Joint Laboratory for Petascale Computation

From Damaris to CALCioM
Mitigating I/O Interference in HPC Systems

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Within the Data@Exascale associated team

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Urbana-Champaign, November 2013

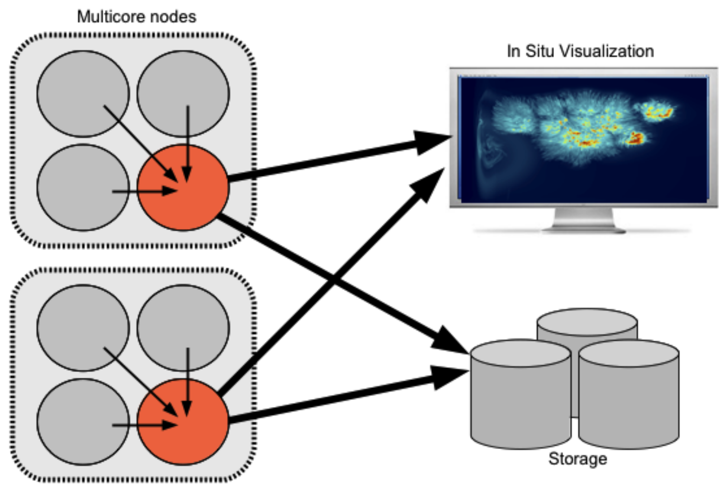
Outline

- Damaris: After 3 years of collaboration…
- CALCioM: Towards cross-application coordination

Damaris after 3 years…

Originated from the *"Shared Buffering System"* designed in 2010 during an internship at NCSA, Damaris proposes to dedicate cores in multicore SMP nodes to data management, i.e. storage, in situ analysis and visualization.

Overview



Implementation

- Version 0.7.3 available
  - http://damaris.gforge.inria.fr
- Version 1.0 for summer 2014
- 15095 lines of code
- API for C, C++ and Fortran simulations
- Easy configuration with XML
- In situ visualization with VisIt
- Python and C++ plugins

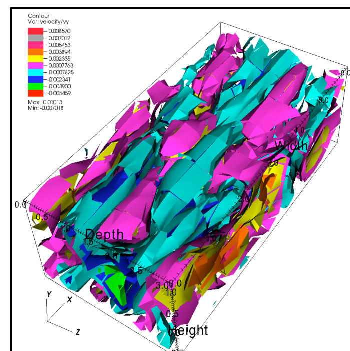
Damaris after 3 years…

People Involved

Matthieu Dorier, Gabriel Antoniu,
Lokman Rahmani, Roberto Sisneros,
Dave Semeraro, Bob Wilhelmson,
Rob Ross, Tom Peterka, Dries Kimpe,
Marc Snir, Franck Cappello, Leigh Orf

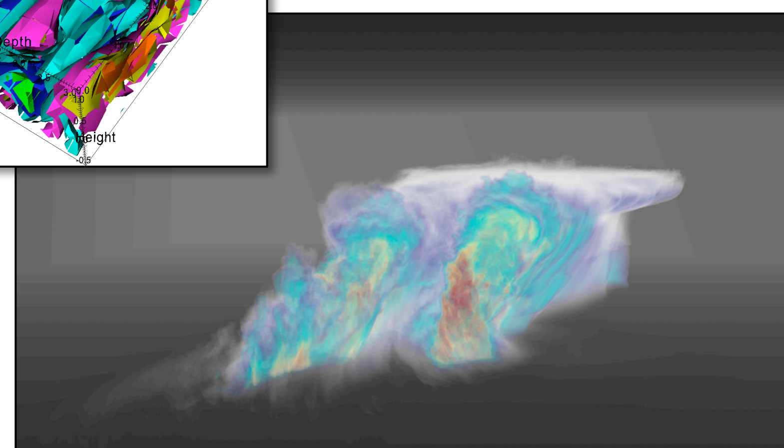
Evaluated on

Blue Waters, Intrepid, Kraken, Jaguar, Grid’5000, Blue Print, Surveyor



Evaluated with

CM1, Nek5000, OLAM



Publications

M. Dorier, advised by G. Antoniu. Damaris - Using Dedicated I/O Cores for Scalable Post-petascale HPC Simulations. ICS 2011

M. Dorier, G. Antoniu, F. Cappello, M. Snir, L. Orf. Damaris: How to Efficiently Leverage Multicore Parallelism to Achieve Scalable, Jitter-free I/O. in Proc. of IEEE CLUSTER 2012.

M. Dorier, advised by G. Antoniu. Efficient I/O using Dedicated Cores in Large-Scale HPC Simulations. PhD forum of IPDPS 2013

M. Dorier, R. Sisneros, T. Peterka, G. Antoniu, D. Semeraro. Damaris/Viz, a Nonintrusive, Adaptable and User-Friendly In Situ Visualization Framework. in Proc. of IEEE LDAV 2013

Mitigating I/O Interference in HPC Systems

Introduction to cross-application interference

Interference: Performance degradation observed by an application in contention with other applications for the access to a shared resource.

