Performance Optimization and Productivity

EU H2020 Center of Excellence (CoE)

ISC 2017 BOF

POP improves HPC applications

Frankfurt, June 20th 2017

POP CoE

- **A Center of Excellence**
  - **On Performance Optimization and Productivity**
  - **Promoting best practices in performance analysis and parallel programming**
- **Providing Services**
  - Precise understanding of application and system behavior
  - Suggestion/support on how to refactor code in the most productive way
- **Horizontal**
  - Transversal across application areas, platforms, scales
- **For academic AND industrial codes and users**

Partners

- **Who?**
  - BSC (coordinator), ES
  - HLRS, DE
  - JSC, DE
  - NAG, UK
  - RWTH Aachen, IT Center, DE
  - TERATEC, FR

A team with

- Excellence in performance tools and tuning
- Excellence in programming models and practices
- Research and development background AND
  proven commitment in application to real academic and industrial use cases

Motivation

Why?

- Complexity of machines and codes
  → Frequent lack of quantified understanding of actual behavior
  → Not clear most productive direction of code refactoring
- Important to maximize efficiency (performance, power) of compute intensive applications and the productivity of the development efforts

Target

- Parallel programs , mainly MPI /OpenMP … although can also look at CUDA, OpenCL, Python, …

3 levels of services

? Application Performance Audit

- Primary service
- Identify performance issues of customer code (at customer site)
- Small Effort (< 1 month)

! Application Performance Plan

- Follow-up on the service
- Identifies the root causes of the issues found and qualifies and quantifies approaches to address the issues
- Longer effort (1-3 months)

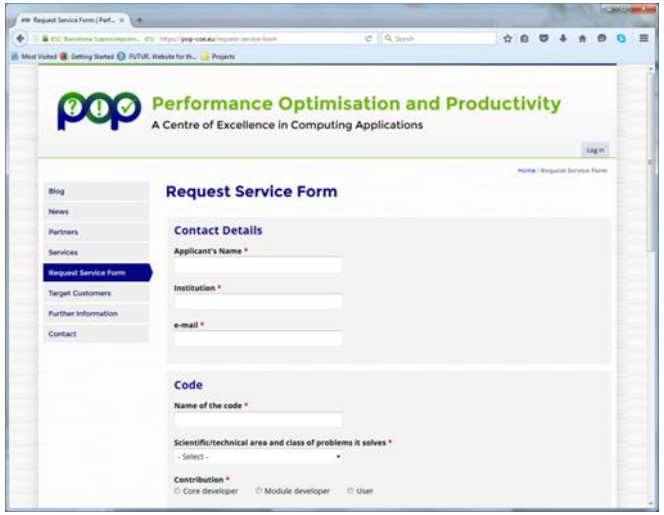
✓ Proof-of-Concept

- Experiments and mock-up tests for customer codes
- Kernel extraction, parallelization, mini-apps experiments to show effect of proposed optimizations
- 6 months effort

