HYDRA

A FEDERATED RESOURCE MANAGER FOR DATA-CENTER SCALE ANALYTICS

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Microsoft
BIGDATA SCHEDULING: A JOURNEY...

Hadoop MR,
Centralized sched.
[euros07, vldb08]

Distributed sched.
+tooling/optimizer,
+scale, +high utilization
[osdi14]

Hydra

+multi-framework
+security
+scheduler expressivity
[socc13]

MR
Tez
Spark

YARN

Scope, Centralized sched.

Scope
Scope1
Scope2
Scope3

2003 2008 2013 2019
BIGDATA SCHEDULING: A JOURNEY...

- Hadoop MR
- Centralized sched.

- Scope
  - Centralized sched
  - Hydrea

- Hydra
  - MR
  - Centralized sched
  - Tooling/optimizer
  - Scale
  - High utilization

- [eurosyst07, vldb08]

- [socc13]

- Distributed sched
  - + tooling/optimizer
  - + scale
  - + high utilization

- [osdi14]

- > 99% tenants migrated
- > 250K servers
- > 500k daily jobs
- > 1 Zetabyte data processed
- > 1 Trillion tasks scheduled

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HYDRA CHALLENGES

1. Support multiple application frameworks [socc13]
2. Simplify writing new app frameworks [vldb14,sigmod15,tocs17]
3. Achieve good ROI, i.e., high CPU utilization [atc15, eurosys16]
4. Scale to large clusters, many jobs, large jobs [nsdi19]
THE SCALE/UTILIZATION CHALLENGE...

Cluster(s):
> 50K nodes

Job(s):
> 2M tasks, > 5PB input

Scheduler:
> 70K QPS

Utilization:
~ 60% avg CPU util

Tasks:
10 sec 50th %ile
NEED **SCALE, UTILIZATION**?
GO DISTRIBUTED!
NEED **SCHEDULING CONTROL AND MULTI-FRAMEWORK**
GO CENTRALIZED!

WANT IT ALL?

YOU GOTTA FEDERATE!
HYDRA ARCHITECTURE

Router

State Store
StateStore Proxy

RM

sub-cluster 1

RM

sub-cluster 2
HYDRA ARCHITECTURE

Router

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NM
HYDRA ARCHITECTURE
SCHEDULING DESIDERATA

• Global goals:
  • High Utilization
  • Scheduling invariants (e.g., fairness)
  • Locality (e.g., machine preferences)
POLICIES

- AMRMProxy routing of requests
  - Enforce locality?
- Per-cluster RM scheduling decisions
  - Enforce quotas?

**Root:**

- $Q_A$ 50% demand: 12
- $Q_B$ 50% demand: 4

- demand: 12
- demand: 12

- ✓ Locality, Fairness
- ✓ Utilization
- ✓ Utilization, locality
- ✓ Fairness
- ✓ Locality
- ✓ Utilization, Fairness
- ✓ Fairness
- ✓ Locality
KEY IDEA

DECOUPLE:

• Share determination
  • How many resources should a queue get?
• Placement
  • On which machine should each task run?
PROPOSED SOLUTION*

1. Periodically gather queue information at GPG
2. Determine resources for each queue at each sub-cluster centrally
   - Logically reassign all resources, accounting for demand skew (and already assigned resources)
3. Propagate capacity decisions to each sub-cluster's RM, which perform local task allocation

* More advanced than what in prod. (details in paper)
HANDLING GPG DOWNTIME

- If GPG is down, we would fallback to local decisions
  - Problematic if they “diverge” too much from global one

- Leverage LP-based “tuning” of local queue allocation
  - Historical demand as a predictor of future demand
PRODUCTION EXPERIENCE

Matching a distributed scheduler via federation
WORKLOAD

• Microsoft-wide production workload
  • 5 clusters with over >250k total servers
  • >500k daily jobs
  • ~2B daily tasks
  • Highly skewed in job and task size/duration
HIGH SCHEDULING RATE AT LOW ALLOCATION LATENCY!

*not in the paper, updated as of Jan/Feb 2019*
FEDERATED DESIGN IMPROVES LOAD BALANCING, WHILE RETAINING UTILIZATION!
PERFORMANCE

JOBS PERFORM JUST AS WELL (AND TASKS ARE AS EFFICIENT)!

![Graph showing ECDF of runtime and resource usage ratios](image)
QUALITATIVE EXPERIENCE

• In-place migration: we changed and engine mid-flight

• Happy customers can now play with OSS tech + MS stack!

• Federated design improved **operability**:
  • Experiment at sub-cluster granularity
  • OSS innovation is easier to leverage

• Policy-driven design:
  • Allows us to dynamically adapt and experiment
CONCLUSION

- Hydra’s federated architecture got us:
  - Multi-framework / Scale / Utilization / Operability
- Exciting journey from 0 to:
  - >250k nodes
  - >200K LoC open-source code
  - 11 published papers

If you want to be part of our next project, we are hiring!