Process Allocation Strategies for Runtime Optimization

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MPI (Process-based runtime systems)

Performance of MPI programs depends on many factors:

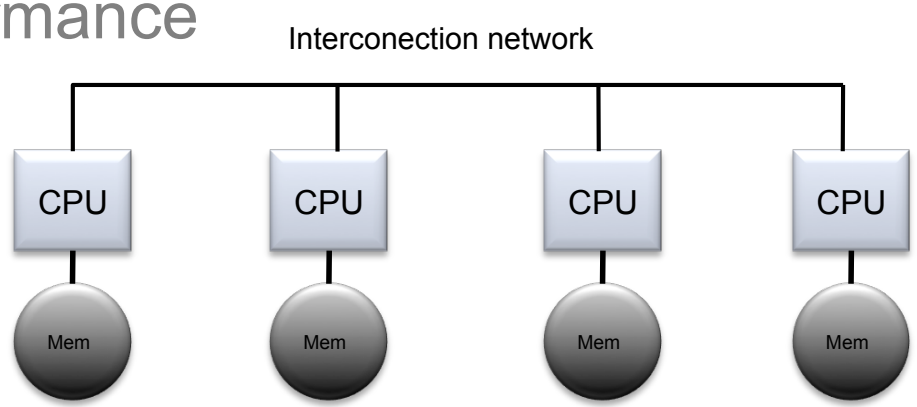
- Implementation of the standard (e.g. collective com.)
- Parallel algorithm(s)
- Implementation of the algorithm
- Underlying libraries (e.g. BLAS)
- Data Layout
- Hardware (processors, cache, network)
- etc.

But…

Process Placement

The MPI model makes little (no?) assumption on the way processes are mapped to resources

It is often assume that the network **topology is flat** and hence the process mapping has little impact on the performance



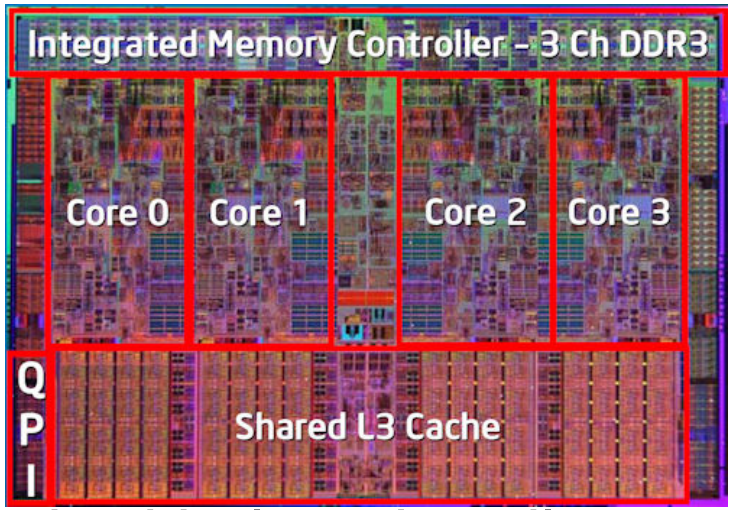
The Topology is not Flat

Due to multicore processors current and future parallel machines are hierarchical

Communication speed depends on:

- Receptor and emitter
- Cache hierarchy
- Memory bus
- Interconnection network

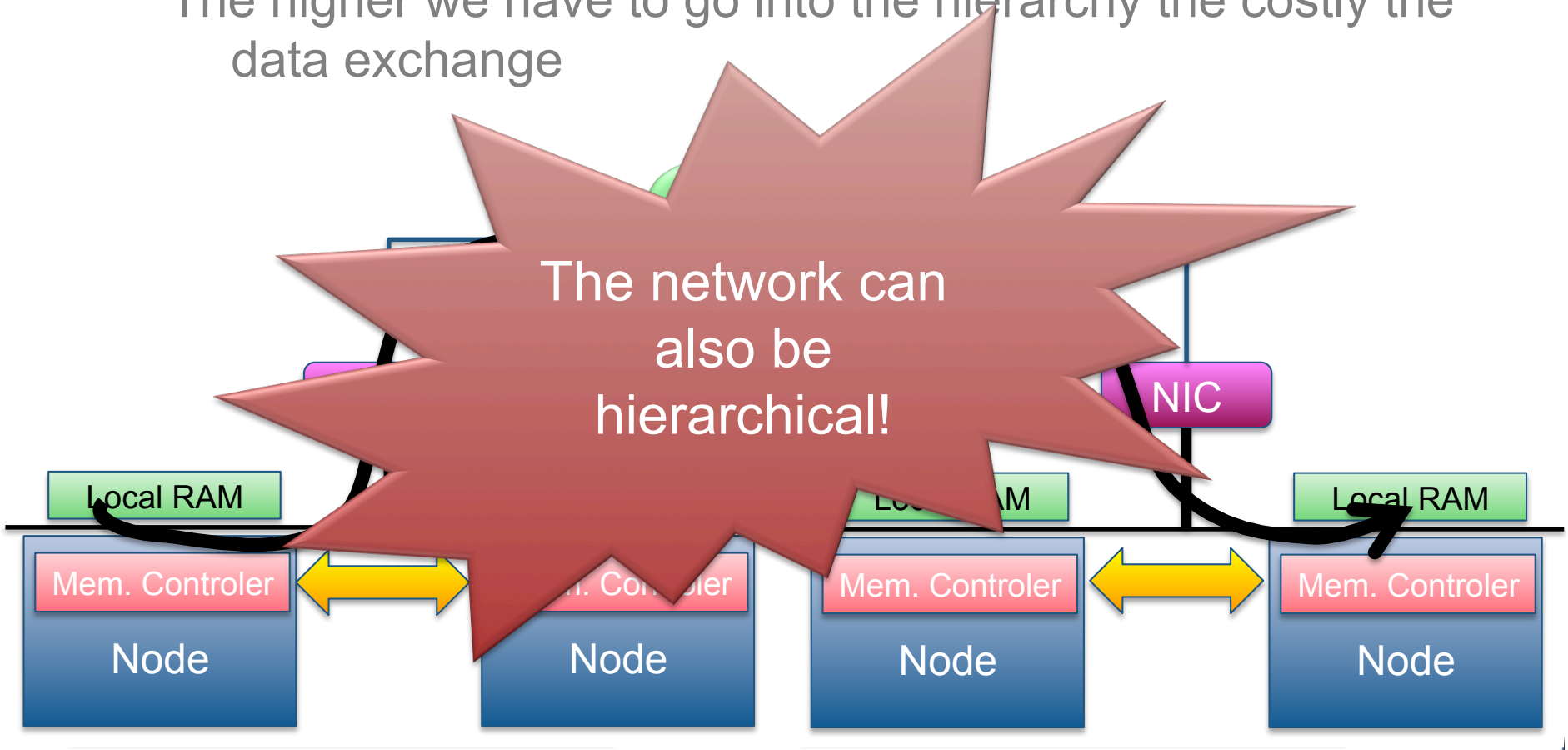
etc.



