Kaapi / Charm++ preliminary comparison

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22-24 June 2010, Bordeaux

Outline

Objective: efficiency

- 90% of efficiency on 10000 cores $\equiv$ 1000 cores not used
- strong scalability (fixed problem size)

Comparison of middlewares for exascale architecture

- Overhead of parallel programming API
  - overhead with respect to the execution time of sequential program
- Scheduling
  - quality of scheduling algorithm
- Fault tolerance
  - cost of fault tolerance protocol (coordinated checkpoint/rollback)

Cost of developping parallel application

- Parallel programming complexity
- Add fault tolerance to application
- Other criteria (smallest timestep, memory) for futur comparisons

Overview

Charm++

- Library/Compiler (C, C++, Fortran, ...)
- Low level interface: Object based (Chares), message driven
- High level interface: Structured dagger, Charisma, ...
- Production tool

Kaapi

- C++ library, template based, Fortran interface
- High level interface: Data flow graph (Athapascan)
  - At runtime based on active messages + threads + scheduling algorithms ...
- Research software

Which comparison ?

Key points

- Programming model
  - Preliminary work: skew due to Charm++/Low level - Kaapi/High level
  - Futur work: Charisma versus Kaapi
- Performance of execution
  - Overhead with respect to execution time of a sequential program
  - Multi-core
  - Cluster and grid
- Fault Tolerance capability
  - Checkpoint / Restart protocols $\Rightarrow$ experimental costs

Methodology

- "Same benchmark" using both frameworks + sequential version
- Experimentation and Analysis

Programming models comparison

Charm++ (Low level interface: object based, message driven)

- Simple: Model and syntax close to the classic object model

++ Good documentation, many examples, stable

⇒ Easy to understand, easy to use

++ Several "production quality" applications

⇒ large scale experiments, including the FT protocol

++ Automatic dynamic load balancing

⇒ Required for irregular computation

+/– Non deterministic execution

⇒ Results can depend on the reception order

– Explicit communications, required some synchronizations

⇒ Source of bugs (race conditions)

– Non-transparent fault-tolerance

⇒ Requires source code modification

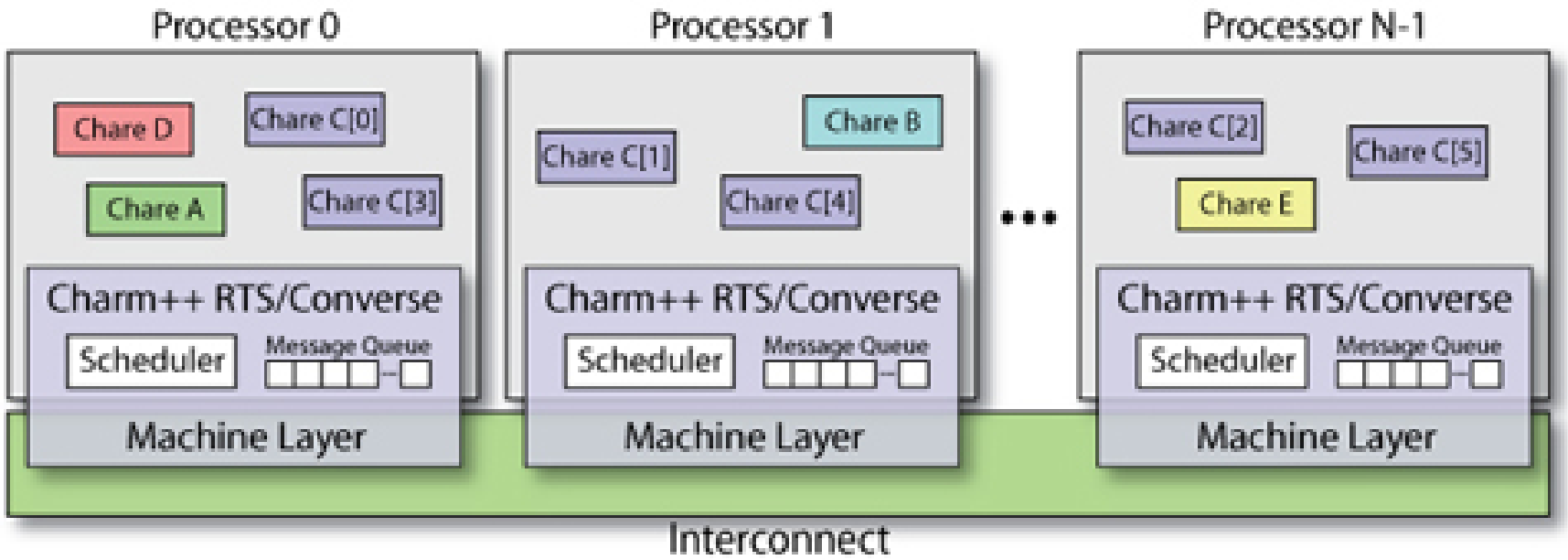
Programming models comparison

Kaapi (High level interface: macro data flow)

- • Complex/unusual programming model: macro data flow
- ++ Sequential semantic / Implicit communications and synchronizations
  - ⇒ Once the (sequential) program is written and run on 1 (or 2) processors, very few bugs (in the application source code)
- ++ Automatic dynamic load balancing
- ++ Transparent fault-tolerance
  - ⇒ No modification in the source code
- +/– Deterministic execution
  - ⇒ Always the same results
- – Simple documentation, research software
  - ⇒ Harder to understand and to start with ?
- – Not a language: C++ Template based
  - ⇒ Error messages at compilation are very ugly

