The DEEP-ER way of approaching Exascale I/O and resiliency

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NorduGrid Conference 2015

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreements 287530 (DEEP) and 610476 (DEEP-ER)

DEEP and DEEP-ER

EU-Exascale projects
20 partners
Total budget: 28,3 M€
EU-funding: 14,5 M€
Joint duration: 5 years

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www.deep-project.eu

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How to Address the Exascale Challenges?

- Power consumption
- Heterogeneity
- Huge levels of parallelism
- Programmability
- Scalability
- Resiliency
- Exploding data requirements
- Algorithms and application readiness

DEEP/-ER way

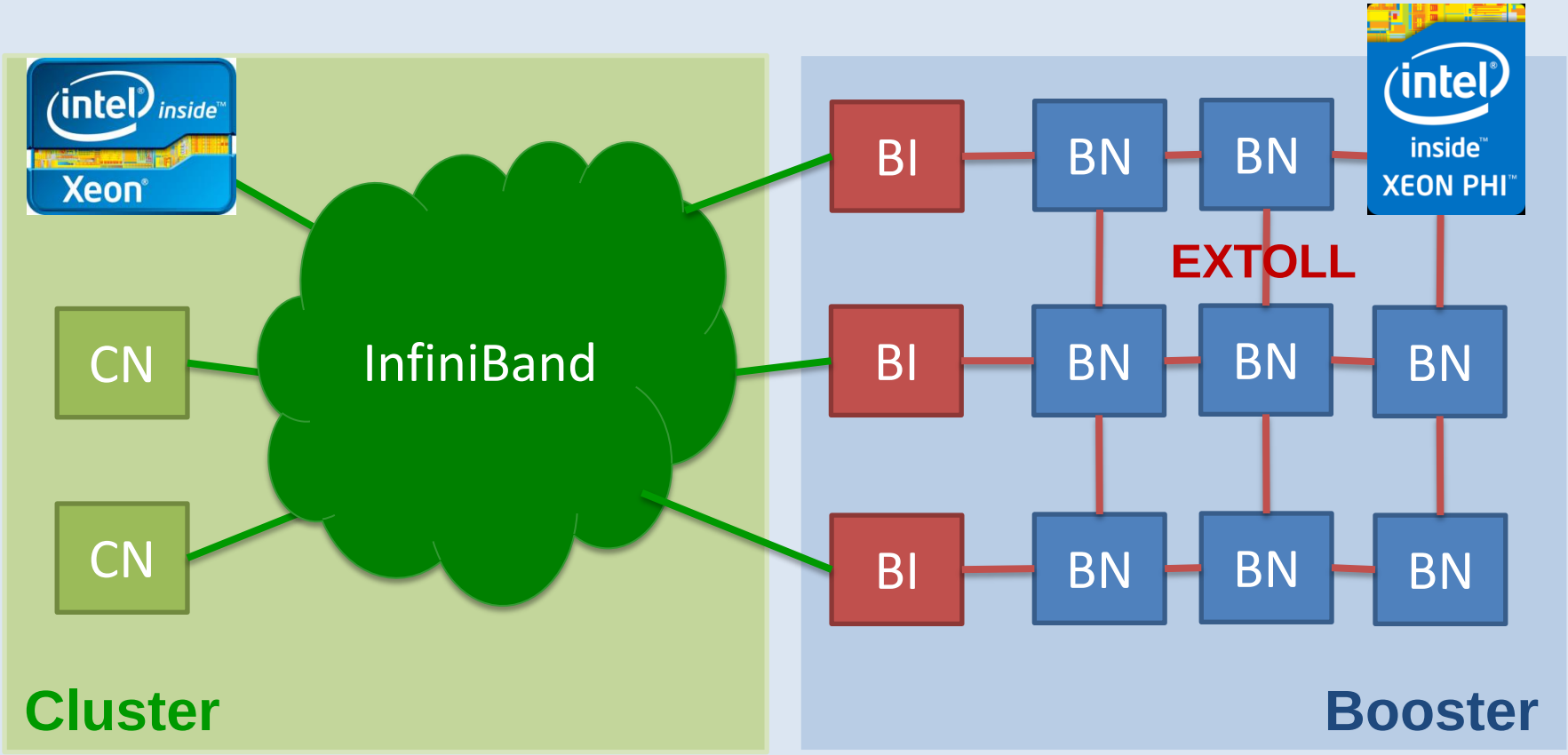
Develop an Exascale architecture tailored to the application requirements

- Match HW characteristics with application scalability patterns
- Exploit benefits of processor heterogeneity
- Profit from new memory technologies
- In an overall energy efficient envelope

reducing burden onto the programmer

- With a complete software stack based on standard components
- Hiding underlying hardware complexity
- Providing a familiar programming environment
- Including tools to analyse and optimise application performance
- Provide I/O and resiliency capabilities for data-intensive apps.