Almost nothing in the MPI standard help to handle these factors

Example on a Parallel Machine

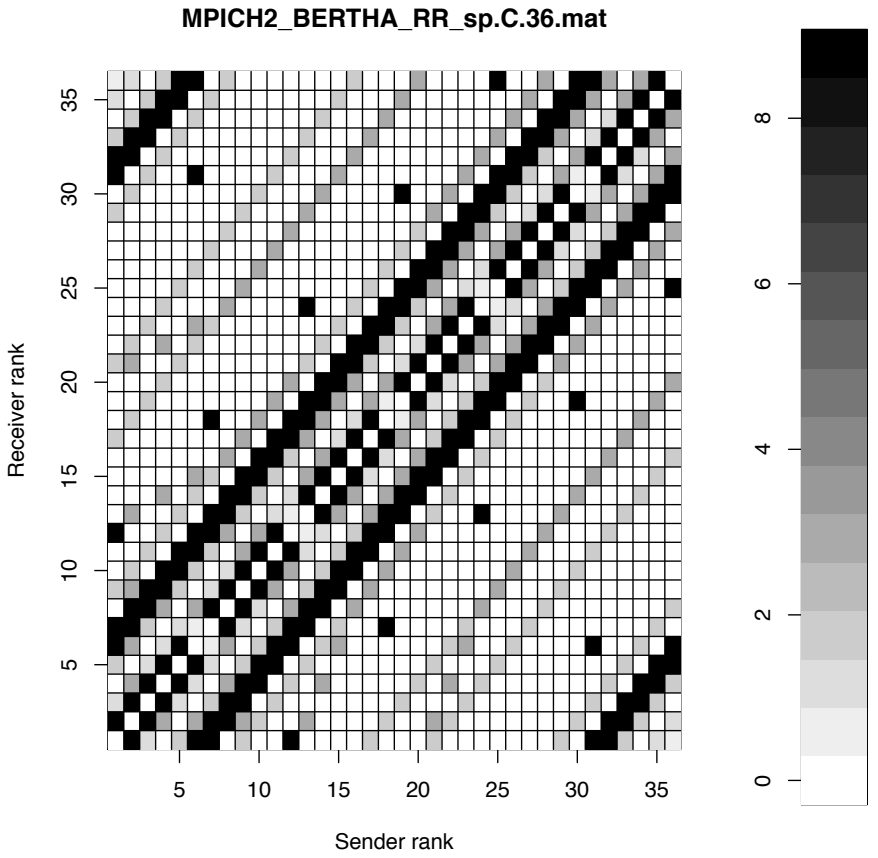
The higher we have to go into the hierarchy the costly the data exchange



