Hybrid bulk synchronous parallelism library for clustered SMP architectures

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Hybrid Bulk Synchronous Parallelism Library for Clustered SMP Architectures

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Outline

- Introduction
- BSP model
- BSP++ library
- Hybrid programming support
- Experimental results
- Conclusion & future works

Introduction

- Today's machines are hierarchical

  Cluster, SMP, Multi-cores

- Hard to efficiently program

  low level programming model MPI, OpenMP

- Performance depends on

  Application: data size, comm/comp pattern

  Architecture: CPU, bandwidth, …

High level parallel programming tools

- High level parallel programming models
- High performance
- Easy to manipulate

BSP Model (Leslie G Valiant:1990)

- Three components:
  - Machine Model
  - Programming Model
  - Cost model

BSP Model (Leslie G Valiant:1990)

1- Machine Model

- Describes a parallel machine
  - Set of Processors
  - Point to point communication
  - Synchronization
- Experimental Parameters

  P: Number of processors

  r: CPU speed (FLOPS)

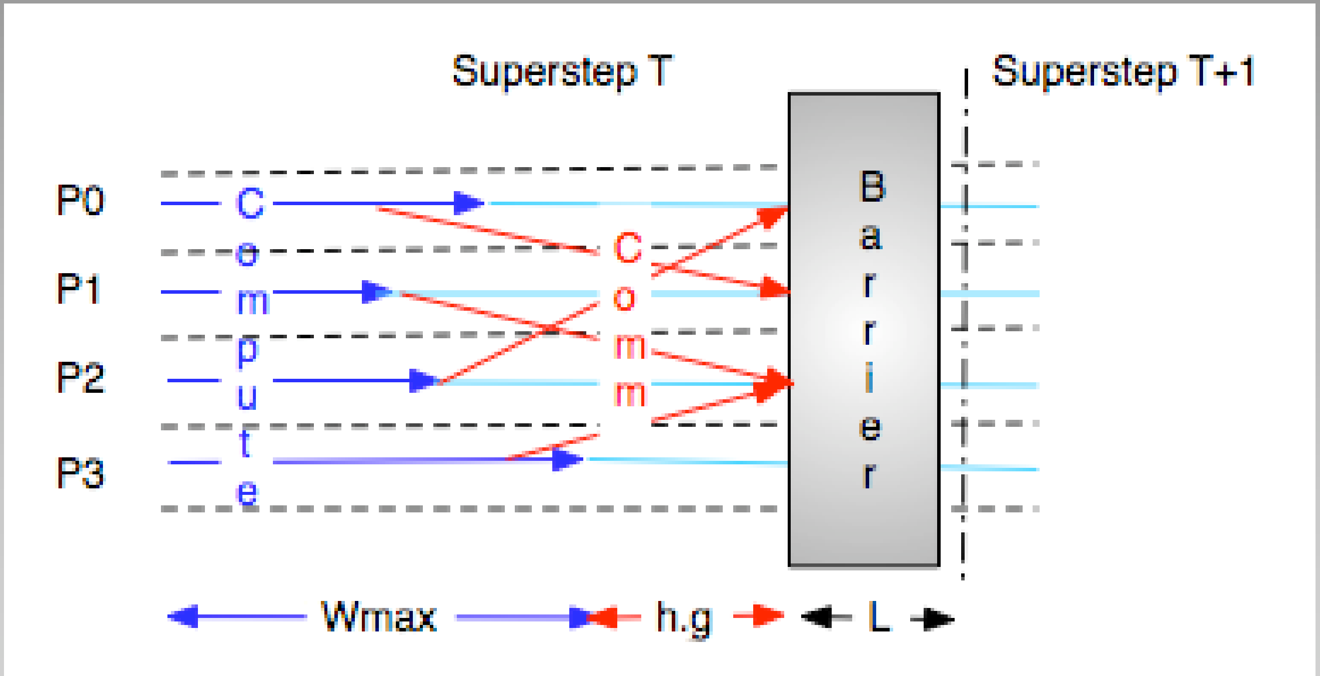
  g: Communication speed (sec/byte)

  L: Synchronization time (sec)

BSP Model (Leslie G Valiant:1990)

2- Programming Model

- Describes the structure as a sequence of steps



BSP Model (Leslie G Valiant:1990)

3- Cost Model

- Estimates the time

$T = \sum \delta_i$

$\delta = W\_max + \max h.g + L$

BSP++

- Object-oriented implementation of the BSML Library [gava:09] in C++
- Notion of Parallel vector
- Functional programming support

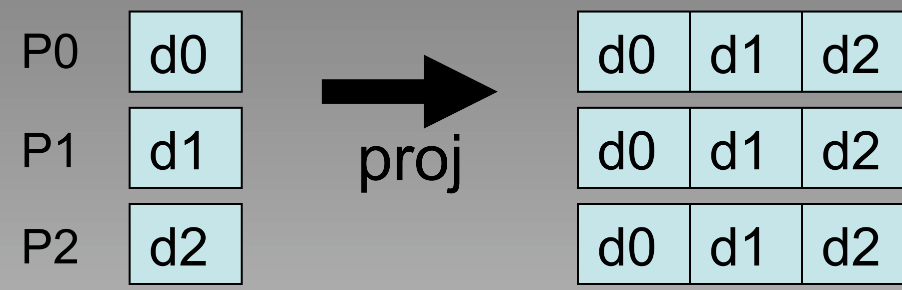
  Boost.Phoenix and C++ lambda-function

BSP++ API

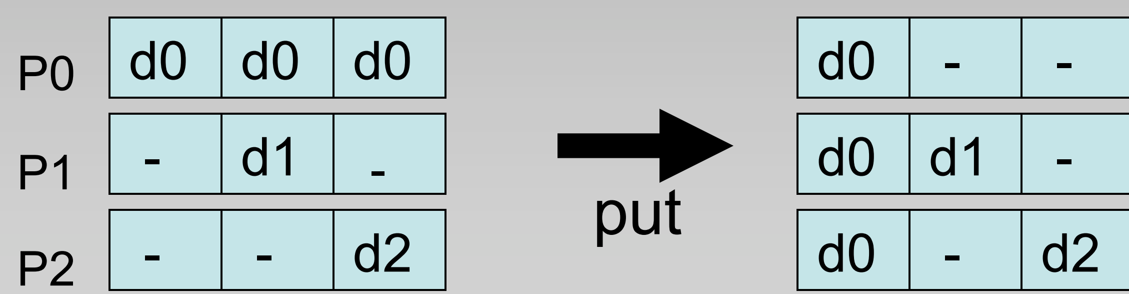
- par<T> : Concept of parallel vector, many constructors
- sync (): Explicit synchronization, MPI or OpenMP barrier
- proj : result_of::proj<T> proj (par<T> &)
- put: result_of:: put<function<T(int)> > put (par<function<T(int)> >&)

BSP++ API

- proj : MPI_allgather and asynchronous OpenMP copy
  + sync ().

