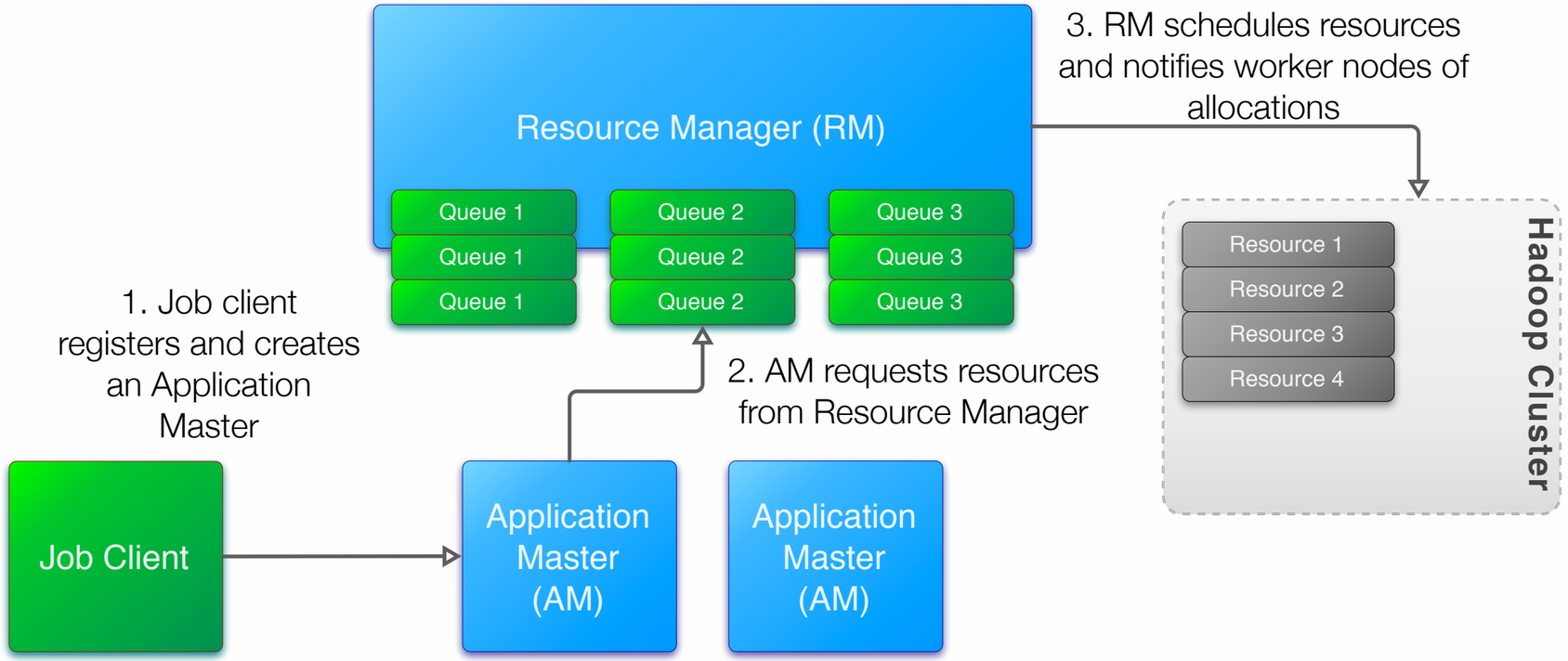

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More on the Application Master

- Creating an Application Master involves two round trips to the central Resource Manager
- An Application Master only lasts as long as the job does
- AM creation latency is much higher than resource acquisition

YARN is focused on batch processing

- Hadoop comes from batch-processing via MapReduce
- Batch job runtimes are usually dominated by the time to actually process the data
- So MapReduce can afford the cost of AM registration protocol, and of allocating resources centrally
- Number of concurrent jobs is usually in the hundreds
- Median job time usually > 10s

Hadoop is no longer only about batch

- Cloudera Impala, announced a year ago, brings **interactive, low-latency SQL queries** to Hadoop
- Serves a number of critical use cases as more and more data migrates to Hadoop
  - Such as Business Intelligence, exploratory analytics, general SQL processing
- Query times routinely sub-second. Concurrent query volumes can be closer to 1000.
- **The overhead of YARN is much more significant**

How do we bring the two worlds together?

