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Barcelona Supercomputing Center
Centro Nacional de Supercomputación

PERFORMANCE ANALYSIS WITH BSC-TOOLS DIMEMAS SIMULATOR

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PATC Tools Training. Barcelona,
Oct. 14-18th 2013

Introduction

What?

- Coarse grain trace driven simulator
- Message-passing applications

Use?

- Developers → Understand applications
- System administrators → Evaluate hardware

Introduction (II)

Key factors

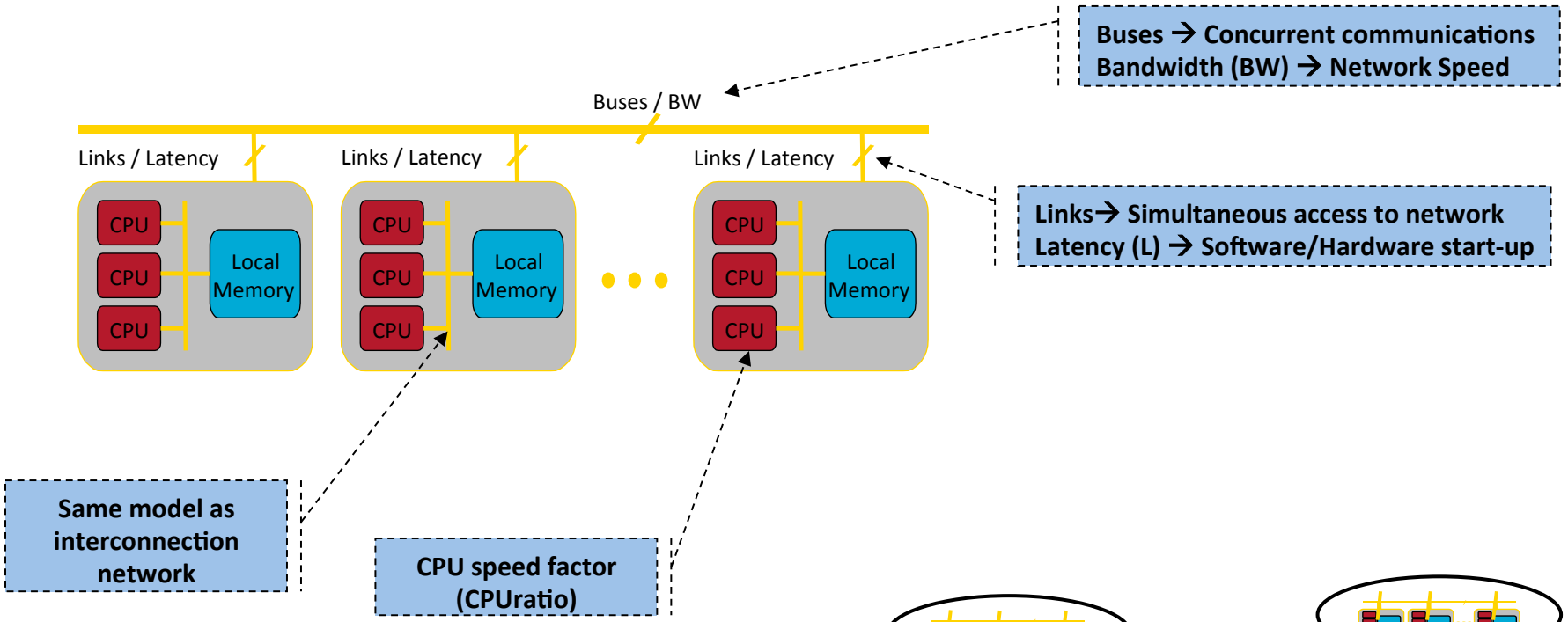
- Abstract architecture
  - Network of SMPS
- Basic MPI protocols
- No attempt to model details

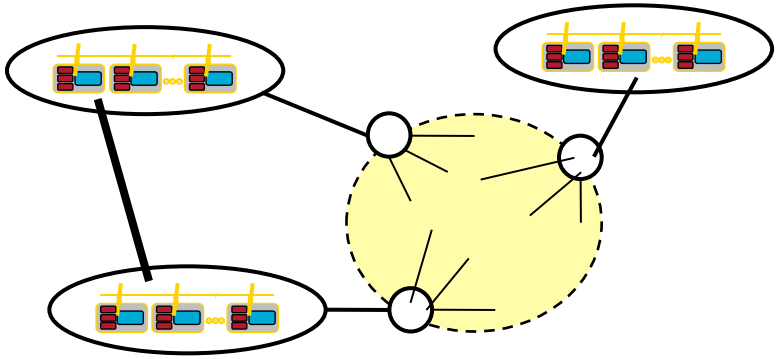
Objectives

- Simple / General
- Fast simulations

DIMEMAS MODEL

DIMEMAS simulated architecture





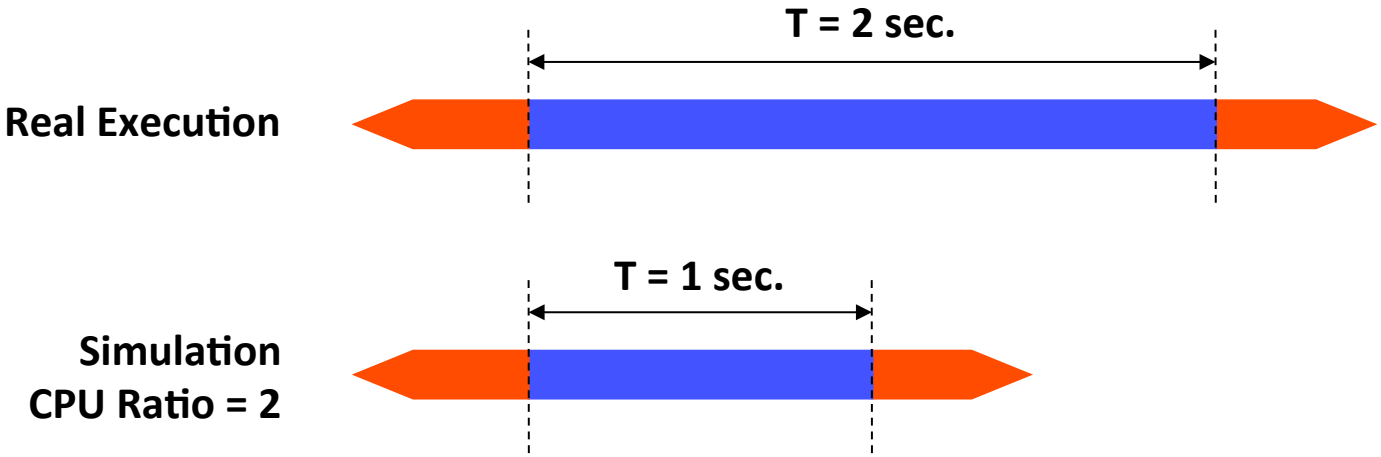
DIMEMAS Primitives: CPU bursts

What?

- Sequential computations

How?

- Clock advance
- *CPU Ratio* divisive factor



DIMEMAS Primitives: p2p communications

What?

- Message transmission between 2 partners

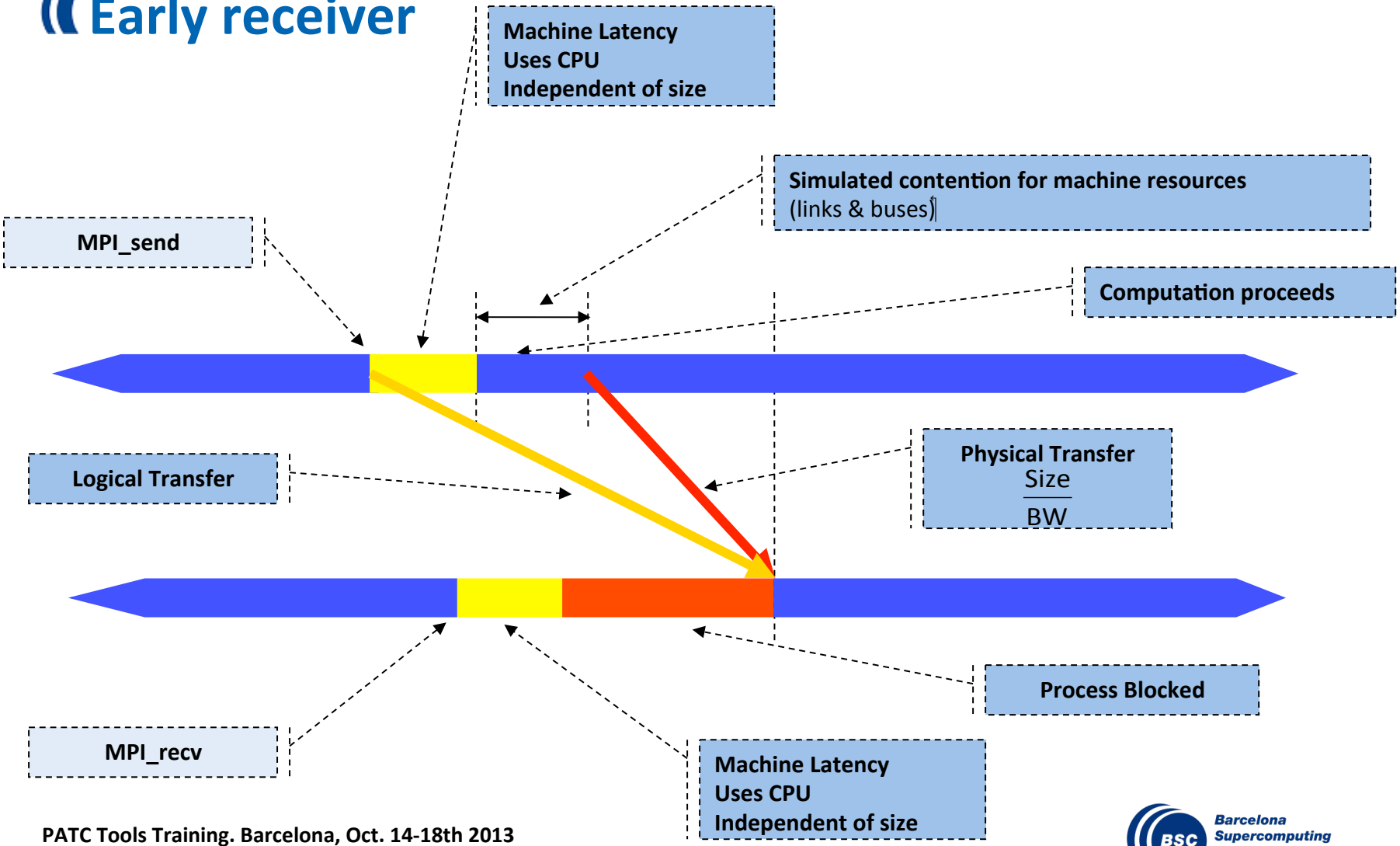
How?