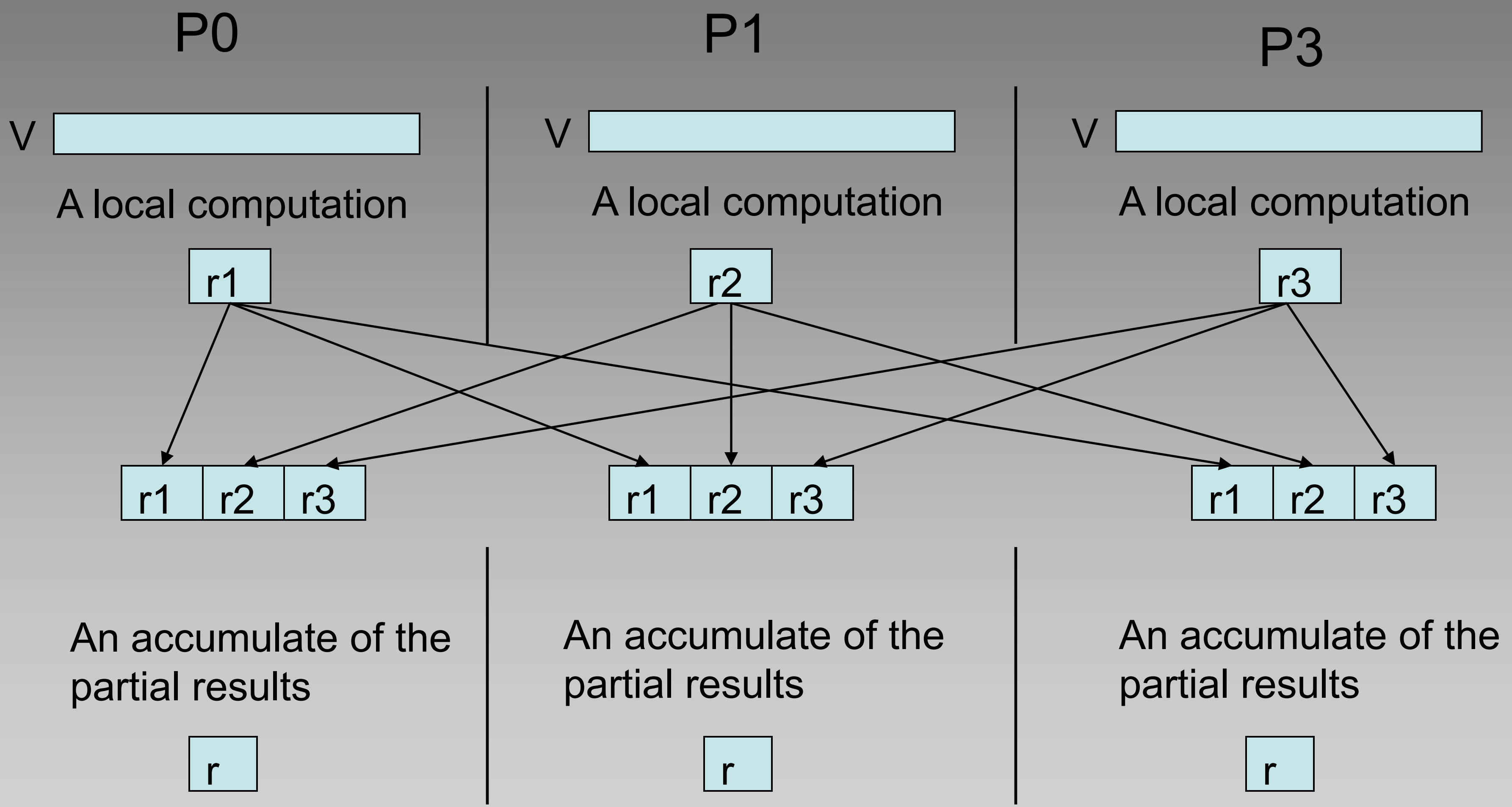


- put: Matrix P: Pij = value of Proc i to send to Proc j
  MPI_alltoall and asynchronous OpenMP copy.
  + sync ().



Example

Inner product program



Example

BSP++ Inner product

```
# include<bsppp/bsppp.hpp>
    int main (int argc, char** argv)
    {
      BSP_SECTION(argc, argv)
      {
         par<vector<double> >   v;
         par< double >          r;

         // step 1 :  perform local inner-product
         *r=std::inner_product( v->begin(),  v->end(), v->begin(), 0.);

         // the global exchange
         result_of::proj<double> exch = proj (r);

         // step 2 :    accumulate the partial results
         *r= std::accumulate (exch.begin(), exch.end() );

         sync ();
       }
     }
```

Hybrid programming support

Objection of BSP is the cost of L

(dominant for large parallel machines)

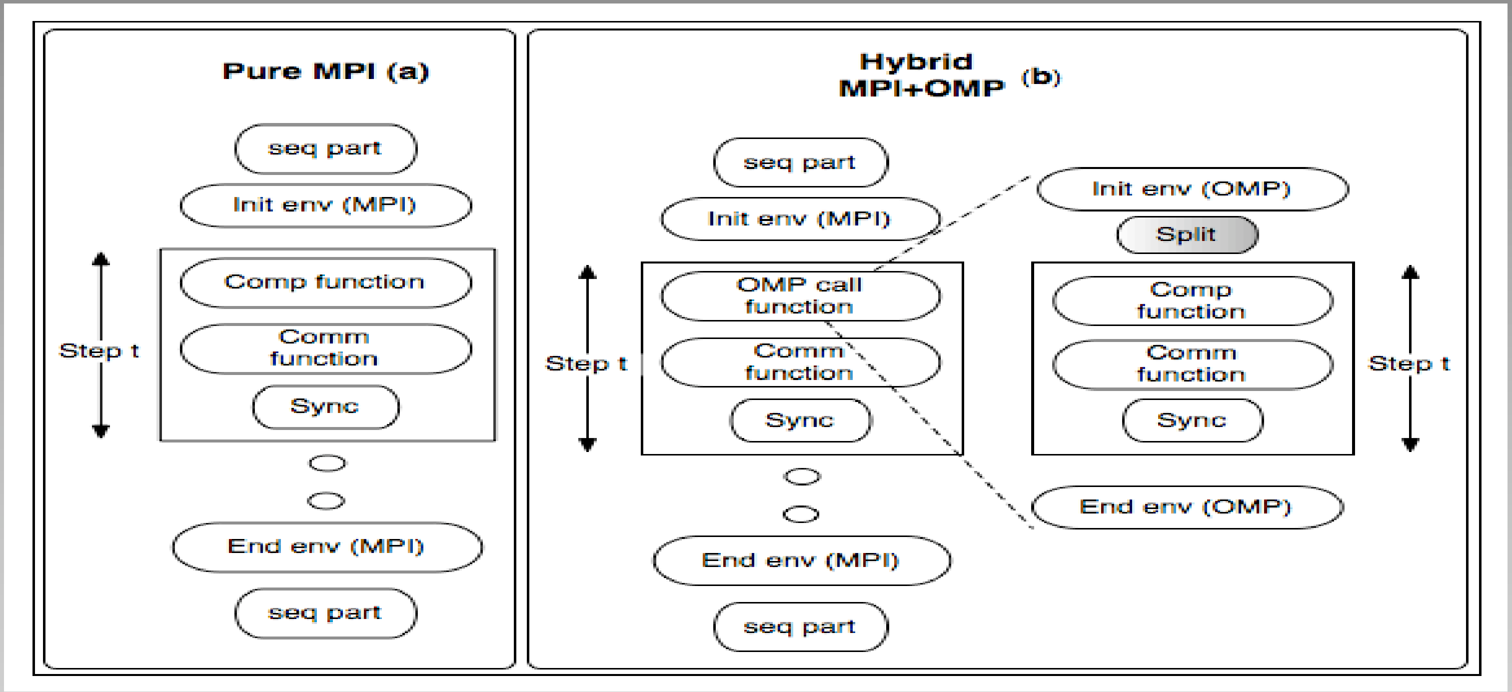
Table. Variation of L (in ms) and g (in second per M b) on A 4x4 cores machine (AMD machine)

	MPI			OpenMP		
P	4	8	16	4	8	16
g	0.087	0.22	1.69	0.025	0.069	0.68
L	4.46	20.8	108.0	2.94	8.13	13.1

- Impact of OpenMP: synchronization is up to 8 times faster
- Turn the hybrid BSP machine into two BSP machines with different values of L and g

Hybrid BSP with BSP++

- Same code for both MPI and OpenMP
- Add a split function



δ = Wmax + h_mpi .g_mpi + h_omp .g_omp + L_mpi + L_omp

Hybrid BSP++ example

```
double omp_inner_prod (vector<double> const& in, int argc, char ** argv )
{
  double value;
  BSP_SECTION(argc, argv)
  {
    par<vector<double> > v= split (in);
    par<double>                          r;
    *r = std::inner_product(v->begin(), v->end(), v->begin(), 0.);
    result_of::proj exch = proj(r);
    value = std::accumulate (exch.begin(), exch.end());
  }
  return value;
}
```

```
BSP_SECTION(argc, argv)
{   par<vector<double> >     data;
    par<double>                result;
    *result= omp_inner_prod (*data, argc,argv);
    result_of::proj<double> exch= proj(result);
    *result= std::accumulate (exch.begin(), exch.end() );
}
```

Experimental results

- Platforms :

1- AMD machine:

* 2 GHz Quad processor quad cores (16 cores)
* 16 Gb of RAM (shared memory)
* gcc4.3, OpenMP 2.0 and OpenMPI 1.3

2- CLUSTER machine:

* Grid5000 platform; Bordeaux site
* 4 nodes, Bi-processor Bi-cores (2,6 GHz)
* gcc4.3, MPICH2.1.0.6 library

Experimental results

- Protocols :

1- BSP++ vs BSPlib:

* AMD machine
* EDUPACK benchmarks (Inprod, FFT, LU)