Scheduling of Charm++ program

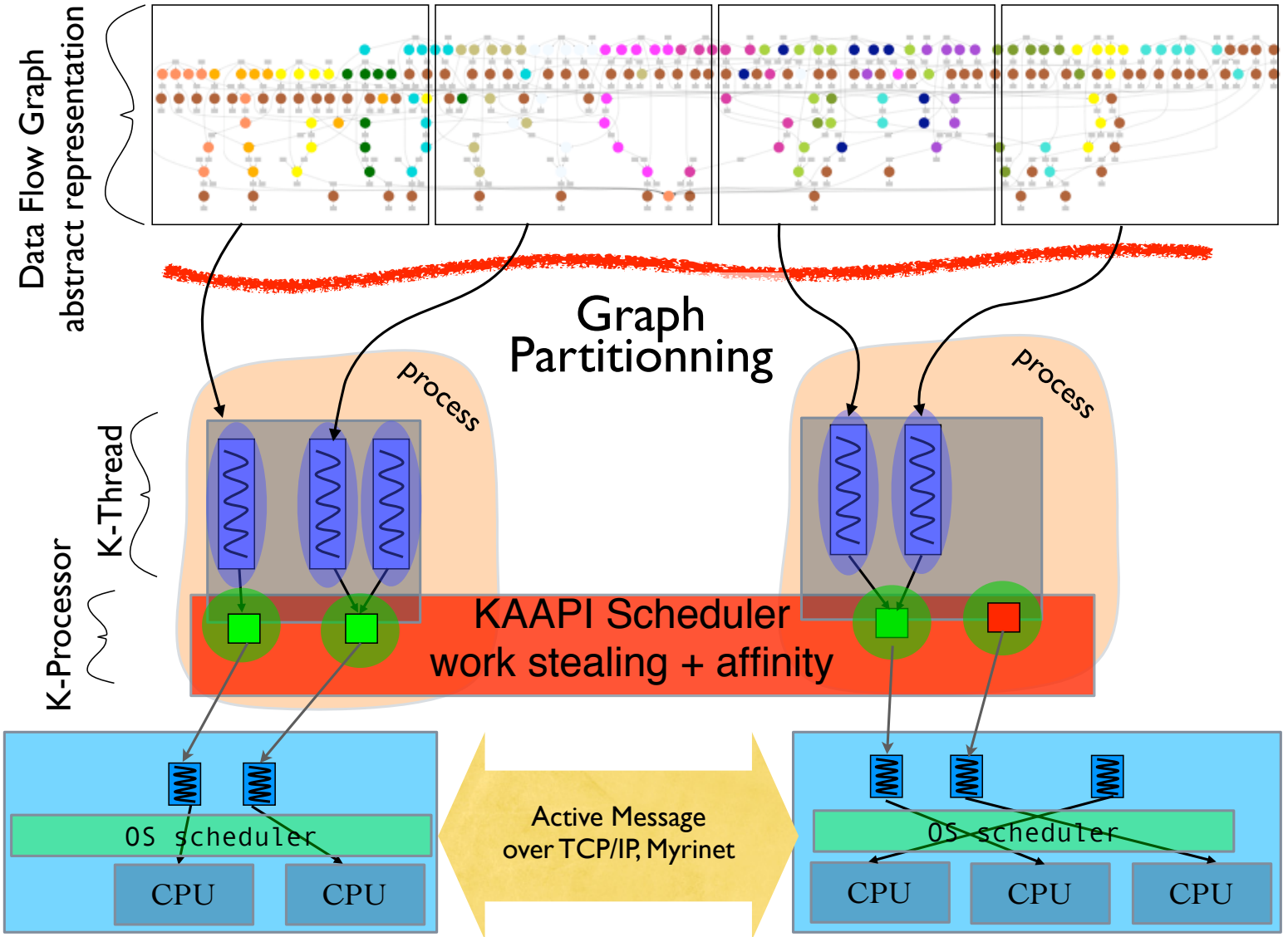
- A Charm++ program ⇒ a set of Chares



- Scheduler of message queue (priority, ...)
- Dynamic Load balancing algorithm
  - GreedyLB, MetisLB, RecBisectBfLB, NeighborLB, ...
  - Based on automatic instrumentation of the application by the runtime

Scheduling of Kaapi program

- A Kaapi program ⇒ a data flow graph



The benchmark: Poisson3D

Problem

- Solve Poisson equation on a 3D domain: $A \times X = B$
- Parallelized by domain decomposition
- Jacobi iterative method

$$x_i^{k+1} = \frac{1}{a_{ii}}(b_i - \sum_{j=1, j \neq i}^{N} a_{ij}\, x_j^k) \text{ for } i \text{ from 1 to N}$$

Benchmark data

- X, X': computation domain & temporary computation domain
- A: Jacobi stencil (sparse matrix)
- B: right-hand side
- S: solution (here the solution is known to check the result)

Source code

- Common code for "sequential" kernel: 671 lines
- Same data structure and allocation

	Lines of code (raw values)	
	Charm++	Kaapi
(De)serialization	105	125
Task encapsulation	-	160
Interface file (.ci)	50	-
Computation Kernel	140	50
FT/LB	50	-
Total	483	481

- Sequential program without decomposition: 50 lines
- Sequential program with decomposition: 112 lines

