I/O Scheduling in HPC systems

Guillaume Aupy

Project page: **https://project.inria.fr/dash/**

Collab. with JT Acquaviva (DDN), O Beaumont (Inria), L Eyraud-Dubois (Inria), E Jeannot (Inria), A Gainaru (Vanderbilt), V Le Fèvre (ENS Lyon), N Vidal (Inria)

Motivation

IO congestion in HPC systems:

- HPC applications are generating lots of data for PFS.
- Idea is to use a buffer when the I/O bandwidth is fully occupied
- The buffer can be emptied at a later time.

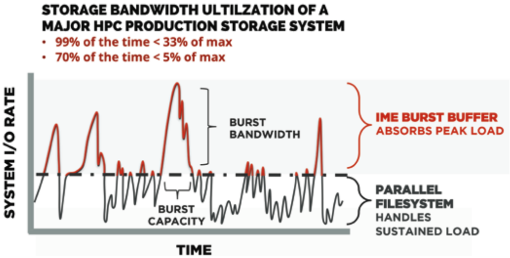

Figure: Burst-buffers to absorb IO peaks (DDN material)

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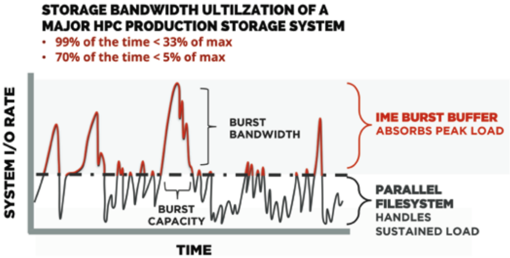

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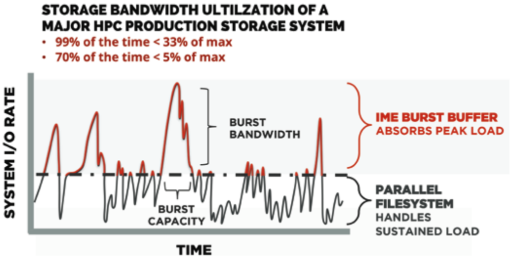

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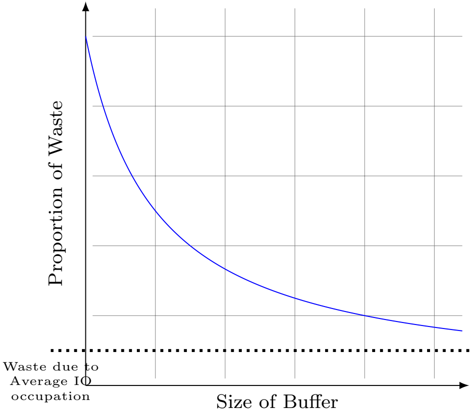
Finding the right size

Overall, for various parameter we obtain something that looks like this:



Naive strategy:

- If IO bandwidth avail.:
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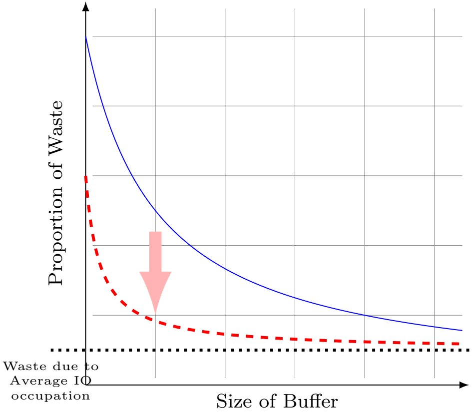

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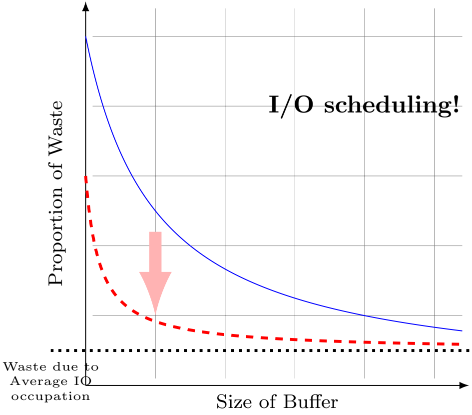

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Previously in IO scheduling.