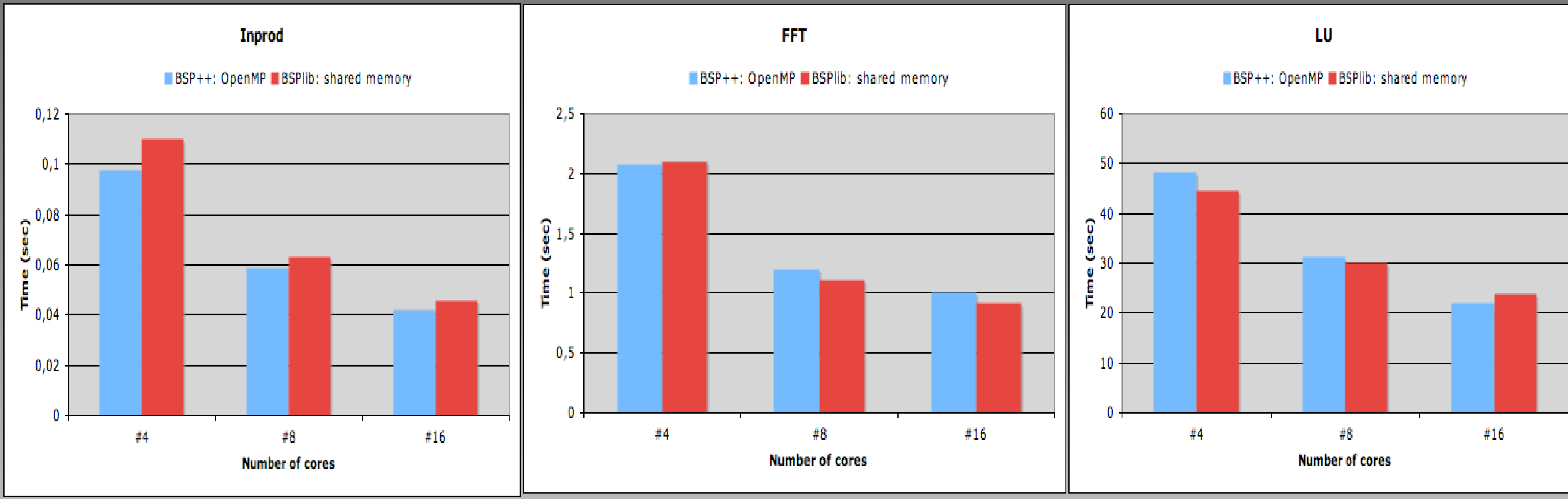
2- BSP++: MPI vs OpenMP:

* AMD machine
* Inprod, Matrix-vector Multiplication GMV, Matrix-matrix Multiplication GMM and Text Count function of the google MAP reduce Algorithm Benchmarks

3- BSP++: MPI vs Hybrid:

* Cluster machine
* Same benchmarks

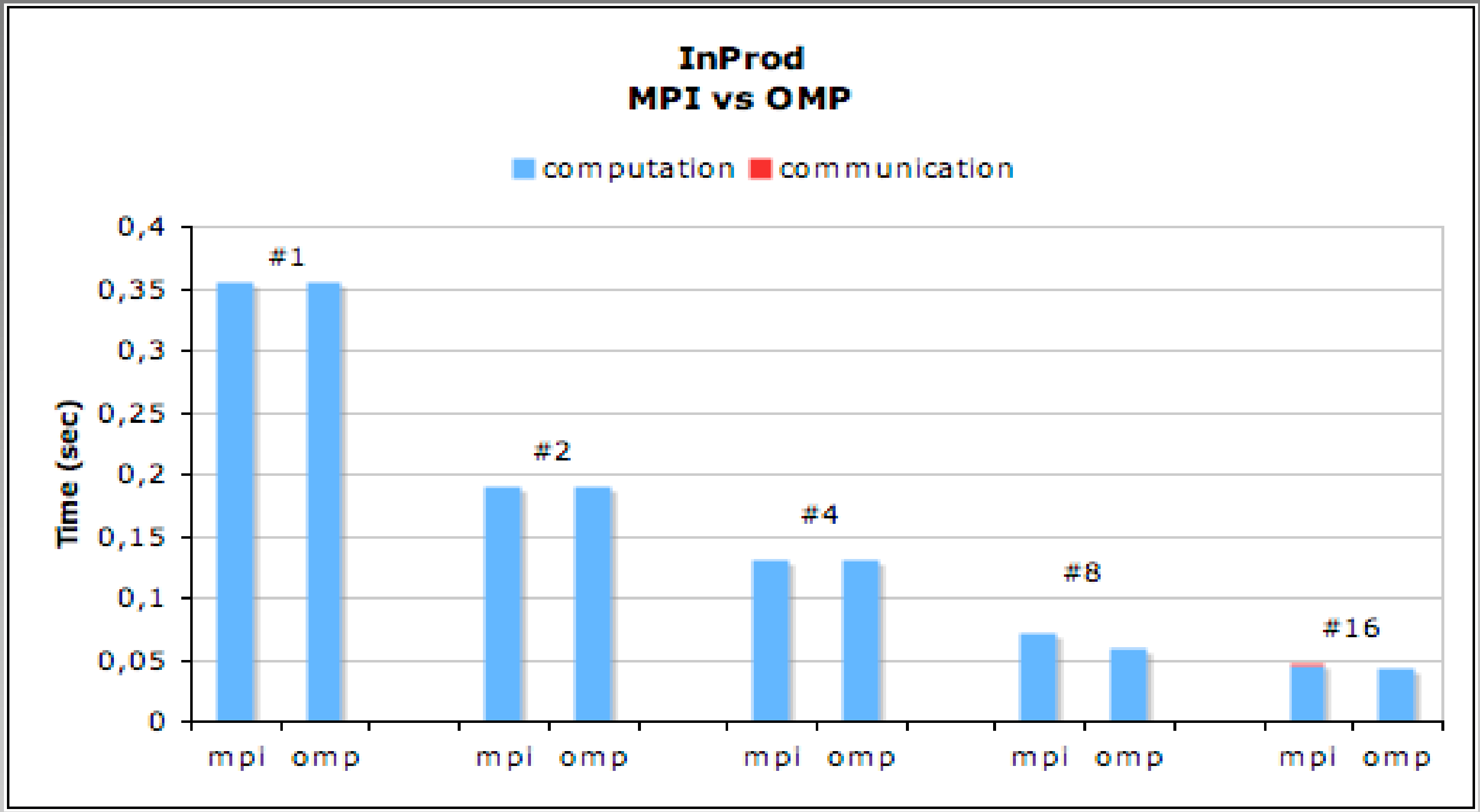
1- BSP++ vs BSPlib



Overall execution time for BSP++ on OPENMP and the BSPlib EDUPACK benchmarks on the AMD machine

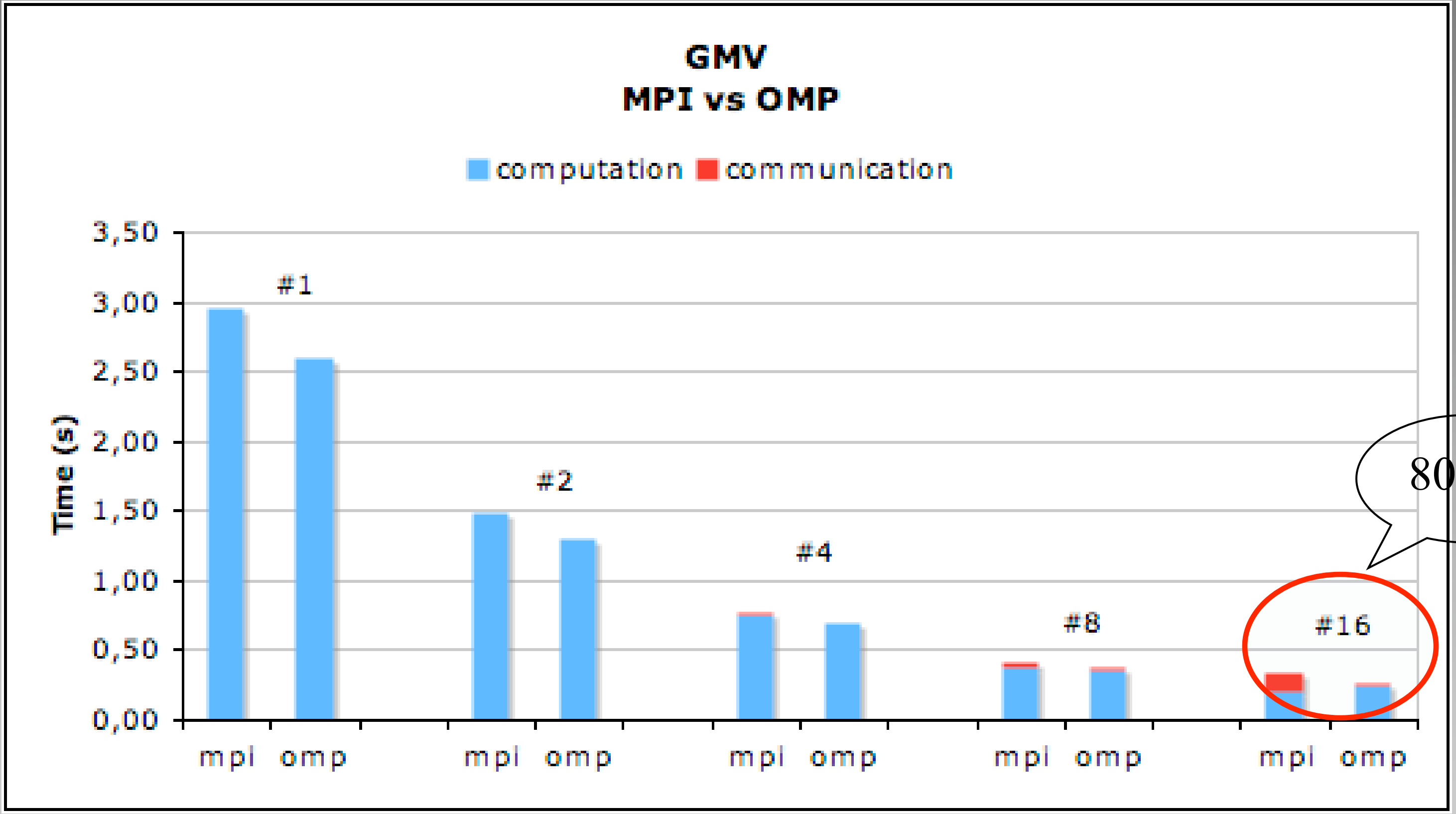
- Same performances
- No overhead of the generic template implementation