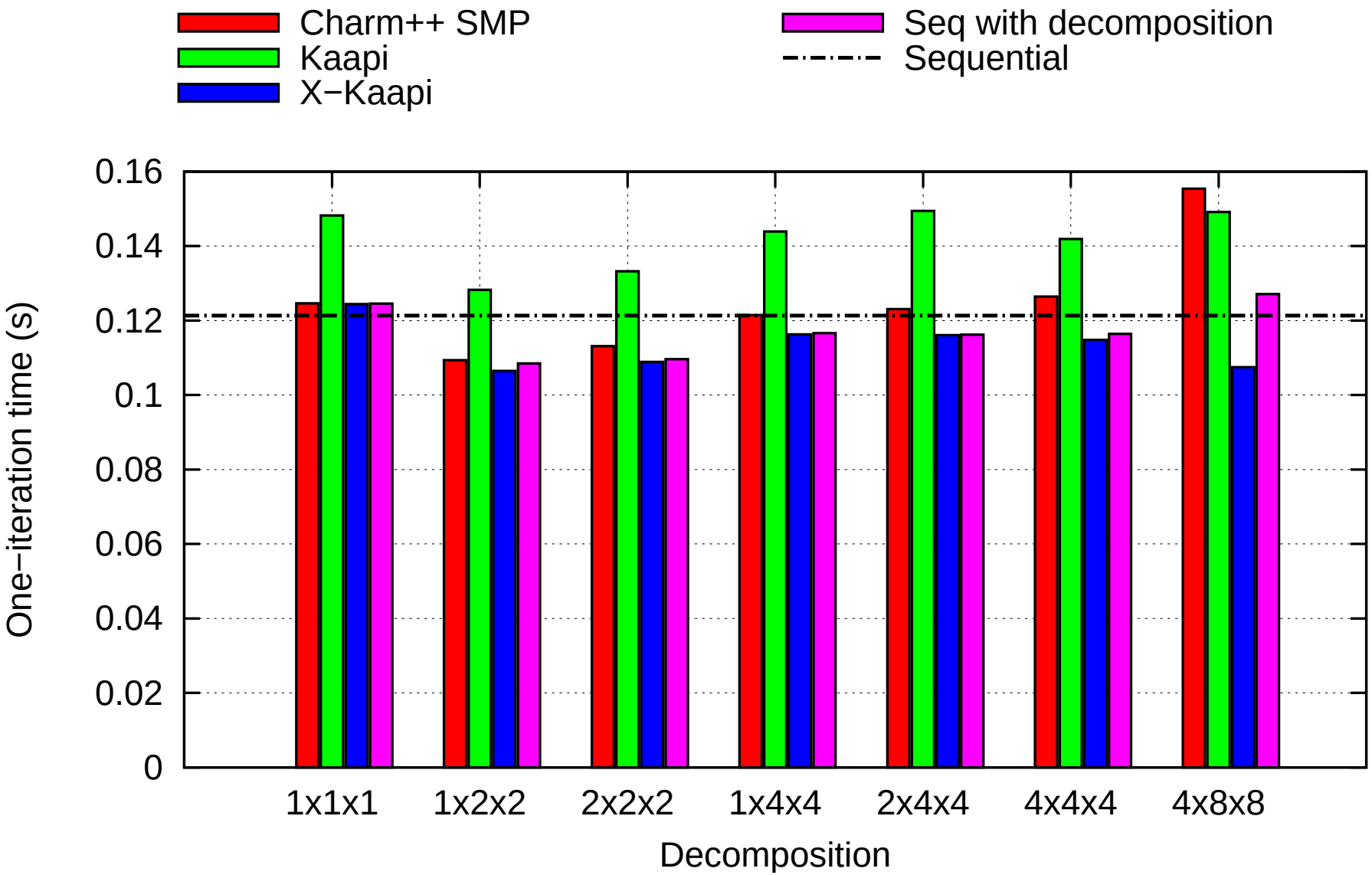
Experiments

- NUMA machine "idkoiff"
  - 8 Opteron 875 dual core, 2.2Ghz, 30GBytes. 8 memory banks
  - gcc/g++ 4.5. All programs compiled with -O4.
- Charm++ 6.2.0 (multicore-linux64.tar.gz)
  - +p 1: one process
  - +ppn <n> : number of PEs per process
  - +setcpuaffinity : useCPU affinity
  - +excludecore <coreid> : to exclude some core
- Kaapi 2.4 (http://kaapi.gforge.inria.fr)
  - Same mapping of threads onto core for Charm++/Kaapi
  - using util.thread.cpuset
- XKaapi 0.1beta
  - New C kernel for Kaapi. Currently only for multi-core machine.