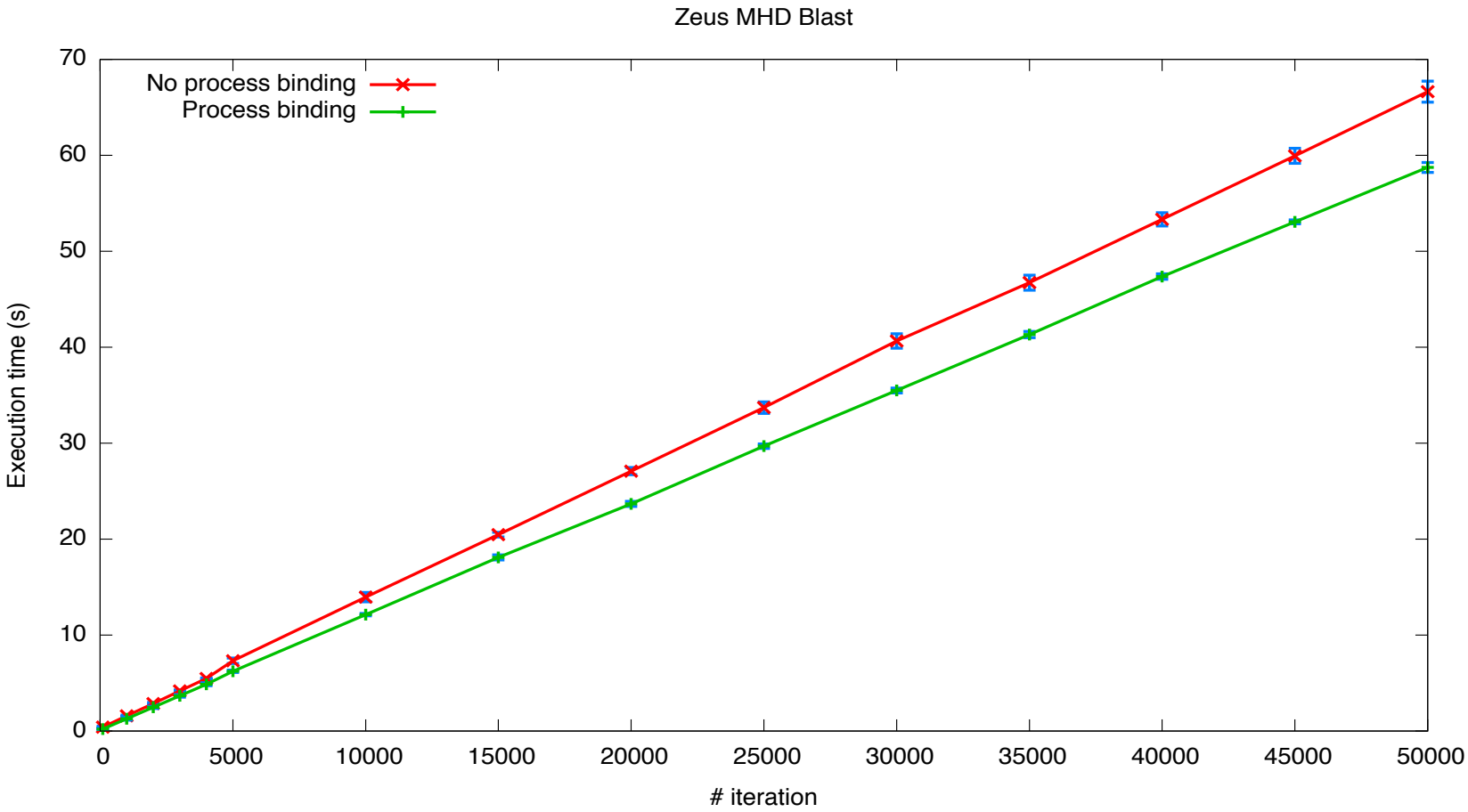
Rationale

Not all processes exchange the same amount of data

The speed of communications, and hence performance of the application depends on the way processes are mapped to resources.



Do we Really Care: to Bind or not to Bind?



Zeus MHD Blast. 64 Processes/Cores. Mvapich2 1.8. + ICC

Process Placement Problem

Given :

- Parallel machine **topology**
- Process **affinity** (communication pattern)

Map processes to resources (cores) to reduce communication cost. A nice algorithmic problem:

- Graph partitionning (Scotch, Metis)
- Application tuning [Aktulga et al. Euro-Par 12]
- Topology-to-pattern matching (TreeMatch)

Reduce Communication Cost?

Systems	2010	2018	Difference Today & 2018
System peak	**2 Pflop/s**	**1 Eflop/s**	**O(1000)**
Power	**6 MW**	**~20 MW**	
System memory	0.3 PB	32 - 64 PB **[.03 Bytes/Flop]**	O(100)
Node performance	125 GF	1,2 or 15TF	O(10) - O(100)
Node memory BW	25 GB/s	2 - 4TB/s **[.002 Bytes/Flop]**	O(100)
Node concurrency	12	O(1k) or 10k	O(100) - O(1000)
Total Node Interconnect BW	3.5 GB/s	200-400GB/s (1:4 or 1:8 from memory BW)	O(100)
System size (nodes)	18,700	O(100,000) or O(1M)	O(10) - O(100)
Total concurrency	225,000	O(billion) [O(10) to O(100) for latency hiding]	O(10,000)
Storage	15 PB	500-1000 PB (>10x system memory is min)	O(10) - O(100)
IO	0.2 TB	60 TB/s (how long to drain the machine)	O(100)
MTTI	days	O(1 day)	- O(10)

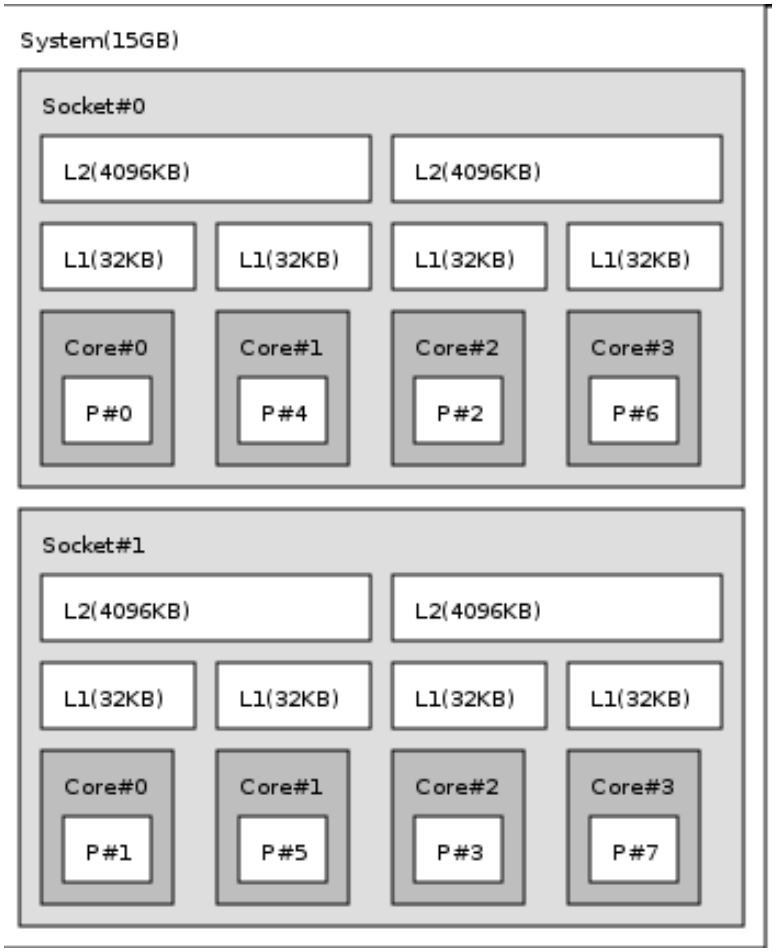
Taken from one of J. Dongarra's Talk.

Obtaining the Topology (Shared Memory)

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

HWLOC



http://www.open-mpi.org/projects/hwloc/

Obtaining the Topology (Distributed Memory)

Not always easy (research issue)

MPI core has some routine to get that

Sometime requires to build a file that specifies node adjacency.