2- BSP++: MPI vs OpenMP



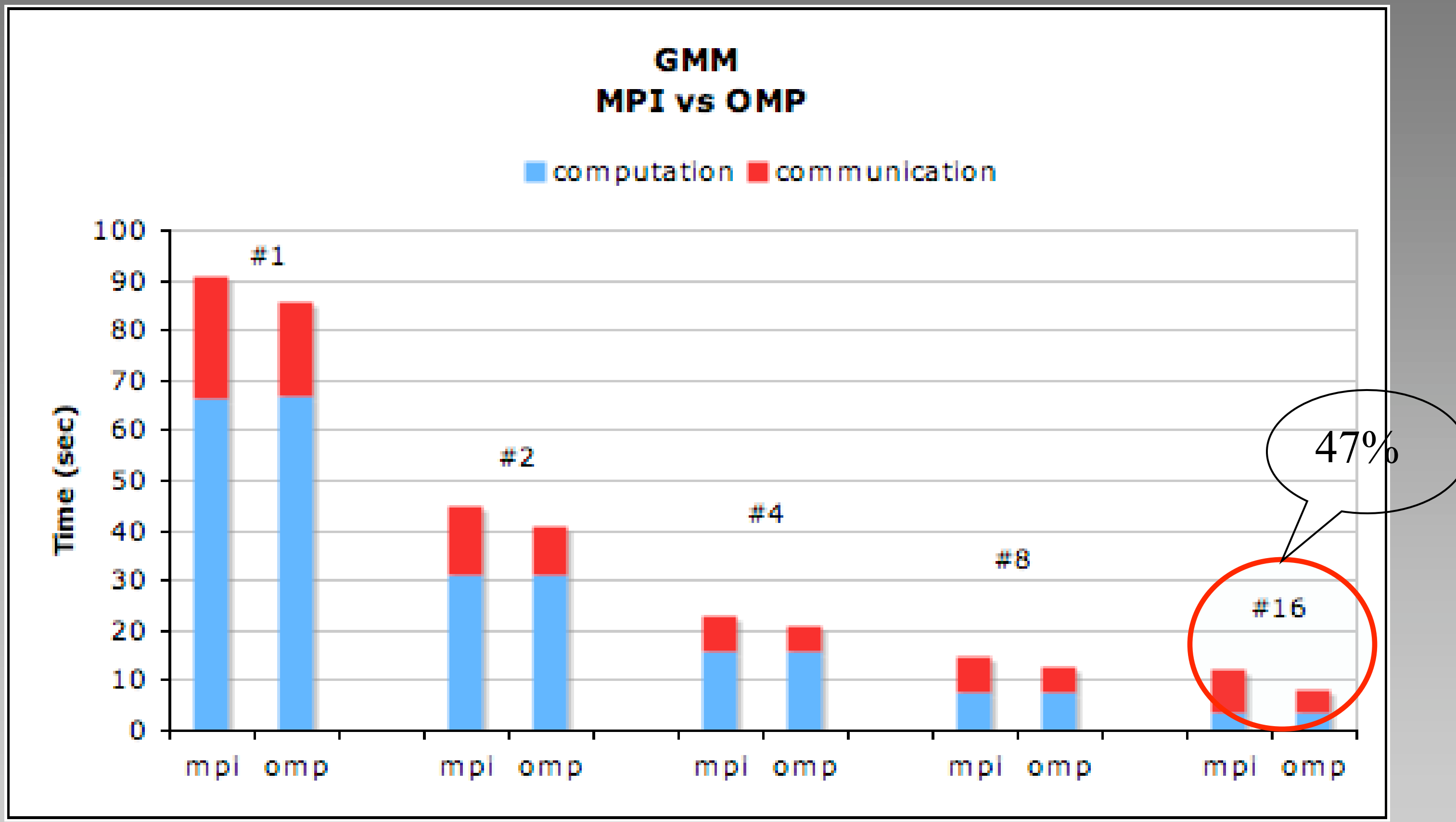
Execution time of the InProd benchmark on the AMD machine for 64 10^6 elements

2- BSP++: MPI vs OpenMP



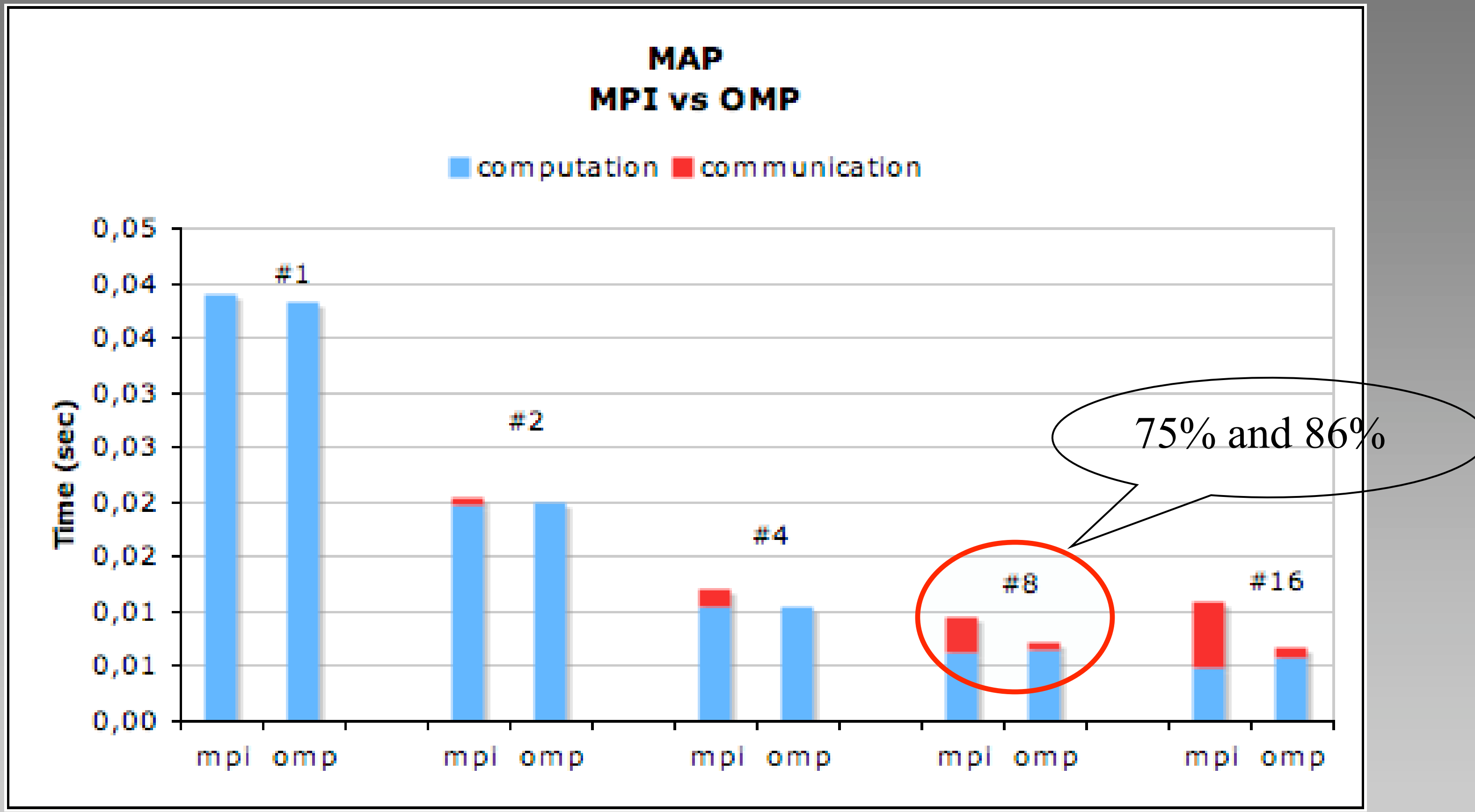
Execution time of the GMV benchmark on the AMD machine with a 8192 x 8192 matrix