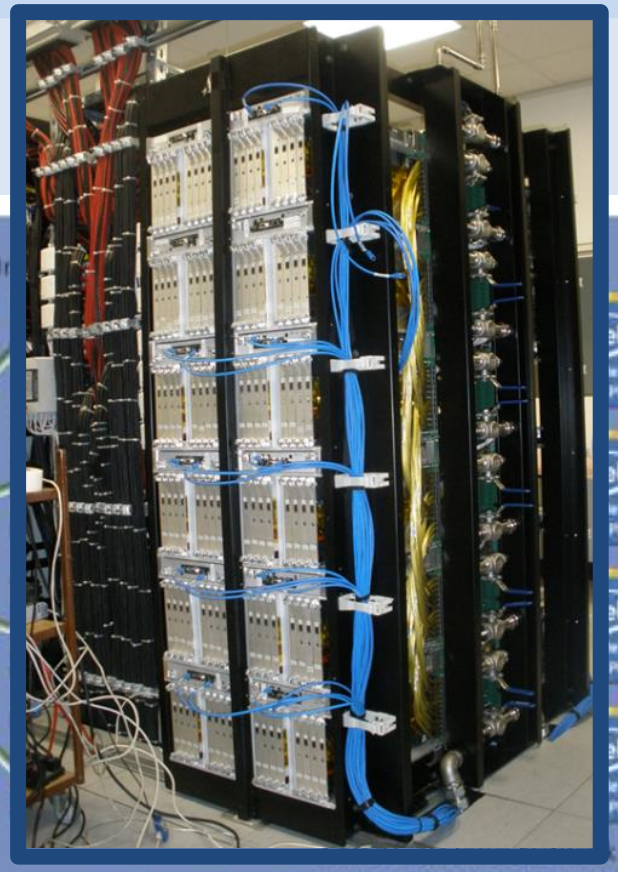
Cluster-Booster architecture



Low/Medium scalable code parts

Highly scalable code parts

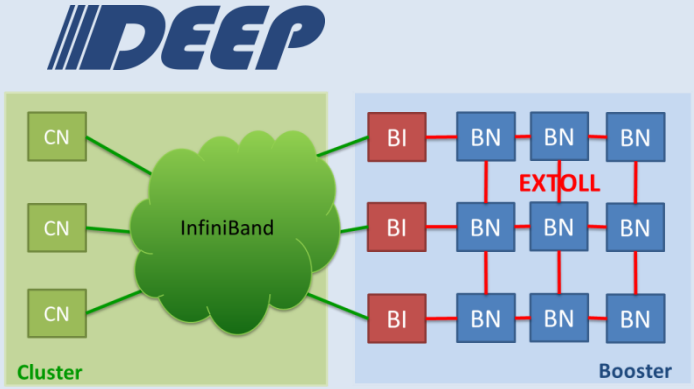