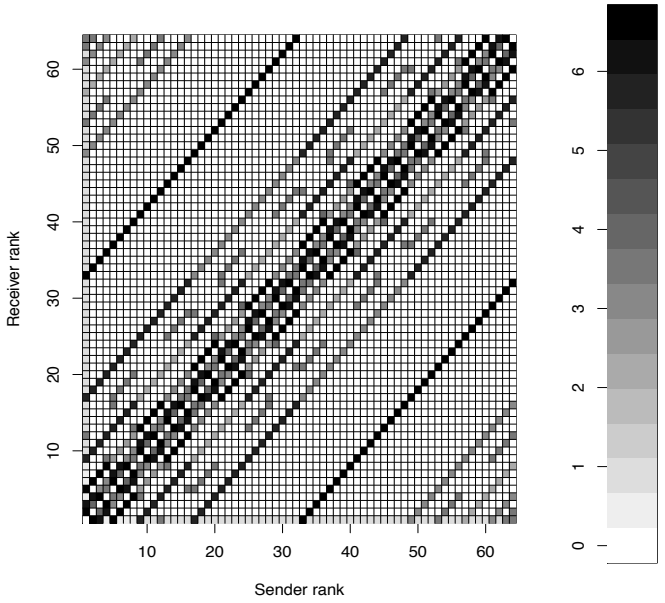
Netloc.

Getting the Communication Pattern

No automatic way so far…

Can be done:

- Through application monitoring
- During execution (Load-balancing)
- With a « blank execution »
- From the application design (stencil, etc.)
- From the data partitionning



State of the Art

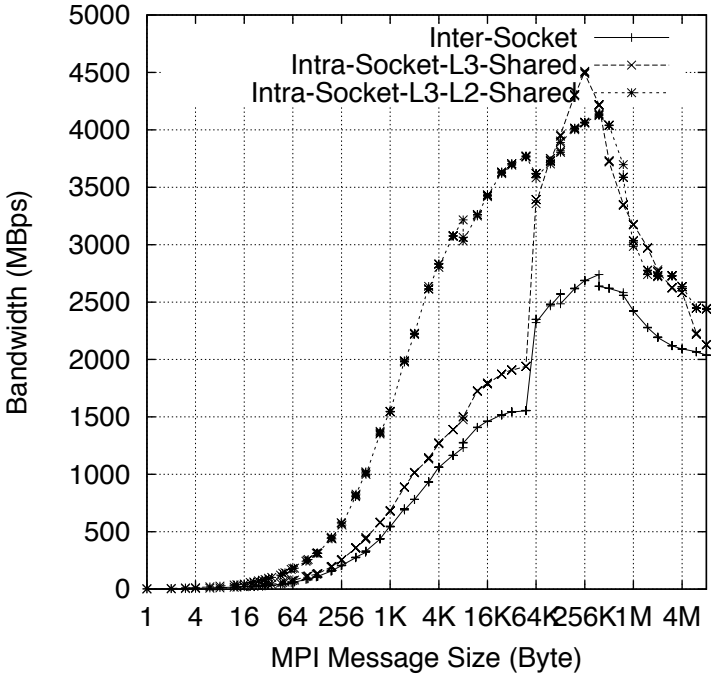
Process placement fairly well studied problem:

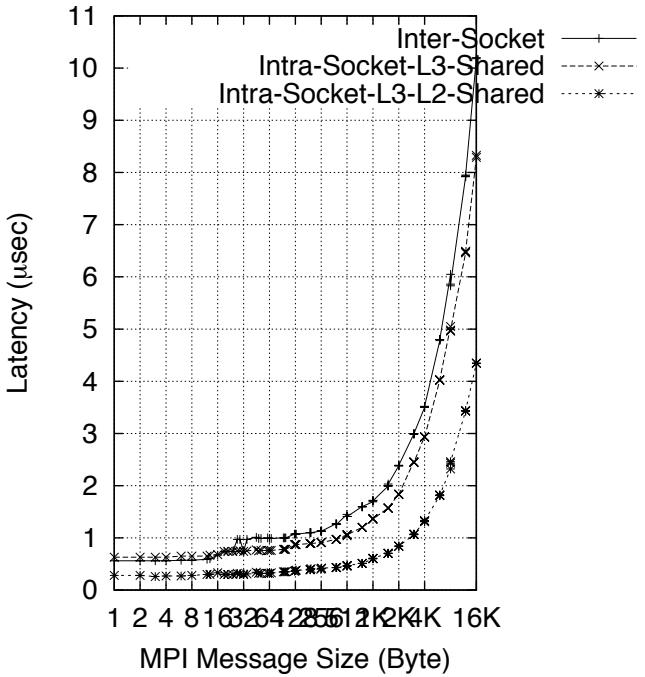
- [Träff 02]: placement through graph embedding and graph partitioning
- MPIPP [Chen et al. 2006]: placement through local exchange of processes until no gain is achievable
- [Clet-Ortega & Mercier 09]: placement through graph renumbering (Scotch)
- LibTopoMap [Hoefler & Snir 11]: placement through network model + graph partitioning (ParMetis)

All these solutions require a **quantitative** knowledge of the topology.

Problems with quantitative knowledge

Netpipe on a 2 sockets, 8 cores each NUMA node





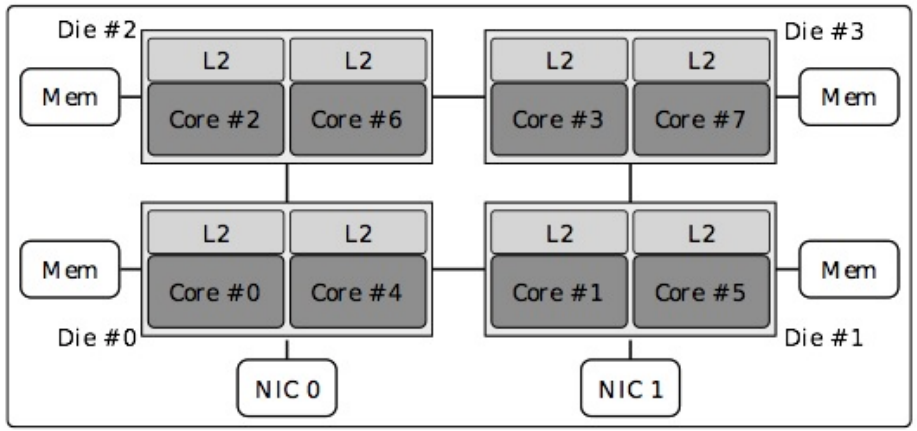
It is generaly faster to use cache or to stay within a socket

