Distributed communication-aware load balancing with TreeMatch in Charm++

The 9th Scheduling for Large Scale Systems Workshop, Lyon, France

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July 1, 2014

Introduction

Scalable execution of parallel applications

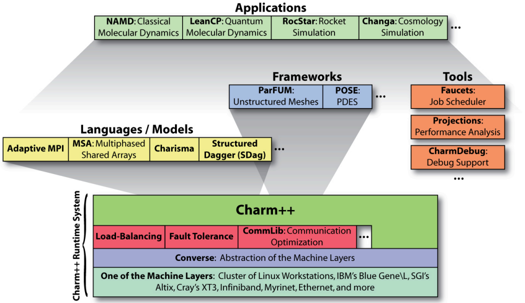
- Number of cores is increasing
- But **memory per core** is decreasing
- Application will need to communicate even more than now

Our solution

- Process placement should take into account **process affinity**
- Here: **load balancing in Charm++** considering :
  - CPU load
  - process affinity (or other communicating objects)
  - topology : network and intra-node

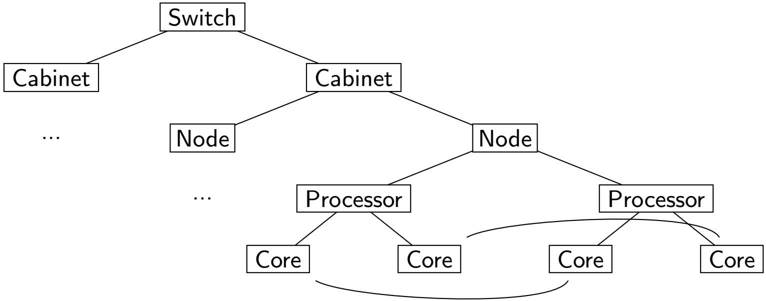
Features

- Parallel object-oriented programming language based on C++
- Programs are decomposed into a number of cooperating message-driven objects called **chares**.
- In general we have more chares than processing units
- Chares are mapped to physical processors by an adaptive runtime system
- Load balancers can be called to **migrate** chares
- Charm++ is able to use MPI for the processes communications



Why we should consider it

- Many current and future parallel platforms have several levels of hierarchy
- Application chares/processes do not exchange the same amount of data (affinity)
- The process placement policy may have impact on performance
  - Cache hierarchy, memory bus, high-performance network...

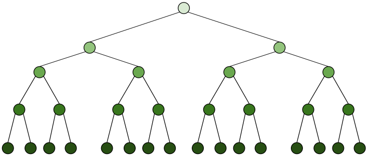


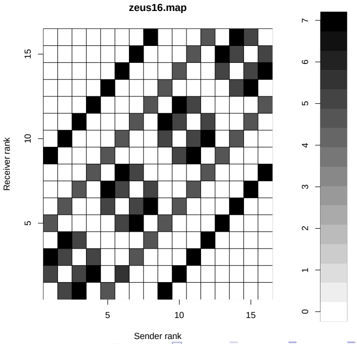
Problems

Given

- The parallel machine topology
- The application communication pattern

- Map application processes to physical resources (cores) to reduce the communication costs (NP-complete)





The TreeMatch Algorithm

- Algorithm and environment to compute processes placement based on processes affinities and NUMA topology
- Input :
  - The communication pattern of the application
    - Preliminary execution with a monitored MPI implementation for static placement
    - Dynamic recovery on iterative applications with Charm++
  - A model (tree) of the underlying architecture : Hwloc can provide us this.
- Output :
  - A processes permutation σ such that σ_i is the core number on which we have to bind the process i
- TreeMatch can only work on tree topologies. How to deal with 3d torus ?

Network placement

libtopomap

- T. Hoefler and M. Snir, "Generic Topology Mapping Strategies for Large-Scale Parallel Architectures" *Proc. Int'l Conf. Supercomputing (ICS)*, pp. 75-84, 2011.
- Library that enables to map processes on various network topologies
- Used in TreeMatchLB to consider the Blue Waters 3d torus

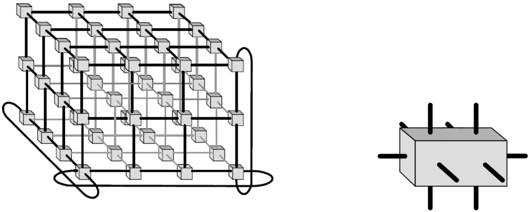


Figure: 3d Torus and a Cray Gemini router

Load balancing

Principle

- Iterative applications
- load balancer called at regular interval
- Migrate chares in order to optimize several criteria
- Charm++ runtime system provides:
  - chares load
  - chares affinity
  - etc. . .