Reports

Software demonstrator

Apply @
http://www.pop-coe.eu

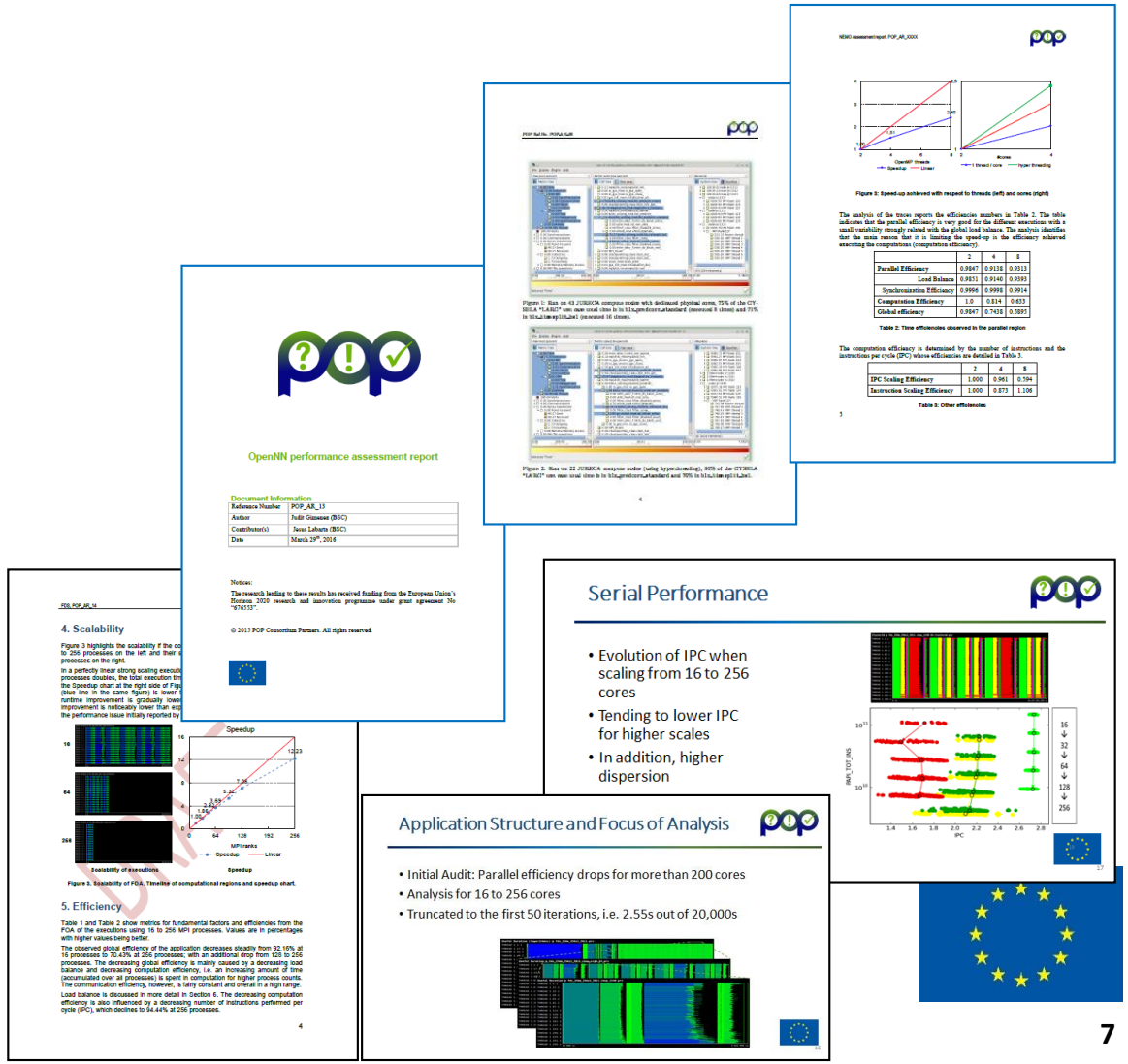


Target customers

- **Code developers**
  - Assessment of detailed actual behavior
  - Suggestion of more productive directions to refactor code
- **Users**
  - Assessment of achieved performance on specific production conditions
  - Possible improvements modifying environment setup
  - Evidences to interact with code provider
- **Infrastructure operators**
  - Assessment of achieved performance in production conditions
  - Possible improvements modifying environment setup
  - Information for allocation processes
  - Training of support staff
- **Vendors**
  - Benchmarking
  - Customer support
  - System dimensioning/design

Activities (May 2017)

- **Services**
  - Completed/reporting: 59
  - Reporting: 7
  - Codes being analyzed: 16
  - Waiting user / New: 18
- **Type**
  - Mostly Audits
    - 5 -15 pages
    - Level of detail