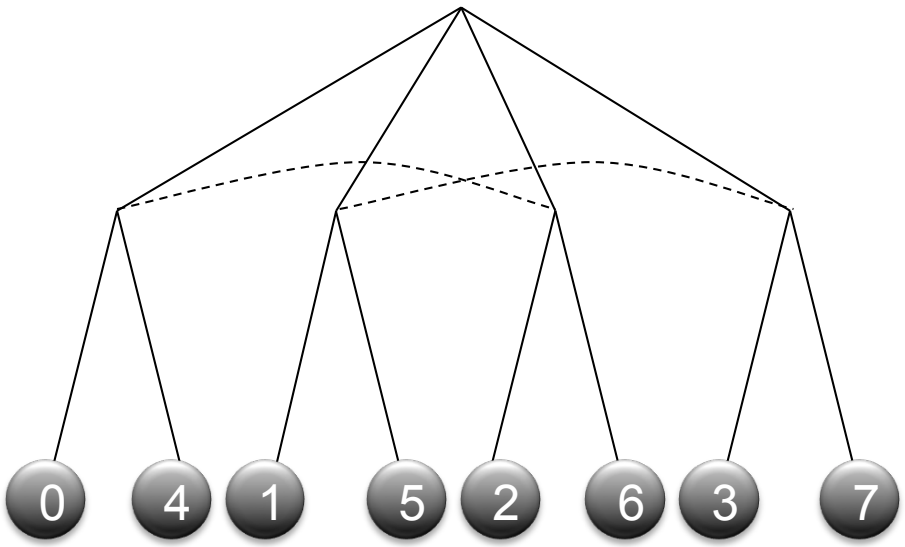
But the acceleration ratio depends on message size:

- It is not linear (not affine either)
- Contention makes things even harder

Dealing with Qualitative Knowledge

Abstract the topology with a **tree**
Assume communication always cost more when you need to reach higher levels





The structure is sufficient. No need to deal with latency or bandwidth.

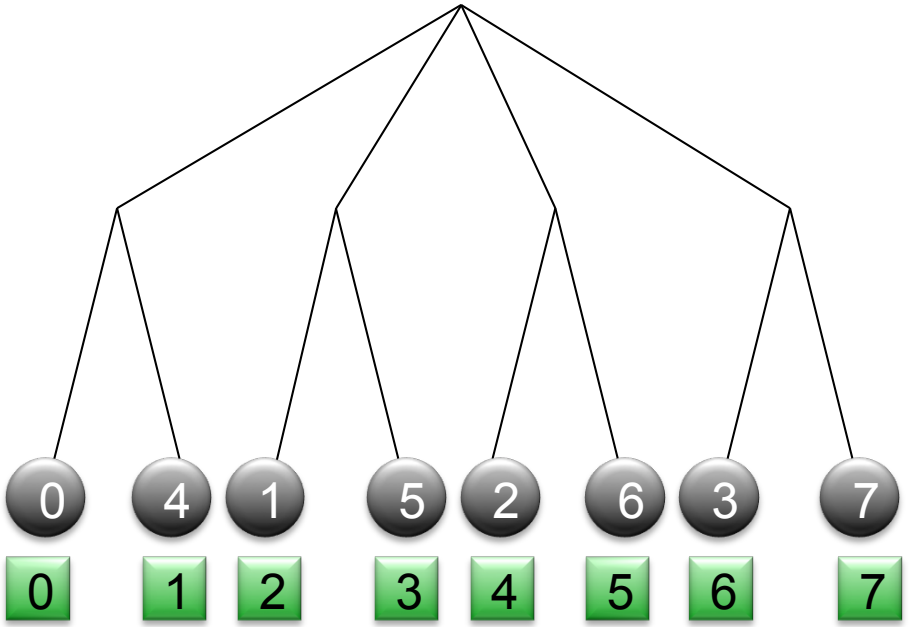
TreeMatch Algorithm

C: communication matrix

0	1000	10	1	100	1	1	1
1000	0	1000	1	1	100	1	1
10	1000	0	1000	1	1	100	1
1	1	1000	0	1	1	1	100
100	1	1	1	0	1000	10	1
1	100	1	1	1000	0	1000	1
1	1	100	1	10	1000	0	1000
1	1	1	100	1	1	1000	0

