Topology-Aware Data management

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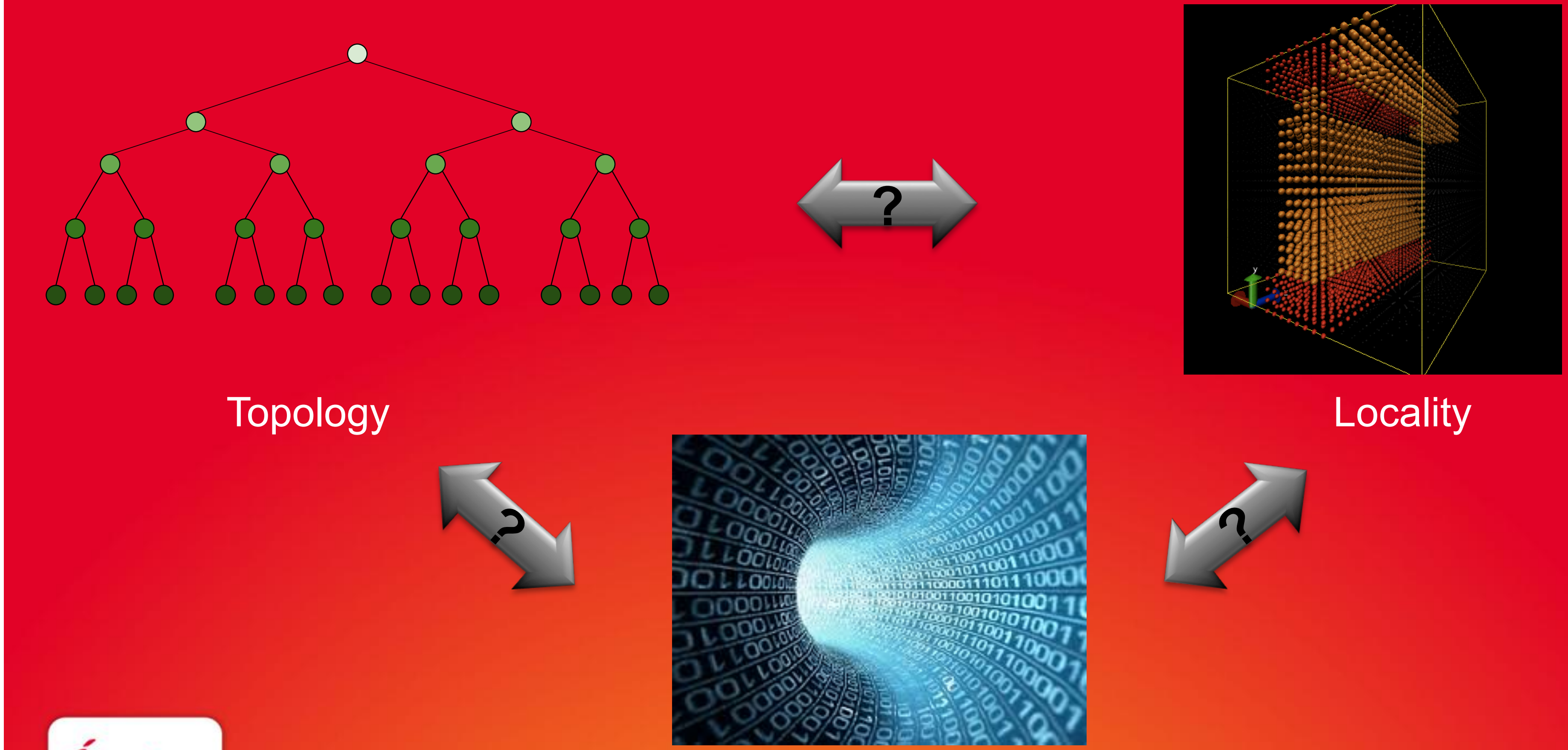
January 16, 2015

INTRODUCTION

Data mangement for high-performance computing



Topology

Locality

Data

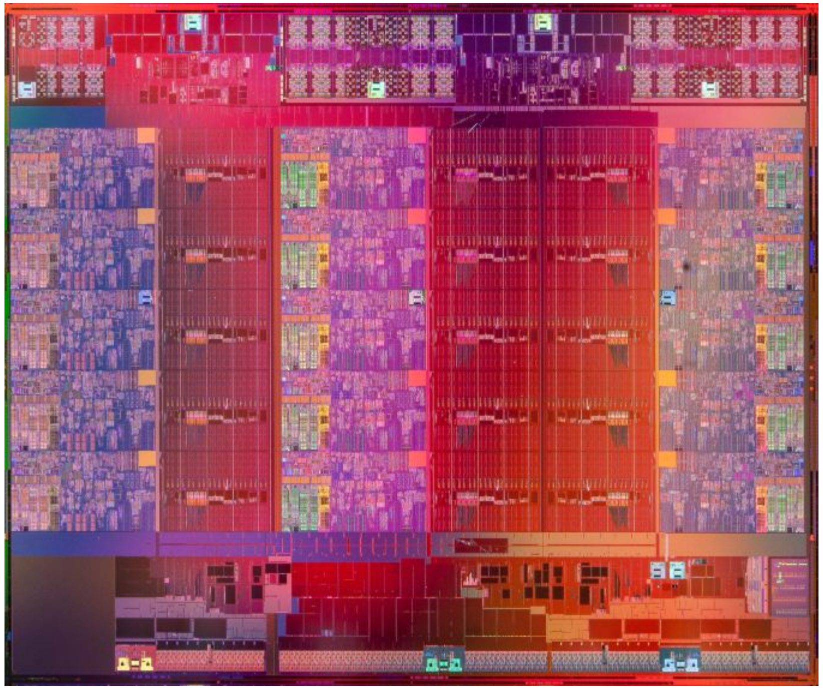
2

Topology-Aware Data Management

High-performance computing sysrtems more and more complex

Memory hierarchy is deepening:

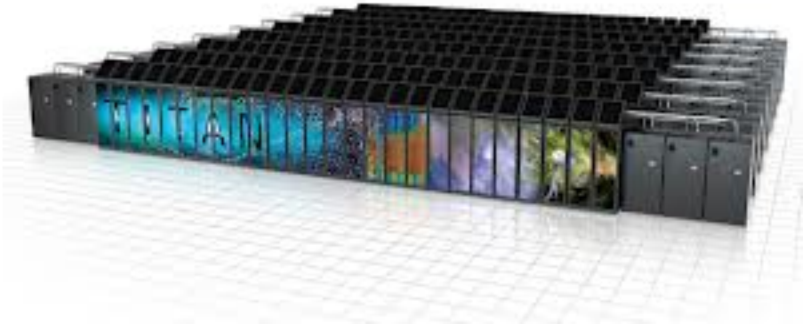
- Cache
- Ram
- NVRAM
- Flash
- etc.



Networks are larger and more intricate.