Best practices in Performance analysis

- **Powerful tools …**
  - Extrae + Paraver
  - Score-P + Scalasca/TAU/Vampir + Cube
  - Dimemas, Extra-P
  - Other commercial tools
- **… and techniques**
  - Clustering, modeling, projection, extrapolation, memory access patterns,
  - … with extreme detail …
  - … and up to extreme scale
- **Unify methodologies**
  - Structure
    - Spatio temporal / syntactic
  - Metrics
    - Parallel fundamental factors: Efficiency, Load balance, Serialization
    - Programming model related metrics
    - User level code sequential performance
  - Hierarchical search
    - From high level fundamental behavior to its causes
- **To deliver insight**
- **To estimate potentials**

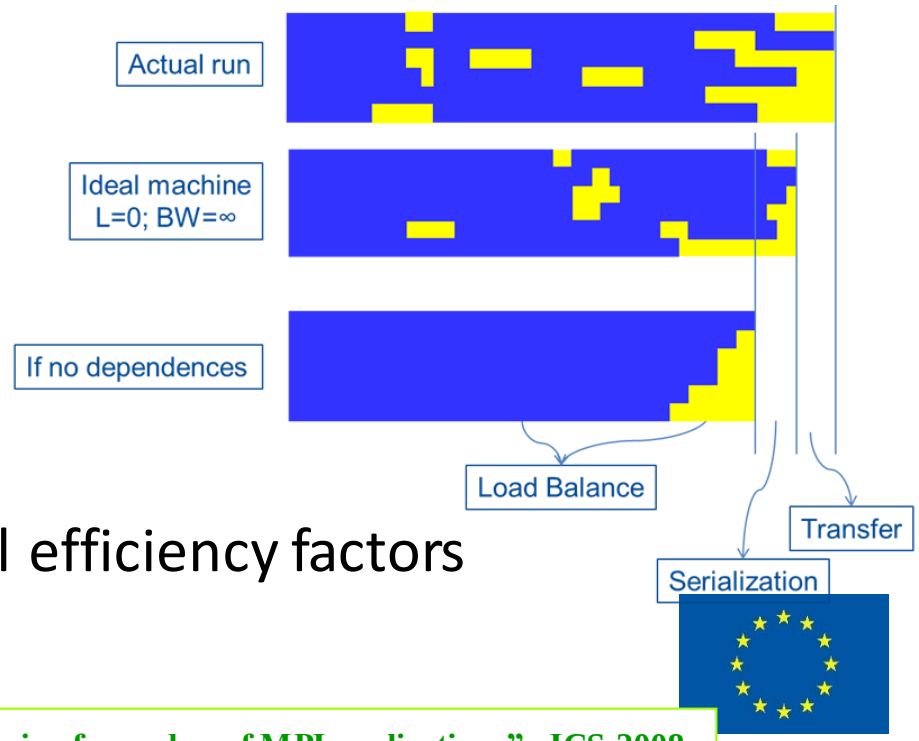
Fundamental performance factors

- Factors modeling parallel efficiency
  - **Load balance** (LB)
  - **Communication**
    - **Serialization** (or Micro load balance)
    - **Transfer**

$$\eta_{\|} = LB * Ser * Trf$$

CommEff

- Factors describing serial behavior
  - Computational complexity: **#instr**
  - Performance: **IPC**
  - **Core frequency**
  - Actual values, scaling behavior, impact on parallel efficiency factors



M. Casas et al, "Automatic analysis of speedup of MPI applications". ICS 2008.

Efficiencies

	2	4	8	16
Parallel Efficiency	0.9834	0.9436	0.8980	0.8478
Load Balance	0.9871	0.9687	0.9099	0.9177
Serialization efficiency	0.9975	0.9770	0.9938	0.9395
Transfer Efficiency	0.9988	0.9970	0.9931	0.9833
Computation Efficiency	1.000	0.9590	0.8680	0.6953
Global efficiency	0.9834	0.9049	0.7795	0.5894

	2	**4**	**8**	**16**
IPC Scaling Efficiency	1.000	0.9932	0.9591	0.8421
Instruction Scaling Efficiency	1.000	0.9721	0.9393	0.9075
Core frequency efficiency	1.000	0.9932	0.9635	0.9098