- Impala wants to participate fully in resource management to allows users to get the resources their workloads deserve
- YARN is not yet prepared for the latency and throughput requirements that Impala, Spark and other similar frameworks will bring.
- **How do we overcome the impedance mismatch?**

Resource management and Impala

- First part (most of the rest of this talk): integrating Impala with YARN, and overcoming the most significant hurdles

- Second part: Future plans to improve performance even further

1. Fixing the Impedance Mismatch

Fitting a square peg into a round hole

Too many Application Masters

- As we saw, YARN's model is one AM-per-job
- We quickly discovered this doesn't scale well to very high query volumes
- Impala submits thousands of queries-per-minute
- Something's got to give

Long-Lived Application Masters

- We created a new component called the **Long-Lived Application Master**
- The idea is to register only one AM per-queue-per-framework
- Takes the load off YARN (far fewer AMs)
- And takes the load off queries (AMs already established)

Long-Lived Application Masters

- We created a new component called the **Long-Lived Application MAster**

Long-Lived Application Masters

- We created a new component called the **Long-Lived Application MAster: LLAMA**

Photo credit: Wikipedia

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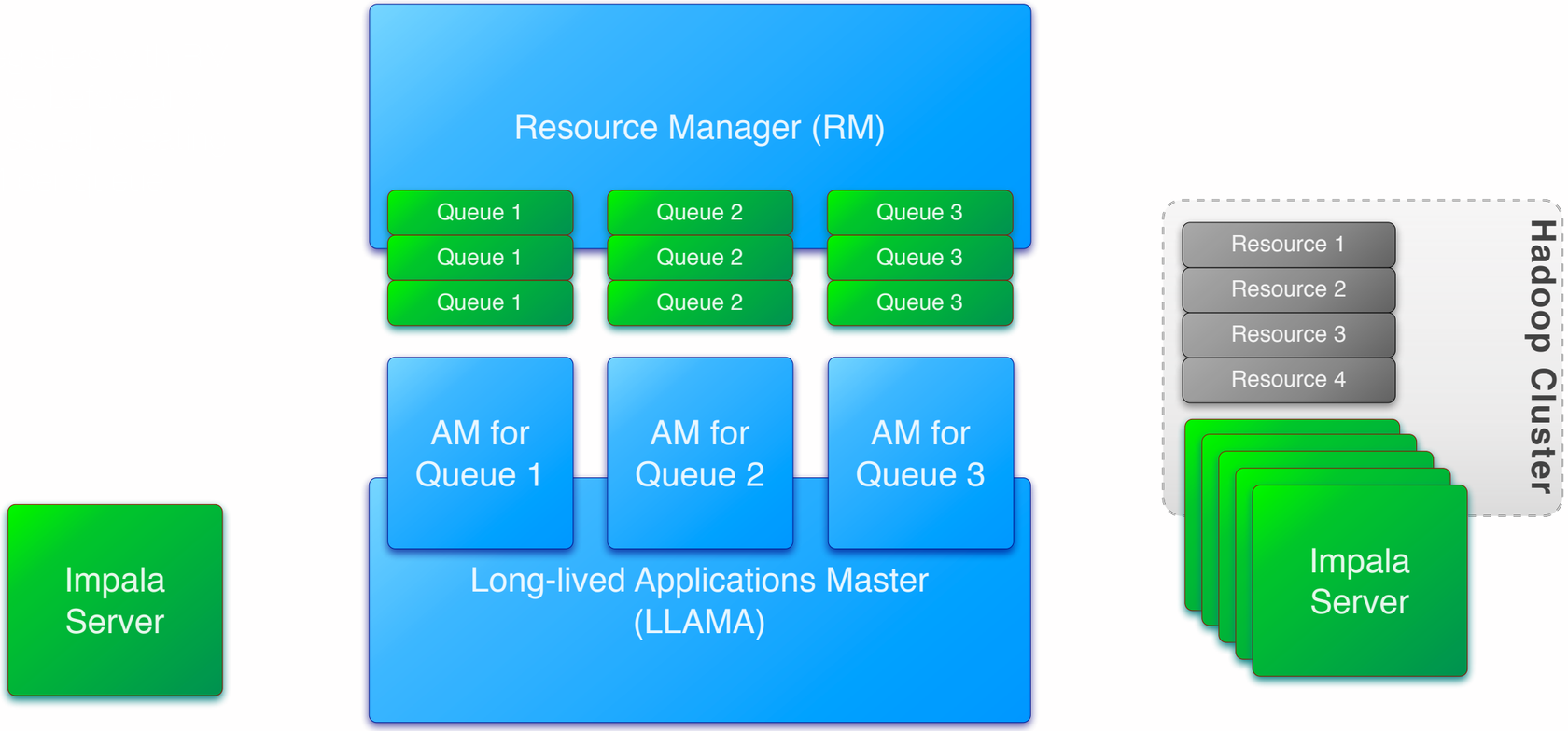
How Llama fits in