- Resource allocation time (non-linear)
- Resource usage time (linear)

$$T = L + \frac{MessageSize}{BW}$$

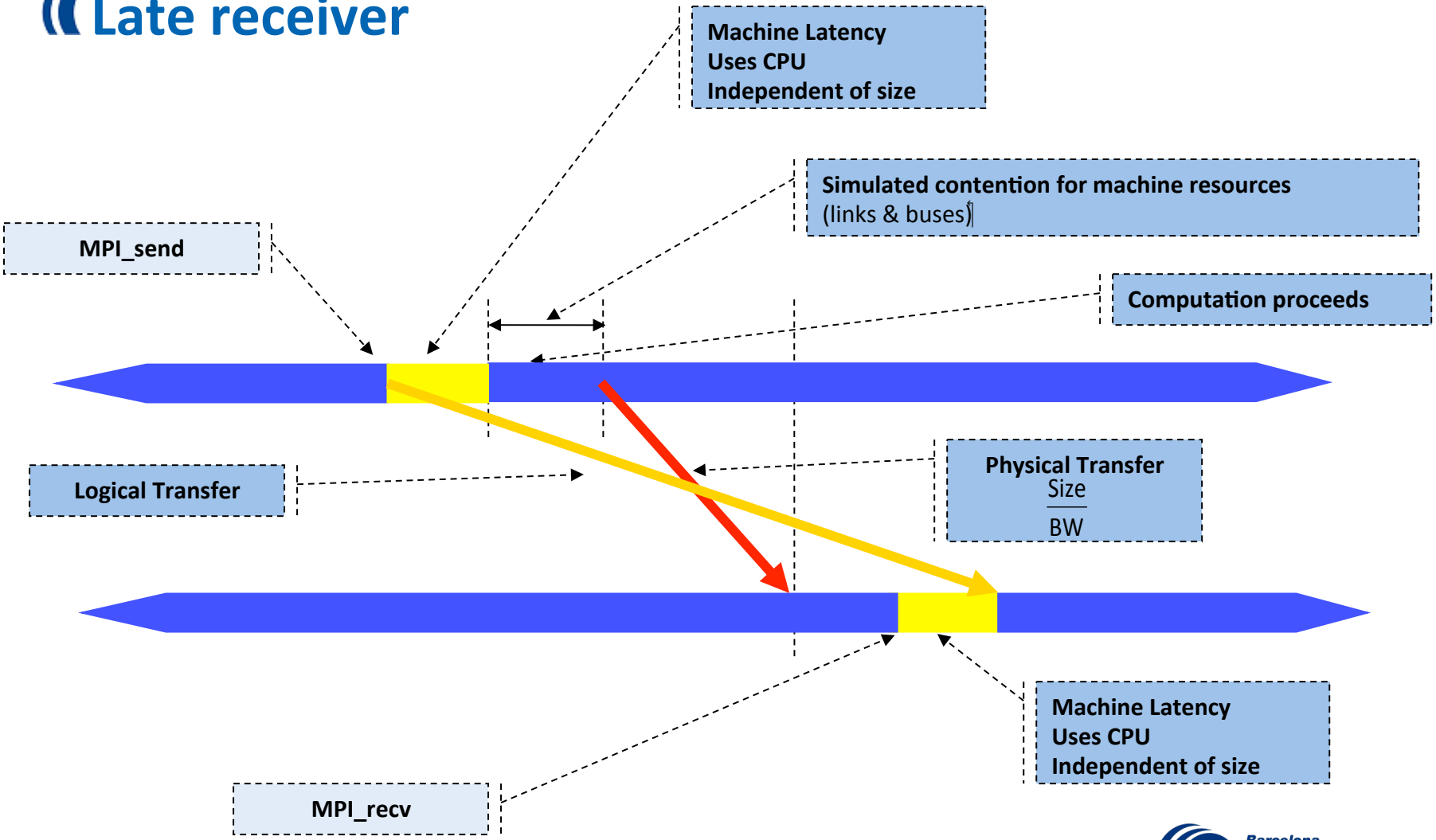
p2p communication model

Early receiver



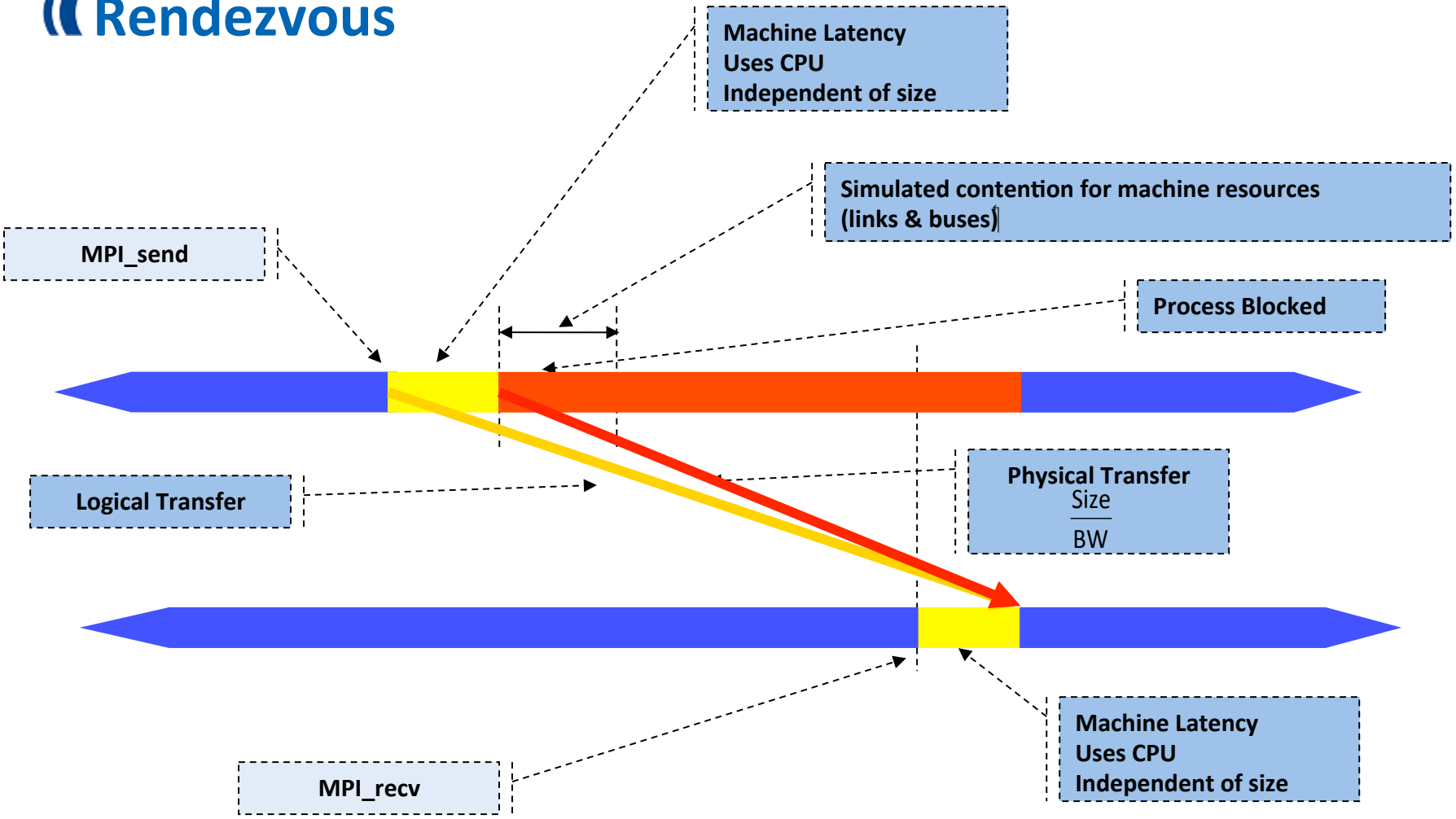
p2p communication model

Late receiver



p2p communication model

Rendezvous



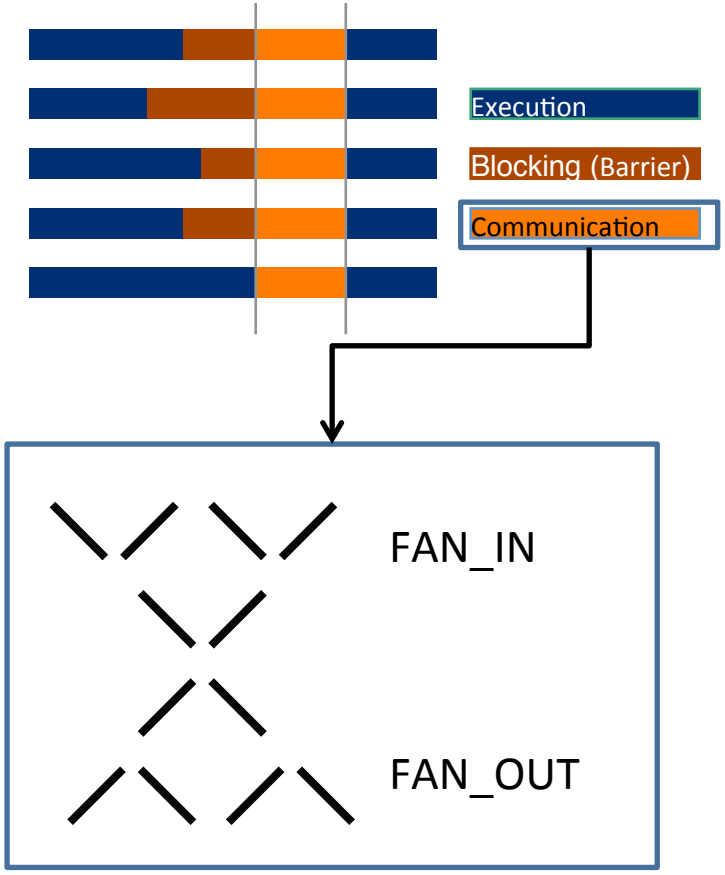
DIMEMAS Primitives: collective communications

What?