Grouped matrix

0	1012	202	4
1012	0	4	202
202	4	0	1012
4	202	1012	0



Communication matrix + Tree Topology
= Process permutation

Process reordering

TreeMatch: process permutation

If process already bound: rank reordering within the MPI code

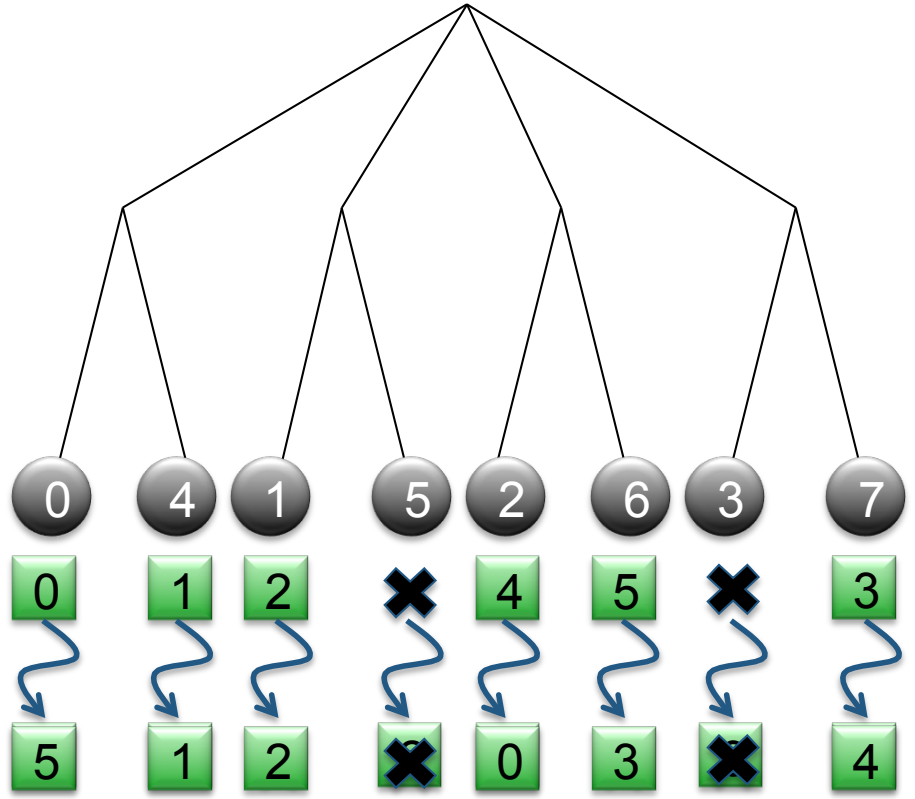
Build a **new communicator** that optimizes the execution

Problem: how to take into account placement constraints

Dealing with already mapped applicatons

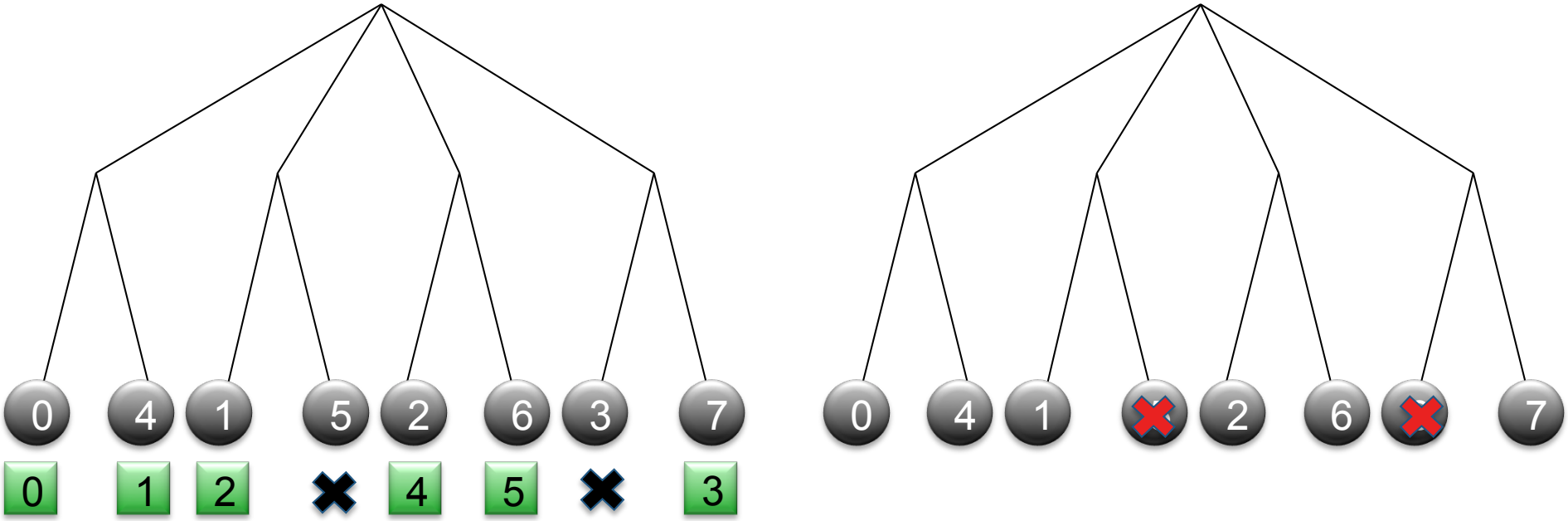
Problem:

- Given a hierarchichal topology
- An already mapped application onto a subset of the nodes
- Reorder process while ensuring only this subset is used



Prevent Treematch to use some cores.