Llama's role in Impala resource acquisition



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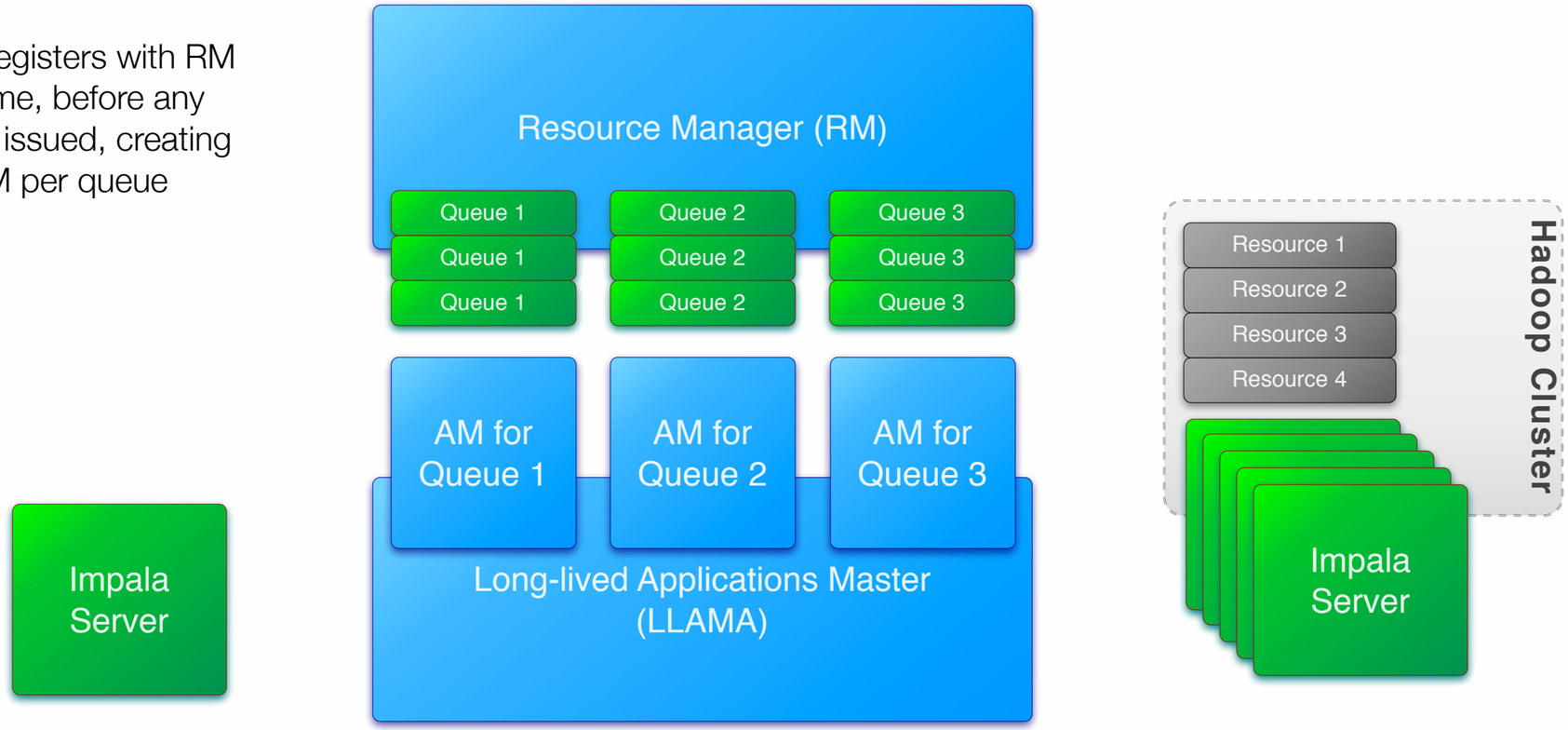
Llama's role in Impala resource acquisition