Computing is easy, accessing data is difficult

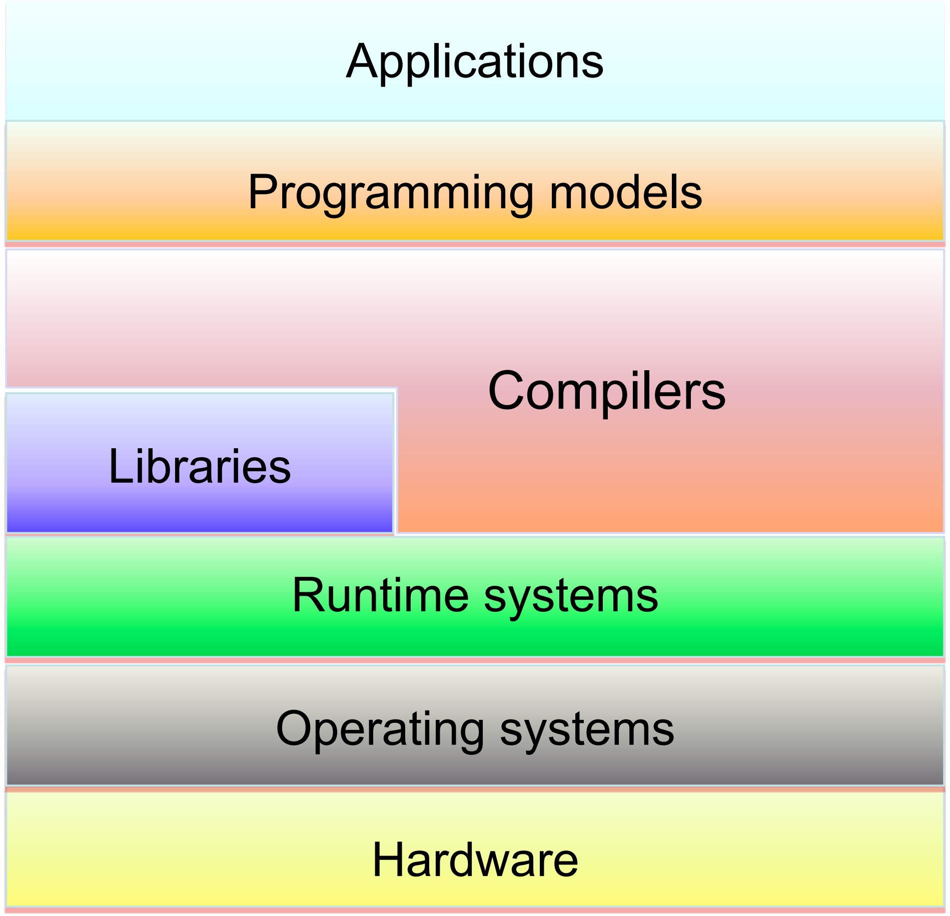
Lot of computing power.



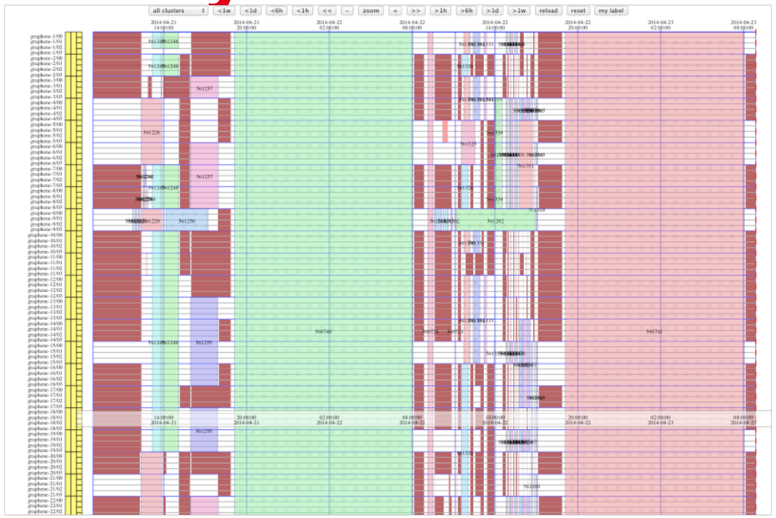
Complex topology + low mem/core :

- Bringing data at the **right place** at the **right time** is the challenge.

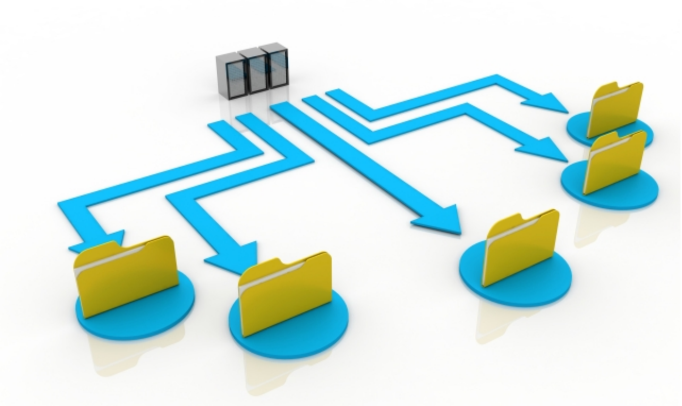
The application and its ecosystem


Applications
Programming models
Compilers
Libraries
Runtime systems
Operating systems
Hardware

SW stack



Batch scheduler



Storage

Optimizing execution

Once the application has been written in **nice language** with **performing libraries** and **efficient data layout** there is still room for optimizations:

- Not everything is known at compile time
- allocated resources
- input data

Our goal: take the application as it is and **optimize its execution on its ecosystem** (sw stack + batch scheduler + storage system + …)

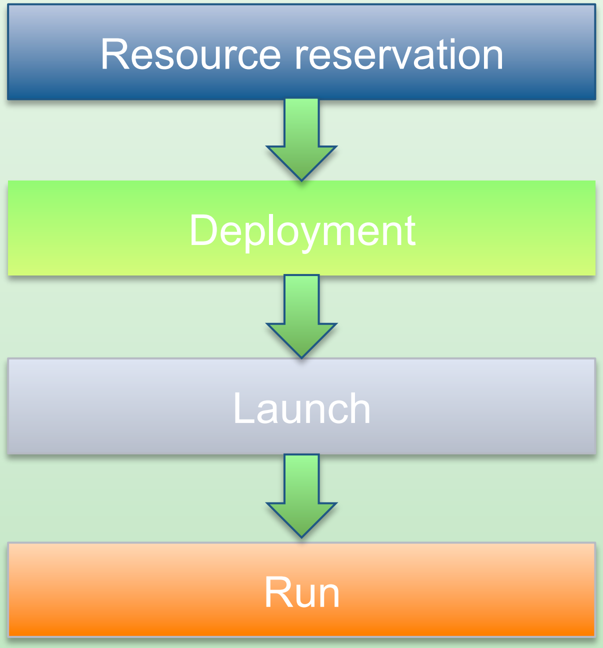
Not that simple…

Execution is not always completely decoupled from application design.