Other activities

- **Promotion and dissemination**
  - Market and community development
  - Dissemination material and events
- **Customer advocacy**
  - Gather customers feedback, ensure satisfaction, steer activities
- **Sustainability**
  - Explore business models
- **Training**
  - Best practices on the use of the tools and programming models
    - Cooperation with other CoEs (EoCoE)
    - Lot of interest … customers want to learn how to do it themselves

Performance Optimisation and Productivity

A Centre of Excellence in Computing Applications

Contact:

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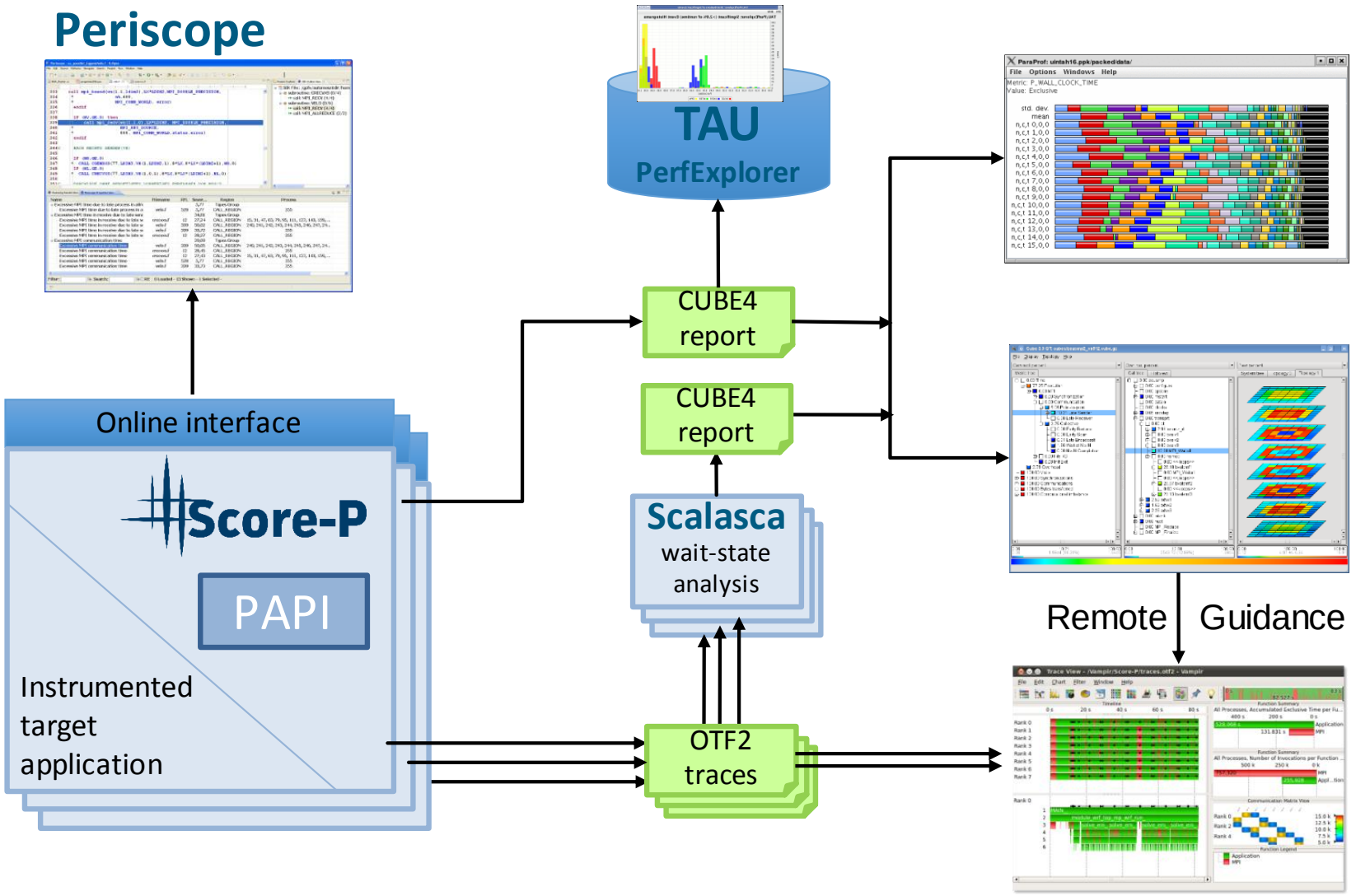
Scalasca (www.scalasca.org)