1. LLAMA registers with RM at start time, before any queries are issued, creating one AM per queue



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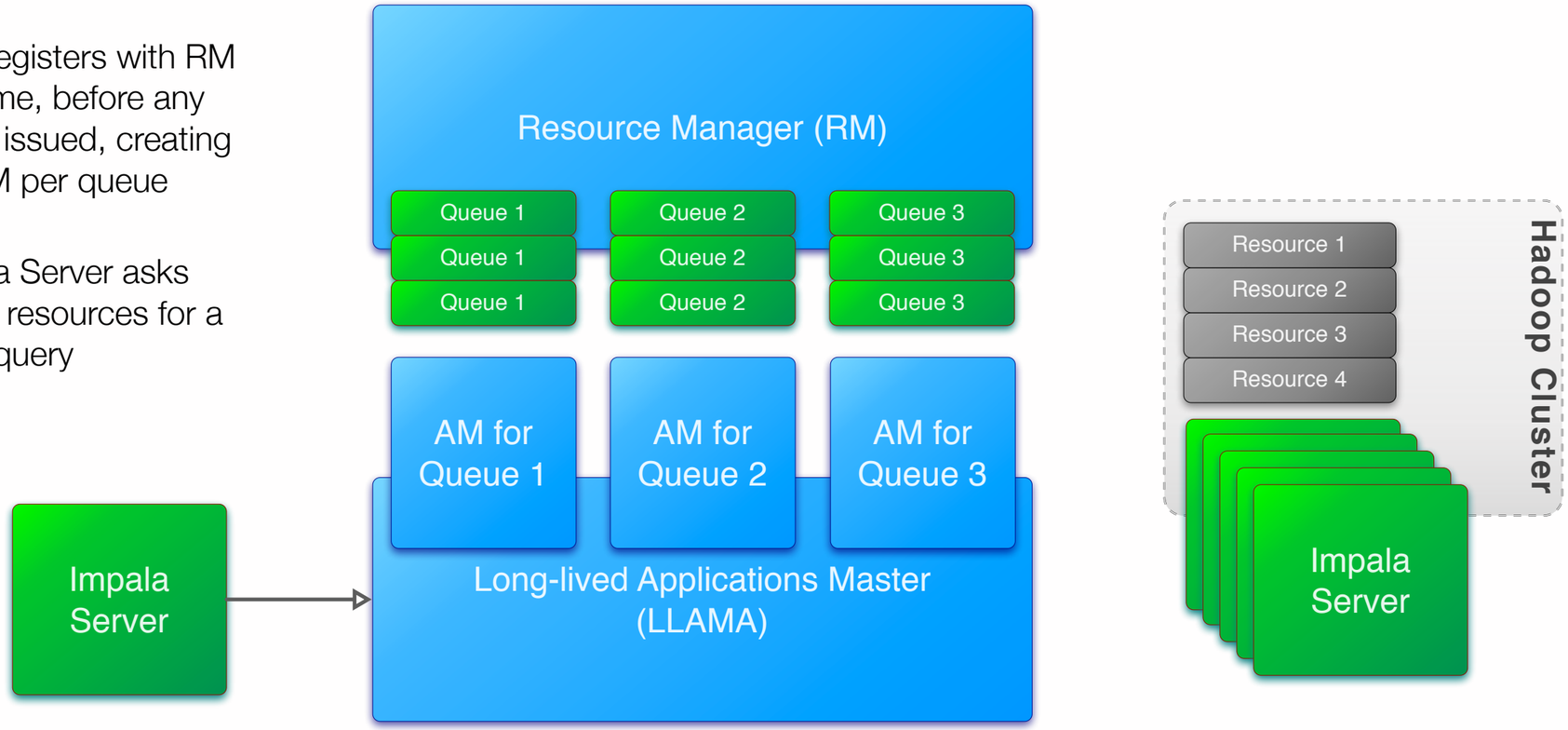