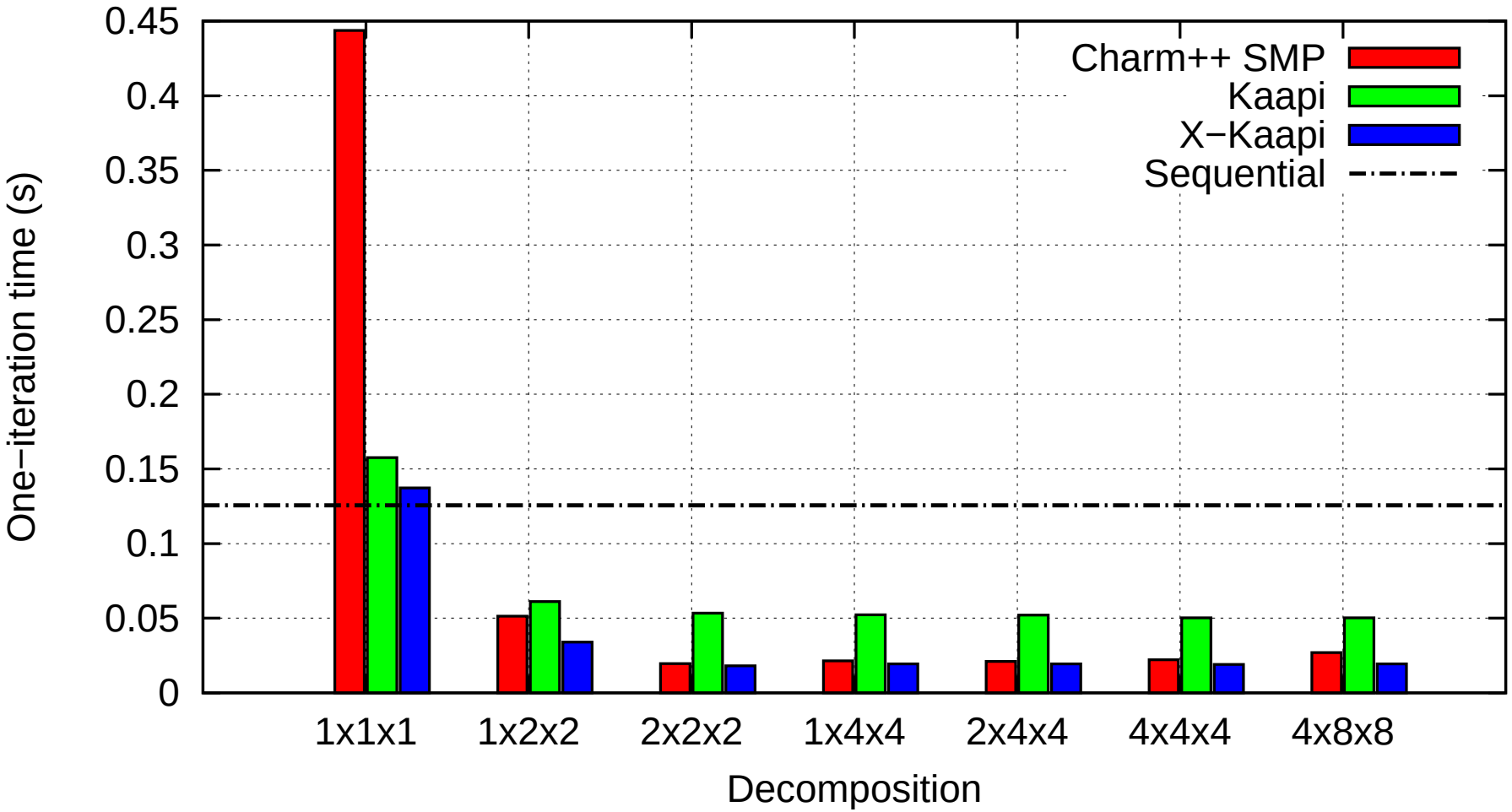
Timings

- Domain size: 4×10^6 doubles (100x200x200) split in $i \times j \times k$ subdomains
  - 1 run = average time of one iteration over 50 iterations.
  - Get the best average over 10 runs

Execution time: 1 core (among 16 cores)