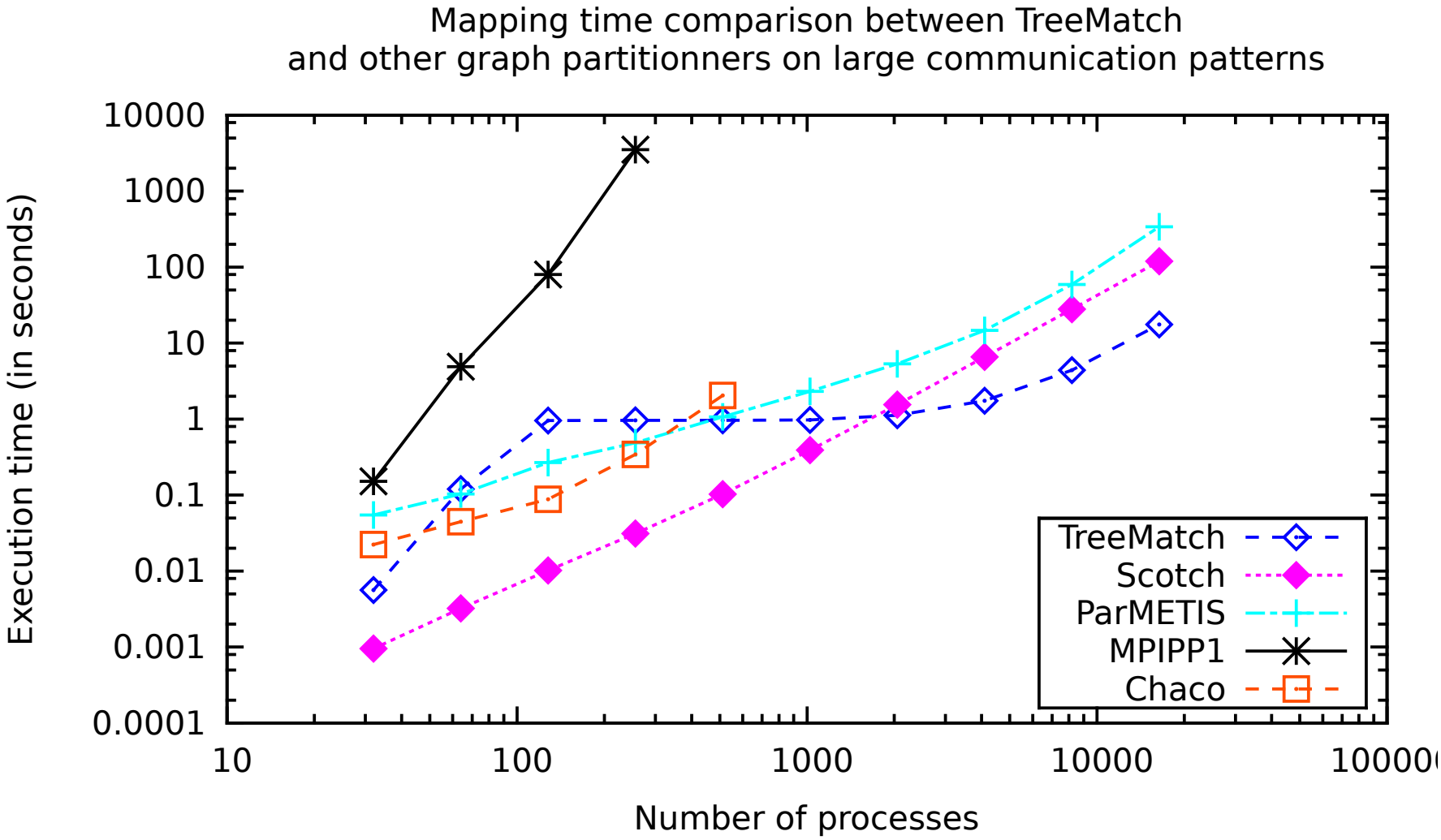
New Version of TreeMatch to Deal With Unbalanced Tree



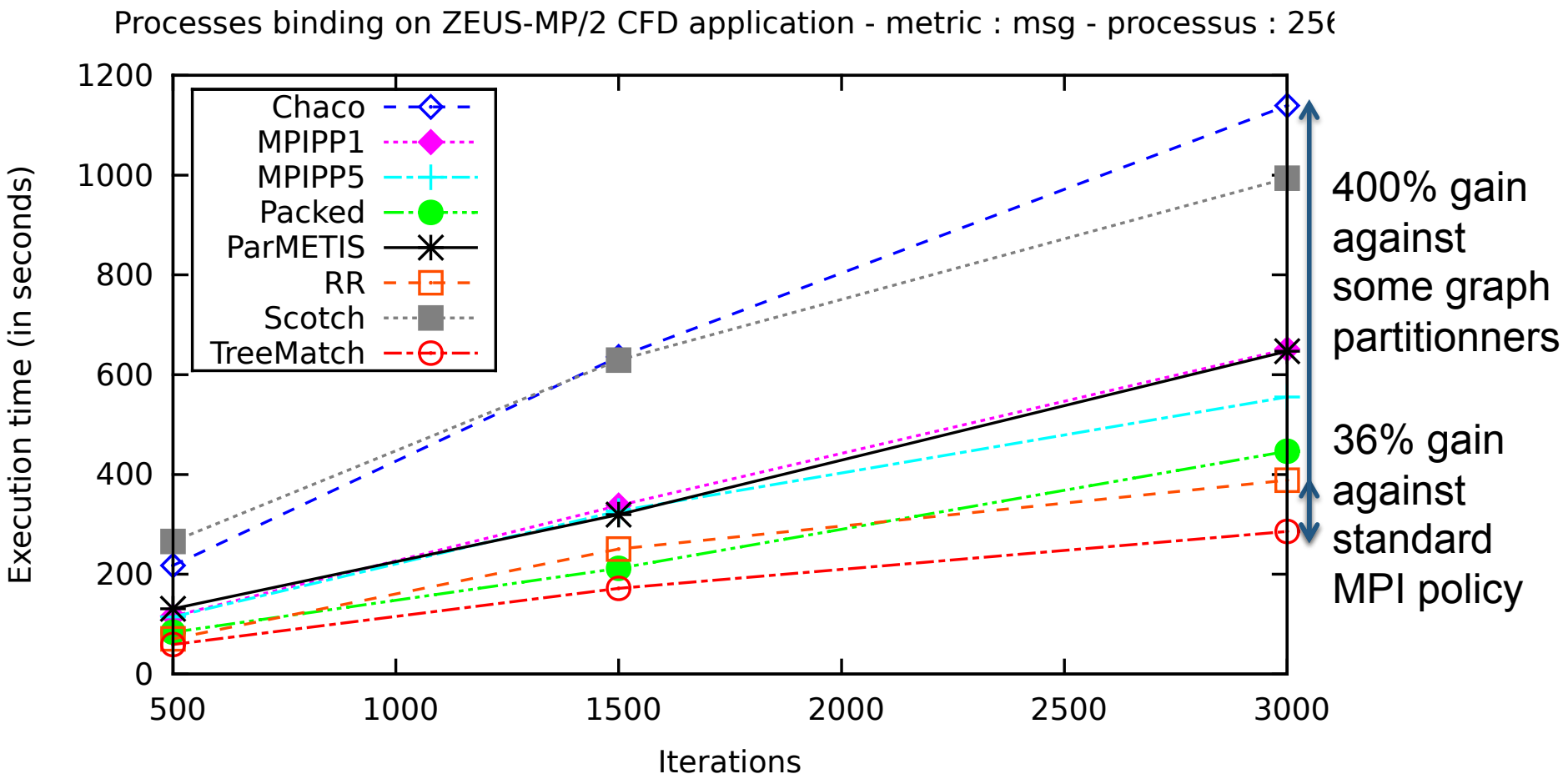
Solution:

- Extend the communication matrix with dummy nodes
- Process the tree backward by doing k-partitionning
- Force each partition to have the right number of dummy nodes
- Process recursively

Results: placement computation time



Results

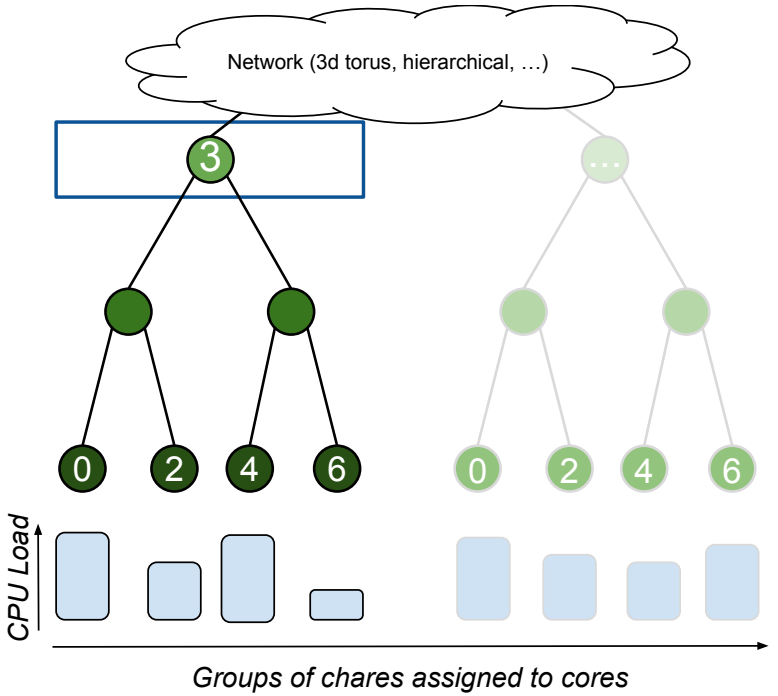


64 nodes linked with an Infiniband interconnect (HCA: Mellanox Technologies, MT26428 ConnectX IB QDR).
Each node features two Quad-core INTEL XEON NEHALEM X5550 (2.66 GHz) processors.

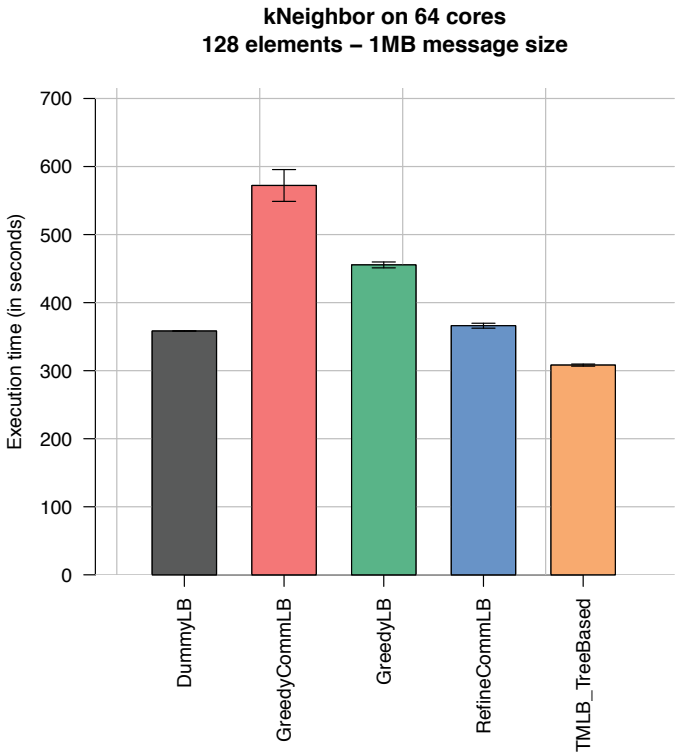
Topology-aware load balancing

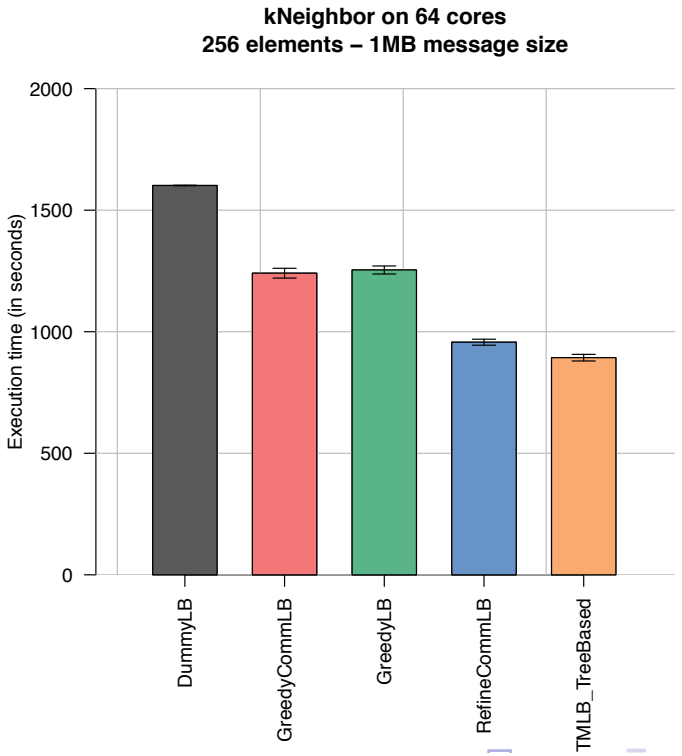
Within Charm++
Taking into account:

- CPU load
- Process affinity
- Toplogy



Result with k-neighbour





Conclusion

To ensure performance protability one must take into account the topology of target machine

Process placement according to application behavior and topology helps in increasing performance

We are ready to test our techniques on your applications…

No need to change the code to test TreeMatch

Thanks!

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