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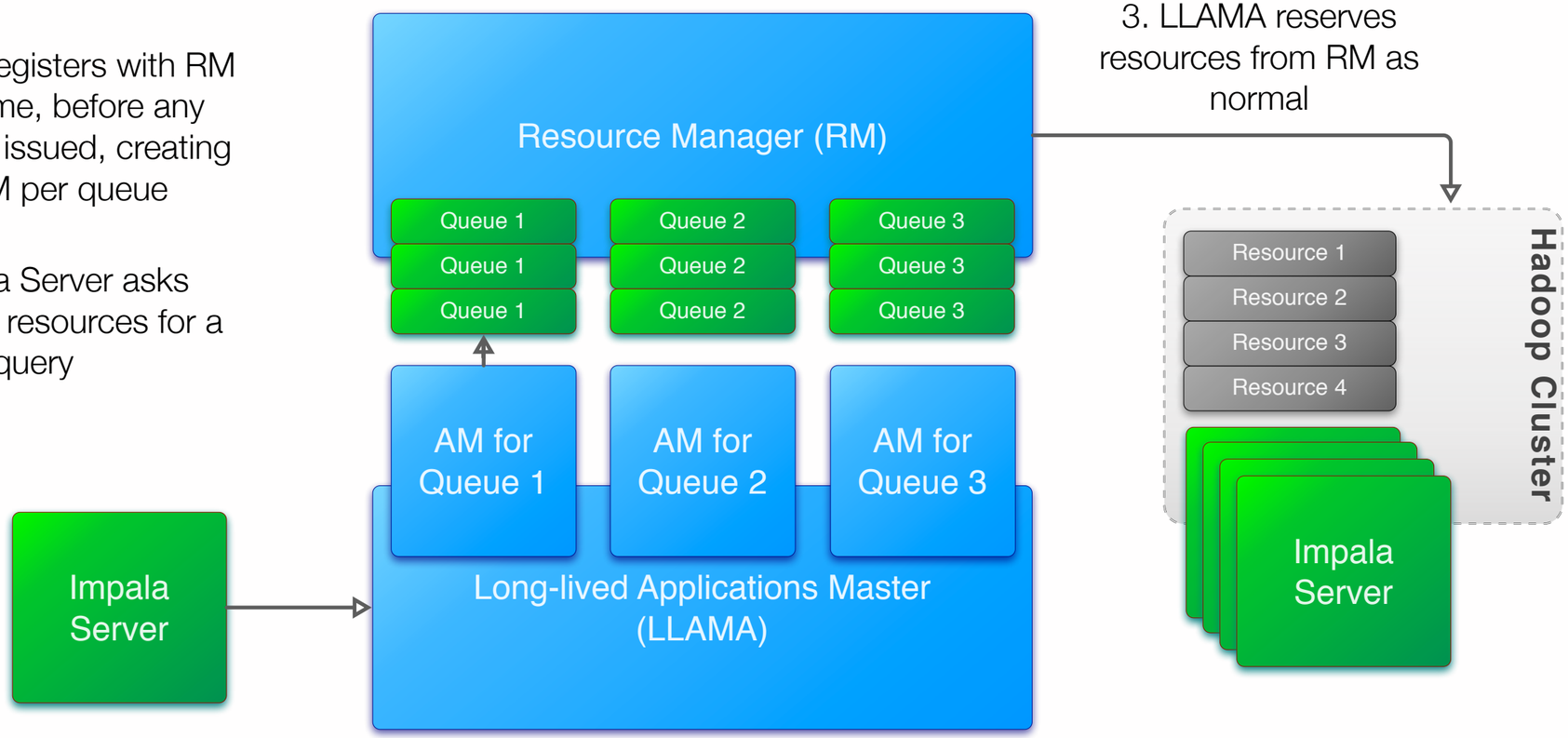