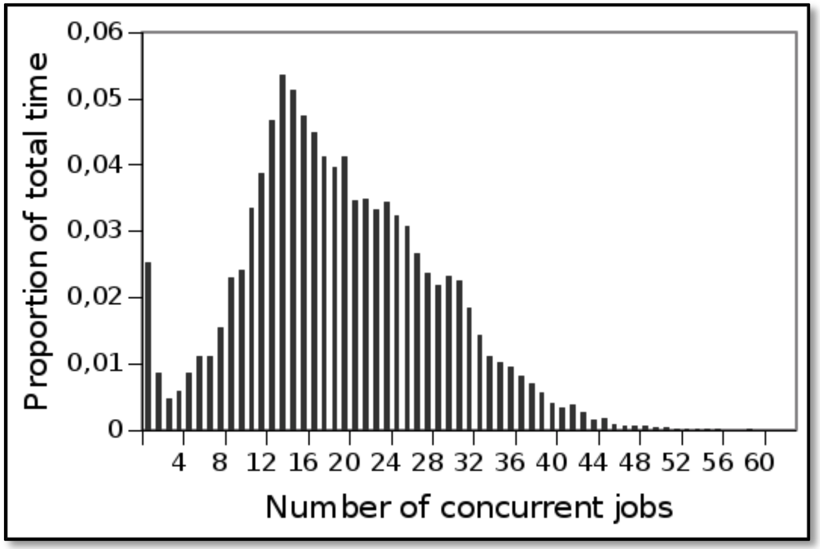
- How often does I/O interference occur?
- What is the effect of I/O interference?
- How do we quantify and visualize it?
- How to mitigate it?

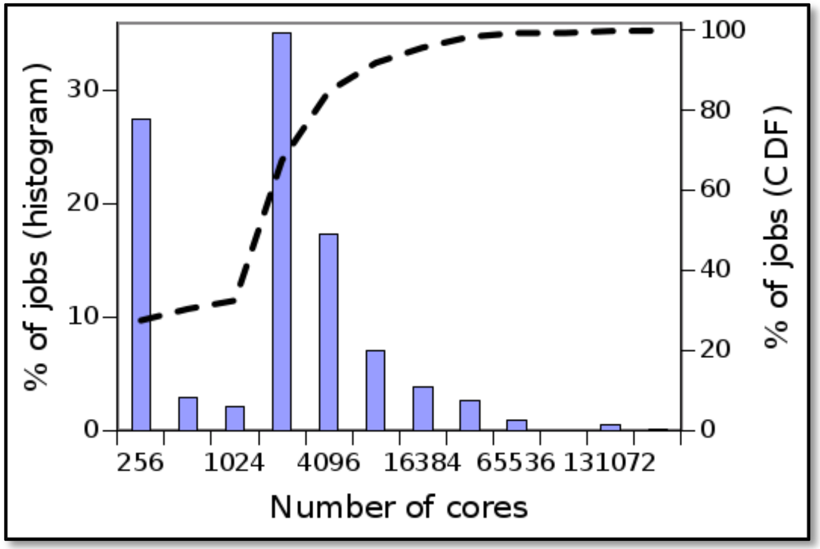
How often
does I/O interference occur?

How often does interference occur?

"Intrepid has a really weird workload compared to most other systems, because of the large number of large jobs."

Narayan Desai (ANL)





How often do interference occur?

I am an application, I start writing, what is the probability that at least one other application is also accessing the file system?

$$P(\text{another is doing I/O}) = 1 - \sum_{n=0}^{+\infty} P(X = n)(1 - E(\mu))$$

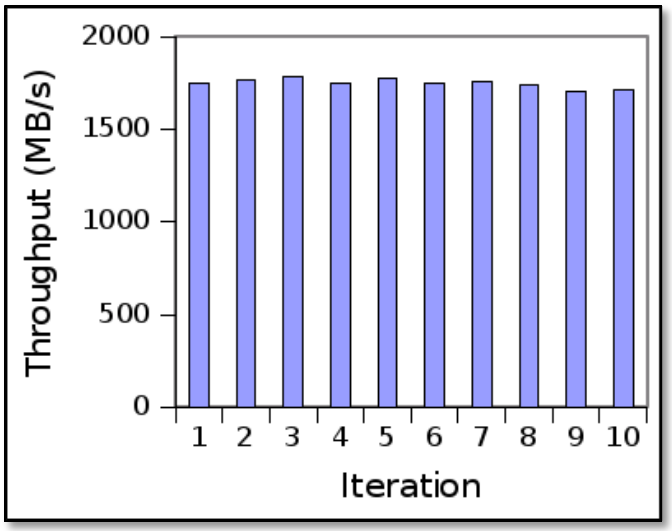
Where X is the number of running application (random variable), μ is the I/O time v.s. computation time ratio of applications (r.v.), Assuming independence between X and μ.

