OStrich: Fair Scheduler for Burst Submissions of Parallel Jobs

Krzysztof Rzadca
Institute of Informatics, University of Warsaw, Poland

joint work with:
Filip Skalski (U Warsaw / Google)

based on work with:
Vinicius Pinheiro (Grenoble)
Denis Trystram (Grenoble)
KEY MESSAGE: A FAIR, MULTIUSER ONLINE SCHEDULING ALGORITHM

• Online problem with multiple users sharing a supercomputer

• Workload composed of campaigns (~job arrays): jobs independent to execute; the owner wants to finish all jobs as soon as possible

• OStrich: an algorithm with a guarantee on worst-case slowdown (stretch) for each user (OStrich ~ per-User Stretch)

• The slowdown depends on the total number of users, and not the total system load

• Implementation as a SLURM scheduler used in a production cluster
MODEL: A TYPICAL SUPERCOMPUTING CENTER

M1
M2
M3
M4
M5
M6

m processors

8
3
2
2
8
10

submission time (not known in advance)

processing time (known when the job appears)

owner (red user)
WHY CAMPAIGNS?

• Modern applications submit many related computing jobs
  • Map/Reduce
  • parameter sweep workflows

• SLURM makes such submissions easier by job arrays (max job array size increased to 1M, so it’s useful)

• But cluster schedulers treat such jobs as independent
WHY A WORST-CASE BOUND FOR EACH USER?

• Many policies based on First-Come-First-Served

• New jobs are put at the end of the queue

• Thus, users with large workloads slow down everyone else

• Hard to manage partial solutions:
  • Limits on number of jobs in the queue,
  • Karma points, priority queues, etc.
  • Fair-share
A CAMPAIGN: A BAG OF INDEPENDENT TASKS

user 1: campaign 1

user 1: campaign 2

user’s goal: campaign completion

think time: next campaign not ready after C1

submission (next campaign) after C1

submission start

C_1^{(1)}

C_2^{(1)}

\Delta_1^{(1)}

\Delta_2^{(1)}

\sigma_1^{(1)}

\sigma_2^{(1)}

\Delta_1^{(1)}

\Delta_2^{(1)}

\sigma_1^{(1)}

\sigma_2^{(1)}

\sigma_1^{(1)}

\sigma_2^{(1)}

\sigma_1^{(1)}

\sigma_2^{(1)}
PRINCIPLE OF THE ALGORITHM: PARETO-OPTIMALITY

A fair-share schedule

Completion times: (20,20)

A Pareto-optimal schedule

Completion times: (10,20)
PRINCIPLE OF THE ALGORITHM: OPTIMIZE SLOWDOWN (BUT NO STARVATION)

Completion (30, 20)
Slowdown (3, 1)

Completion (10, 30)
Slowdown (1, 3/2)
OSTRICH ALGORITHM: A VIRTUAL FAIR-SHARE SCHEDULE DEFINES PRIORITIES FOR CHOOSING JOBS

Virtual

OStrich assigns equal shares to each user

Green user scheduled first, as finishes first in the virtual

Real

two campaigns released at t=0
OSTRICH ALGORITHM: NEW SUBMISSIONS “PREEMPT” CURRENTLY EXECUTING CAMPAIGNS

Virtual

Real

red user has priority

new campaign at t=2
OSTRICH ALGORITHM:
NEXT CAMPAIGN DEFERRED UNTIL
PREV CAMPAIGN VIRTUAL COMPLETION

Virtual

red campaign deferred in the virtual
until the previous campaign completes

Real

submitted at t=5
OSTRICH ALGORITHM:
NEXT CAMPAIGN DEFERRED UNTIL
PREV CAMPAIGN VIRTUAL COMPLETION
SOME PROOFS?

http://www.supercoloring.com/
AN UPPER BOUND ON THE CAMPAIGN’S COMPLETION TIME

\[ C_{i,q} \leq t_{i}^{(u)} + k \frac{W_{i-1}^{(u)}}{m} + l \]

wait until the prev campaign completes in virtual
AN UPPER BOUND ON THE CAMPAIGN’S COMPLETION TIME

wait until the prev campaign completes in virtual

upper bound on the surface that can preempt while campaign is executing in virtual