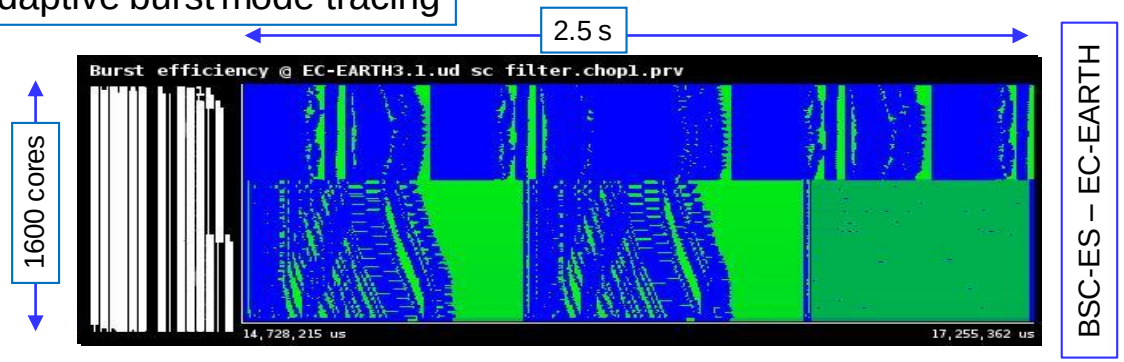
Tool Ecosystem -- Status

- **Score-P** (www.score-p.org)
  - Parallel Program Instrumentation and Profile/Trace Measurement
    - MPI, OpenMP, SHMEM, CUDA, OpenCL, OmpSs support
  - Latest version: 3.0-rc1
    - New: User function sampling + MPI measurement, OpenACC support
- **Scalasca** (www.scalasca.org)
  - Scalable Profile and Trace analysis
  - Latest version: 2.3.1
    - New: More platforms (Xeon Phi, K computer, ARM64, …), Score-P 2.X and 3.x support
- **Cube** (www.scalasca.org)
  - Profile browser
  - Latest version: 4.3.4
    - Soon: Client/server architecture, more analysis plugins, performance improvements

BSC Performance Tools (www.bsc.es/paraver)

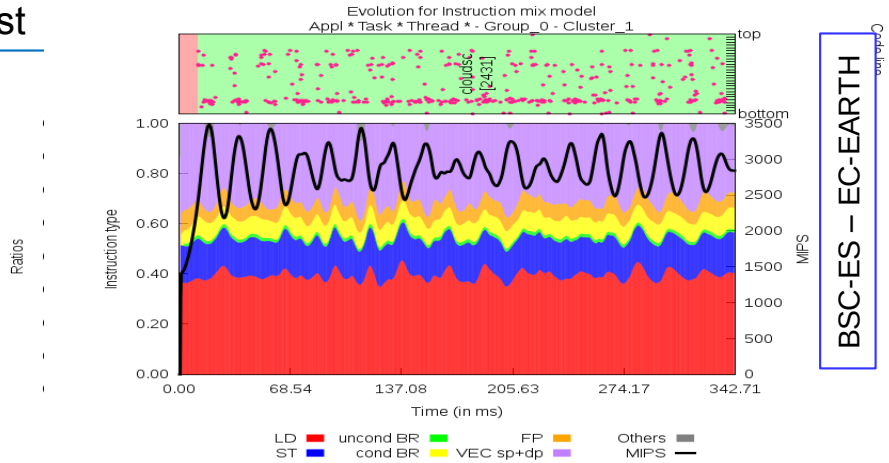
Flexible trace visualization and analysis