On Intrepid:

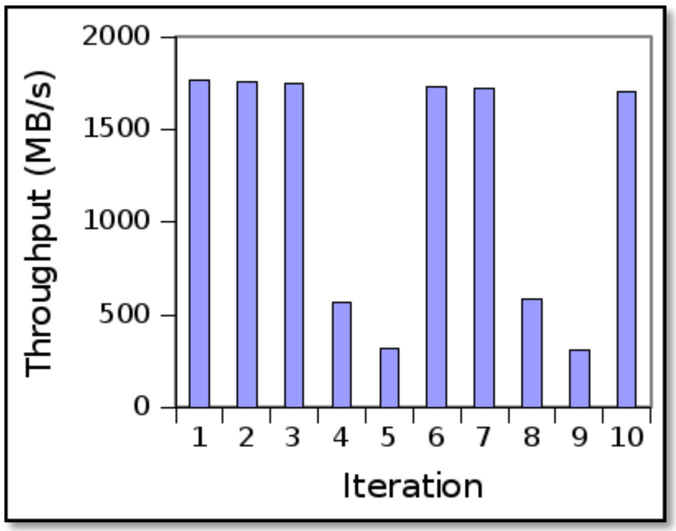
Assuming E(μ) = 5%, **P(another is doing I/O) = 64%**

What is the effect of I/O interference?

What is the effect of I/O interference?



IOR running on 336 cores, writing every 10 seconds in a 35-server PVFS file system on Grid'5000



A second instance is started on 336 other cores, writing the same amount of data every 7 seconds

I/O interference has a large impact on caching mechanisms

How do we quantify and visualize I/O interference?

Interference factor

- The user is interested in the ***factor by which interference increases the I/O time***:

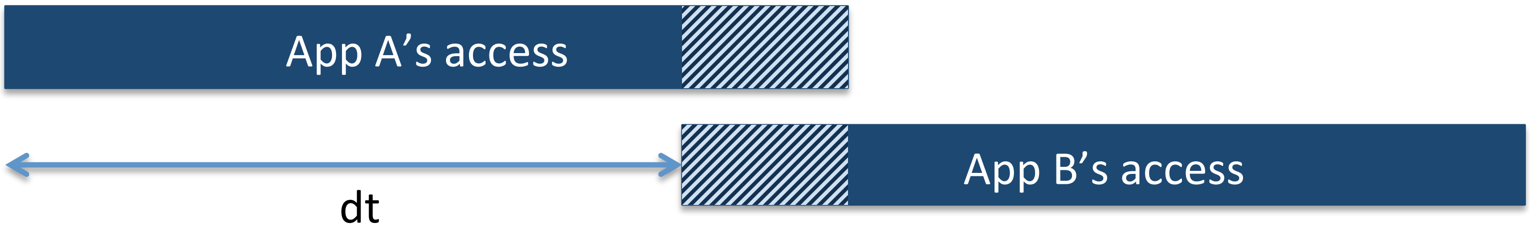
$$I_X = \frac{T_X}{T_{X(alone)}} > 1$$

- Considering *n* applications, we could (for example) want to minimize the ***sum*** of access times:

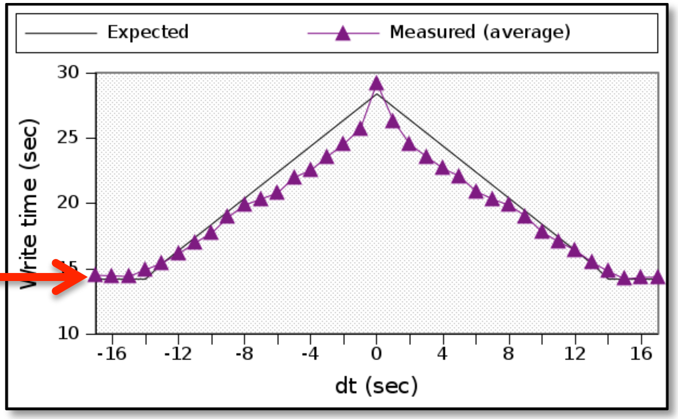
$$f = \sum_{X \in app} T_X$$

- These metrics can be adapted to anything (Energy consumption, CPU cycles, etc.): ***f*** can be generalized as a metrics for machine-wide efficiency.