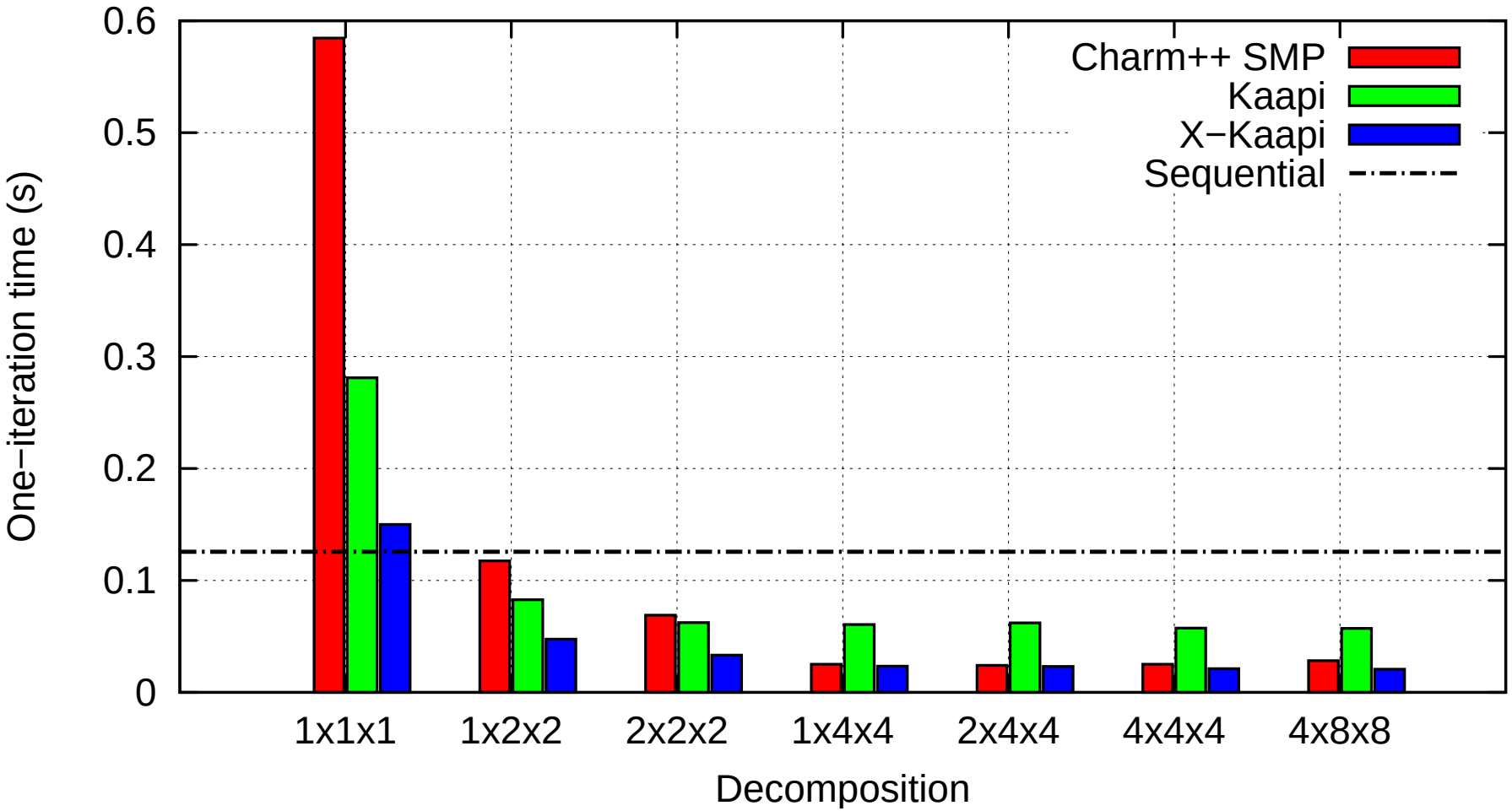


Execution time: 8 cores (among 16 cores)



- Few parallelism $\Rightarrow$ slowdown due to activity of the threads

Execution time: 16 cores (among 16 cores)



- Same slowdown

Distributed execution: experiments

Execution platform

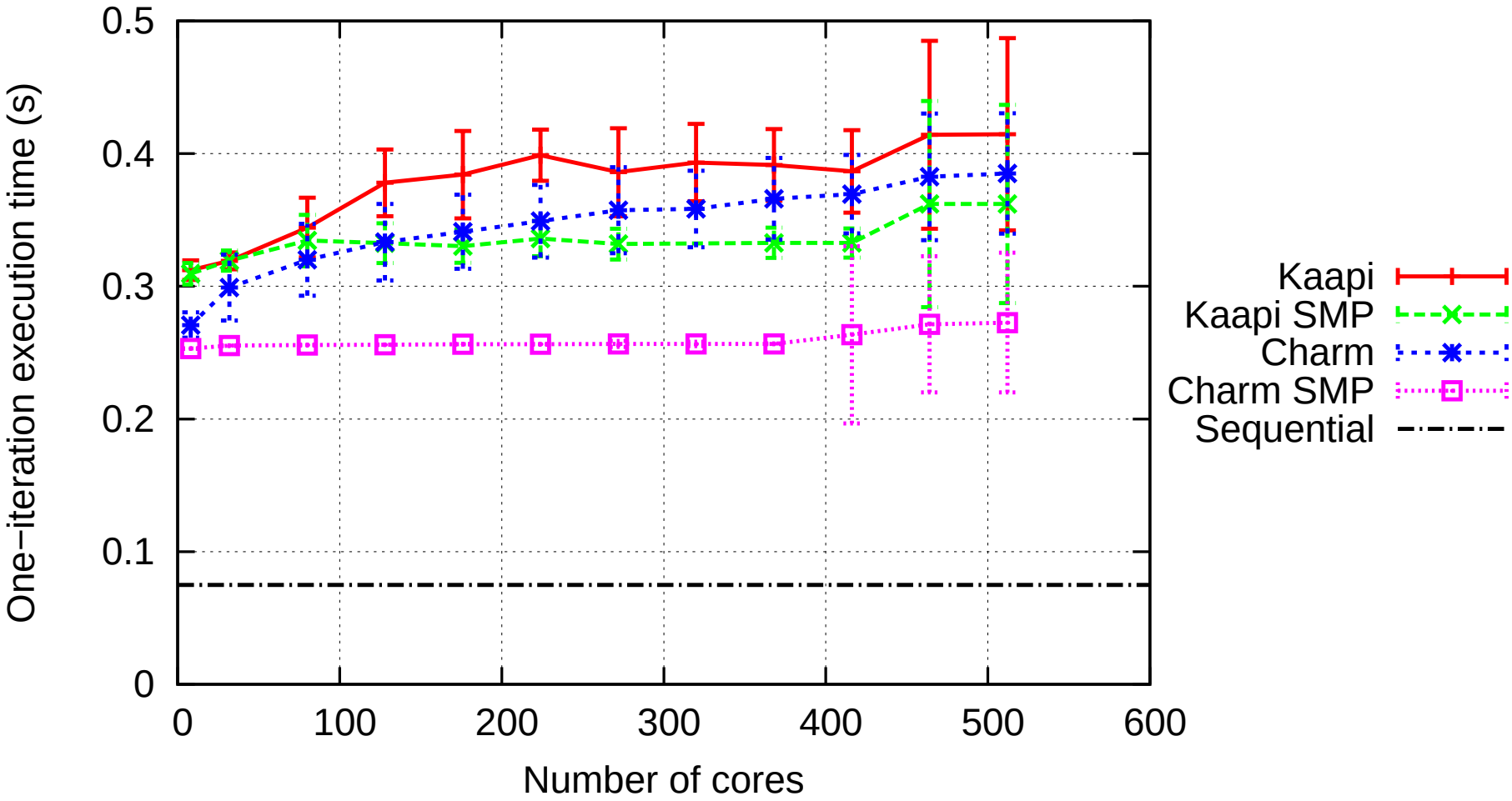
- Two experiments on Grid'5000 clusters:
  - Cluster Griffon at Nancy : 64 nodes with 8 cores, ie 512 cores
  - Cluster GDX at Orsay : 283 nodes with 2 cores, ie 566 cores
- Gigabit ethernet network