$C_{i,q} \leq t_i^{(u)} + k \frac{W_{i-1}^{(u)}}{m} + p_{\text{max}} + (k-1) \frac{W_i^{(u)}}{m} + p_{\text{max}} + \frac{W_i^{(u)}}{n}$
AN UPPER BOUND ON THE CAMPAIGN’S COMPLETION TIME

\[
C_{i,q} \leq t_i^{(u)} + k \frac{W_{i-1}^{(u)}}{m} + p_{\text{max}} + (k-1) \frac{W_i^{(u)}}{m} + p_{\text{max}} + \frac{W_i^{(u)}}{m} + p_{\text{max}}
\]

wait until the previous campaign completes in virtual space

upper bound on the surface that can preempt while campaign is executing in virtual space

standard upper bounds for the current campaign executing on all resources
EACH CAMPAIGN’S SLOWDOWN IS BOUNDED

- campaign slowdown: flow time weighted by the surface

\[ D_i^{(u)} = \frac{C_i^{(u)} - t_i^{(u)}}{W_i^{(u)}} \]

- OStrich guarantee:

\[ D_i^{(u)} \in O(k(1 + \frac{W_i^{(u)}}{W_i^{(u)} - 1})) \]

- \( k \) is the number of active users

- we treat \( p_{\text{max}} \) as constant (and small compared to campaign’s surface)
IMPLEMENTATION IN SLURM
FROM THEORY TO SLURM

• fixed reservations: as idle time

• partitions: as (perhaps overlapping) sets of processors

• users’ estimates are imprecise: simple estimates can be used (not yet implemented!) (in simulations we use the average from 2 last completed jobs)

• campaign from a stream of jobs: we group jobs based on delay from the first submission

3 jobs in a single campaign

threshold

this job starts a new campaign
A SEMI-ACTIVE SCHEDULER

- OStrich is notified about a newly submitted job; assigns 0 priority to this job

- each 1-10 seconds, OStrich recalculates the virtual schedule (new jobs, completed jobs, changed jobs)

- OStrich assigns decreasing priorities to jobs by campaign order

- the main SLURM daemon uses priorities to order jobs for FCFS/backfill
EXPERIMENTS
(still work in progress...)

https://www.flickr.com/photos/rivenimagery/8359976129/
OSTRICH IS FAST!
50K+ JOBS SCHEDULED IN 0.04 SECONDS

we emulated a cluster head node on a normal PC
IN PRODUCTION:
25K+ JOBS
SCHEDULED
SINCE JULY 2014
NO MAJOR PROBLEMS

running on a cluster with
262 nodes, 5056 cores,
heterogeneous architecture
(ICM: Warsaw Supercomputing Center
site report tomorrow at 14:05)
HOW GOOD IS THE ALGORITHM FROM USERS’ PERSPECTIVE?

tests on a simulator using recorded logs from Dror Feitelson’s archive
OSTRICH IS MORE EFFICIENT THAN FAIRSHARE (FOR SOME LOGS !)

Log from ANL Thunder BlueGene/P, 160k cores, 0.9x time compression
THE MORE CAMPAIGN-LIKE THE LOG, THE LARGER THE DIFFERENCE

Log from ANL Thunder BlueGene/P, 160k cores, 0.8x time compression, jobs submitted during 30 minutes grouped and submitted together.
FOR SOME LOGS, OSTRICH IS WORSE THAN FAIRSHARE

LLNL Thunder, 4k cores
0.95x time compression, 30 minutes job groups
CONCLUSIONS

• OStrich guarantees that the slowdown of each campaign (burst submission) is proportional to the number of users in the system

• OStrich maintains a virtual, fair-share schedule

• We have a **SLURM scheduling plugin** and a **simulator** available for download: github.com/filipjs/

• with the simulator you’re able to test the performance on your workload before running in production

• OStrich can use existing configuration (shares) from multi-factor plugin
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Krzysztof Rzadca, krzadca@mimuw.edu.pl
mimuw.edu.pl/~krzadca/ostrich/