Delta-graph



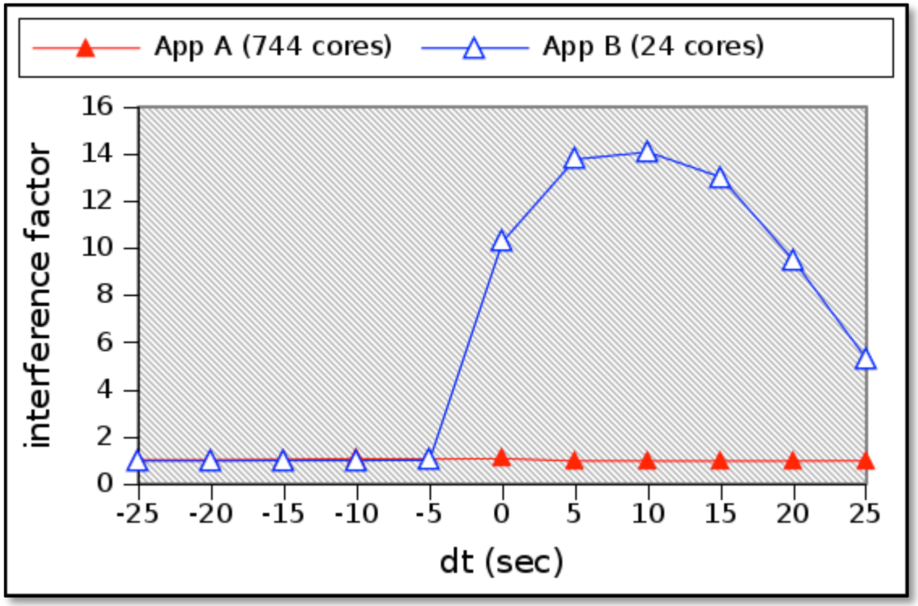
I/O time when the application is alone



Performance degradation due to interferences

Results on Surveyor (2x 2048 cores), each core writes 8MB contiguously. The graph represents the point of view of one of the 2 applications.

Bad luck for small applications

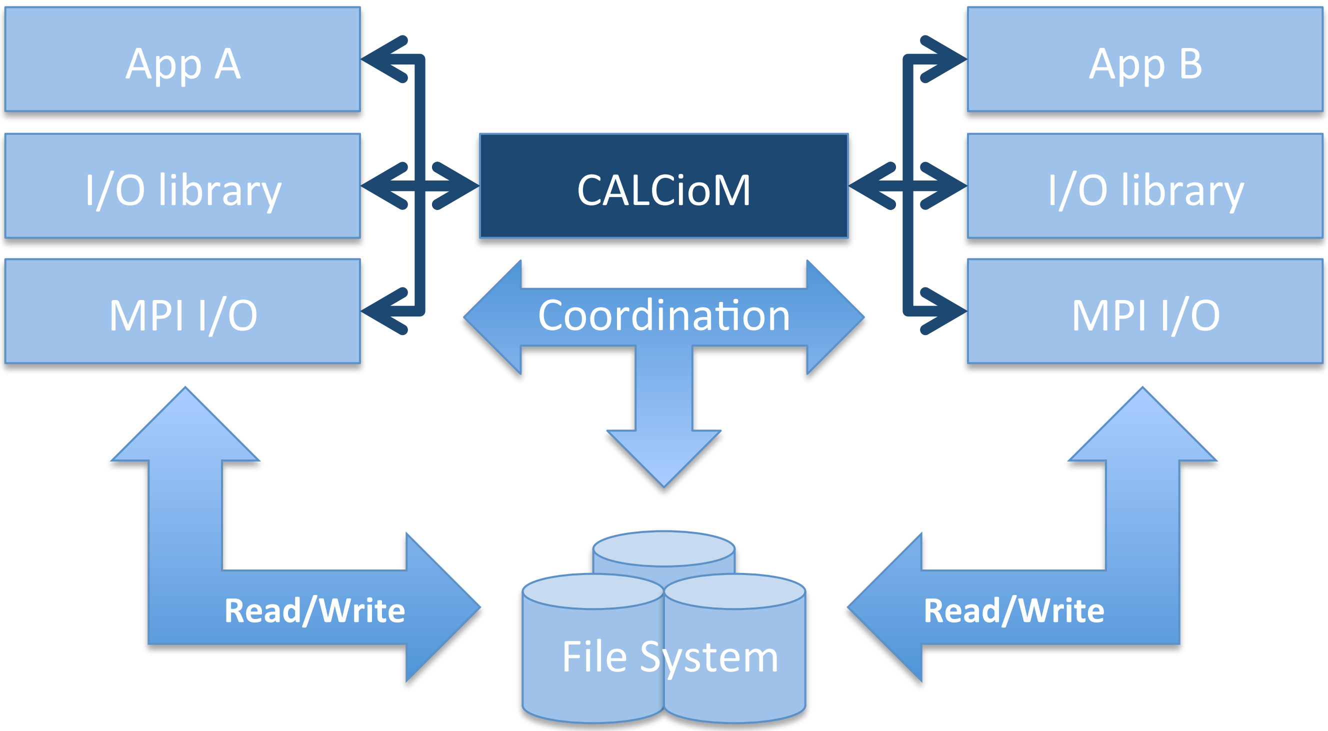


Experiment on Grid'5000,
App B on 24 cores,
App A on 744,
writing 8MB per process

Smallest App observes an up to 14x decrease of performance!
Biggest one does not even see it!