DEEP hardware

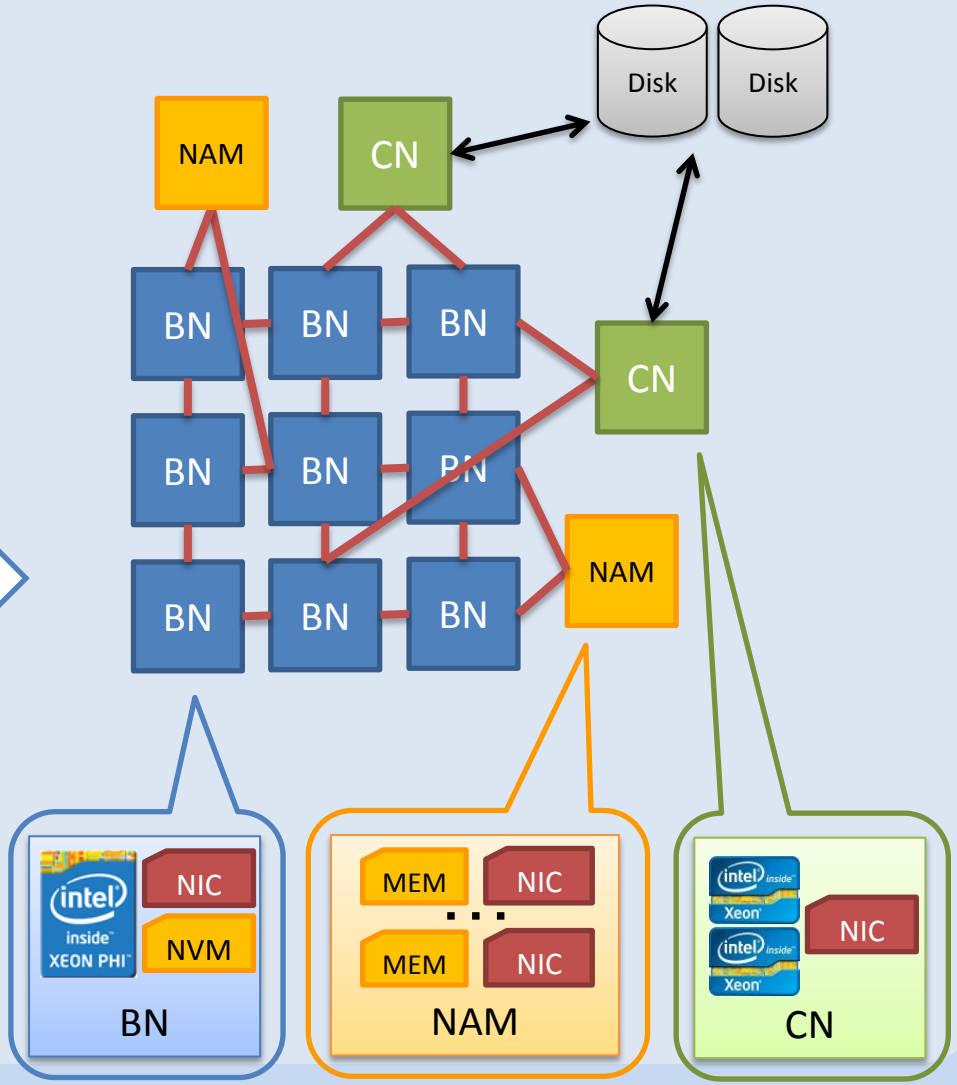


Booster (384 KNC)

Cluster (128 SB)

Enhance DEEP architecture





Legend:

CN: Cluster Node

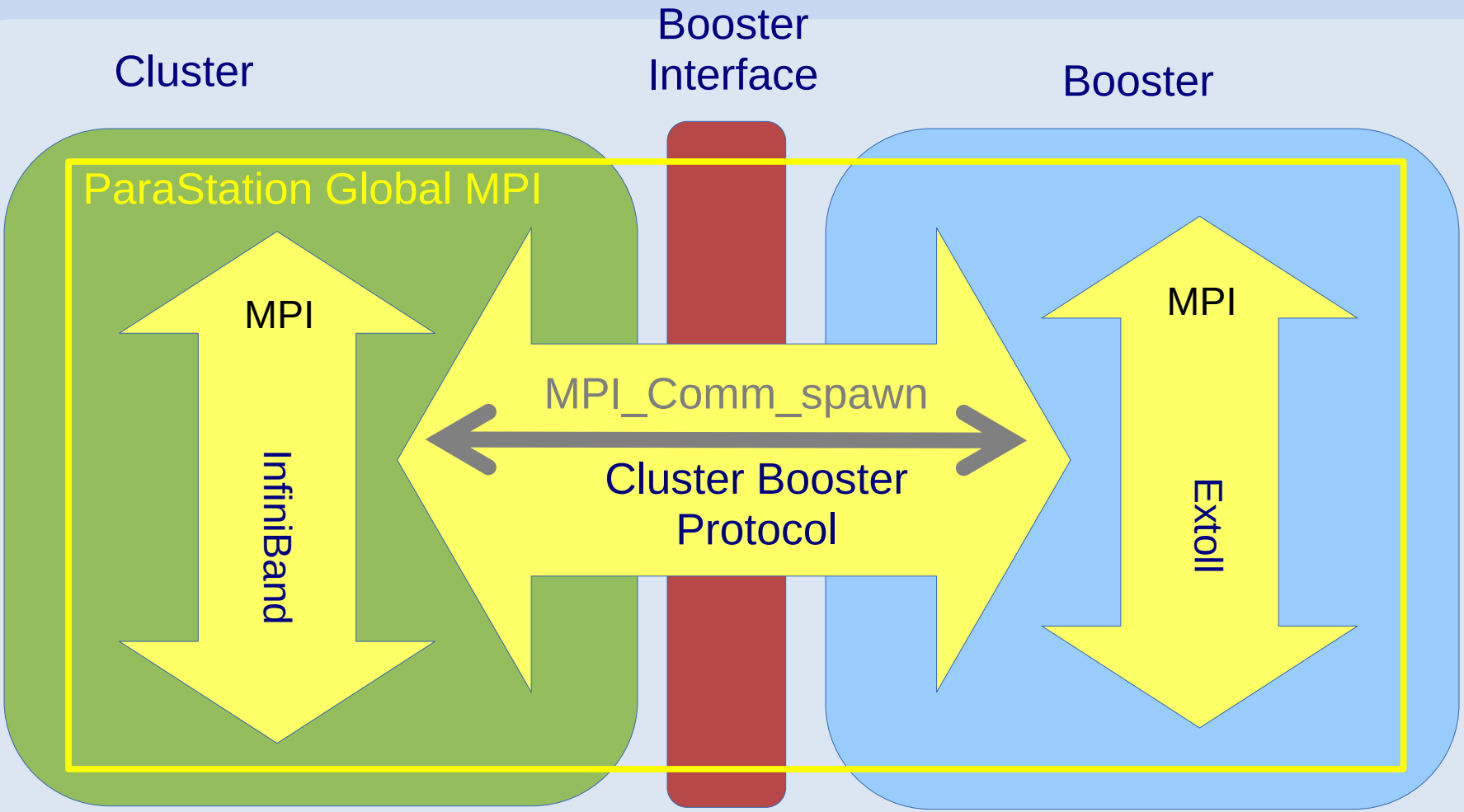
BN: Booster Node

BI: Booster Interface

NAM: Network Attached Memory

NVM: Non Volatile Memory

Programming environment



OmpSs on top of MPI provides pragmas to ease the offload process