"Online" scheduling:

- When an application is ready to do I/O, it sends a message to an I/O scheduler;
- Based on the other applications running and a priority function, the I/O scheduler will give a **GO** or **NOGO** to the application.
- If the application receives a **NOGO**, it pauses until a **GO** instruction.
- Else, it performs I/O.

Gainaru, A., Benoit, Cappello, Robert, Snir,
`Scheduling HPC applications under I/O congestion`, IPDPS'15

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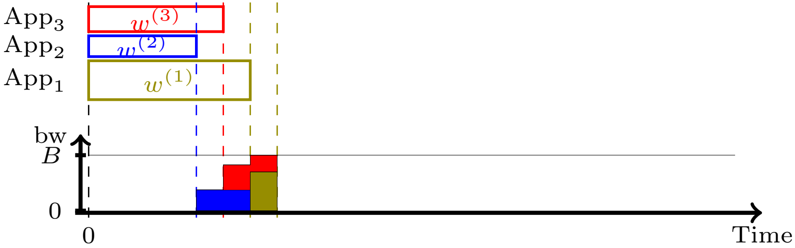

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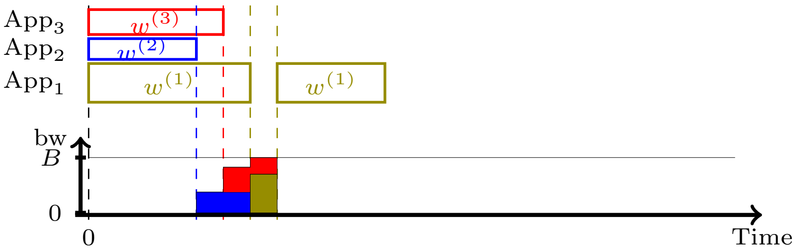

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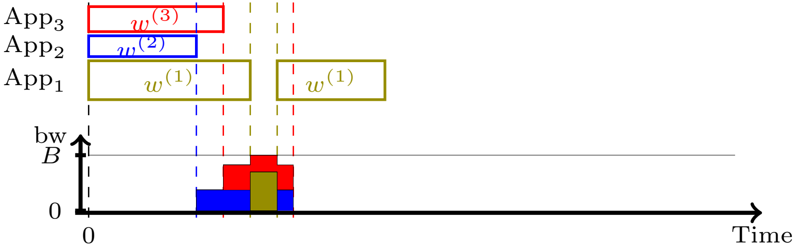

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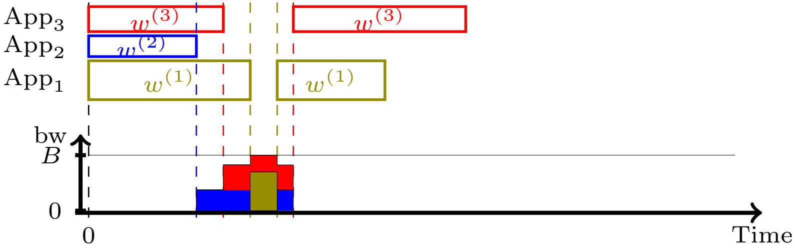

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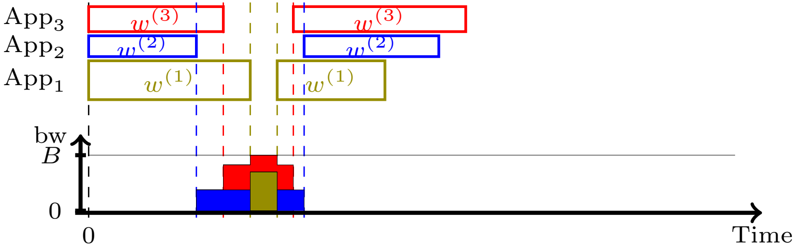

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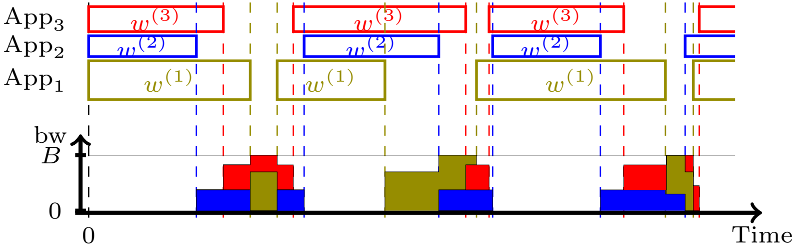

Approx 10% improvement in application performance with 5% gain in system performance on Intrepid.