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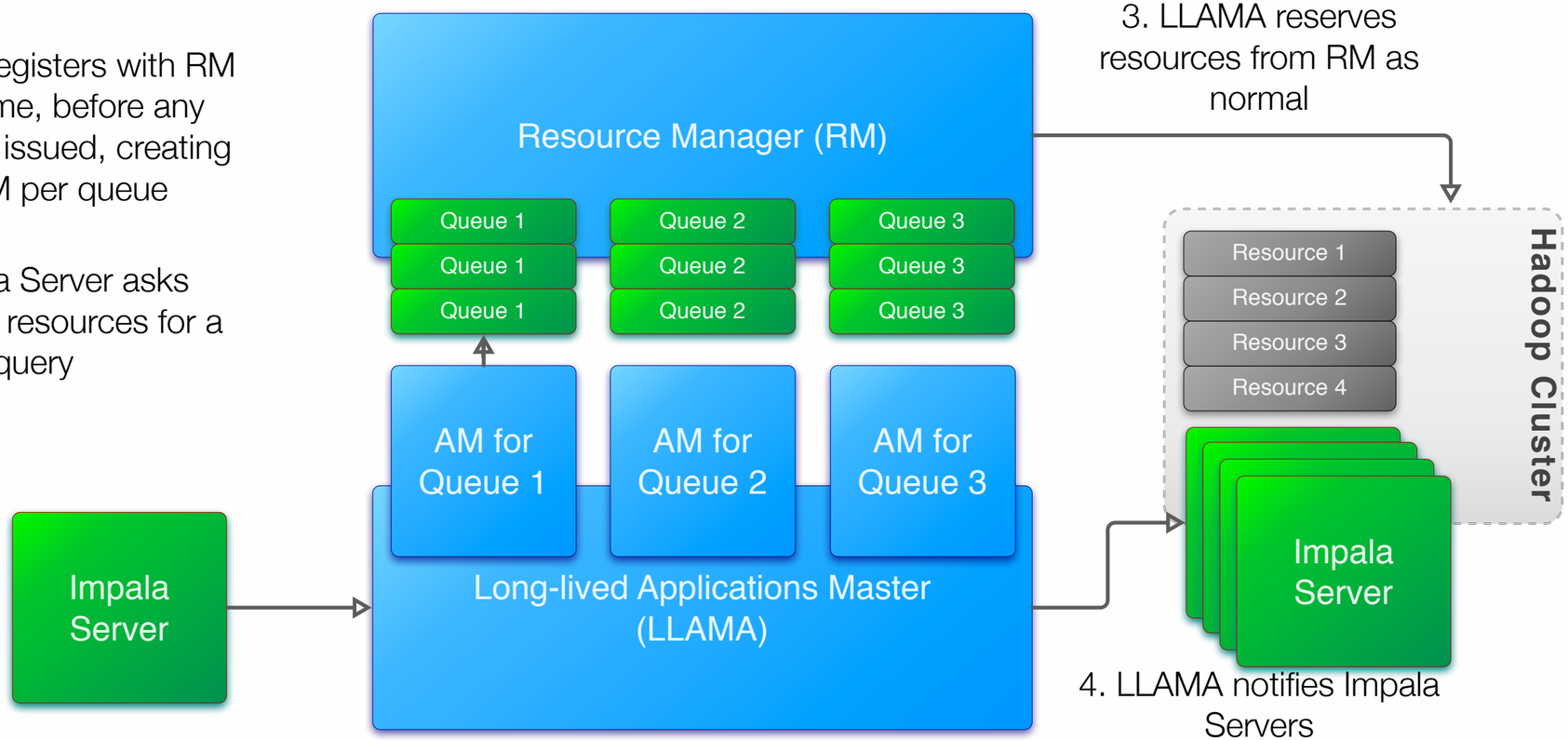

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Gang scheduling

- YARN returns resources in a trickle, as they become available
- For MR this is perfect, as tasks are mostly independent (and checkpoint to disk)
- For low-latency queries, we require all resources to be available **at once** so that query tasks can stream results to one another
- Llama buffers resources between YARN and Impala to make resource requests appear **atomic** and **indivisible**

Framework-based resource enforcement

- In MR, YARN is responsible for enforcing memory and CPU resource constraints
- The only reasonable way to do this is to manage tasks at the **process** level
- YARN uses **cgroups** to control per-process resource usage
- One process <-> one cgroup
- YARN starts the process, and puts it in its cgroup

Single-process enforcement

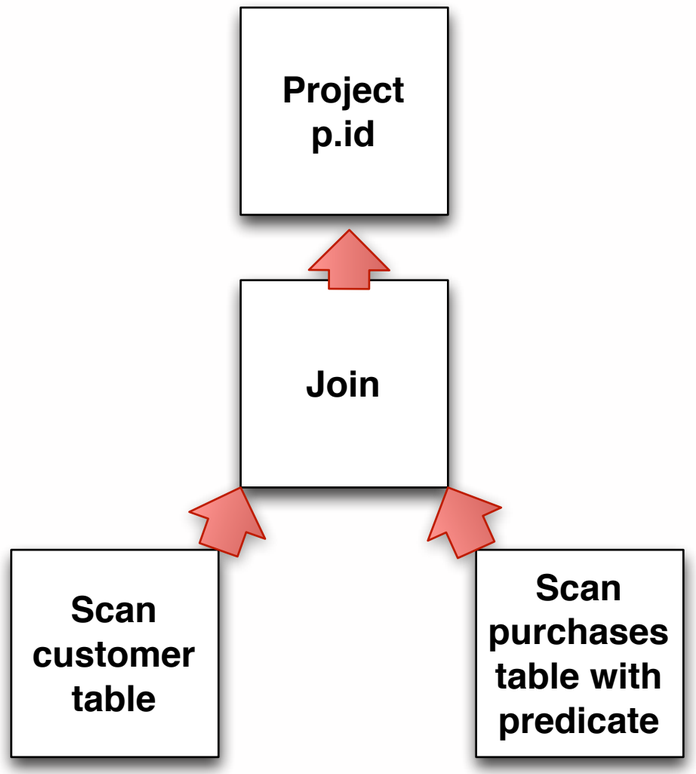
- **Problem:** that presumes that one process belongs to exactly one job
- This does not hold for Impala, which runs all queries in the same process, reusing threads for multiple queries
- YARN still wants a process to manage
- So we trick it! We tell YARN to run a process that does nothing, and Impala uses the resources granted to it