- Information transmission between multiple partners

How?

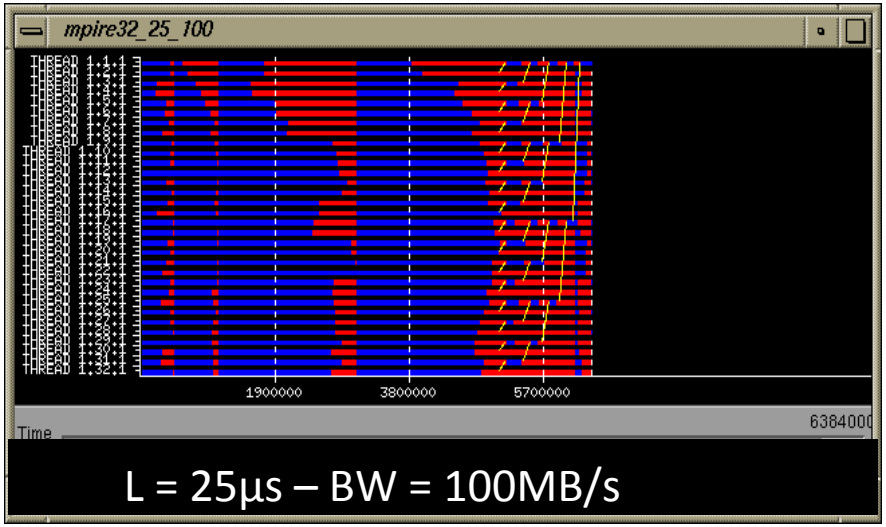
- Barrier: synchronization (non-linear)
- FAN_IN: information gathering
- FAN_OUT: information scattering
- Each FAN similar to p2p communication but taking into account # processes



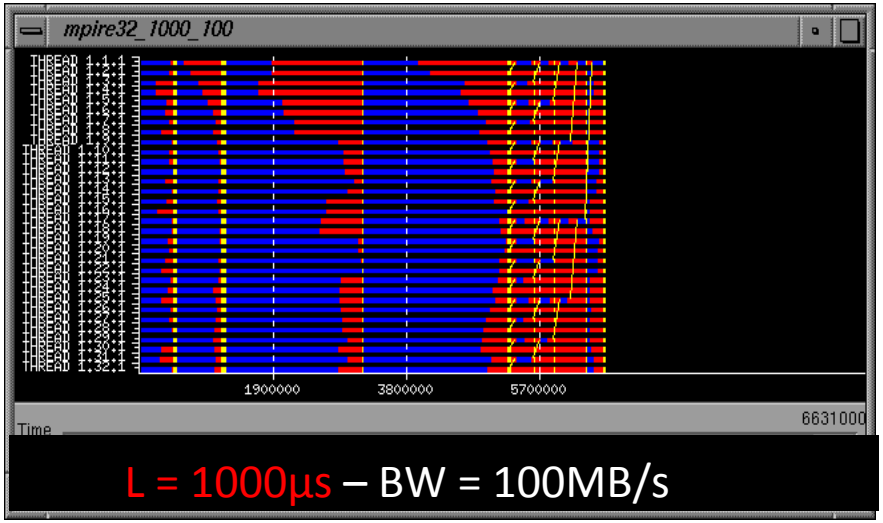
USE CASES

Network sensitivity (I)

MPIRE 32 tasks, no network contention



L = 25µs – BW = 100MB/s



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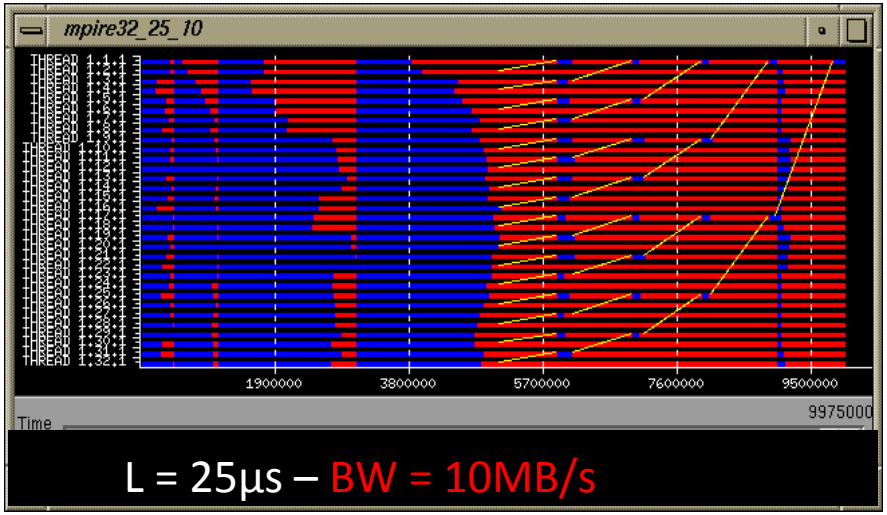


L = 25µs – BW = 10MB/s

All windows same scale

Network sensitivity (II)

WRF

- Iberia 4Km, 4procs/node
- NMM / ARW models
  - 128/256/512 procs. per model

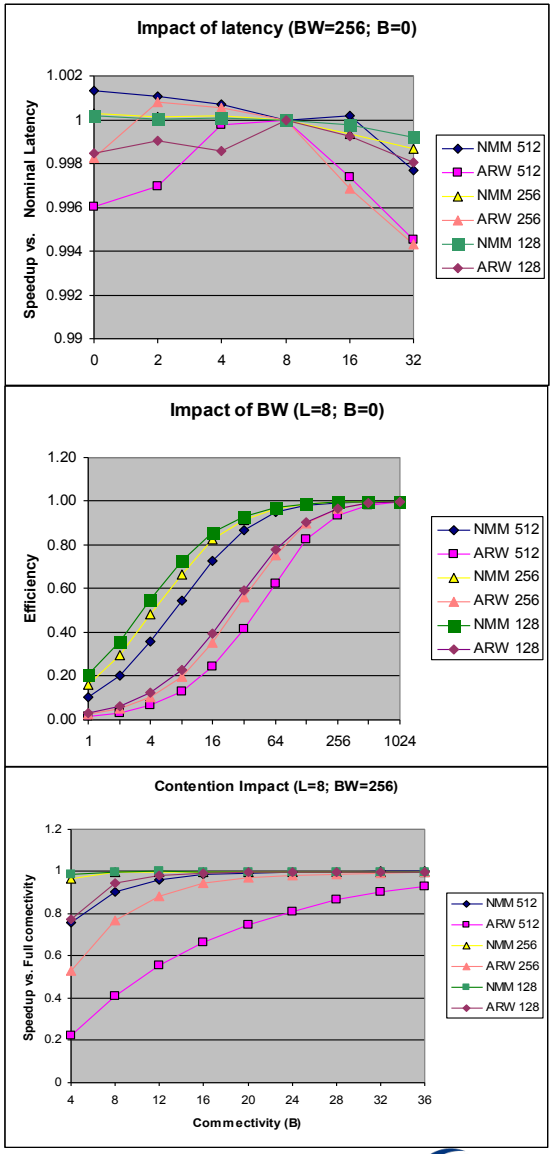
None sensitive to latency (L)

Bandwidth (BW)

- NMM: req. 256MB/s
- ARW: req. 1GB/s

Contention (B)

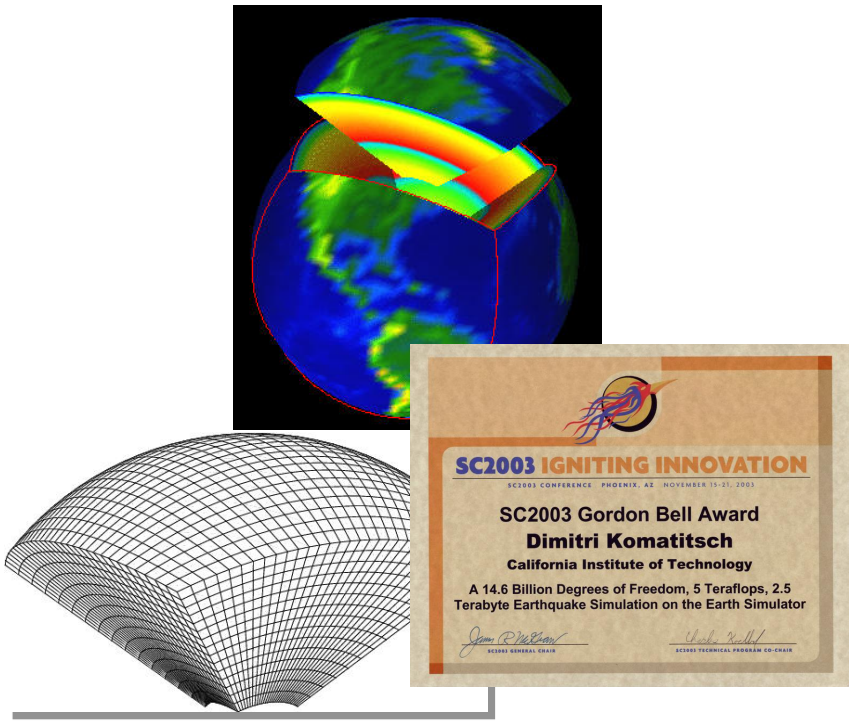
- NMM: sensitive at 512 procs. Scale
- ARW: sensitive at all scales