Can we do better?

Assume we know applications I/O patterns:

- from historical data;
- because of periodic checkpointing;
- average filling speed of buffers

  $\Longrightarrow$ we know that every x min, $y\%$ of the buffer needs to be emptied;
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Can we use this information and enforce efficient static schedules?

Spoiler: it works very well (at least it seems promising)

High-level constraints

- Applications are already scheduled on the machines: not (yet) our job to do it;

A., Gainaru, Le Fèvre, `Periodic I/O scheduling for super-computers`, PMBS'17

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We introduce Periodic Scheduling.

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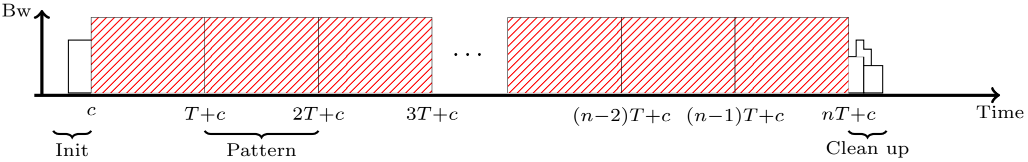
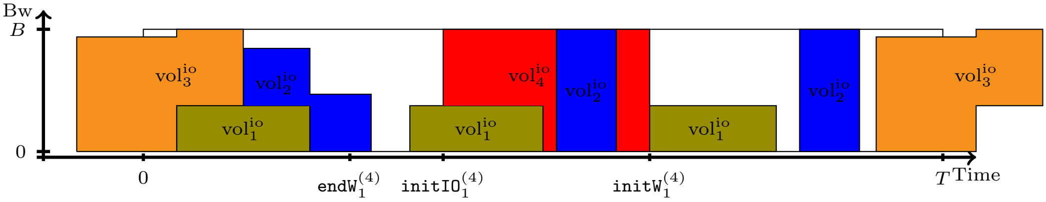
Periodic schedules



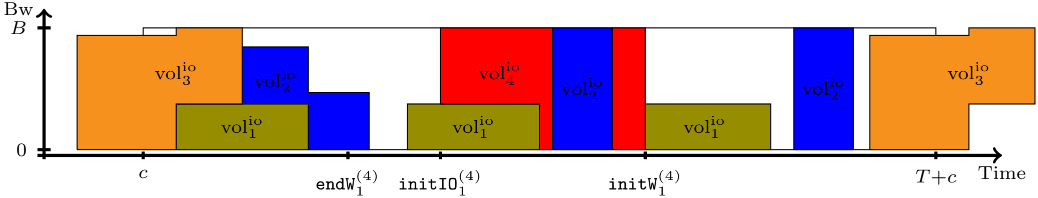
(a) Periodic schedule (phases)



(b) Detail of I/O in a period/pattern

Periodic schedules

Time Schedule vs what Application 4 sees



- Distributed information
- Low complexity
- Minimum overhead

Periodic schedules

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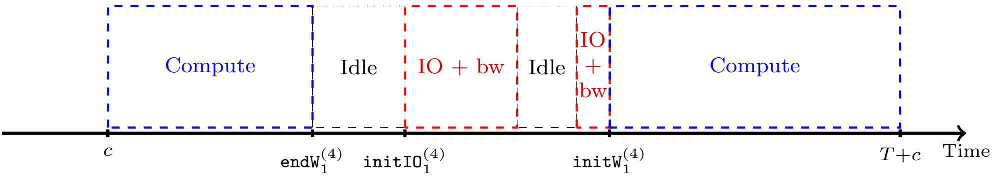

- Distributed information ✓
- Low complexity ✓
- Minimum overhead ✓

Model validation

Setup:

- Applications from the literature, 10 sets with different contention.
- Comparison between simulations and a real machine (Jupiter @Mellanox: 640 cores, $b = 0.01GB/s$, $B = 3GB/s$).
- Instations with IOR benchmark (ideal world, no other communication than I/O transfers).