Resource Estimation

- Parts of Impala were extensively re-tooled to support integration with YARN via LLAMA
- Most interesting change: **resource estimation**
- Impala has to compute how much CPU and memory each query is likely to require
  - Too little: query can't run
  - Too large: resources are wasted

Resource estimation

```
select p.id from customer c join purchases p on
    c.id = p.cid AND p.date > "01/01/2013"
```



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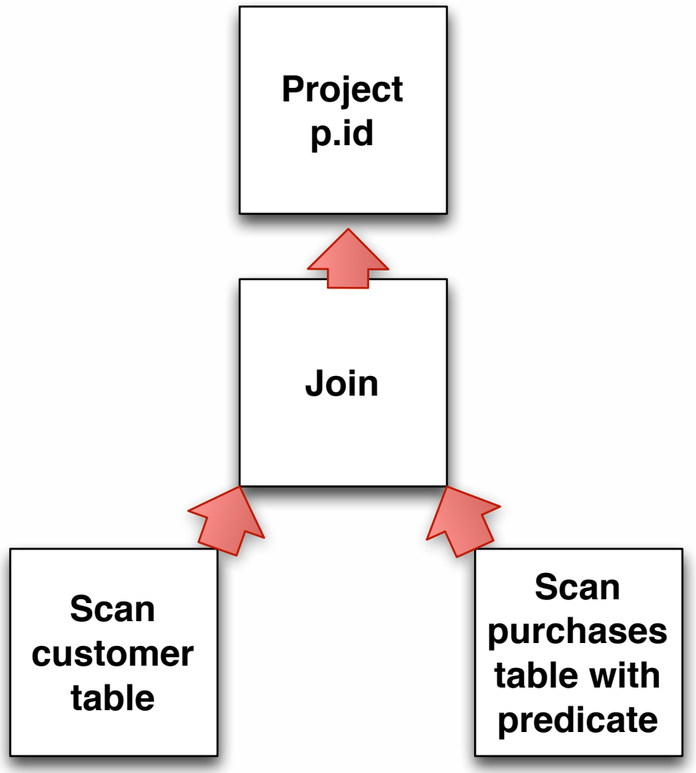

How many rows are expected to match the predicate?

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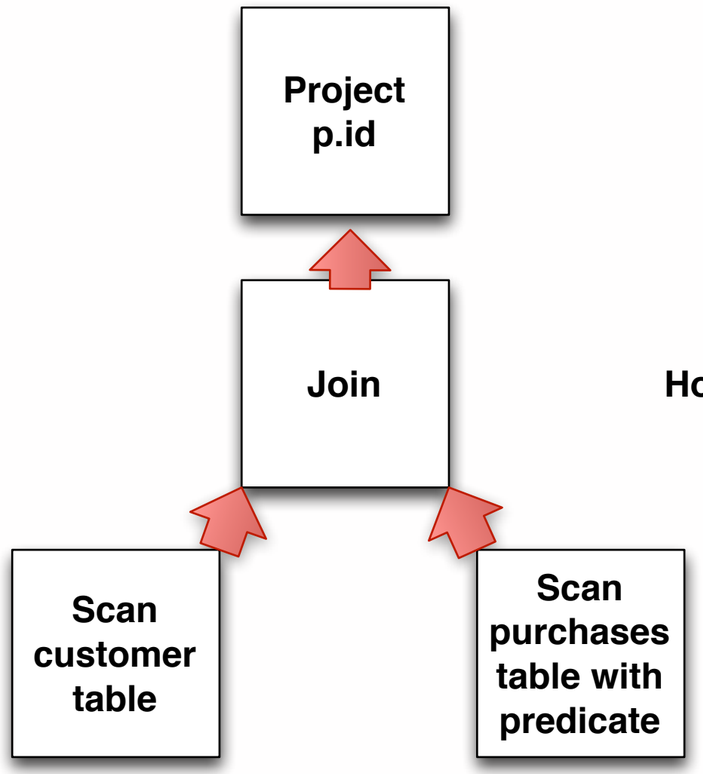

How big does the hash-table need to be?