How to mitigate I/O interference?
The CALCioM approach

The CALCioM architecture



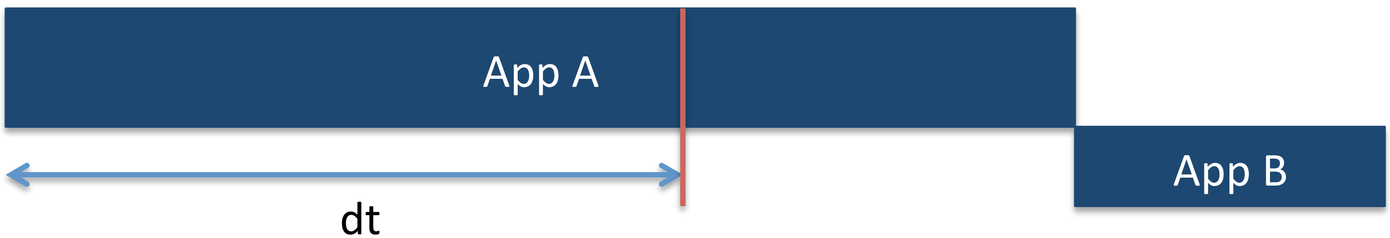
Cross-Application Layer for Coordinated I/O Management

CALCioM's API

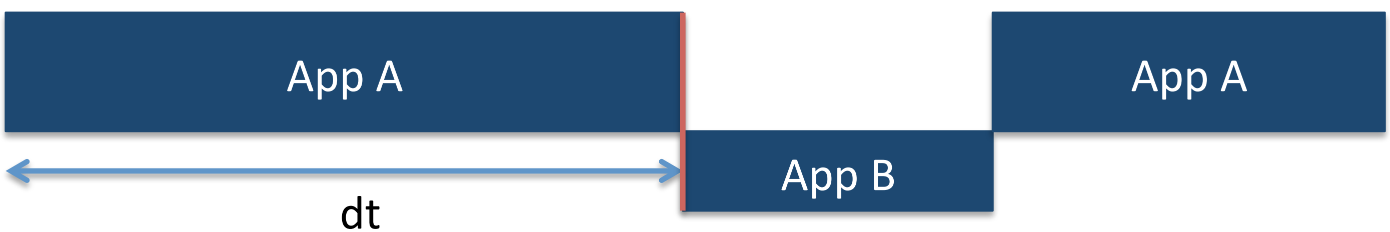
```
CALCioM_Init(MPI_Comm c)
CALCioM_Prepare(MPI_Comm c, MPI_Info i)
CALCioM_Ask()
CALCioM_Check(int* status)
CALCioM_Wait()
CALCioM_Release()
CALCioM_Complete()
CALCioM_Finalize()
```

Possible coordination strategies

“First come first served” (FCFS) Serialization



Interruption



How to choose a coordination strategy

Q: Given application A with expected access time T_A and application B with expected access time T_B, starting *dt* time units after application A's access,

Should A be interrupted in favor of B?

Or should B wait for A to terminate its access?

Example: if neither A nor B have something else to do, optimizing global performance, i.e. minimizing an interference effect given by