2- BSP++: MPI vs OpenMP



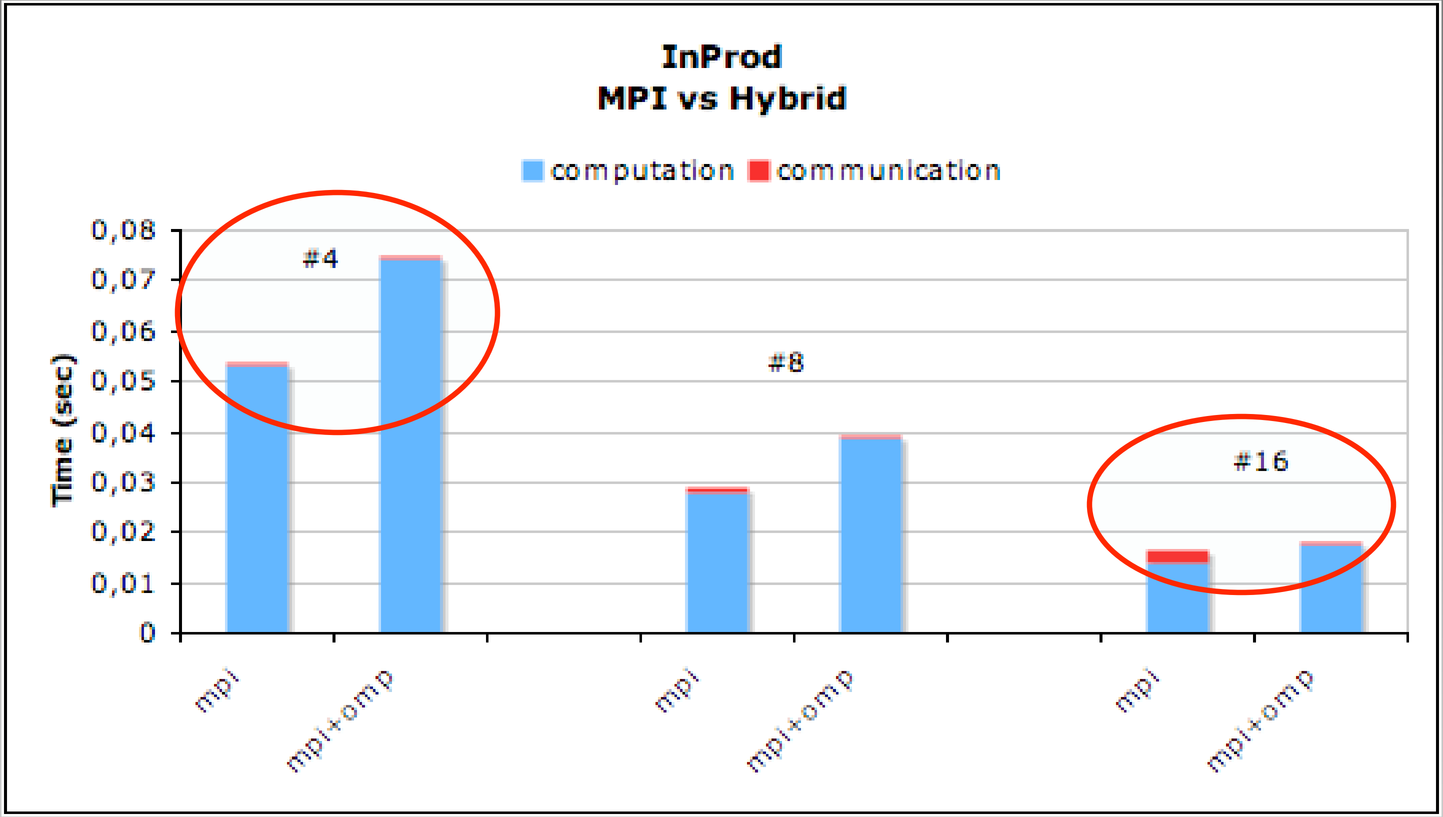
Execution time of the GMM benchmark on the AMD machine with 2048 x 2048 matrices

2- BSP++: MPI vs OpenMP



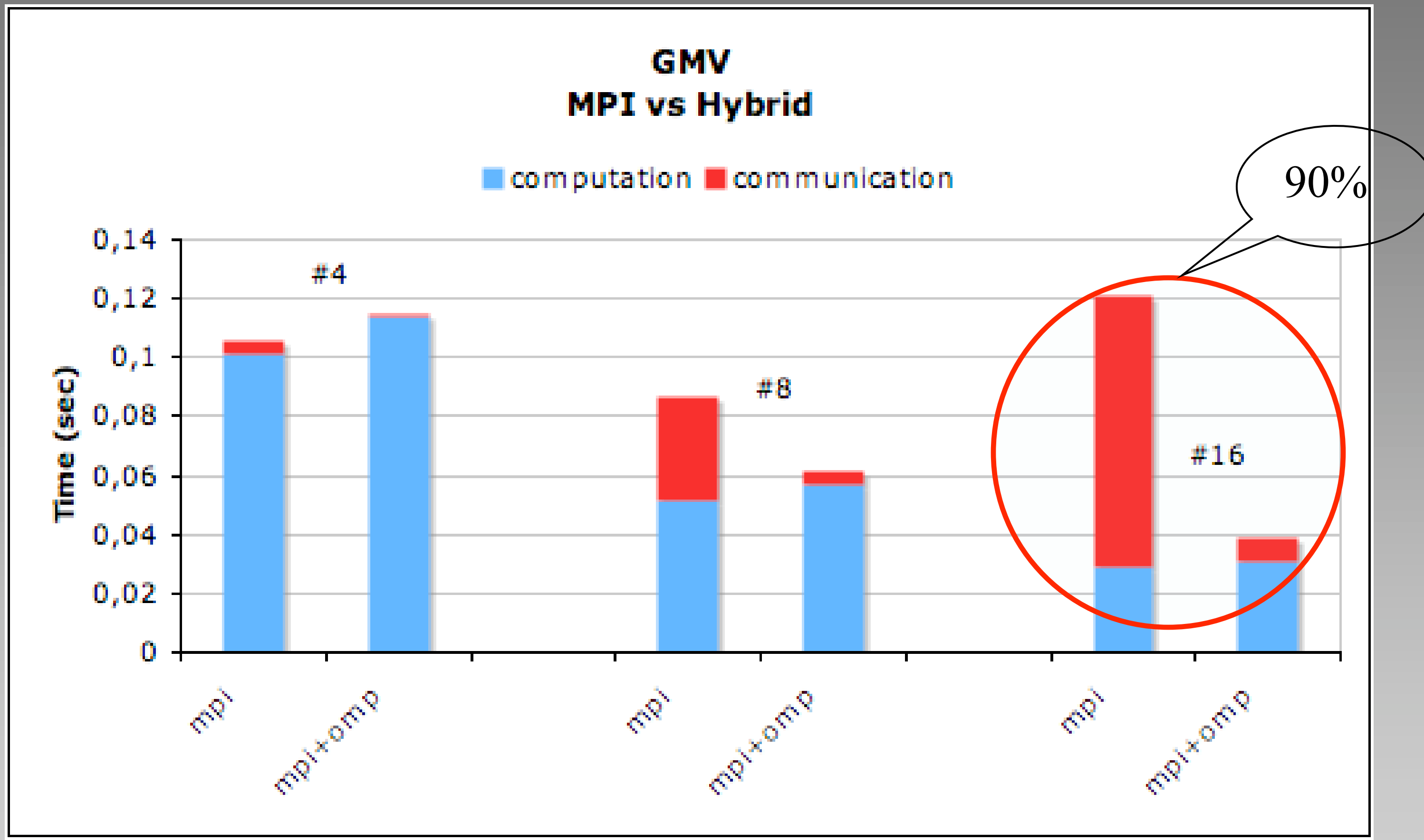
Execution time of the MAP benchmark on the AMD machine for 150000 words list