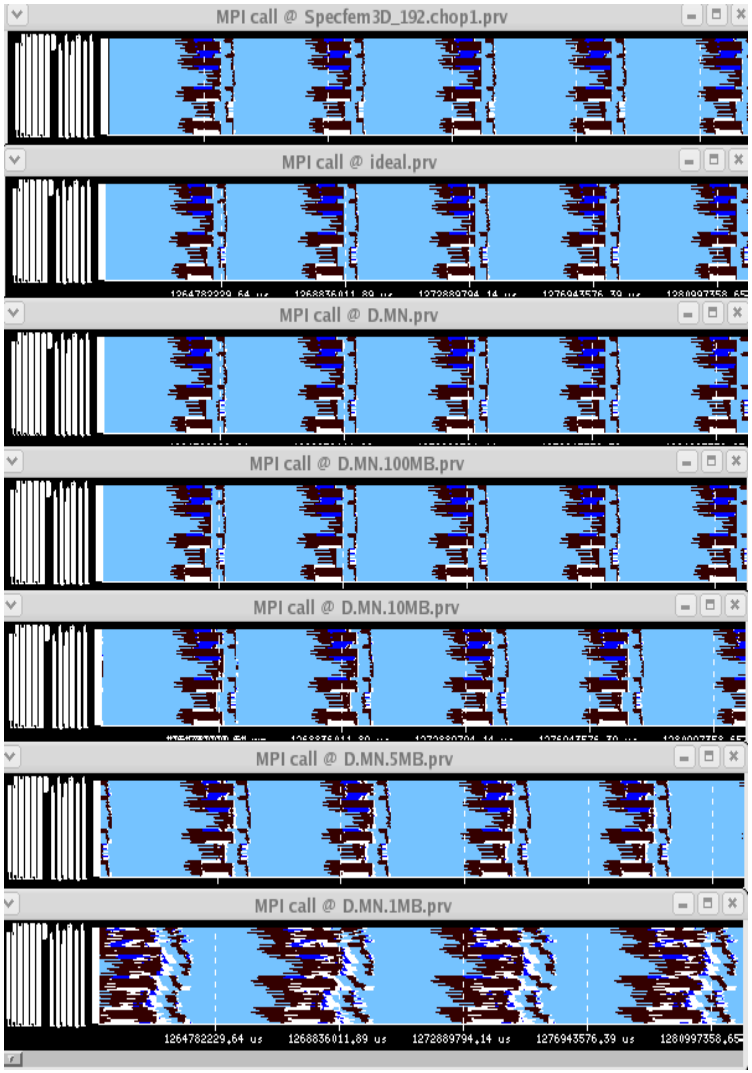
Performance prediction

SPECFEM3D

- Do we need asynchronous communications?



Courtesy Dimitri Komatitsch



Multi-scale simulation

Dimemas + CPU simulator

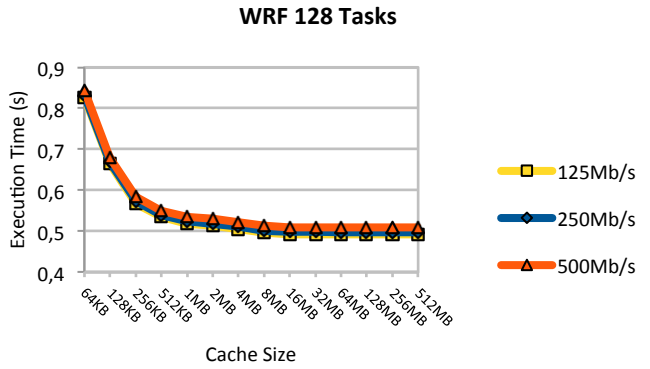
- Execution time using different cache size and network bandwidth

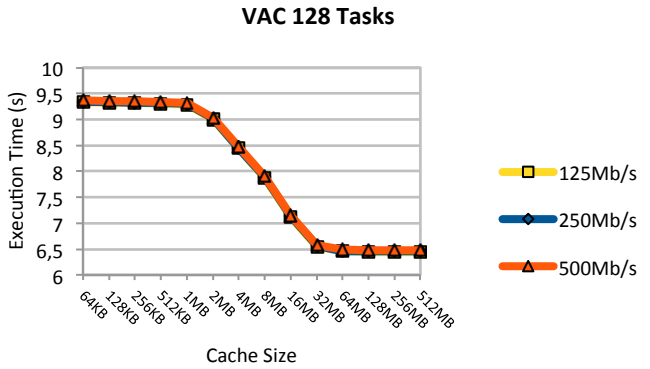
WRF & VAC

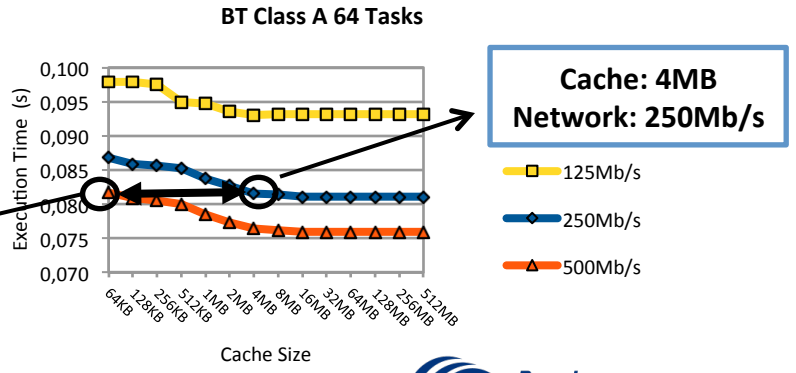
- Dominated by computation

NAS BT

- Can compensate cache reduction with more network BW



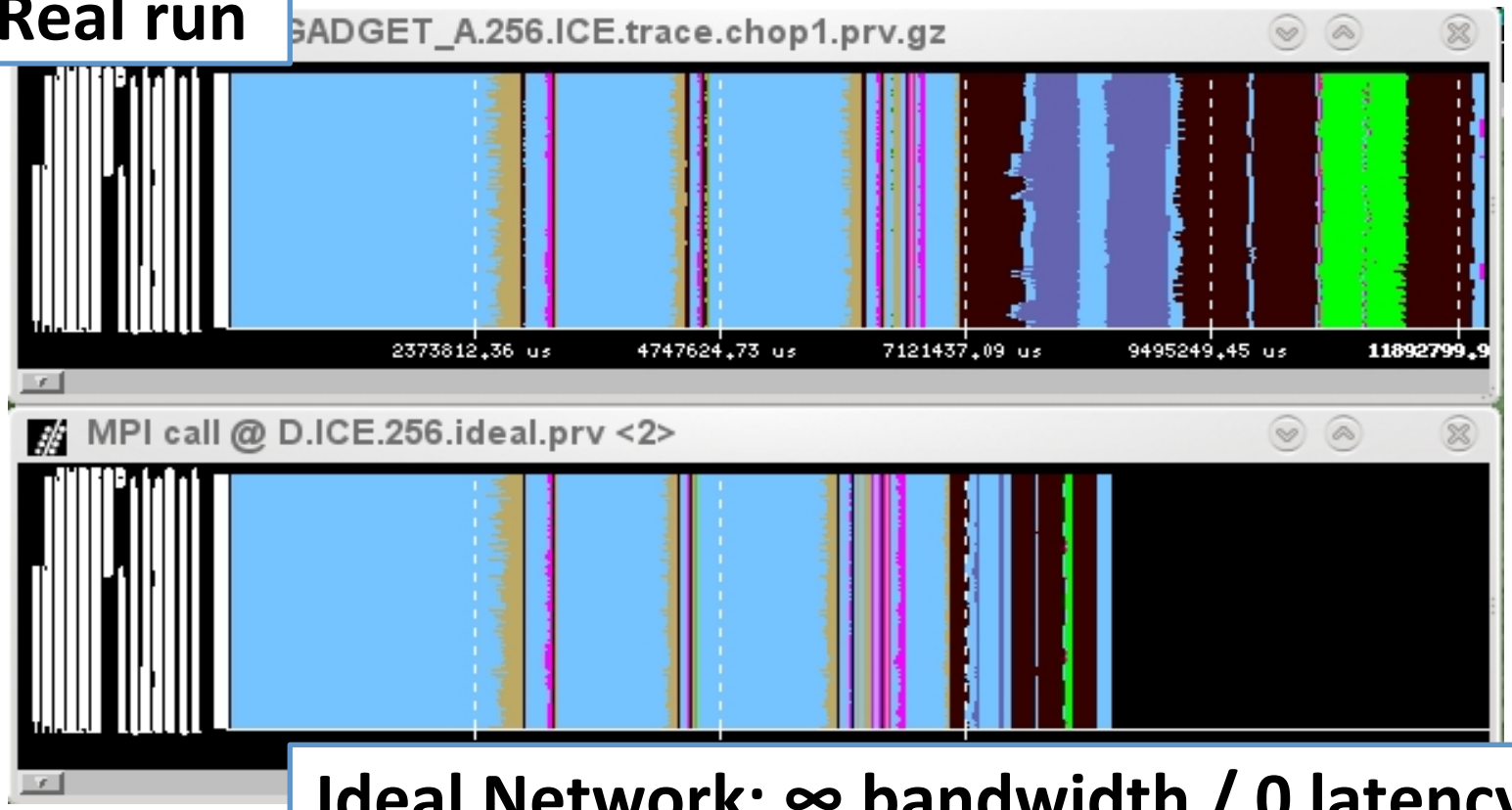




Application limits (I)

Load balance / dependences?