$$f = \frac{T_A}{T_{A(alone)}} + \frac{T_B}{T_{B(alone)}}$$

$$f = T_A + T_B$$

Tells us that B should interrupt A if and only if

$$dt < \frac{T^2_{A(alone)} - T^2_{B(alone)}}{T_{A(alone)}}$$

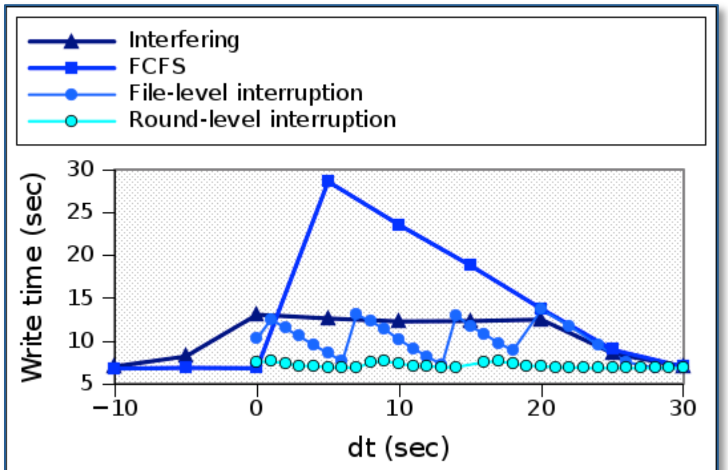
$$dt < T_{A(alone)} - T_{B(alone)}$$

Integration in Mpich

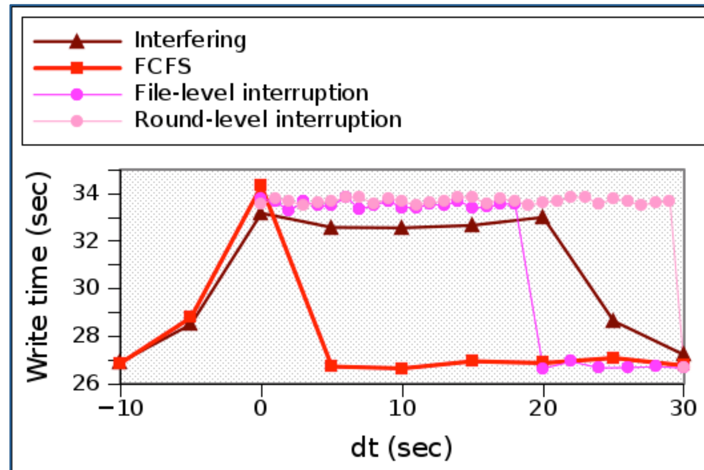
- `MPI_Init` and `MPI_Finalize` overwritten in **libcalciom.a**
- `MPI_File_open("myfile")`
  - **`MPI_File_open`**`("calciom:myfile")`
- `MPI_File_open("pvfs2:myfile")`
  - **`MPI_File_open`**`("calciom:pvfs2:myfile")`
- Connection between applications: could be done through **MPI_Comm_connect/accept** (ideally would benefit from **MPI_Comm_iconnect/iaccept**) + interaction with the job scheduler

Experimental evaluation

Example of application



App B (small I/O load)



App A (big I/O load)

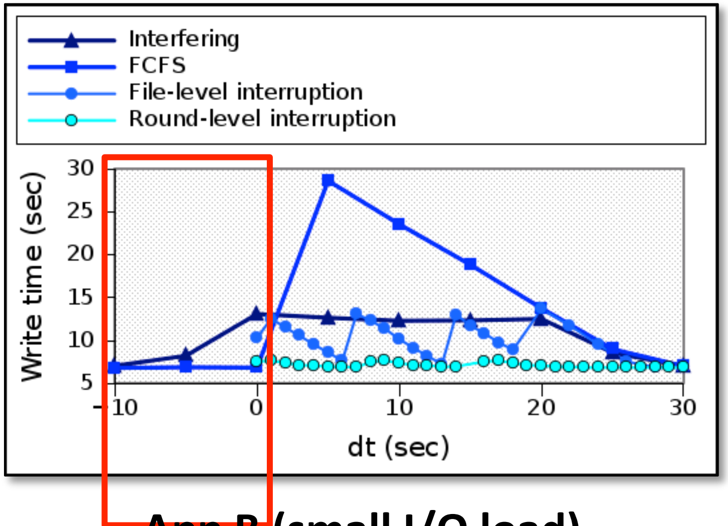
2x 2048 cores on Surveyor

- **App A: 4 files**, 4 MB per file per process, contiguous layout
- **App B: 1 file**, 4 MB per file per process, contiguous layout