Need for information exchange between application and runtime system

TADaaM: Topology-Aware System-Scale Data Management for High-Performance Computing Applications

Application execution phases



Resource reservation

Deployment

Launch

Run

Topology-aware data management research

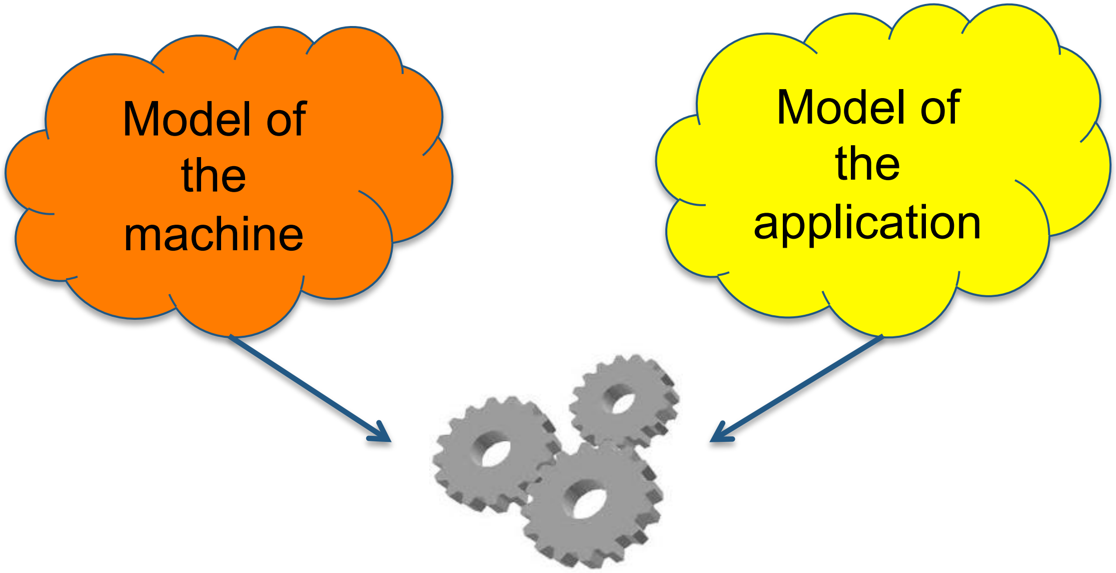
Interaction with the ecosystem

Process placement

Data partitioning
Process reordering
Affinity management
I/O and datapath optimization
Migration
Partitioning refinement
Data realocation

Perf. and platform models

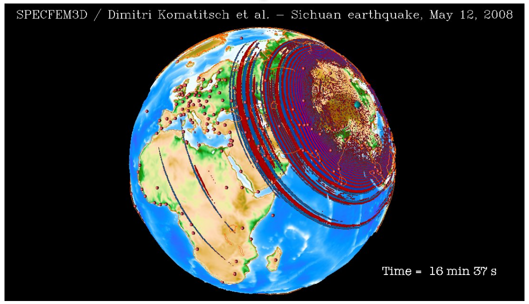
Big Picture



Model of the machine

Model of the application

Optimization algorithm


SPECFEM3D / Dimitri Komatitsch et al. – Sichuan earthquake, May 12, 2008
Time = 16 min 37 s

Optimized execution

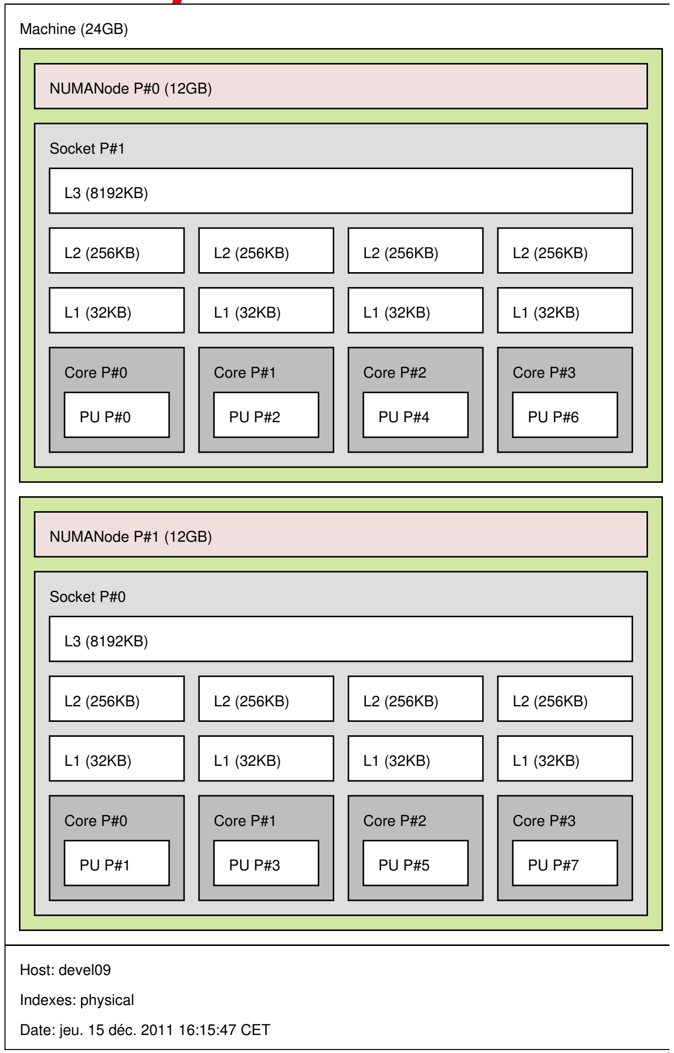
Model of machine (within nodes)

HWLOC (portable hardware locality)

- Runtime and OpenMPI team
- portable abstraction (across OS, versions, architectures, ...)
- Hierarchical topology
- Modern architecture (NUMA, cores, caches, etc.)
- ID of the cores
- C library to play with
- etc.

On going dev. in the team need for:

- dynamic information topology information (within and between nodes)
- API?
- Less bug in the BIOS



Host: devel09

Indexes: physical

Date: jeu. 15 déc. 2011 16:15:47 CET

Model of the machine (network): Netloc

hwloc companion
Takes care of network topology
and joins hwloc and network information