Same Poisson 3D benchmark

- Weak scalability: domain size = 4×10^6 doubles per core
- Two cases for Kaapi and Charm++:
  - 1 process per node (named SMP)
  - 1 process per core
- Charm++ 6.1.3 `net-linux-x86_64[-smp]`
- Kaapi (git version 03/01/2010, branch besseron/master)

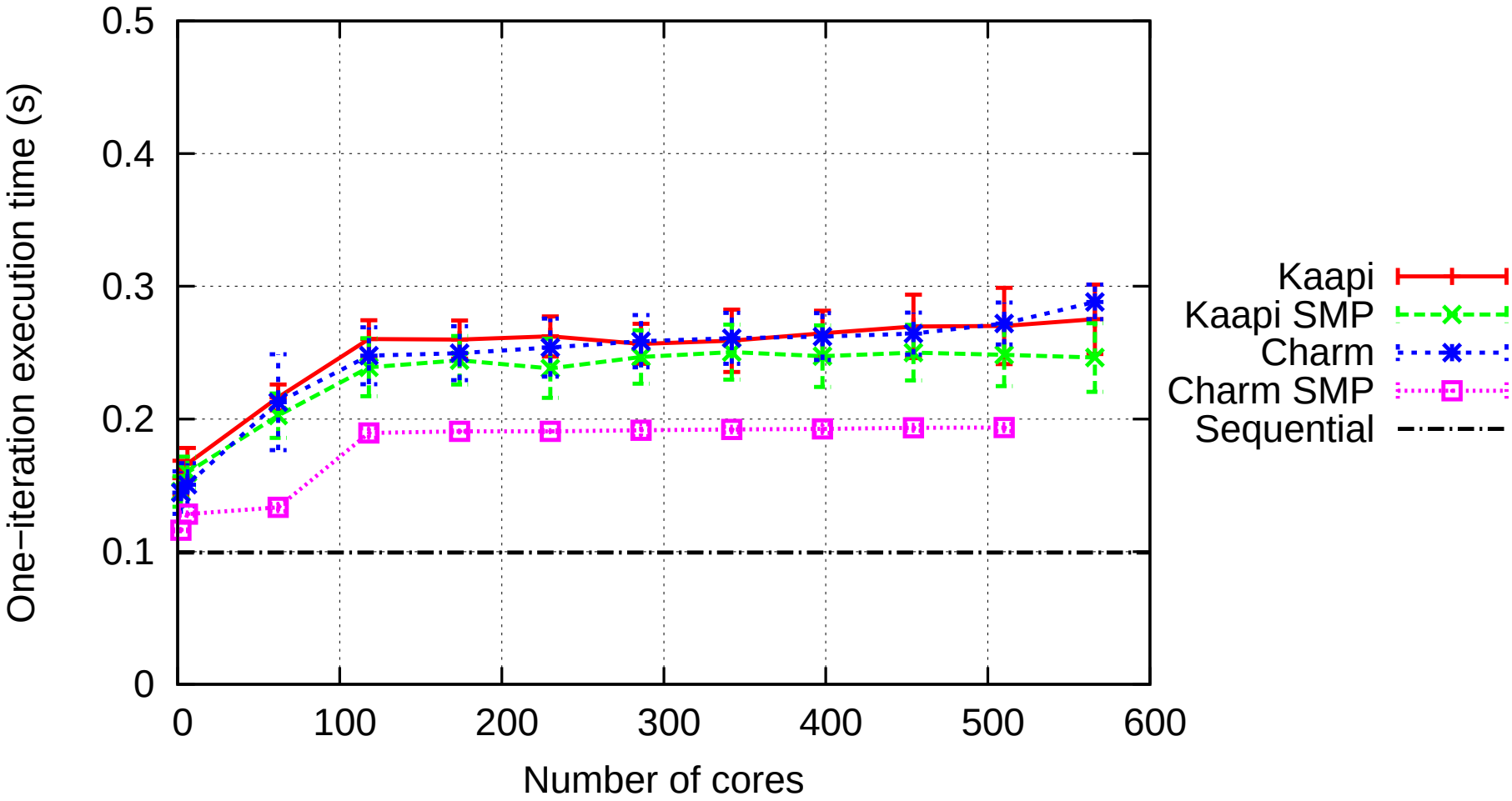
Distributed execution: cluster Griffon

Weak scalability: 4×10^6 doubles per core, 4 subdomains per core
Up to 512 cores (64 nodes of cluster Griffon of Nancy)



Distributed execution: cluster GDX

Weak scalability: 4×10^6 doubles per core, 4 subdomains per core
Up to 566 cores (283 nodes of cluster GDX of Orsay)