Constraints

- Dealing with complex modern architectures
- Taking into account communications between elements

Some other communication-aware load-balacing algorithms

- [L. L. Pilla, et al. 2012] NUCOLB, shared memory machines
- [L. L. Pilla, et al. 2012] HwTopoLB
- Some "built-in" Charm++ load balancers : RefineCommLB, GreedyCommLB. . .

Several issues raised

Not so easy...

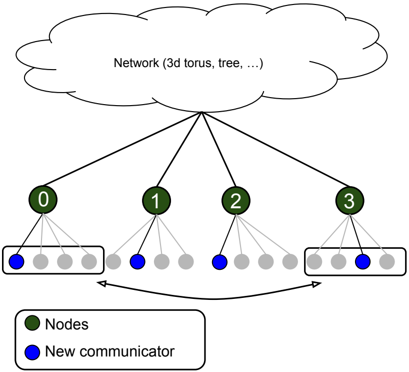
- Several issues raised!
- Scalability of TreeMatch
- How to deal with process mapping (user, core numbering)
  - Intel Xeon 5550 : 0,2,4,6,1,3,5,7
  - Intel Xeon 5550 : 0,1,2,3,4,5,6,7 (!!)
  - AMD Interlagos : 0,1,2,3,4,5,6,7...,30,31
- Need to find a relevant compromise between processes affinities and load balancing
- What about load balancing time?

The next slides will present our load balancer relying on TreeMatch and libtopomap which performs a parallel and distributed communication-aware load balancing.

Strategy for Charm++ - Network Placement

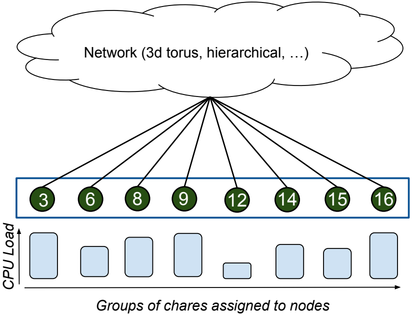
First step : minimize communication cost on network

- libtopomap reorders processes from a communicator
- How to use it to reorder groups of processes (or chares) ? Example : groups of chares on nodes
  - Charm++ uses MPI : full access to the MPI API
  - New MPI communicator with MPI_Comm_split



TreeMatch load balancer

- 1^{st} step : Remap groups of chares on nodes according to the communication on the network
  - libtopomap (example : part of 3d Torus)
- 2^{nd} step : Reorder chares inside each node (distributed)
  - Apply TreeMatch on the NUMA topology and the chares communication pattern
  - Bind chares according to their load (leveling on less loaded chares)
  - Each node carries out its own placement in parallel



Strategy for Charm++ - Intra-node placement

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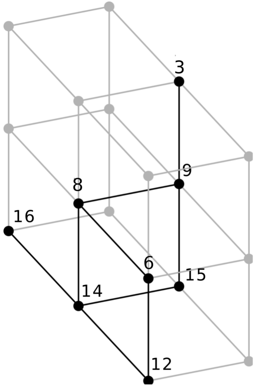

Figure: Part of a 3d Torus attributed by the resource manager

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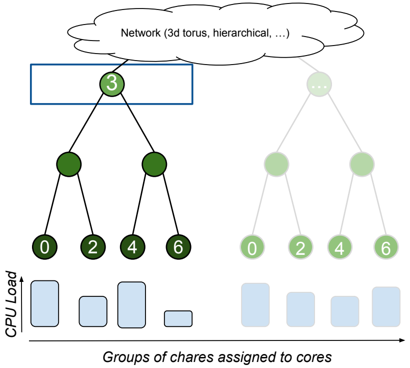