Adaptive burst mode tracing

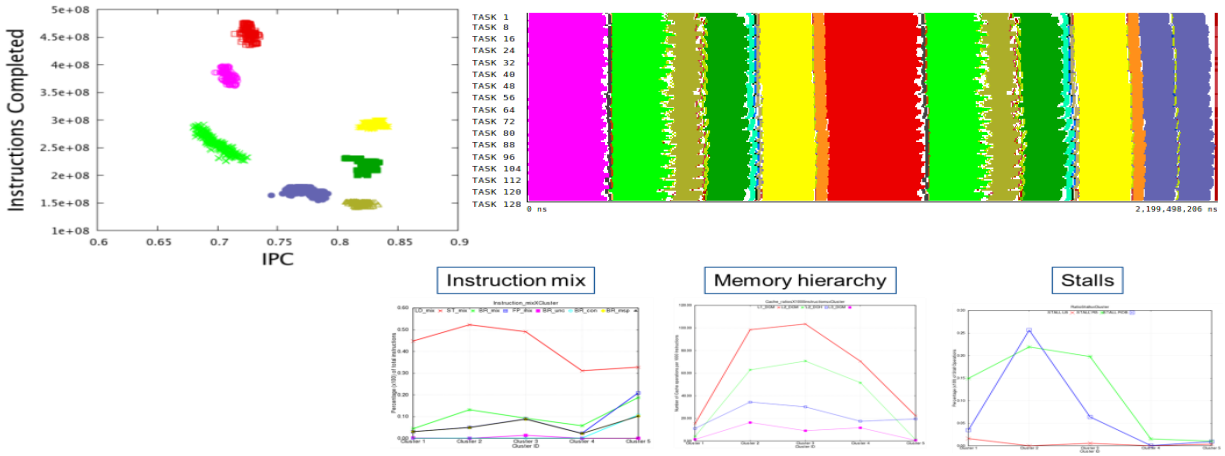


26.7MB trace
Eff: 0.43; LB: 0.52; Comm:0.81

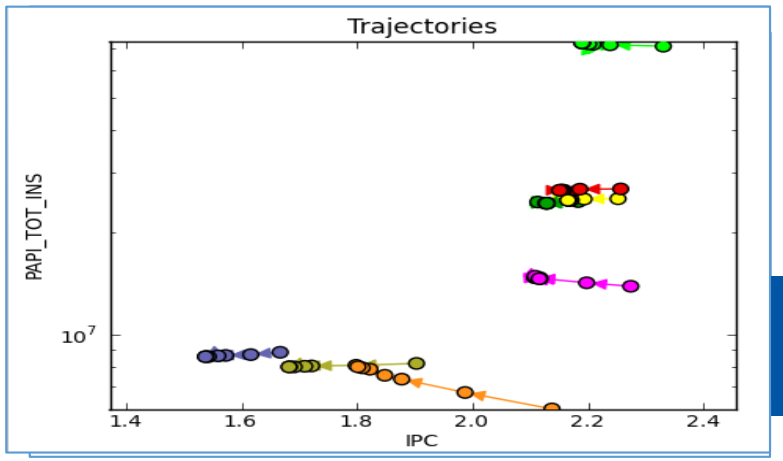
Instantaneous metrics for ALL hardware counters at "no" cost