3- BSP++: MPI vs Hybrid



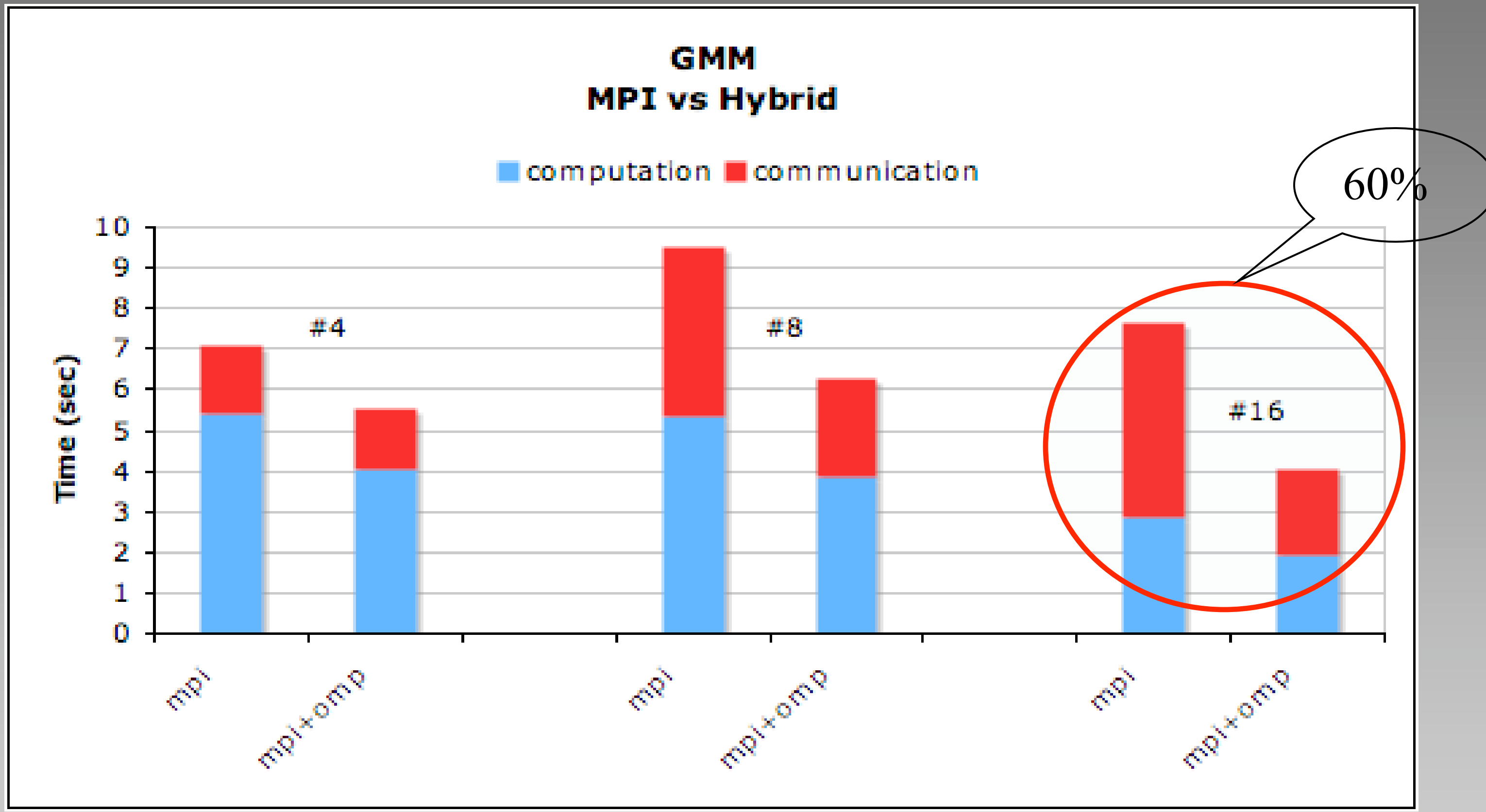
Execution time of the InProd benchmark on the Cluster machine for 64 10^6 elements

3- BSP++: MPI vs Hybrid



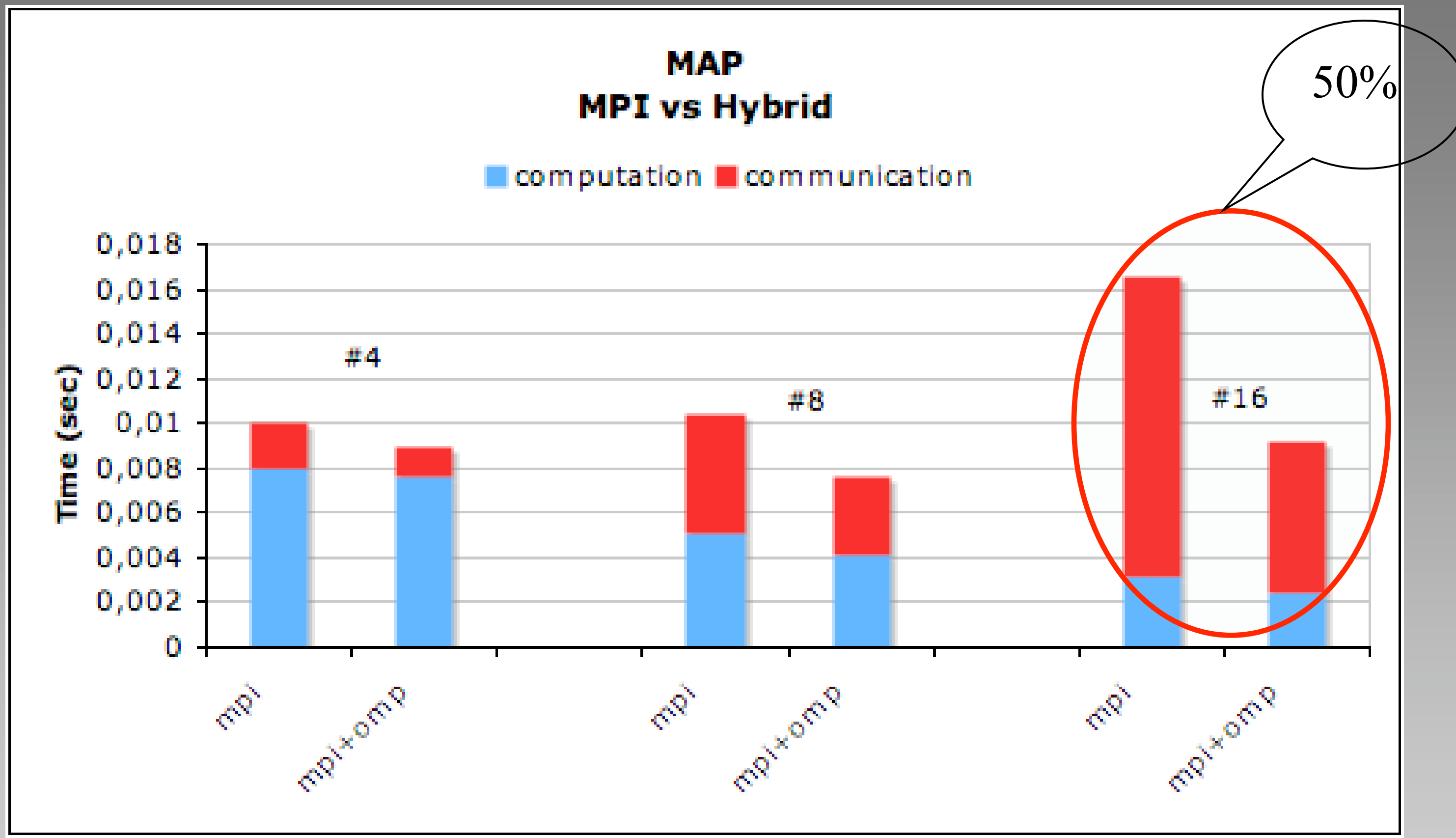
Execution time of the GMV benchmark on the Cluster machine with a 8192 x 8192 matrix

3- BSP++: MPI vs Hybrid



Execution time of the GMM benchmark on the Cluster machine with 2048 x 2048 matrices