Checkpoint protocols in Charm++ and Kaapi

Charm++

Double blocking coordinated checkpoint on disk

- double disk $\equiv$ 2 copies: local and on a remote buddy processor
- $\Rightarrow$ tolerate only 1 failure in worst case
- global consistency requires an explicit barrier in the code

Kaapi

Blocking coordinated checkpoint on disk

- 1 copy per process on a Kaapi checkpoint server
- $\Rightarrow$ assume that checkpoint servers are stable,
- global consistency is ensured by the checkpoint protocol

Experimental conditions

3D Poisson Benchmark

- Cluster Griffon at Nancy : 80 nodes with 8 cores, ie 640 cores
- Domain size = 10^6 doubles per core
- Charm++ `net-linux-x86_64-syncft` (git version on 04/12/2010) with three different load-balancers: NullLB, GreedyLB, OrbLB
- Kaapi with FT support (git version on 04/12/2010, branch besseron/master)

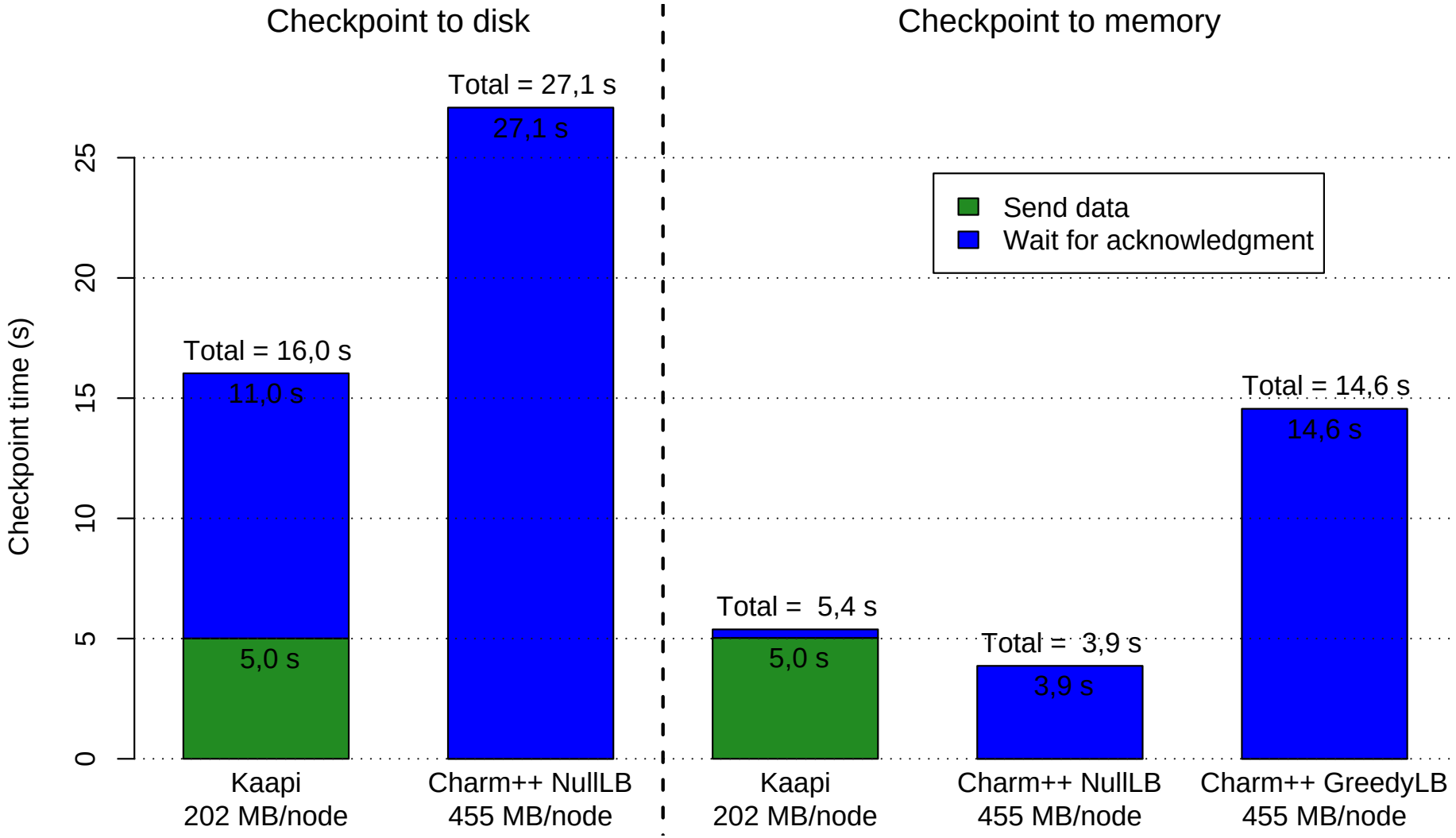
Remote buddy processors / Kaapi checkpoint servers

- Located on the next node (according to the node list)

Charm++ PEs *Kaapi processors*		*Remote buddy processor* *Checkpoint server*
griffon-01	$\longrightarrow$	griffon-02
$\vdots$		$\vdots$
griffon-79	$\longrightarrow$	griffon-80
griffon-80	$\longrightarrow$	griffon-01