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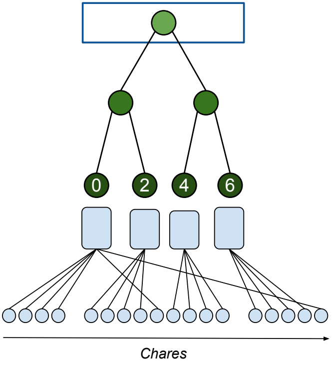

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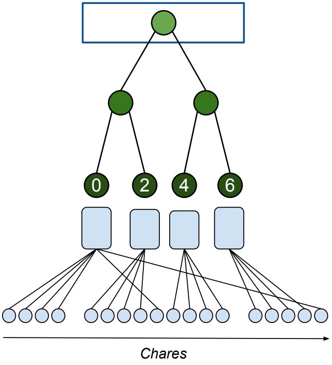

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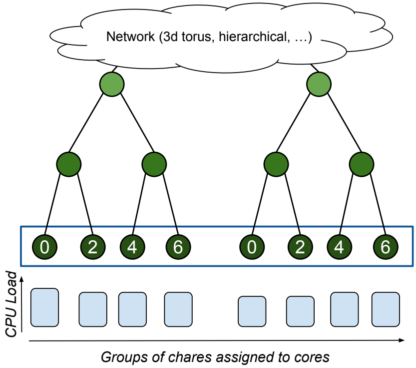
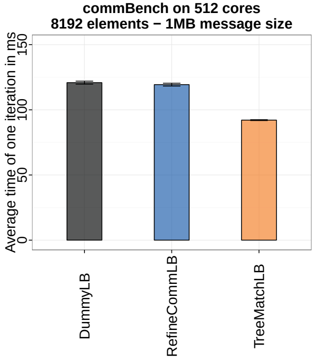


Results

commBench

- Benchmark designed to simulate irregular communications
- Experiments on 16 nodes with 32 cores on each (AMD Interlagos 6276) - Blue Waters Cluster)
- 1 MB messages - 100 iterations - 2 distant receivers for each chare



Results

commBench

- 1 MB messages - 100 iterations - 2 distant receivers for each chare
- TreeMatch applied on a chares communication matrix

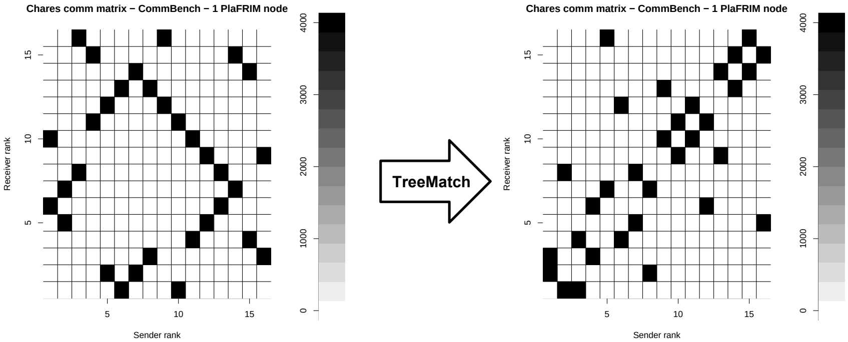
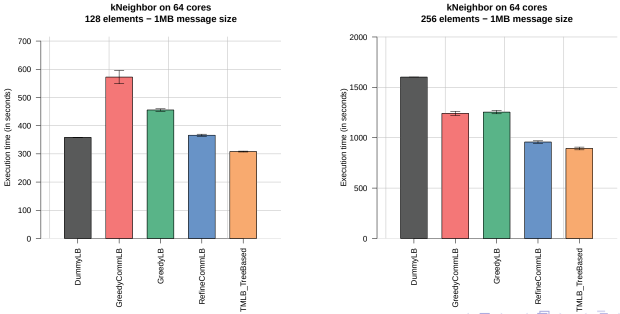