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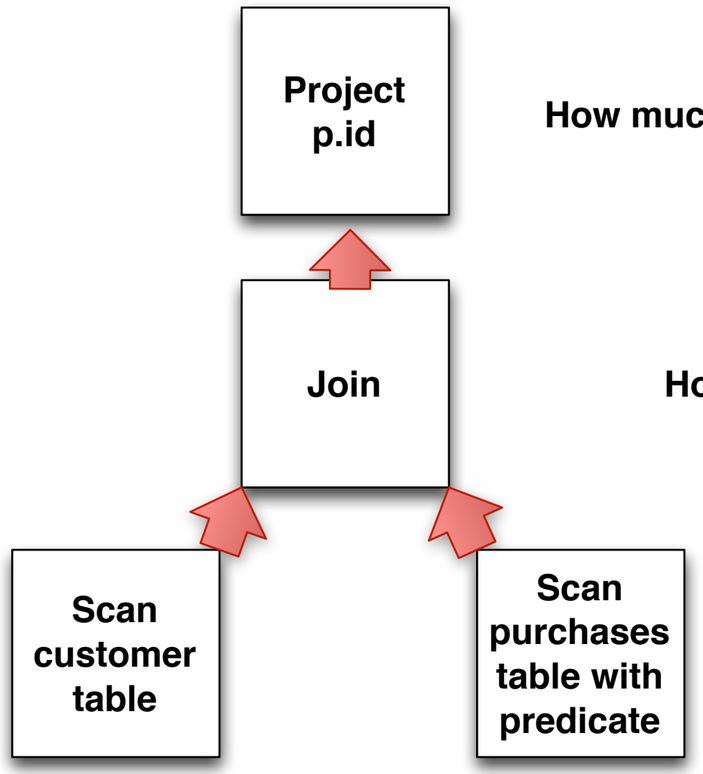

How much memory is required for the ID column?

How big does the hash-table need to be?

How many rows are expected to match the predicate?

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Available Today!

- Cloudera's **CDH5 Beta 1** contains preview support for everything we've seen up until now:
  - LLAMA demon
  - YARN support inside Impala
  - Resource estimation algorithms
- Make sure you have computed **statistics** for your tables, otherwise resource estimation will be wrong
  - Instructions on the Cloudera website

2. Future Work

Better, Bigger, Faster, More!

Cutting the cost of resource management

- Long-lived application masters cut down a lot of the overhead of integrating with YARN
- Resource **acquisition** still requires a round-trip to a central server, and is unlikely to scale to our most aggressive latency and throughput requirements
- For CDH5 GA our focus is on performance, and supporting our customers with the most demanding workloads

Long-lived Containers

- **Idea**: amortise the cost of obtaining a container across many queries.
- Instead of yielding a container after the query finishes, hold on to it for a short time.
- If another query can use it, we already have saved 50% of the resource acquisition cost.
- YARN still enforces the fairness of this approach under load

Routing queries to containers

- How do queries know where the containers are, without asking YARN?
- Impala already has a broadcast mechanism that it uses for table metadata, called the **statestore**
- Each Impala server receives a list of containers and their current usage. New queries get routed to the unused queries first.

Growing and shrinking allocations

- The long-lived container approach works for queries that fit exactly into existing containers
  - Which rarely happens without wastage
- Instead, Impala servers should grow or shrink allocations with demand in small container increments
- Requires running one query in several containers at once
- With some **cgroups magic(tm)** this is possible
- See YARN-1197 for some discussion of a similar approach

Speculative Execution

- **Idea:** Do we even need containers?
- Many queries are small, and take up few resources
- Many cluster don’t always run at 100% capacity
- Let’s run queries in the unused space until it’s needed
- Principle: ask **forgiveness** rather than **permission**
- If the queries are running too long, protect them by **asynchronously** acquiring resources

What we've covered

- YARN is the **resource manager for all Hadoop frameworks**
- Cloudera Impala places new requirements on that crucial subsystem
- We have adapted YARN to help support **low-latency**, **interactive** workloads **alongside traditional batch processing**
- Future work focuses on further improving performance

Further reading

- YARN-1284, YARN-1274, YARN-1253, YARN-1010, YARN-1144, YARN-1137, YARN-1049, YARN-910, YARN-1008, YARN-789, YARN-937, YARN-392 YARN-1321, 1343, YARN-624, YARN-1290, YARN-392, YARN-521…
- http://cloudera.github.io/llama/

Don’t miss!

- **Parquet: An Open Columnar Storage Format for Hadoop**
  - October 29th (**Today**) - 1.45pm, Gramercy Suite
- **Practical Performance Analysis and Tuning for Cloudera Impala**
  - October 30th (**Tomorrow**) - 2:35pm, Murray Hill Suite

Thank you! Questions?

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