Real run

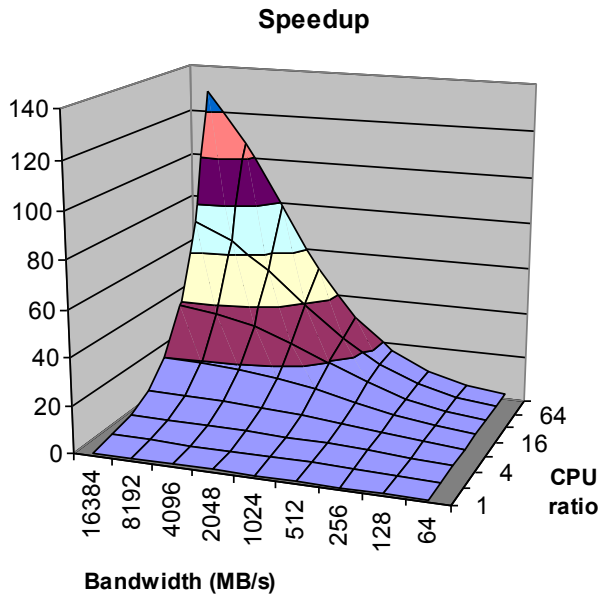


Ideal Network: ∞ bandwidth / 0 latency

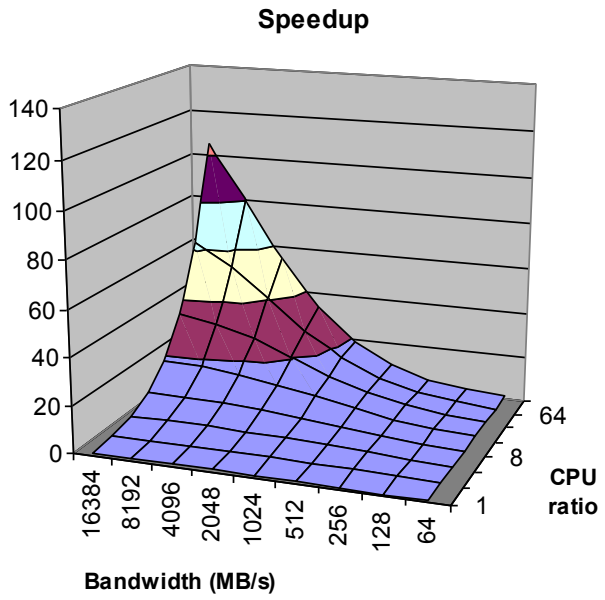
Application limits (II)

- Ideal speeding up ALL computation bursts by the CPUratio factor

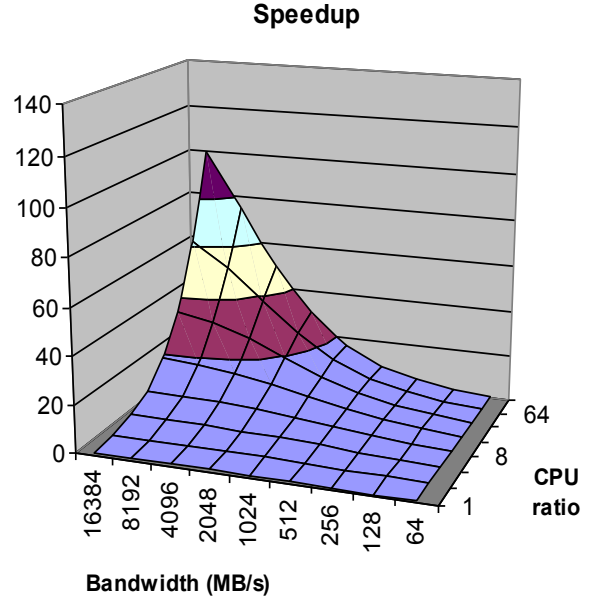
64 tasks



128 tasks



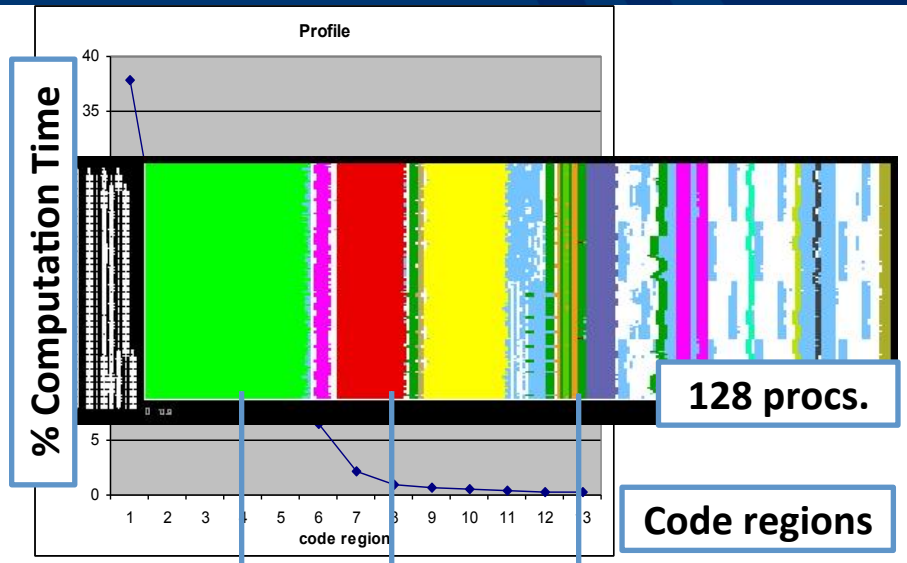
256 tasks

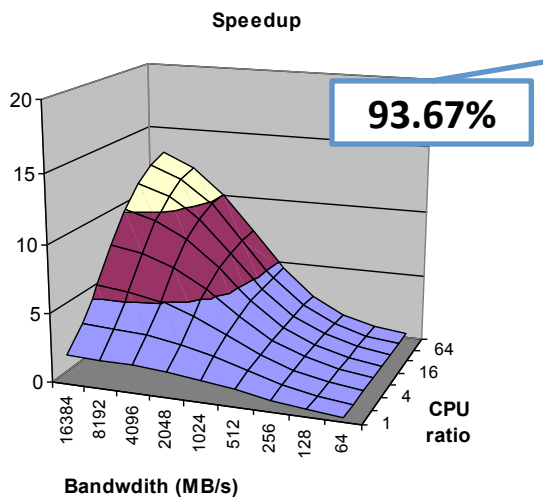


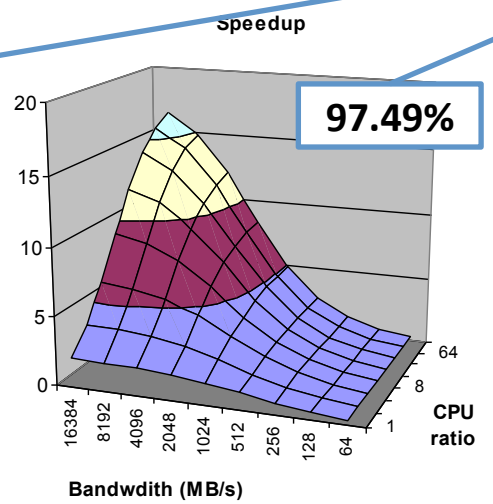
- The more processes, the less speed-up
  - Higher impact of bandwidth limitations!!!!

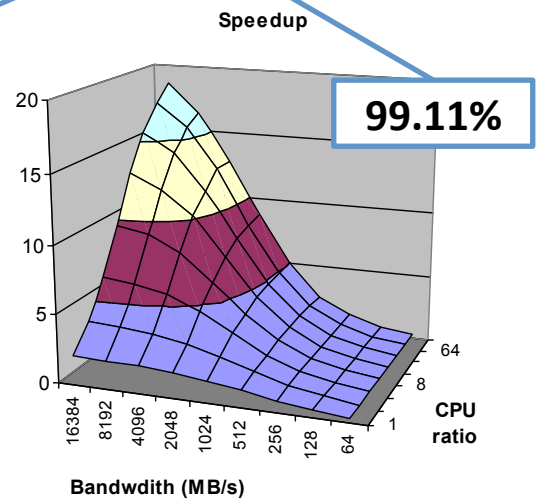
Application limits (III)

- Hybrid/accelerator parallelization
  - Speed-up SELECTED regions by the *CPUratio* factor
- We do need to overcome the hybrid Amdahl's law
  - Asynchrony + Load Balancing









(Previous slide: speed-ups **up to 120x**)

USE CASES

An in-depth study of the parallel efficiency…

Application's Efficiency (I)