- Global « map » of your cluster
  - Connects hwloc objects to network edges

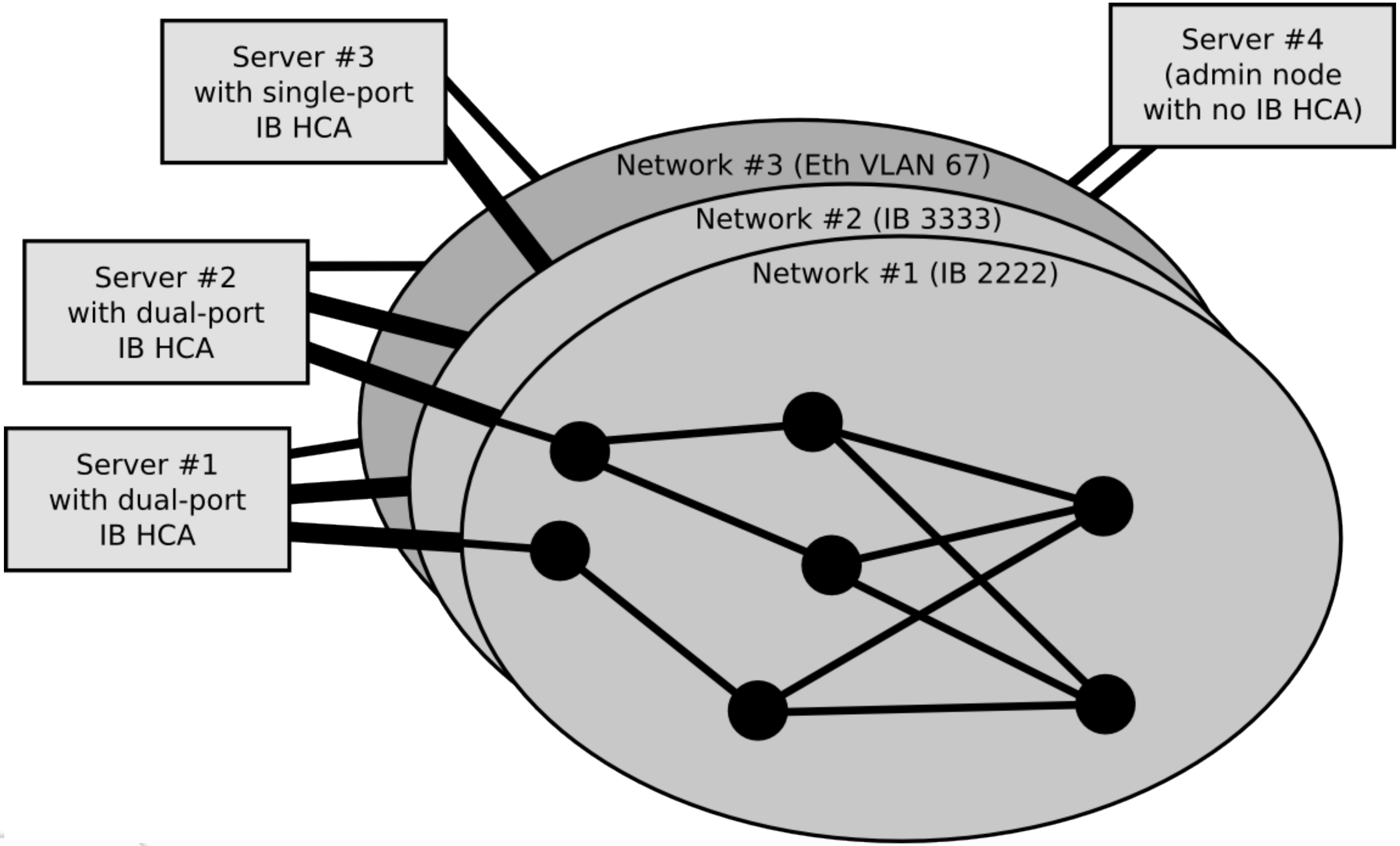
Public API made of

- Network queries (nodes, edges, etc.)
- Global map queries
- hwloc API when looking inside servers

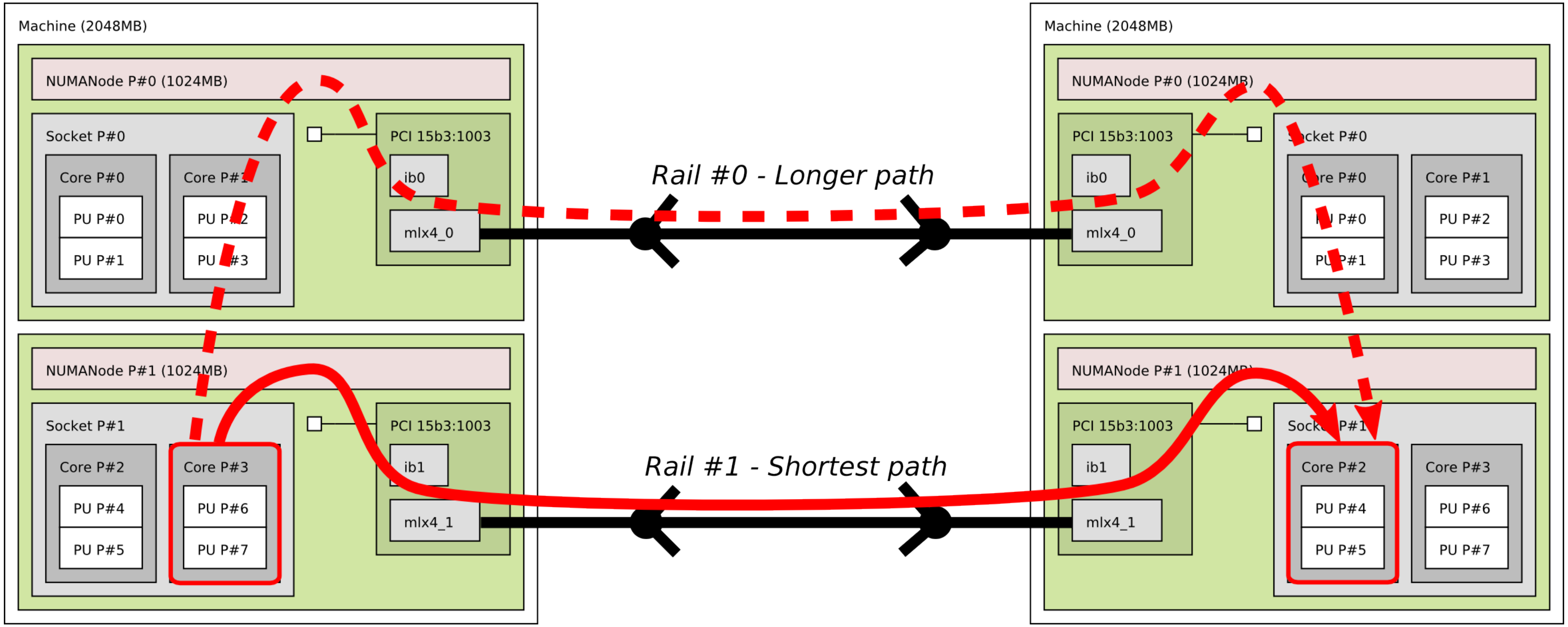
Currently developed by

- University of Wisconsin-LaCrosse (J. Hursey)
- Inria (B. Goglin)
- Cisco (J. Squyres)
- under the umbrella of the Open MPI consortium

Netloc global map



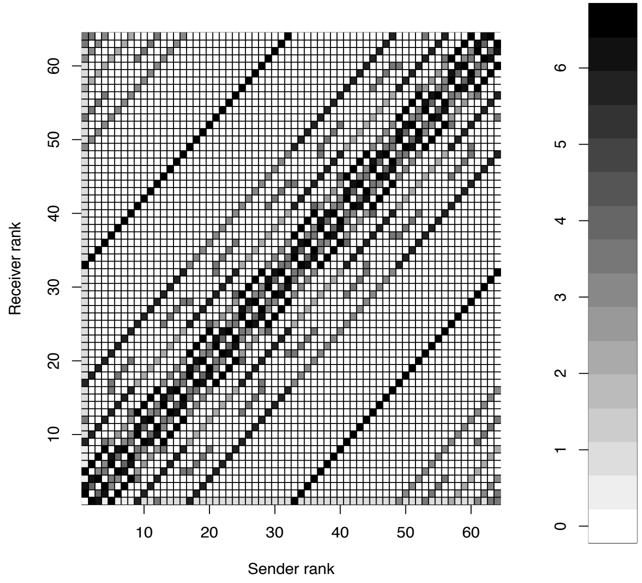
Multirail/multipath Locality



Application model

We target data access.

