Apollo: Scalable and Coordinated Scheduling for Cloud-Scale Computing,

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Cloud-scale jobs

- Jobs are written using SCOPE, a SQL-like high-level scripting language, augmented with user-defined processing logic.
- Jobs are represented by DAGs
- Tasks are the basic unit of computation
- Tasks are grouped in stages
- Execution is driven by the scheduler
Scheduling at Cloud Scale

*minimize job latency while maximizing cluster utilization*

**Challenges:**

- **Scale**
  - Jobs process gigabytes to petabytes of data, 100K scheduling req/sec
  - Clusters run 170K tasks in parallel and each has over 20K servers

- **Heterogeneous workload**
  - Tasks run secs to hours
  - Can be IO or CPU bound
  - Require 100MB to 10GB of memory
  - Short tasks are scheduling sensitive
  - Long tasks are locality sensitive

- **Maximize utilization**
  - Workload fluctuates

*Number of concurrent jobs drops by 40% on weekends*
Apollo Overview

1. Distributed and coordinated architecture
2. Estimation-based scheduling
3. Conflict Resolution
4. Opportunistic Scheduling
Distributed and coordinated architecture
Different factors for optimization

(a) Server map.  (b) Scheduling alternatives.

Figure 4: A task scheduling example.
Estimated task completion time

\[ E_{\text{succ}} = I + W + R \]

\[ C = P_{\text{succ}} \times E_{\text{succ}} + K_{\text{fail}} \times (1 - P_{\text{succ}}) \times E_{\text{succ}} \]

**E**: Estimated task completion time

**I**: initialization time: fetching files for the task

**W**: wait time: a lookup in the wait-time matrix of the target server

**R**: Runtime: both I/O and CPU time
Conflicts Resolution

1. Apollo defers the correction of conflicts
   → (vs Omega where conflicts are handled at scheduling time)

2. Re-evaluates prior decisions

3. Triggers a duplicate if the decision is not optimal with up-to-date data
Opportunistic Scheduling

- Maximize utilization
  - Use the remaining capacity
  - Dispatch more than the resource allocation
  - Tasks only consume idle resources
  - Tasks can be preempted or terminated
  - Tasks can be upgraded

- Limit capacity share of each job
- Random queueing
Evaluation

1. Apollo runs on Microsoft production clusters with over 20K servers each
2. It runs 170K tasks in parallel
3. Tracks 14M pending tasks

Figure 9: Job latencies with different schedulers.
Apollo’s Resource Efficiency

(b) CPU utilization.

(c) CPU time breakdown: regular and opportunistic task.

Figure 7: Apollo in production.
Conclusions

1. Loosely Coordinated Distributed Architecture
2. Deployed to clusters with over 20K servers
3. High Quality Scheduling
4. Minimizes task completion time
5. Consistent performance
6. Maximizes resource utilization
7. Opportunistic scheduling
8. 90% median CPU utilization