Checkpoint time

80 nodes with 8 cores, ie 640 cores
Domain size = 10^6 doubles per core



Restart protocols in Charm++ and Kaapi

Scenario

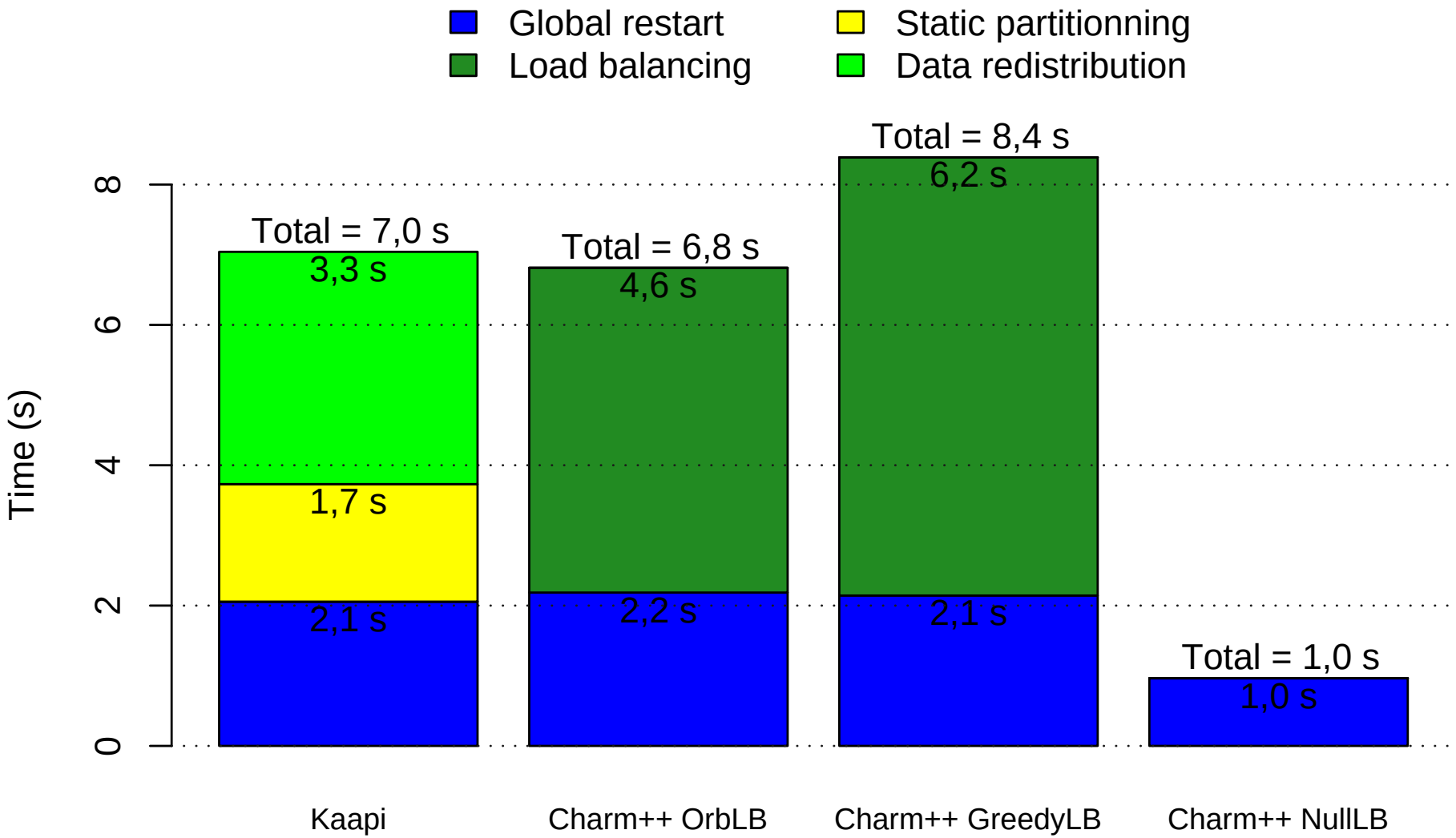
- Domain size = 10^6 doubles per core
- 1 failure $\Rightarrow$ restart on 79 nodes = 632 cores $\Rightarrow$ load balancing

Restart protocols

- Charm++ : Global restart + load balancing
  - Failed processes restart from their remote checkpoint
  - Alive processes restart from their local copy
- Kaapi : Global restart + rescheduling
  - All processes restart from their remote checkpoint
  - Rescheduling: static partitionning + data redistribution

Restart and load balancing time

1 failure ⇒ restart on 79 nodes with 8 cores, ie 632 cores



Conclusion of this preliminary work (1/2)

Two different levels

- Charm++: low level API
  - Charisma will be the next candidate
- Kaapi: high level API
  - Also recursive applications + work-stealing
  - Heterogeneous architecture (CPUs + GPUs)

Execution performance

- NUMA: new XKaapi implementation performs well
  - comparison with NUMA features [Pousa, Méhaut (INRIA), Gioachin, Mei, Kalé (UIUC)] for Charm++
- Distributed execution: SMP Charm++ execution is better

Conclusion of this preliminary work (2/2)

Fault tolerance

- Checkpoint is the most costly part of the protocols
  - Charm++ tolerates only 1 failure in worst case without stable servers
  - Kaapi tolerates the failure of one cluster but required "stable servers"

$\Rightarrow$ Stable memory issues

- diskless checkpointing: k-duplication, erasure encoding, locality

- Restart
  - Global restart is simple, but lost work can be large

  $\Rightarrow$ Partial restart in Kaapi (based on the data flow graph)