We need affinity between processing elements:
communication pattern



Building the communication pattern

- Statically (thanks to compiler)
- Dynamic Monitoring (Charm++)
- Blank execution and tracing (OpenMPI)
- After data partitioning (e.g. Scotch)

Software suite: use-case example

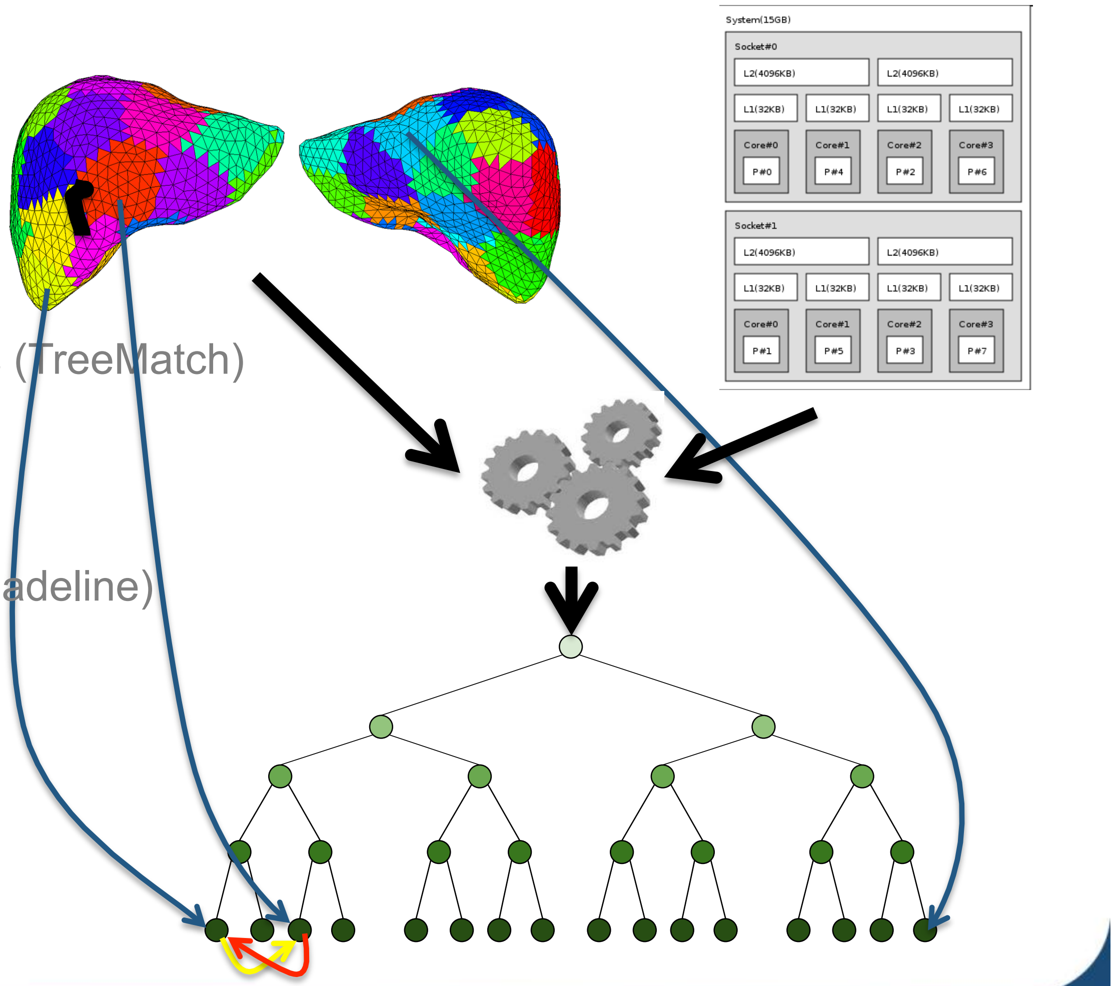
Mesh/graph partitioning (Scotch)

Platform model (Hwloc)

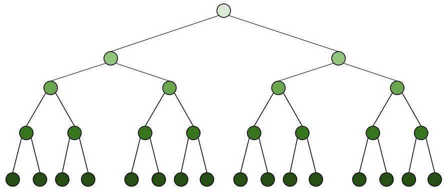
Topology-aware locality mechanisms (TreeMatch)

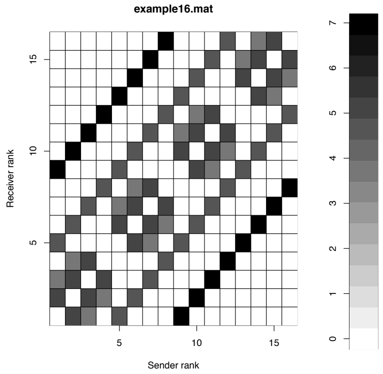
Parallel mesh adaptation

Communication optimization (New Madeline)



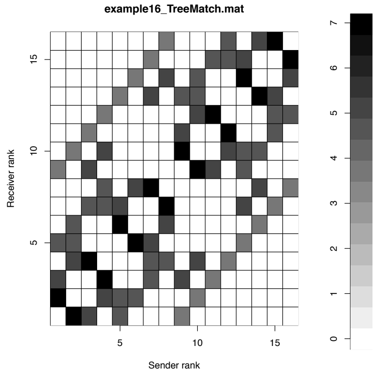
Putting everything together: Process Placement with TreeMatch

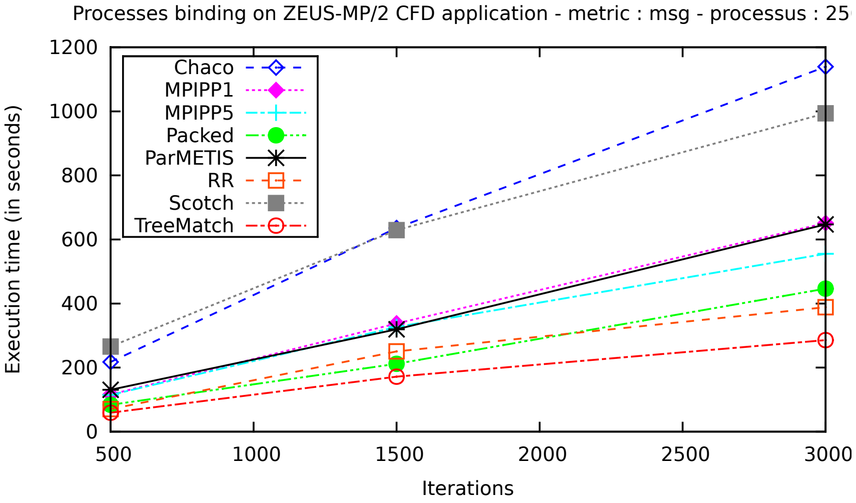




$\sigma = (0,2,8,10,4,6,12,14,1,3,9,11,5,7,13,15)$

$\Longrightarrow$





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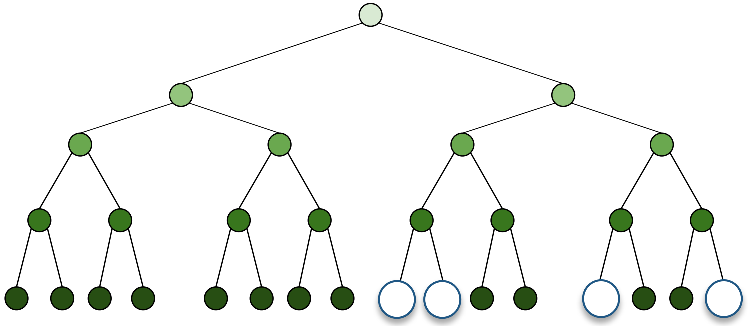
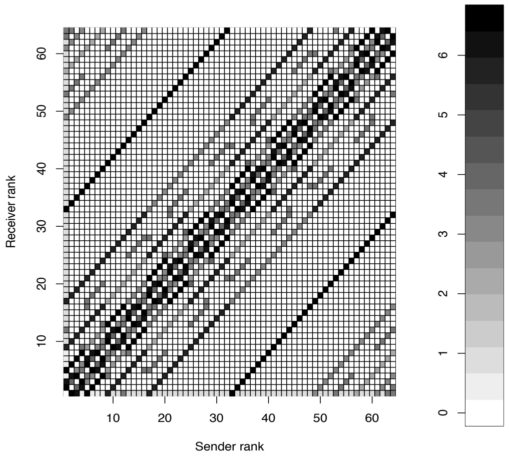
Resource selection