CG-POP mpi2s1D 180x120 – 10 iterations

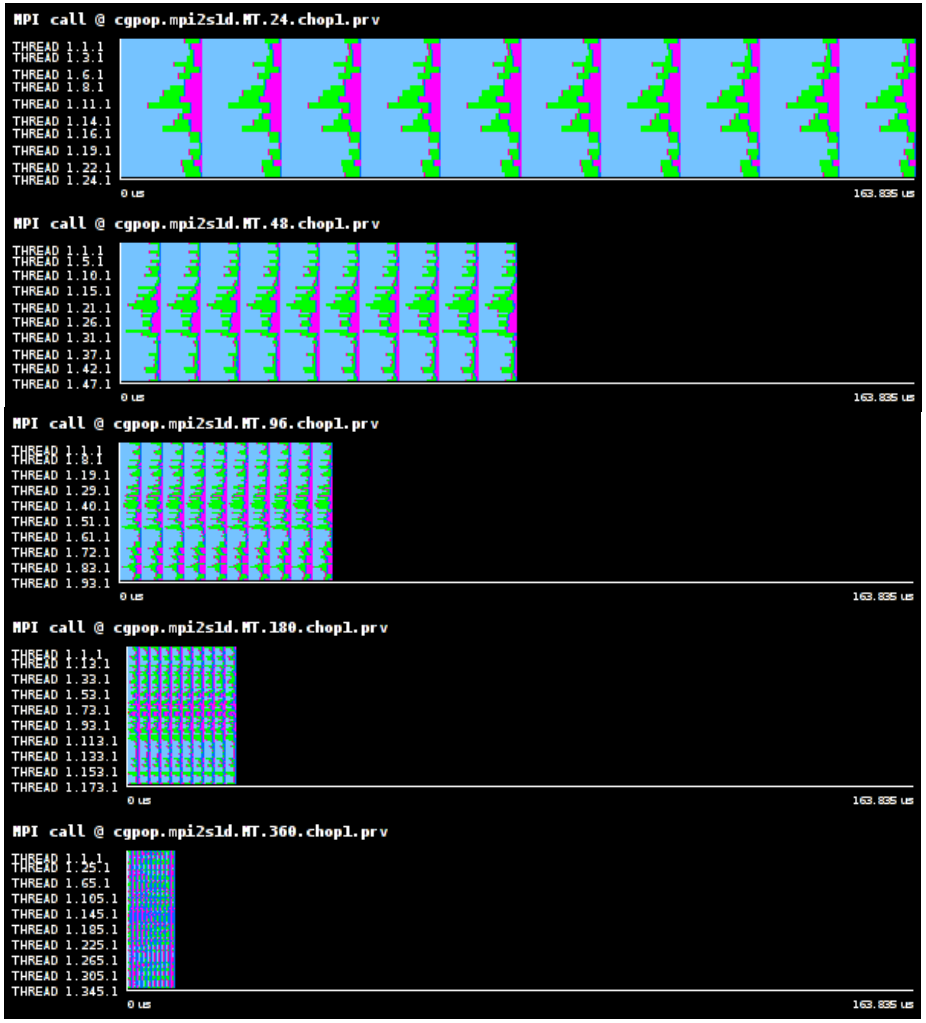
24 tasks

48 tasks

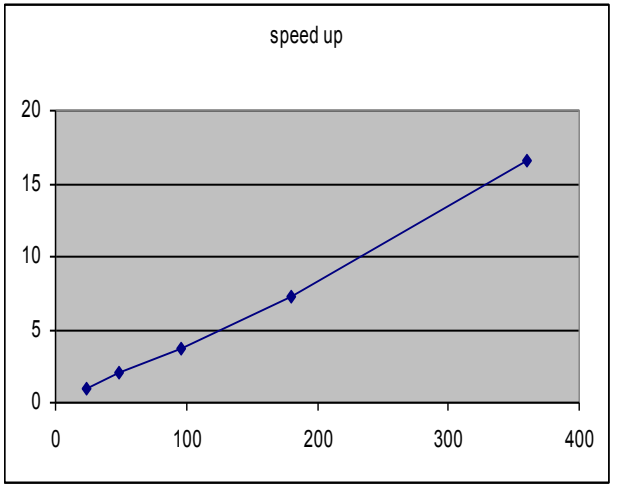
96 tasks

180 tasks

360 tasks

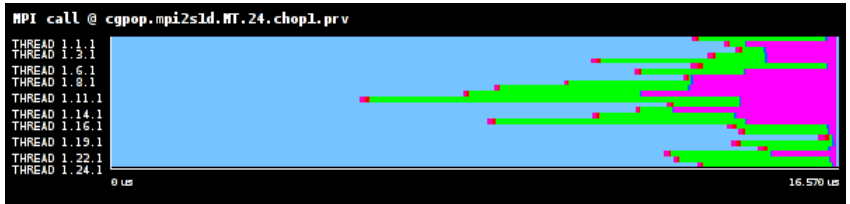
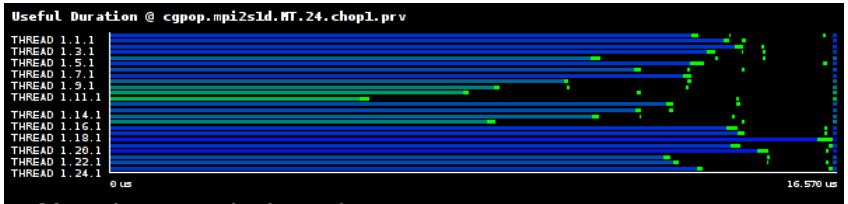
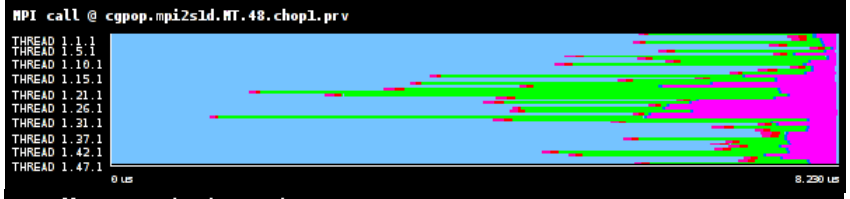
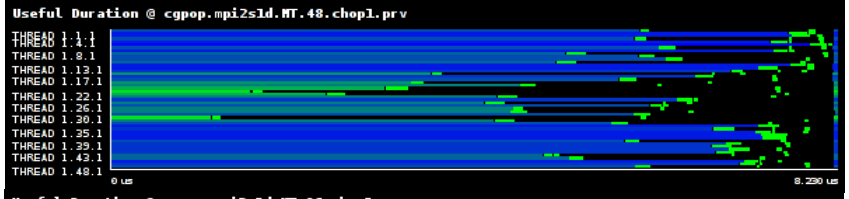
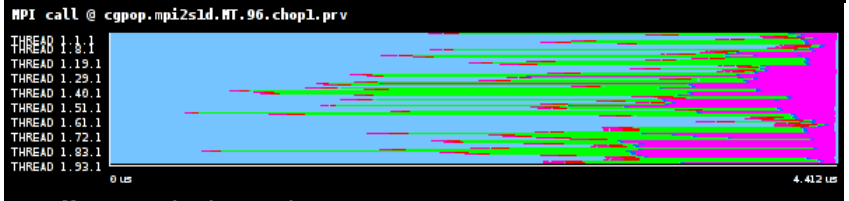
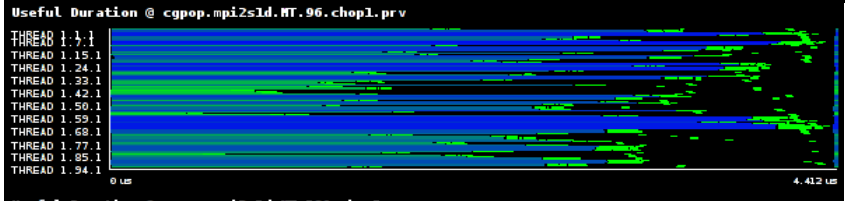
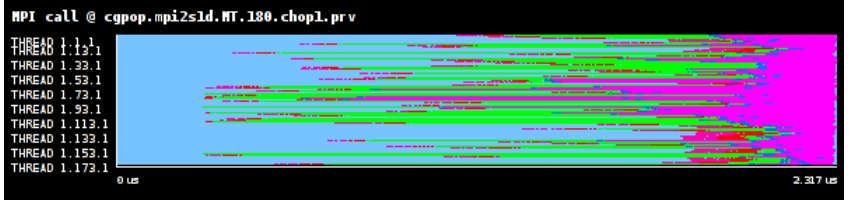
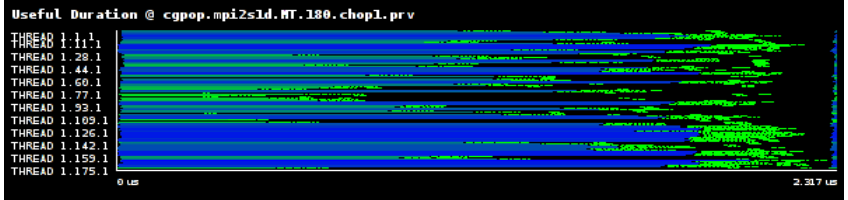
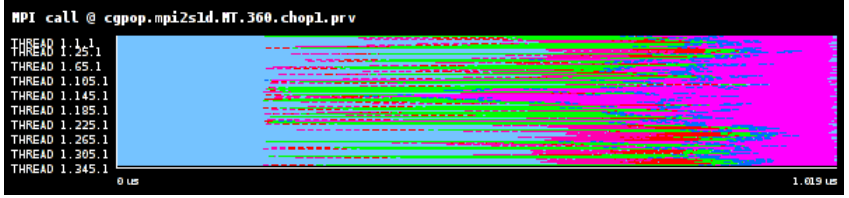
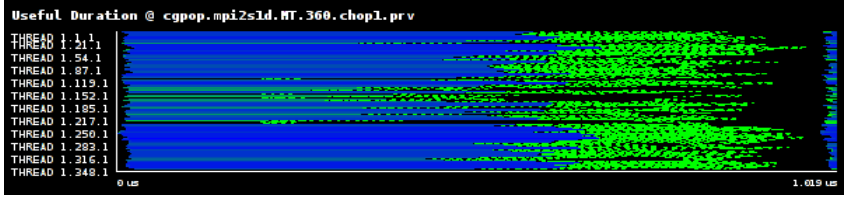


Good scalability!