Advanced clustering algorithms

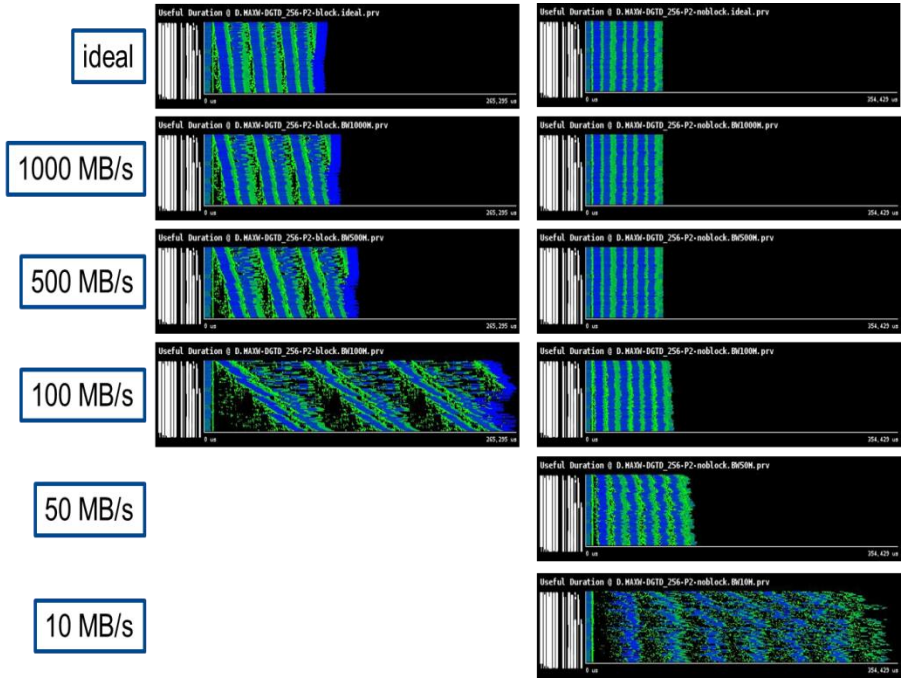


Tracking performance evolution



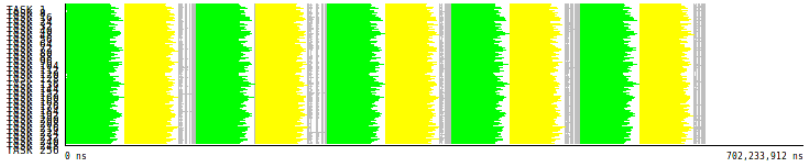
BSC Performance Tools (www.bsc/es/paraver)

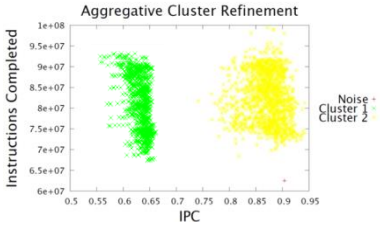
What if



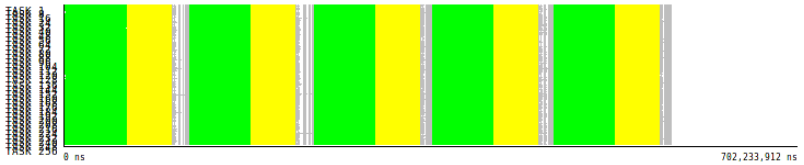
What if …

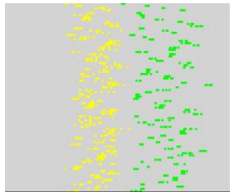
… we increase the IPC of Cluster1?





… we balance Clusters 1 & 2?