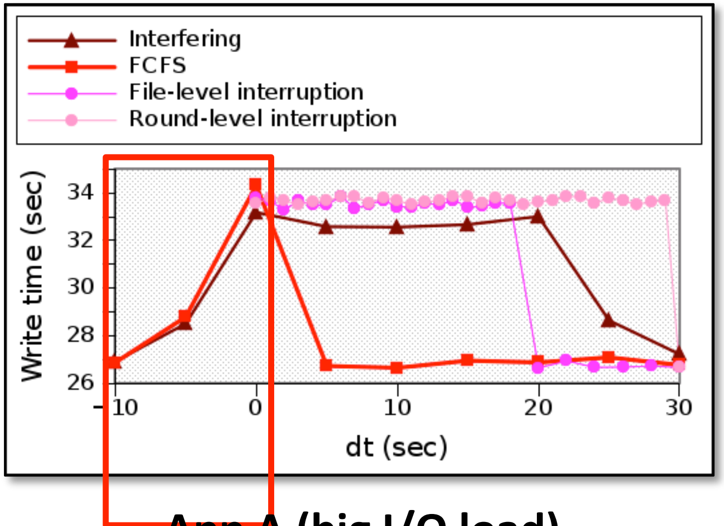
$$f = T_A + T_B$$

$$dt < T_{A(alone)} - T_{B(alone)}$$

Example of application



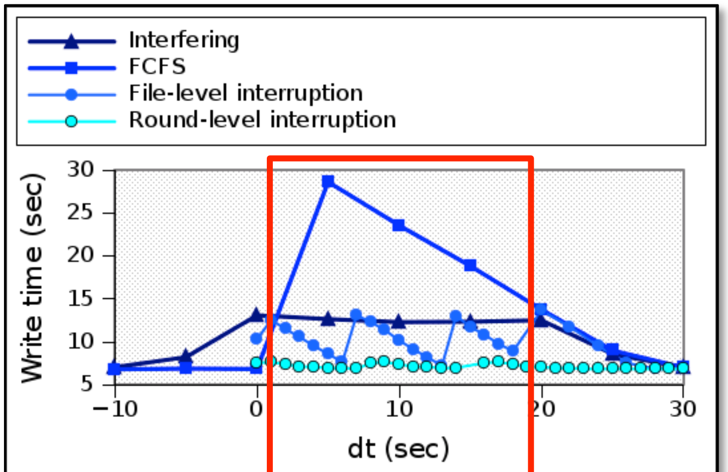
App B (small I/O load)



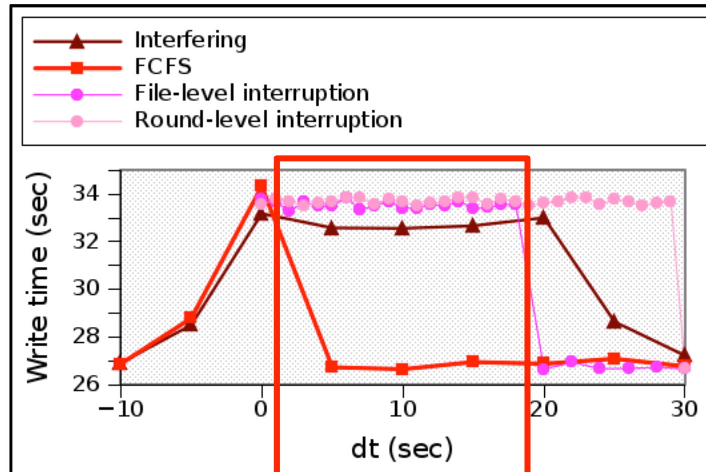
App A (big I/O load)

App B arrives first, App A is serialized after B

Example of application



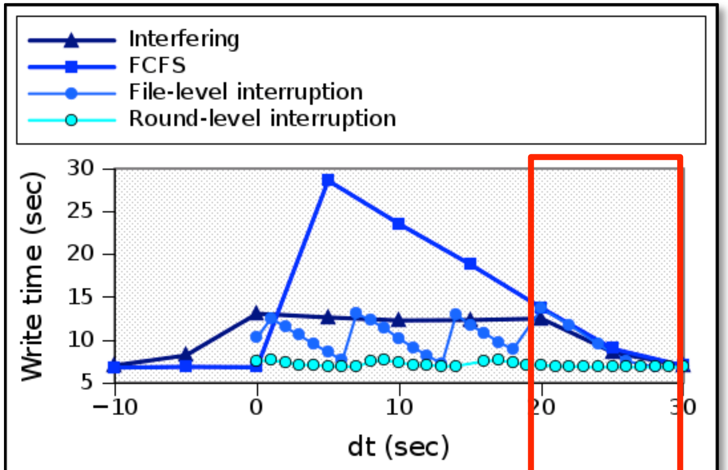
App B (small I/O load)



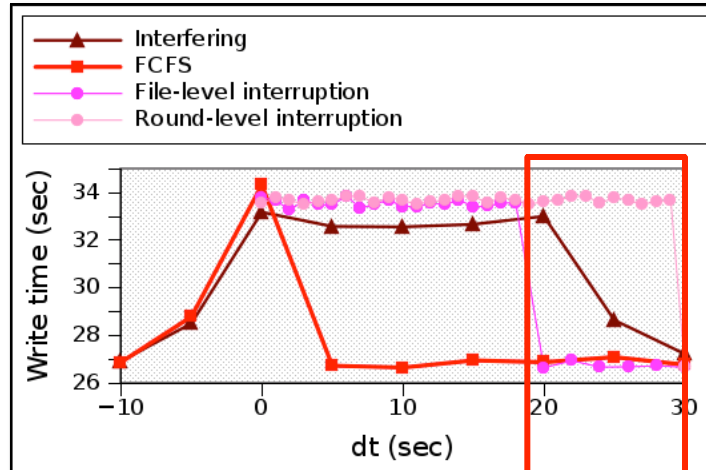
App A (big I/O load)

App B arrives during the write of the 3 first files of App A,
Condition indicates that A should be interrupted.
The level of interruption produces different patterns.