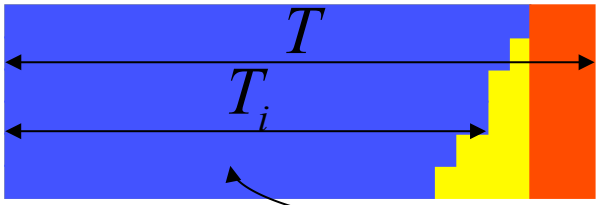
Application's Efficiency (II)

Comparing 1 iteration – different time scale

	MPI call view	Duration of computing phase
24		
48		
96		
180		
360		

Efficiency model: Parallel Efficiency

$$\eta = LB \times CommEff$$

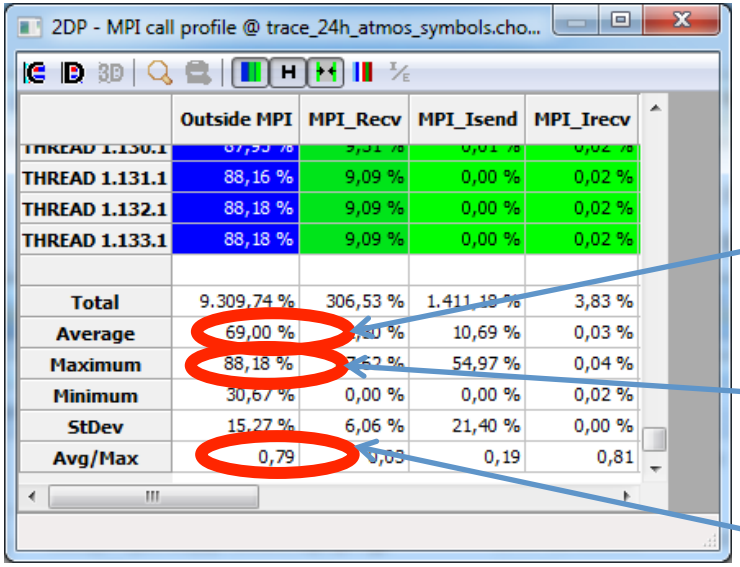


$$eff_i = \frac{T_i}{T}$$

$$CommEff = \max(eff_i) \qquad LB = \frac{\sum_{i=1}^{P} eff_i}{P \times \max(eff_i)}$$

IPC
#instr

Obtained from real execution metrics



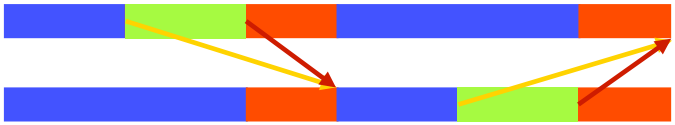
η

CommEff

LB

Efficiency model (II): µLB & transfer

But…



$$LB = 1$$

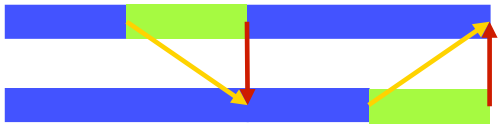
… there is other type of LB! µLB

- **Serializations / Dependences**

$$CommEff = \mu LB \times Transfer$$

We measure it using Dimemas!

- **How? Using an ideal network → Transfer efficiency = 1**



Efficiency model (III): Speedup model

Final model

$$S_P = \frac{P}{P_0} \times \frac{LB}{LB_0} \times \frac{\mu LB}{\mu LB_0} \times \frac{Transfer}{Trasnfer_0} \times \frac{IPC}{IPC_0} \times \frac{\#instr_0}{\#instr}$$

Parallel Efficiency

Computation Efficiency

M. Casas et. Al., *Automatic analysis of speedup of MPI applications*. ICS 2008

Application's Efficiency (I)

Comparing 10 iterations – same time scale

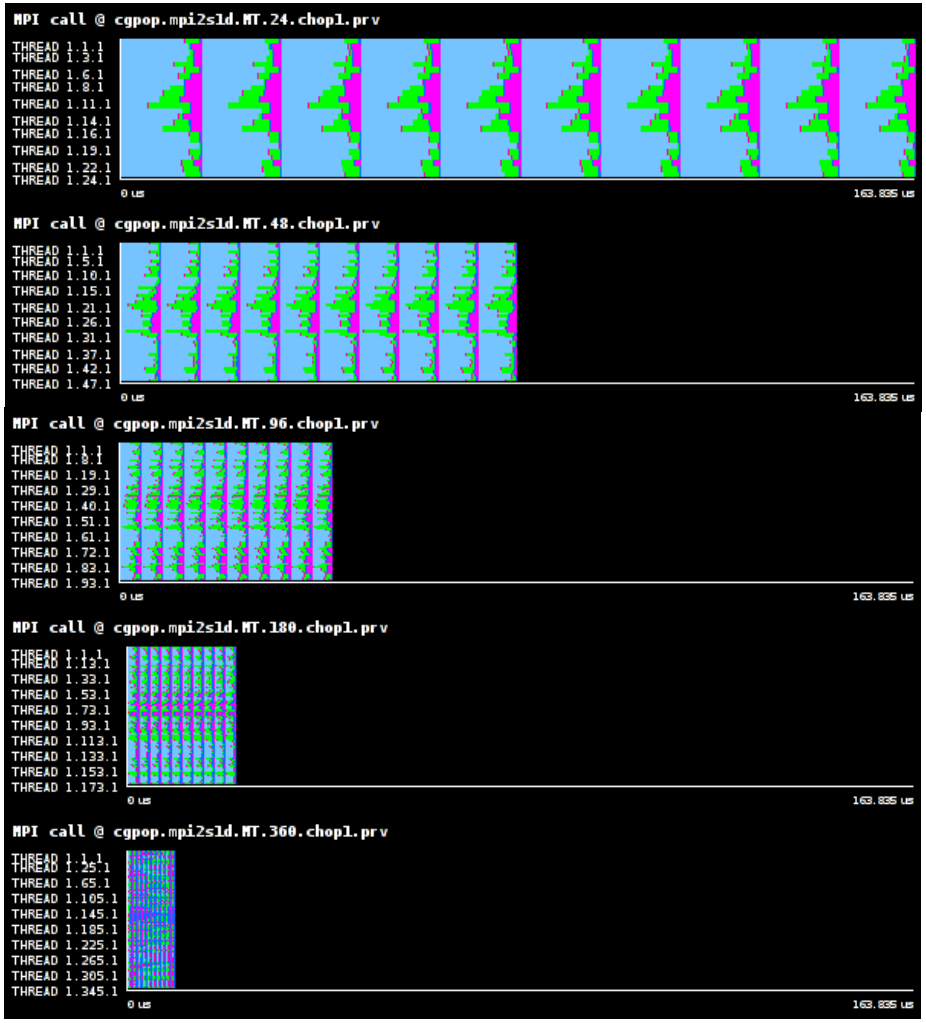
24 tasks

48 tasks

96 tasks

180 tasks

360 tasks



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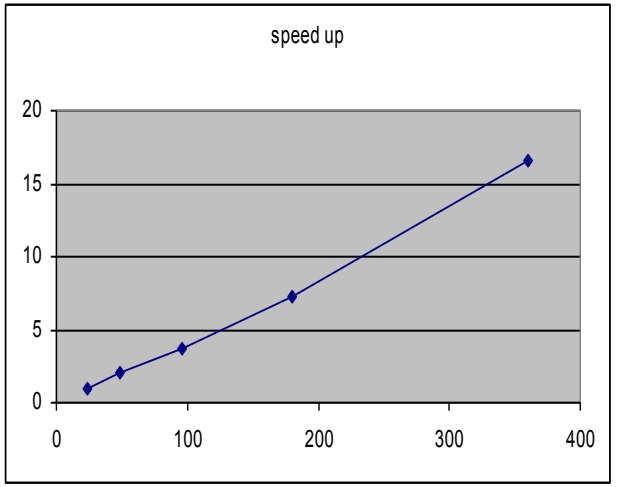
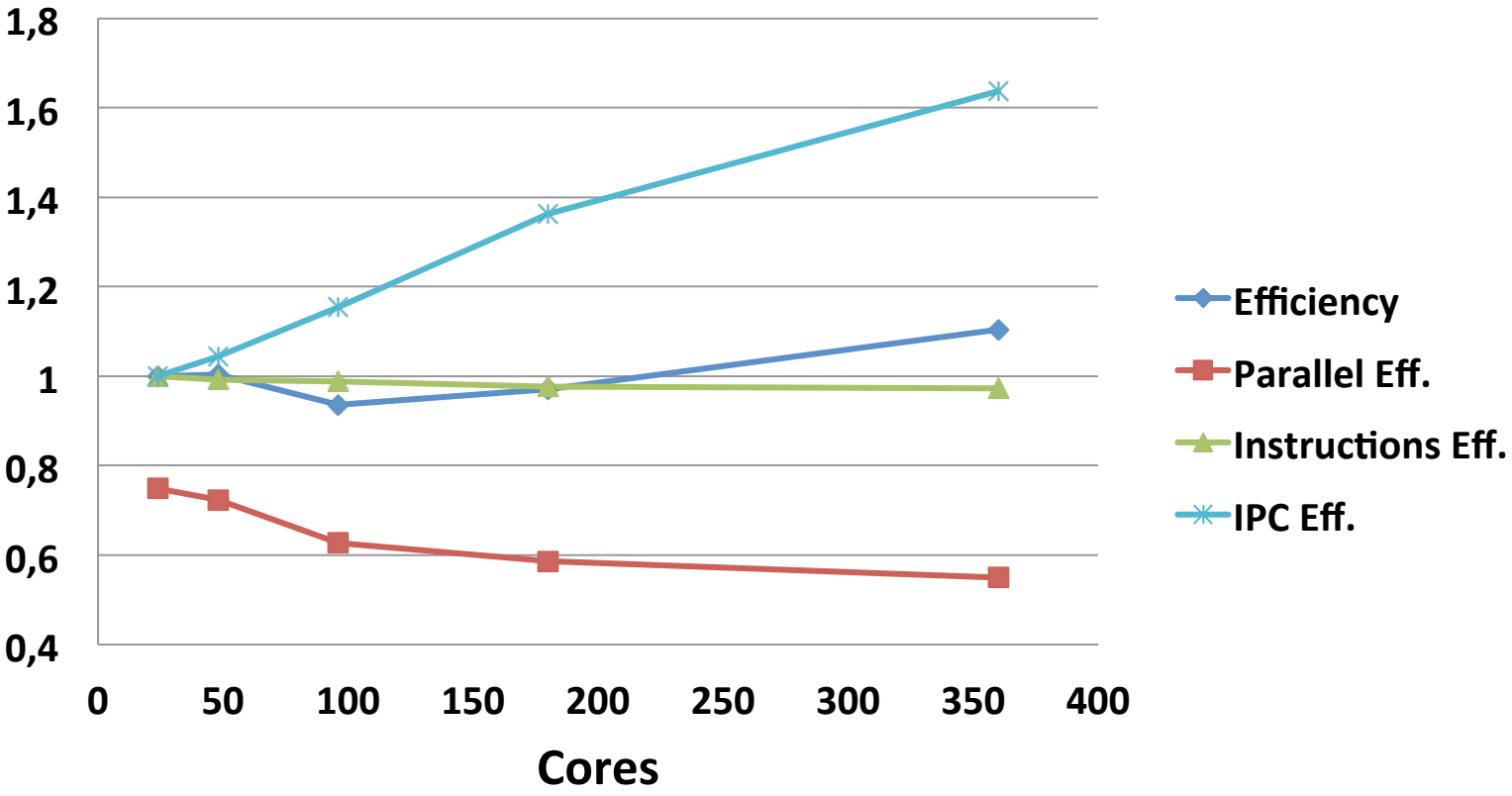