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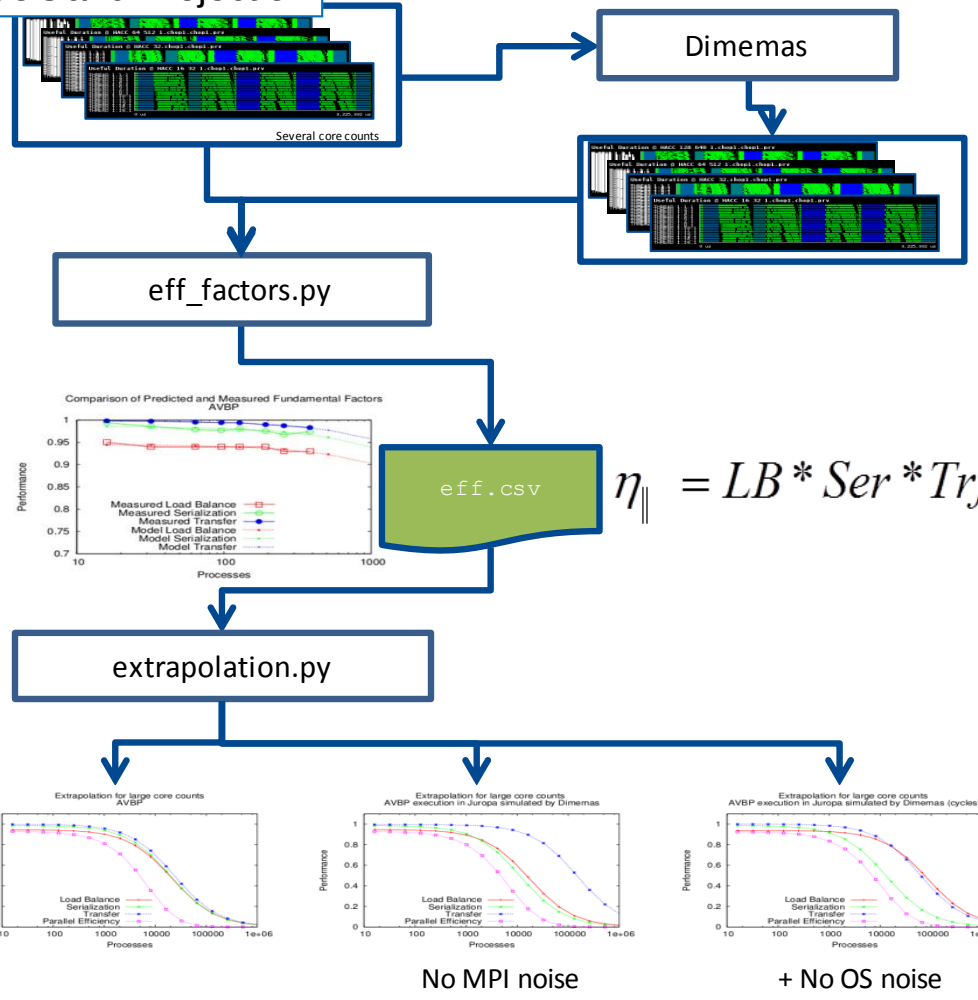
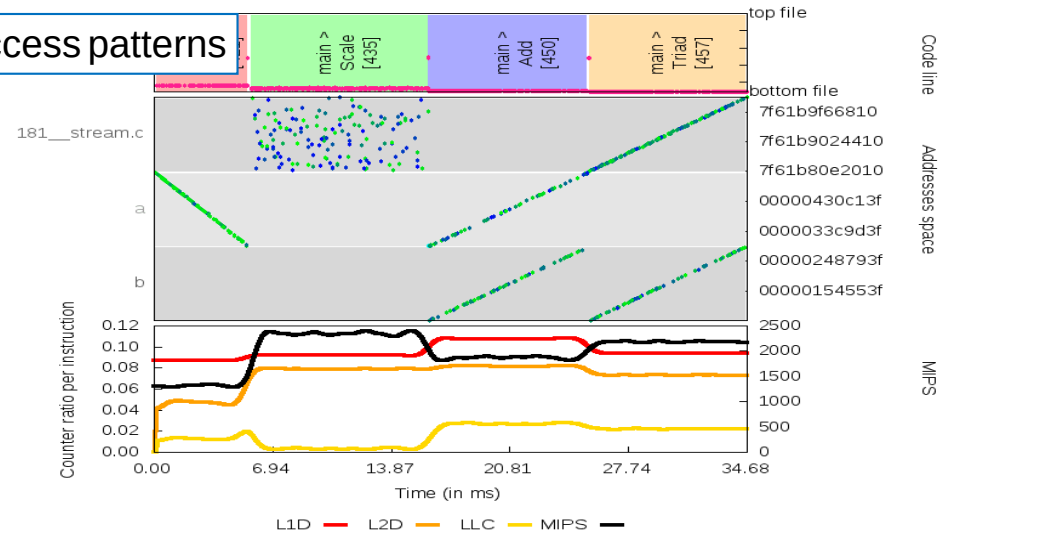
Models and Projection



"Scalability prediction for fundamental performance factors" J. Labarta et al. SuperFRI 2014

Data access patterns



Tareador