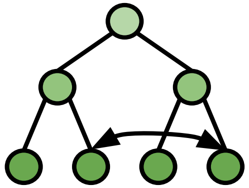
Selecting Resources



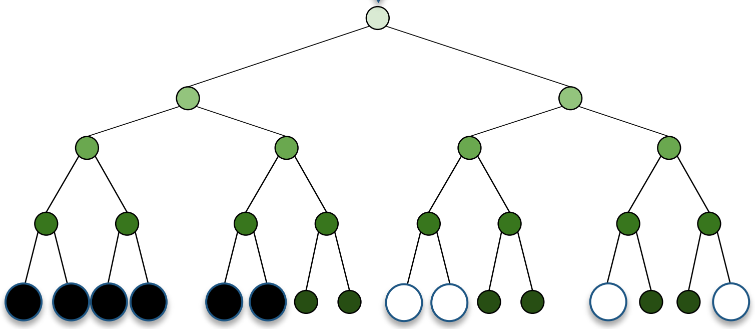
Model of the machine



Model of the application



TreeMatch Algorithm in the batch scheduler



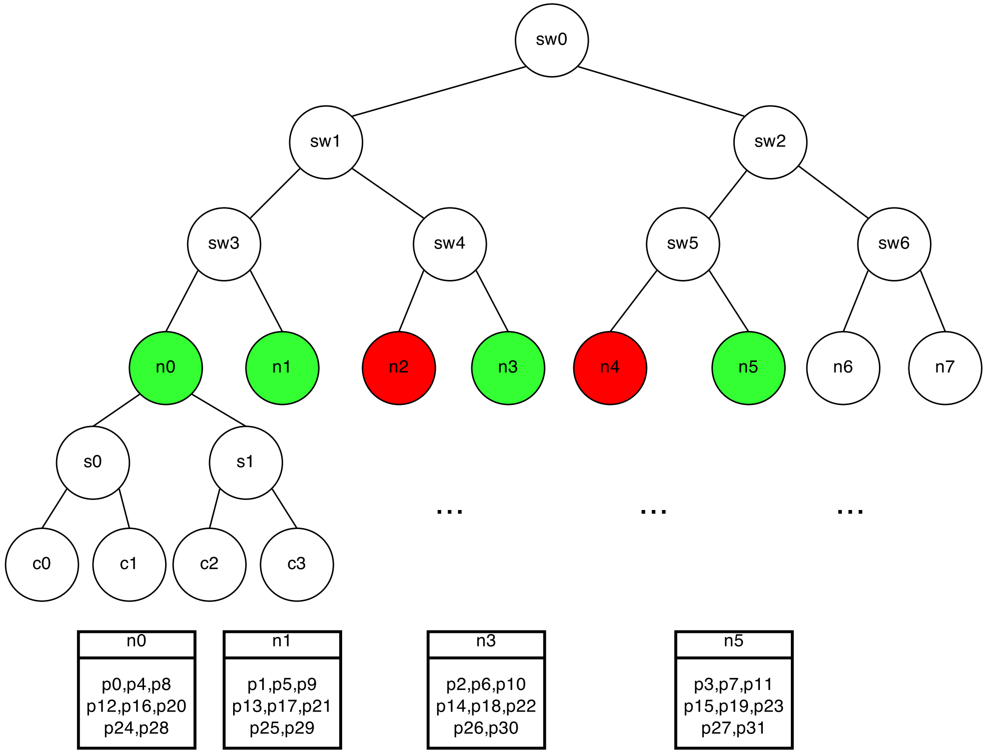
Implementation

- Within SLURM (in collaboration with BULL)
- Plugin
- Resource selection and process placement at the same time

Why topology-aware resource selection could work?

Procs	0-7	8-15	16-23	24-31
0-7	0	1000	0	20
8-15	1000	0	10	0
16-23	0	10	0	1000
24-31	20	0	1000	0

SLURM



n0	n1	n3	n5
p0,p4,p8 p12,p16,p20 p24,p28	p1,p5,p9 p13,p17,p21 p25,p29	p2,p6,p10 p14,p18,p22 p26,p30	p3,p7,p11 p15,p19,p23 p27,p31

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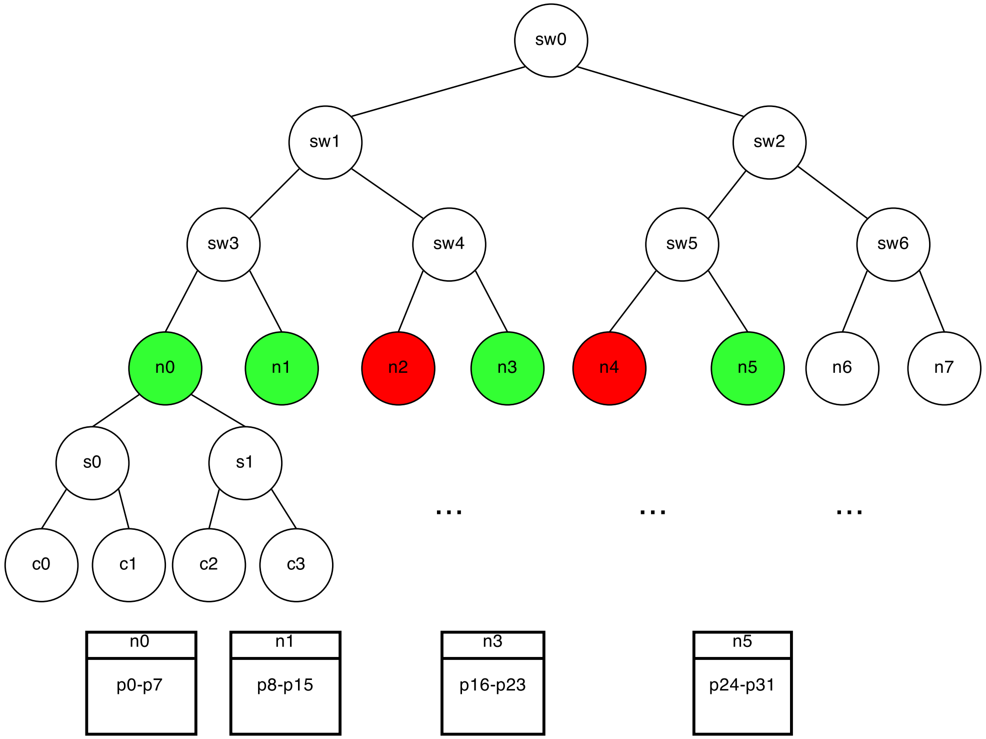
16-23	0	10	0	1000
24-31	20	0	1000	0