3- BSP++: MPI vs Hybrid



Execution time of the MAP benchmark on the Cluster machine for 150000 words list

Conclusion

- MPI and OpenMP as a native targets
  - Both versions scale
  - No overhead of the C++ implementation
- Simplify the design of Hybrid MPI+OpenMP codes
  - Using the same code
- Support a large number of practical development idioms

Framework

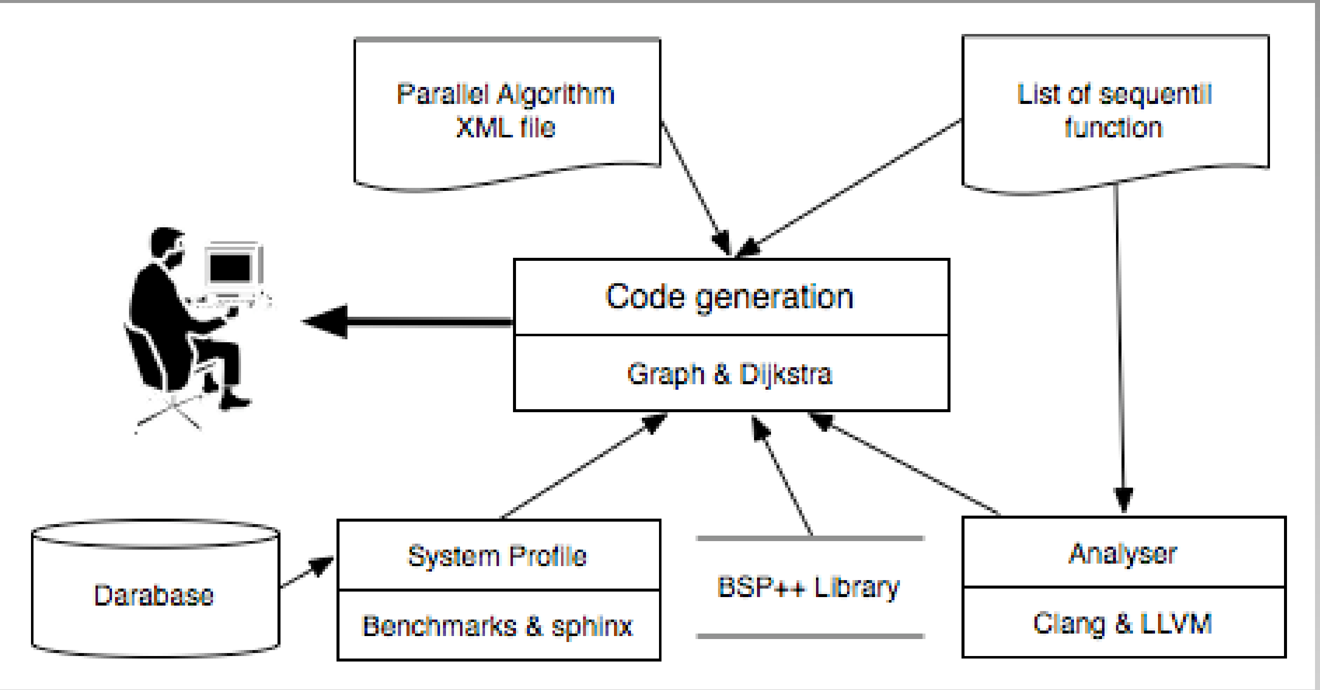
- Use the BSP cost model to estimate the execution time of each step

- Select the best configuration (number of MPI process and number of OpenMP) for each step

- Generate the corresponding code using the BSP++ library

Framework architecture

❖ Three modules : Analyzer, Searcher, Generator



Framework modules

❖ Analyzer: estimates the execution time by predicting the values of Tcomp and Tcomm

- Computing time : count the number of cycles for the sequential function

  Clang: generates the byte-code for the user function

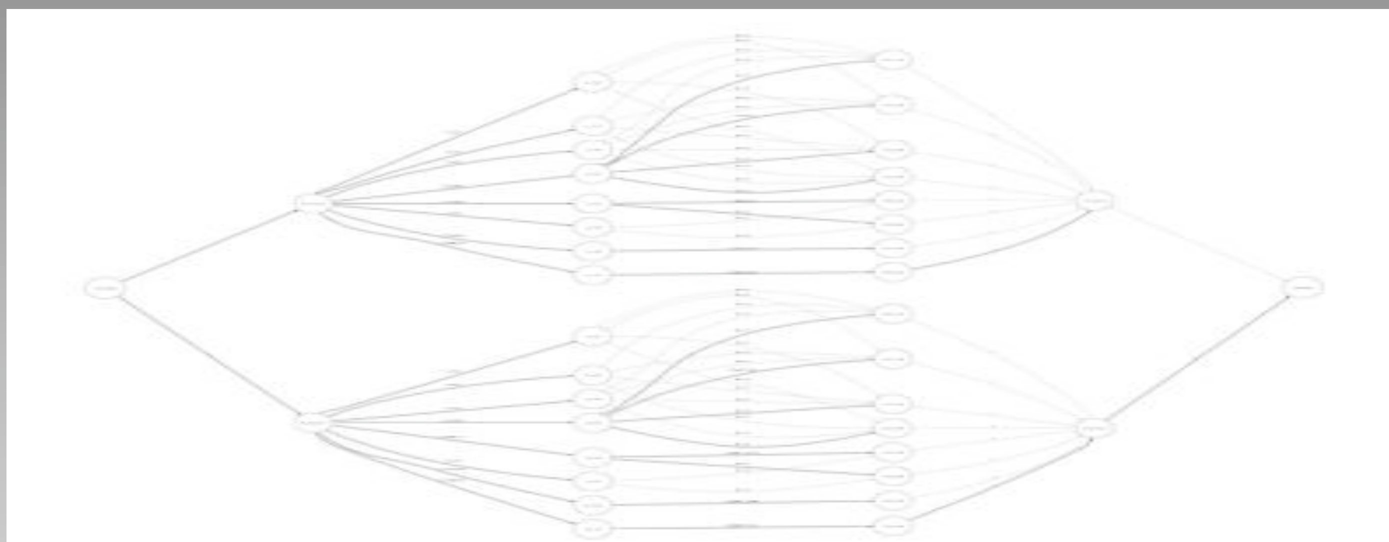
  LLVM: New pass in the compiler to count the number of cycles in the byte-code

- Communication time : estimate the value of g and L for MPI and OpenMP

  Using runtime benchmarks: probe-benchmark and Sphinx tool

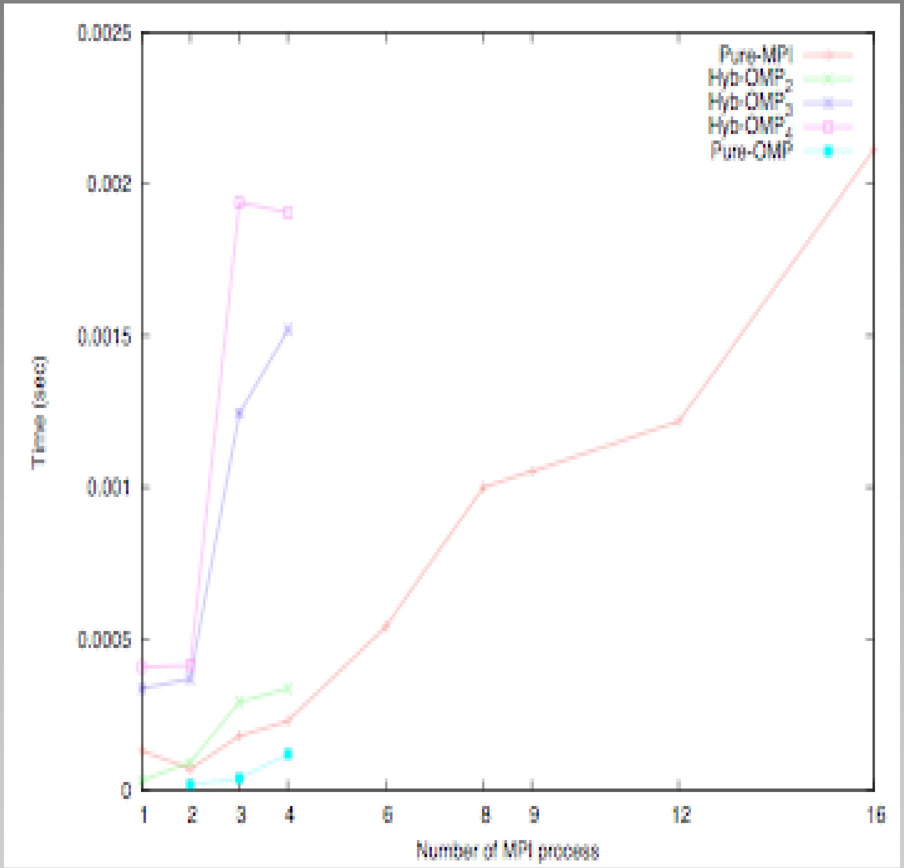
Framework modules

- **Searcher** : find the **best** configurations
  - Build a graph for all valid configuration
  - Use the Dijkstra Short path to find the fastest execution