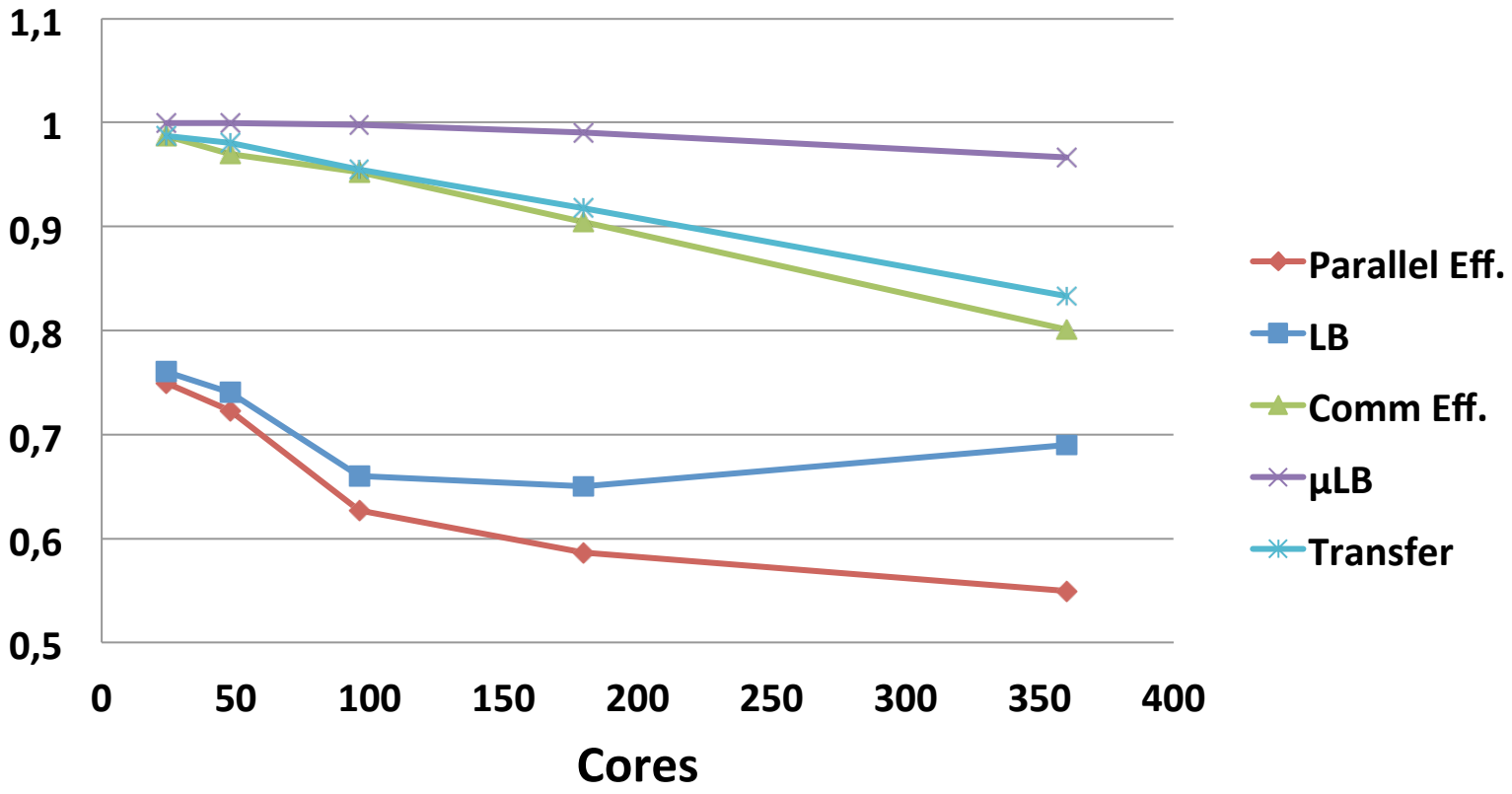
Scaling model results (I)

Comparing 10 iterations program global efficiency



Scaling model results (II)

Comparing 10 iterations parallel efficiency

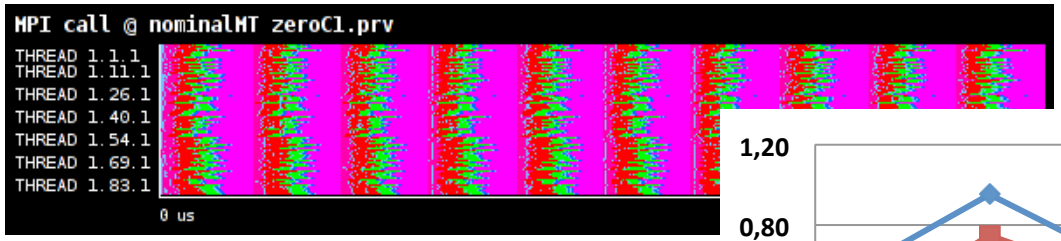


Imbalance

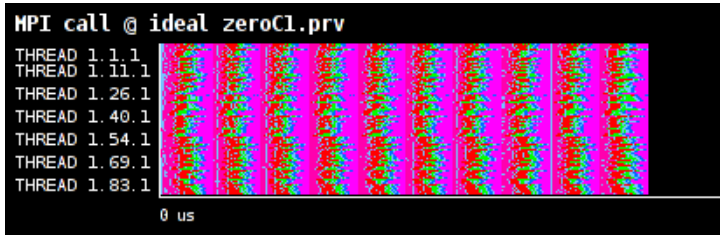
Communication phase only (96 Tasks)

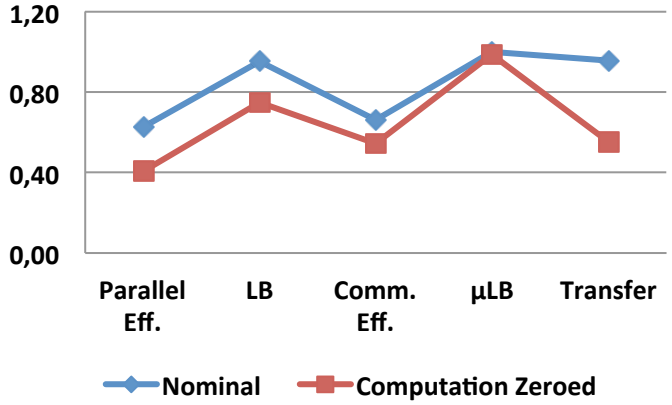
- Small computations point-to-point / collective calls
- MPI calls view / same time scale

Nominal
Main computation = 0

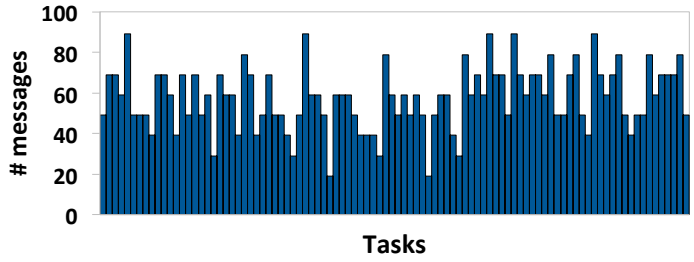


Ideal network
Main Computation = 0





- Imbalance in halo exchange
  - Computation (75%) / # messages (65%)
- Small amount of serialization
- Large transfer time



CONCLUSIONS

What did we learned?

- How network factors affect my application?
- Does it make sense to use asynchronous communications?
- Which is the best combination of computing power and network speed?
- Does my application take into advantage the resources available?
- Is the parallelization of my application efficient?

Wrapping up

- Sometimes things are not as they look like
- Small scale analysis can give us hints to identify problems at larger scales
- DIMEMAS offers a valuable insight to understand our applications and systems

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THANK YOU!

tools@bsc.es

PATC Tools Training. Barcelona,
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