Algos:

- Periodic: our periodic algorithm;
- Online: the best performance of any online algorithm in Gainaru et al. IPDPS'15;
- Congestion: Current performance on the machine.

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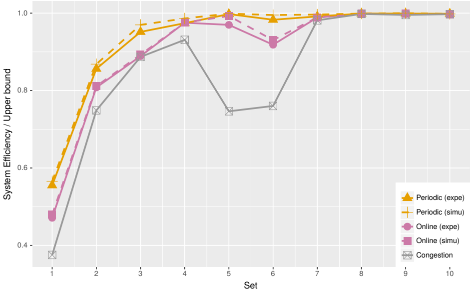
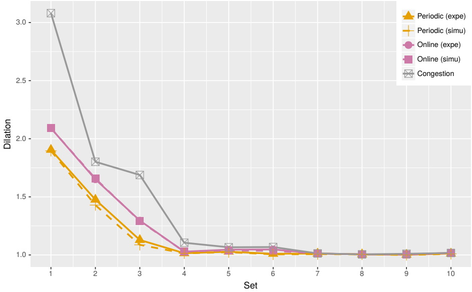


(c) SysEfficiency/Upper bound

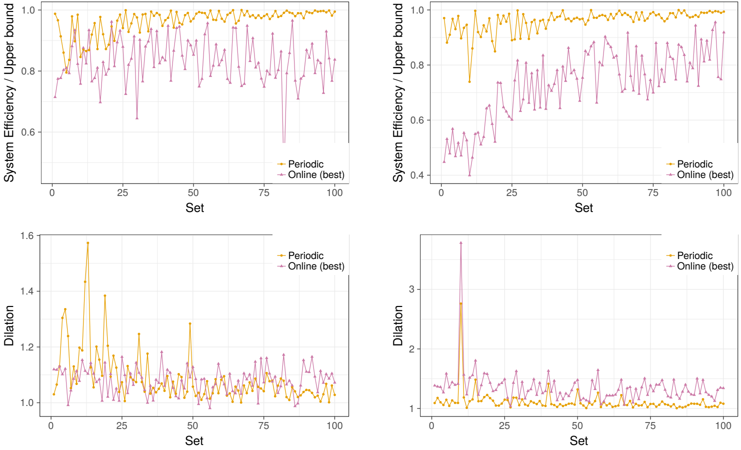


(d) Dilation

The performance estimated by our model is accurate within 3.8% for periodic schedules and 2.3% for online schedules.

More results (simulations)

- We generate more sets of applications
- Simulate on instanciations of Intrepid and Mira.



Intrepid

Mira

The DASH project

- Understanding applications patterns
- Study of robustness: what if w_k and $\mathrm{vol}_k^{\mathrm{io}}$ are not exactly what they were supposed to be?
- Integrating non-periodic application
- Burst-buffers integration/modeling
- Coupling application scheduler to IO scheduler
- Evaluation on real applications

Collaborations needed:

Three steps

1. I/O Modeling
2. Algorithm design
3. Evaluation and Integration

Application/system users:

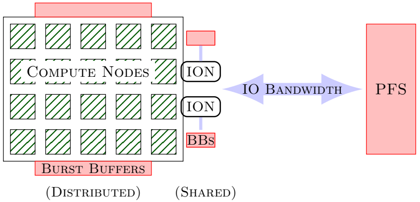
- Data about I/O behaviors: patterns/periodicity, volume etc.
- Discussion about models of I/O scalability

From large-scale IO managers:

- Understanding traces, what kind of properties can we assume on the system?
- Discussion on implementation / integration
- Experiments

Dash

Data-Aware Scheduling at Higher scale



Nicolas Vidal is starting his PhD this October. Talk to him ☺.

Thanks to collab. and co-authors
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Papers, data, code: `https://project.inria.fr/dash/`