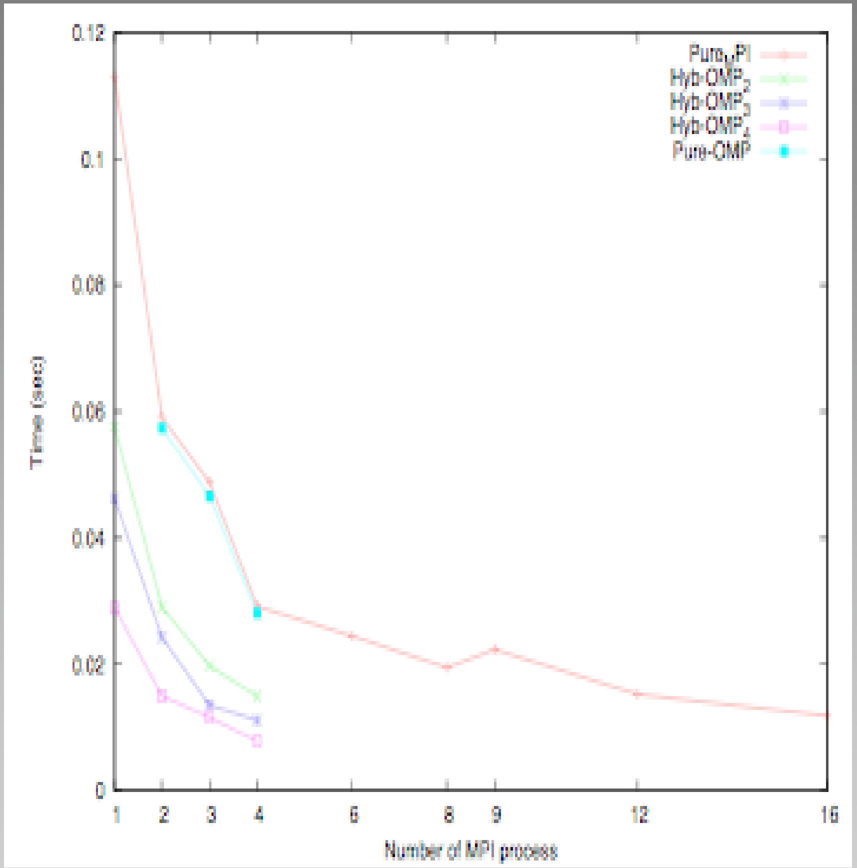


- **Generator** : generates the corresponding code for each configuration in the shortest path by using the BSP++ library

Experimental results

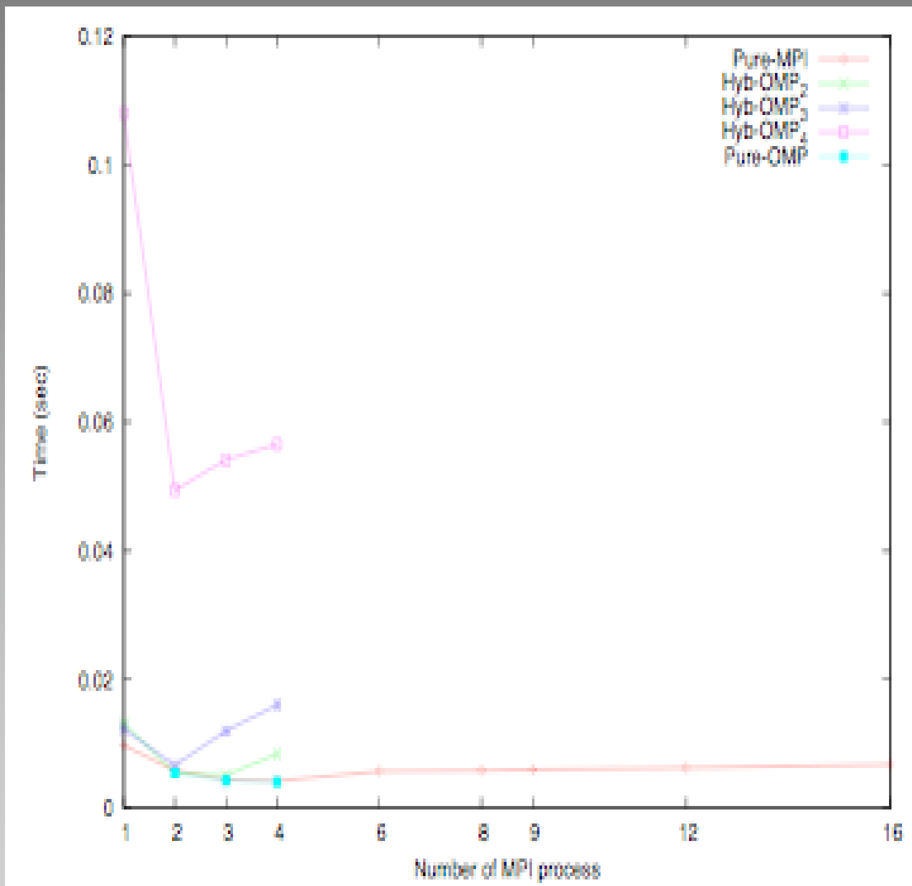


Inner product small size 16K

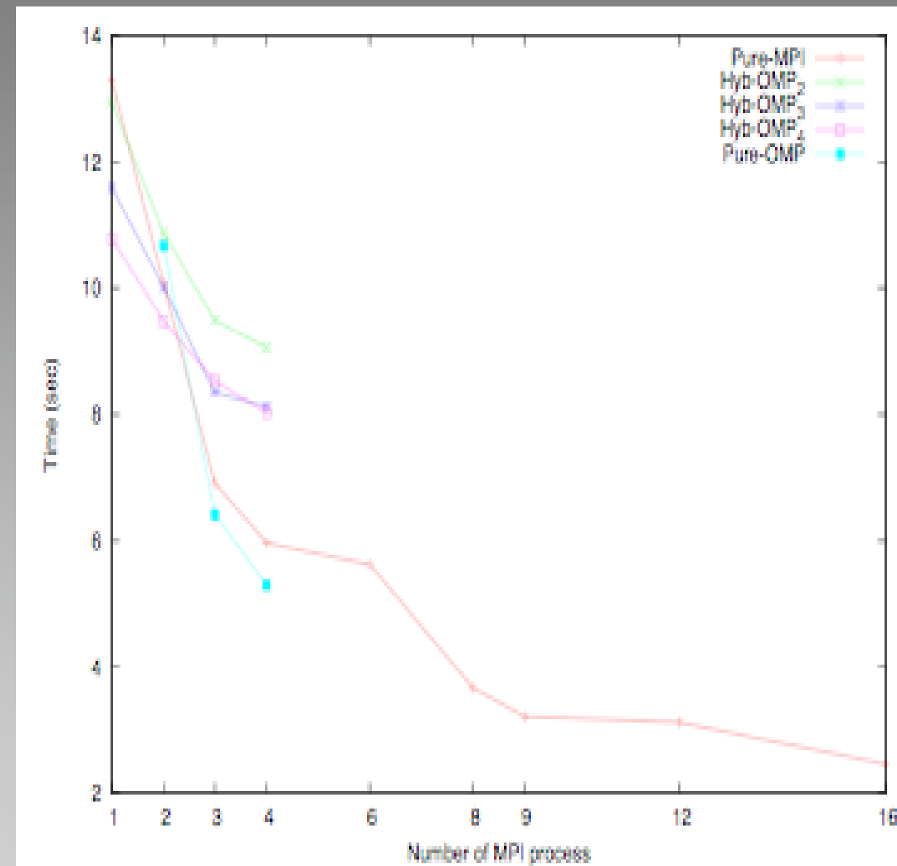


Inner product big size 64M

Experimental results



PSRS small size (81920 elements)



PSRS big size (8192 x 10^4 elements)

Future works

❖ Implementation of BSP++ on Cell and GPU :

Hybrid MPI+OpenMP+GPU

❖ BSP based containers and algorithms:

Write a subset of C++ standard library as BSP algorithm

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