SLURM Then TreeMatch



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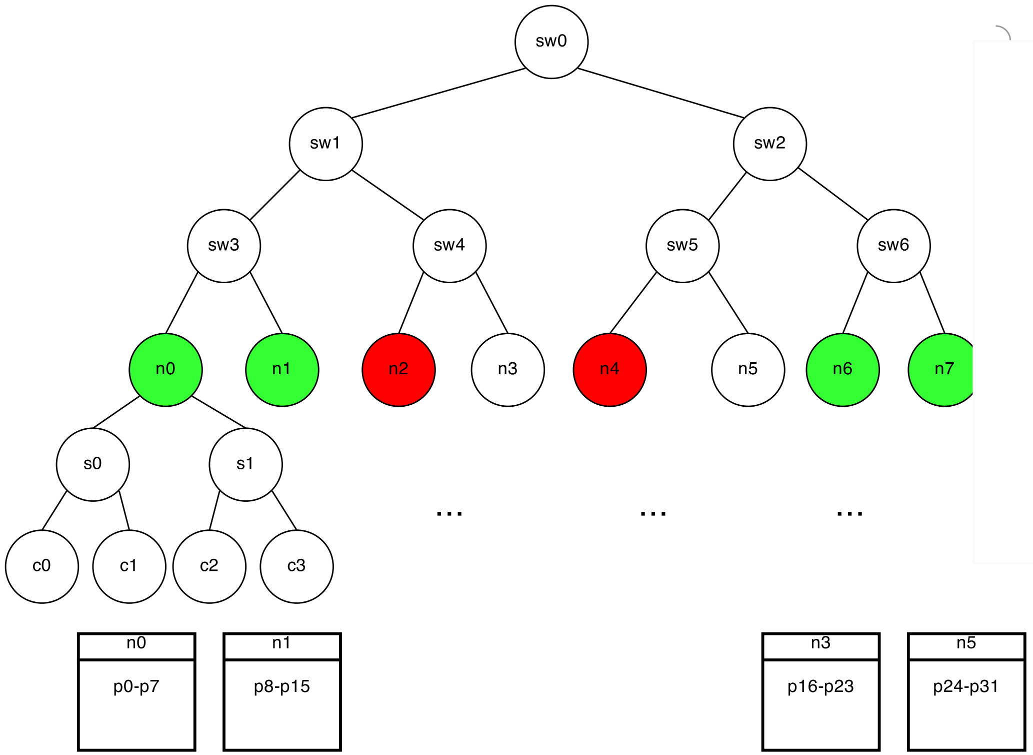
0-7	0	1000	0	20
8-15	1000	0	10	0
16-23	0	10	0	1000
24-31	20	0	1000	0

SLURM and TreeMatch



Early experiments

Same protocol as SLURM/Bull team.

Simulation using real traces of the Curie CEA machine: 80640 cores.

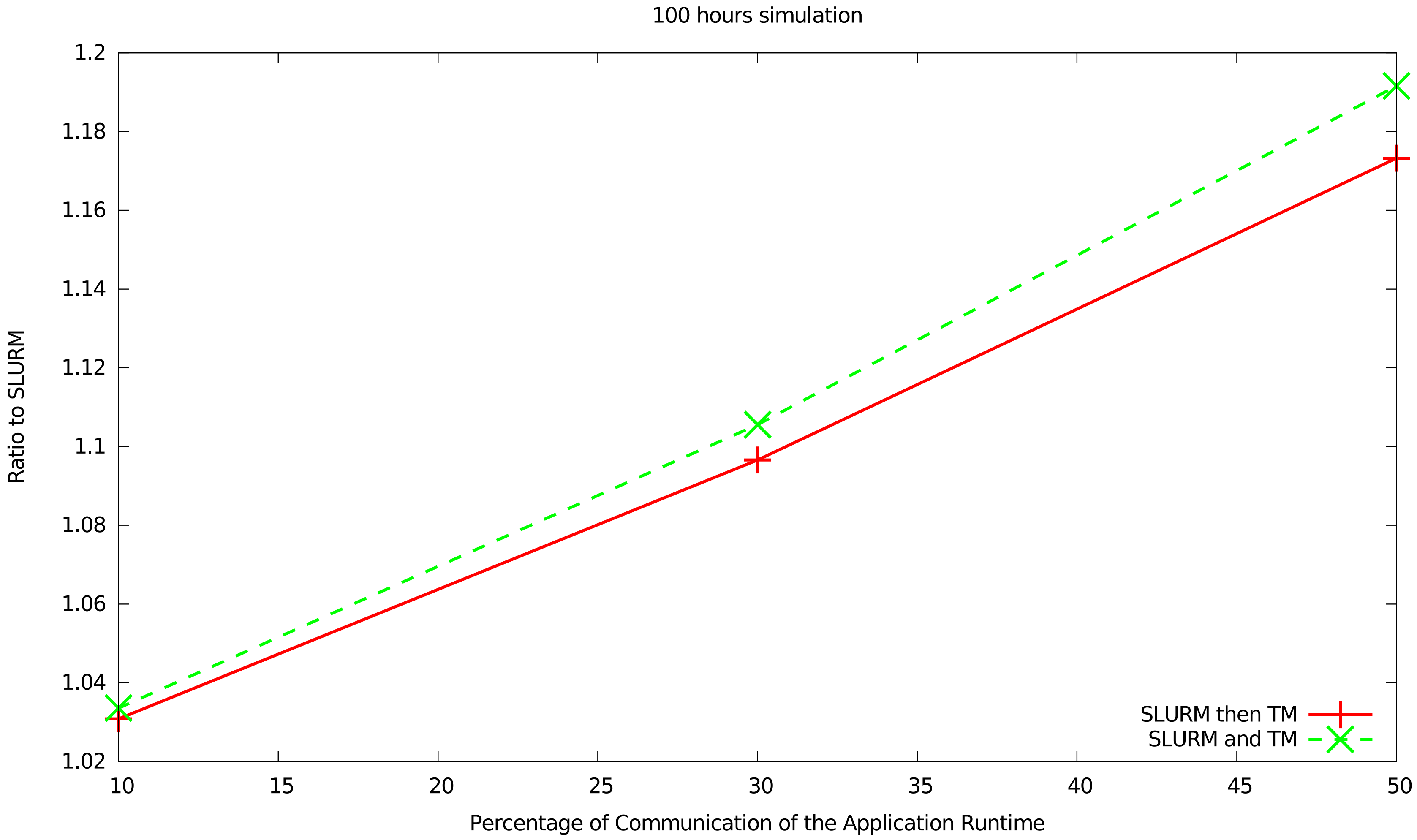
Model of performance gain of TreeMatch depending on the amount of communication performed by application (10%, 30%, 50%).