Figure: $\sigma(i) = 0, 8, 4, 5, 12, 1, 9, 6, 14, 2, 3, 13, 7, 10, 11, 15$

kNeighbor

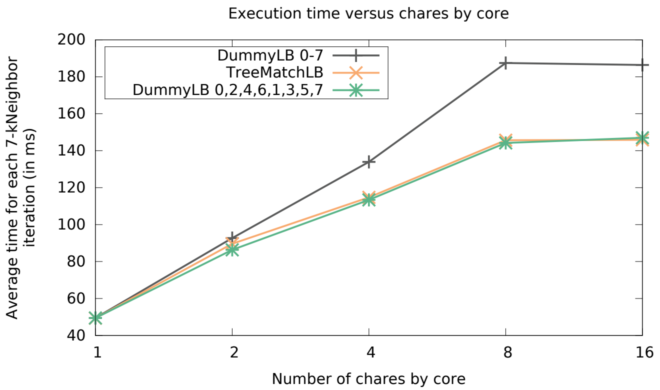
- Benchmarks application designed to simulate regular intensive communication between processes
- Experiments on 8 nodes with 8 cores on each (Intel Xeon 5550) - PlaFRIM Cluster
- Particularly compared to RefineCommLB
  - Takes into account load and communication
  - Minimizes migrations



Results

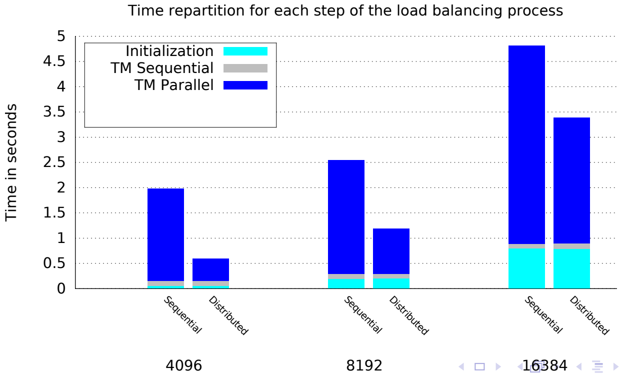
kNeighbor

- Experiments on 16 nodes with 8 cores on each (Intel Xeon 5550) - PlaFRIM Cluster
- 1 MB messages - 100 iterations - 7-Neighbor



What about the load balancing time?

- Comparison between the sequential and the distributed versions of TreeMatchLB
- The master node distributes the data to each node which will compute its own chares placement. This data distribution can be done in parallel (around 20% of improvments)



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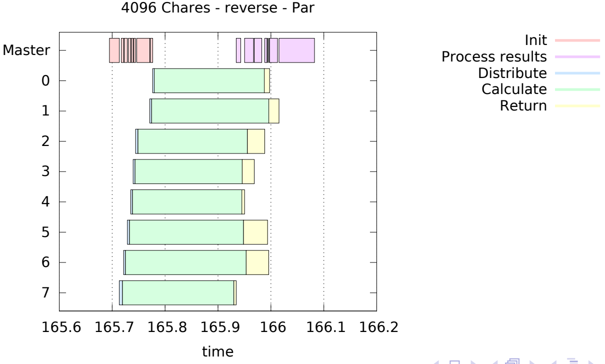

What about the load balancing time?

- Linear trajectory while the number of chares is doubled
- TreeMatchLB is slower than the other Greedy strategies
- RefineCommLB which provides some good results for communication-bound applications is not scalable (fails from 8192 chares)

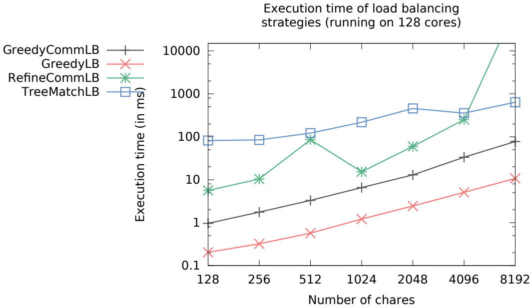

Figure: Load balancing time of the different strategies vs. number of chares for the KNeighbor application.

Future work and Conclusion

The end

- Topology is not flat!
- Processes affinities are not homogeneous
- Take into account these information to map chares give us improvement
- Algorithm adapted to large problems (Distributed)
- Published at IEEE Cluter 2013

Future work

- Find a better way to gather the topology (Hwloc?)
- Improve network part (BGQ routing ?)
- Perform more large scale experiments
- Evaluate our solution on other applications (CFD ?)

Thanks for your attention !
Any questions?