Example of application



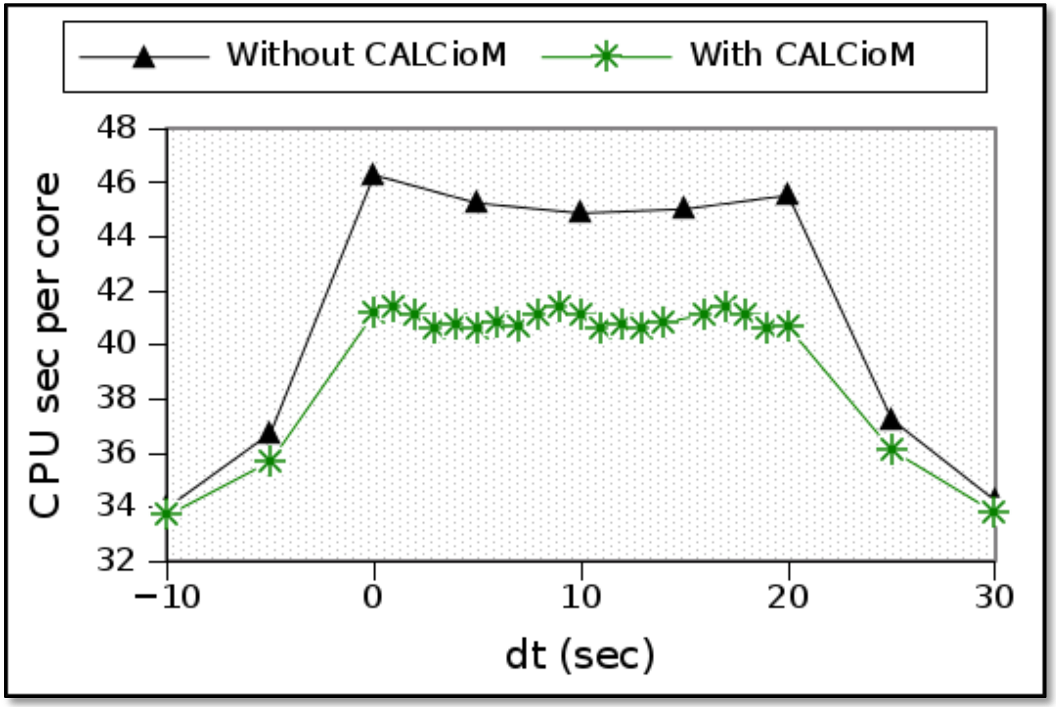
App B (small I/O load)



App A (big I/O load)

App B arrives during the last write of App A.
Condition dictates that B is serialized after A.

Synthesis



CALCioM manages to improve the computational efficiency of the set of applications by avoiding interference, and thus improves the efficiency of the entire machine.

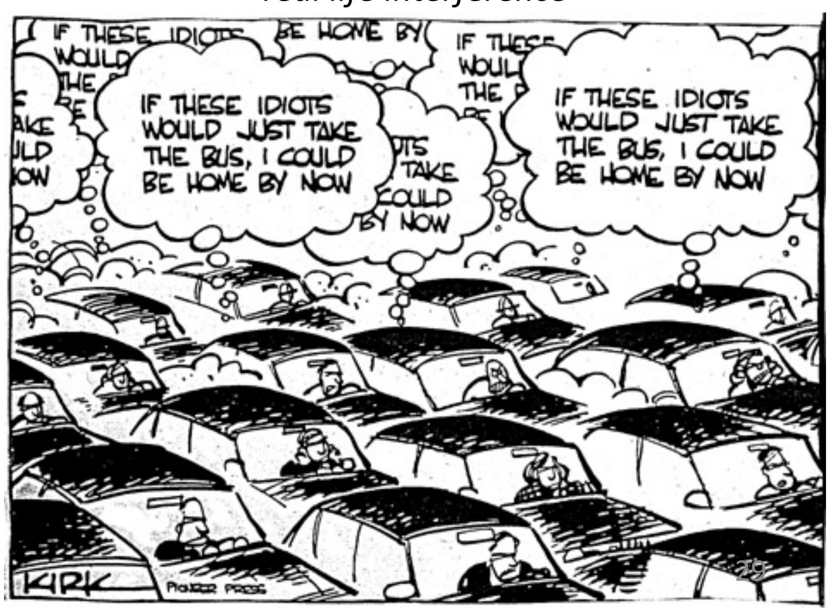
Conclusion

Conclusion

- **Interference between application impacts system efficiency**
- **CALCioM:**
  - Communication layer between independent applications
  - Cross-application coordination through exchange of knowledge on I/O patterns
  - Several policies implemented:

    FCFS, interruption

real life interference



Thank you!

Questions?