Same starting workflow:

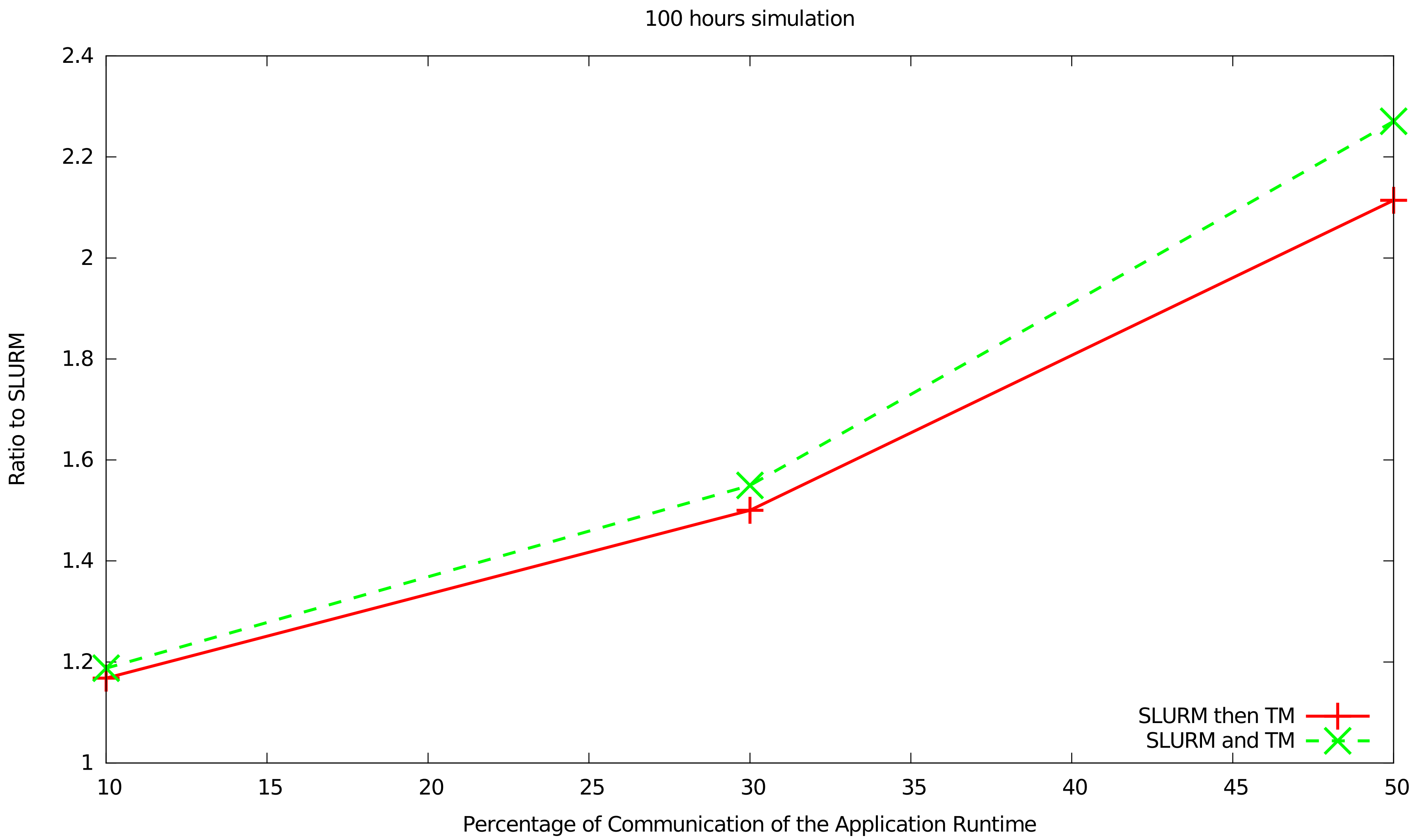
- 130 running jobs
- 26 queued jobs
- 372 submitted jobs (1 hour)

Evaluation on the difference of the submitted jobs.

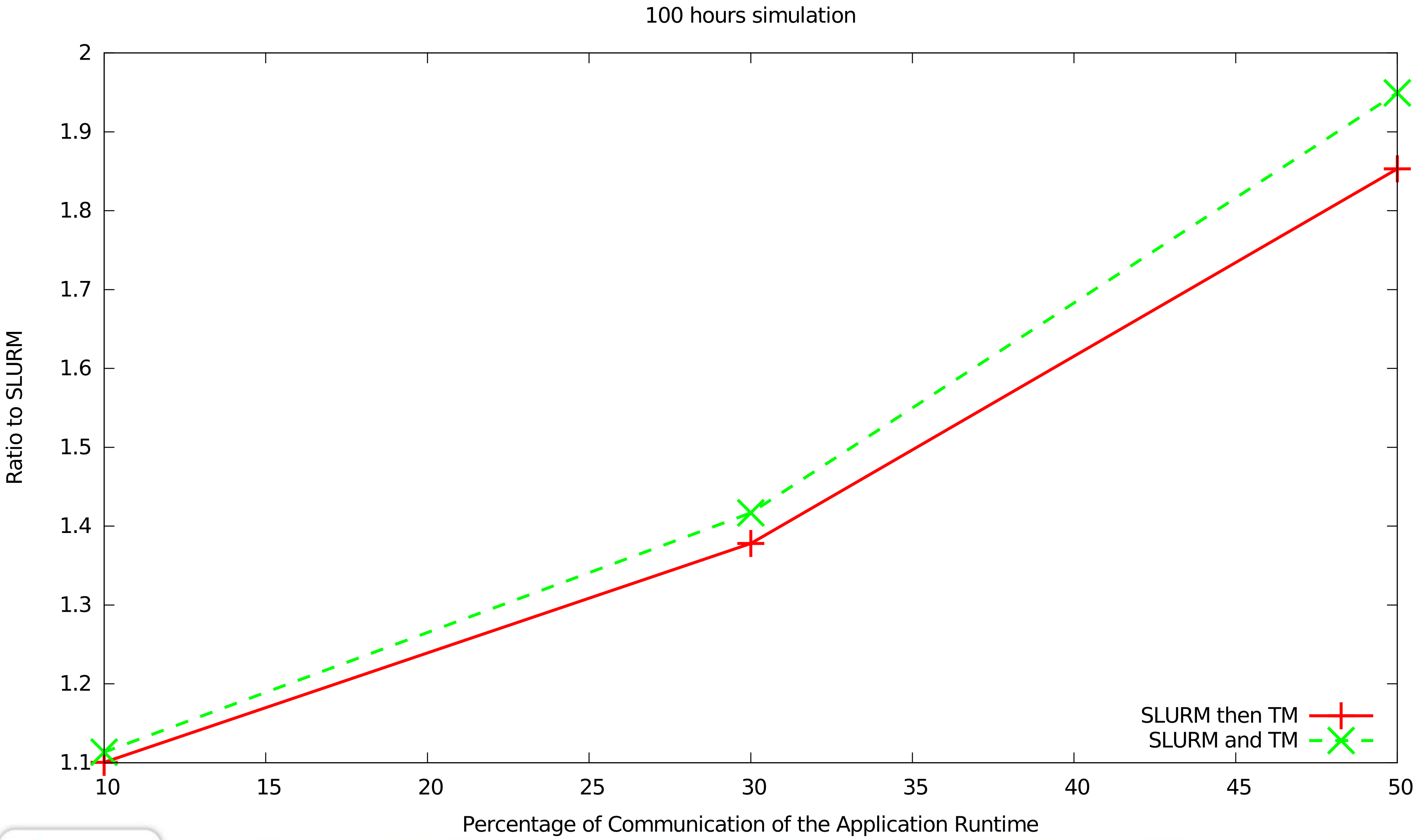
Simulation: makespan



Simulation: average stretch



Simulation: average flow



Conclusion

Take Away Message

Locality! Bytes are more important than flops

Not everything can be optimized statically at compile time

Need for runtime topology-aware data management

Need to take into consideration the whole application ecosystem such as the storage or the batch scheduler