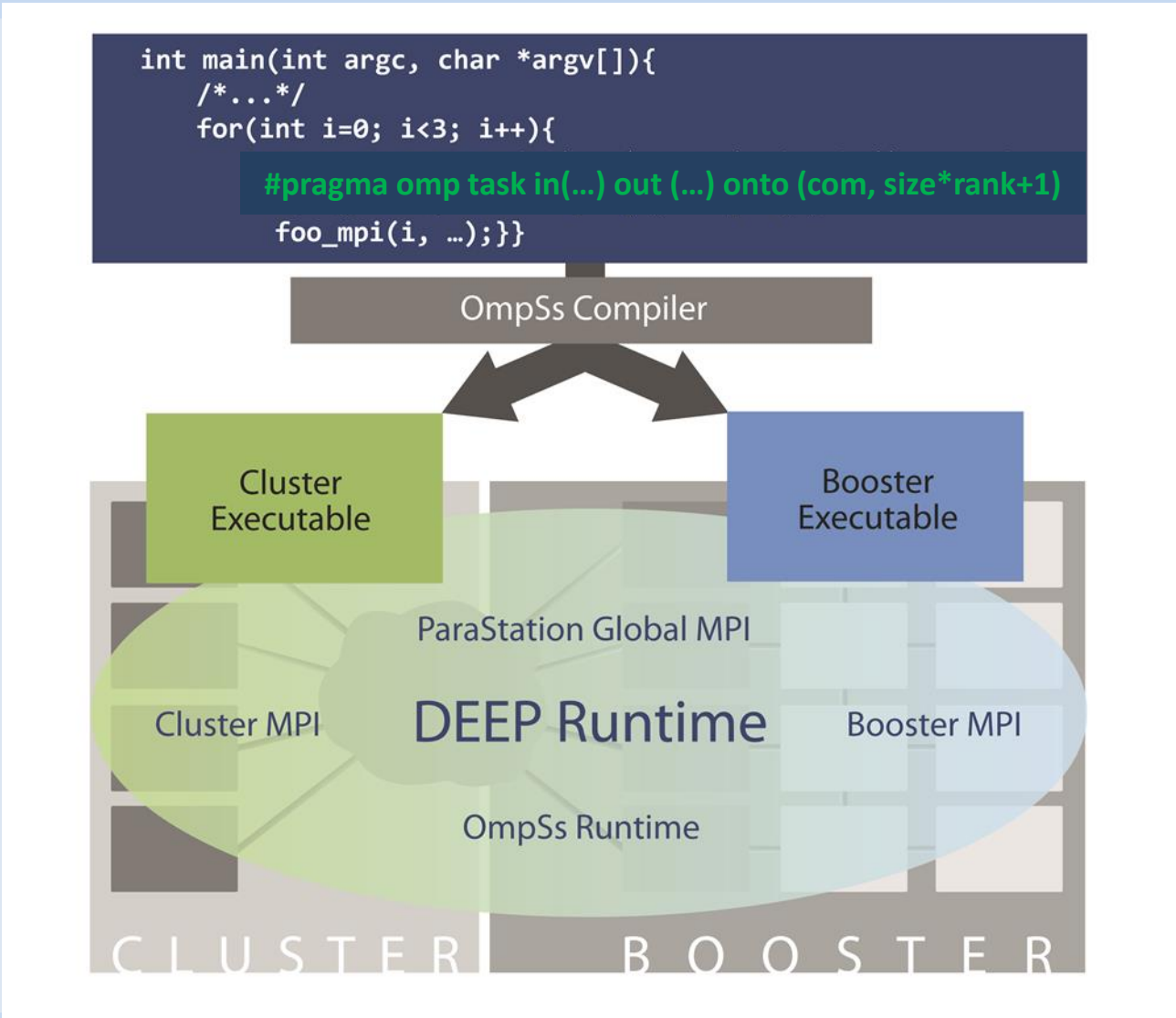
Application running on DEEP/-ER

Source code

Compiler

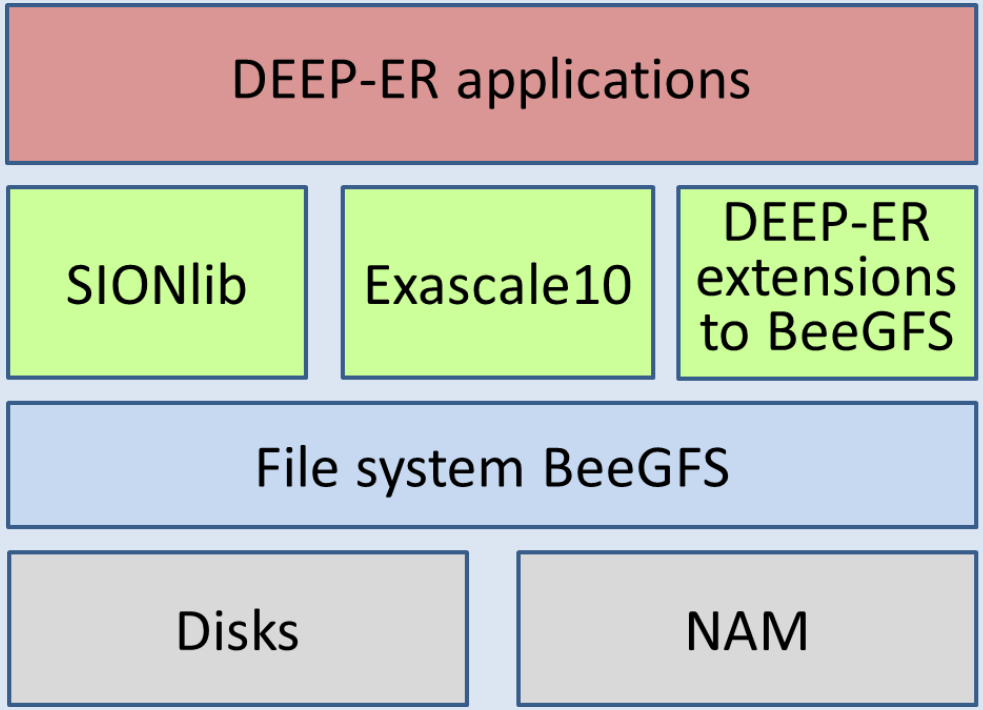
Application binaries

DEEP Runtime



Scalable I/O

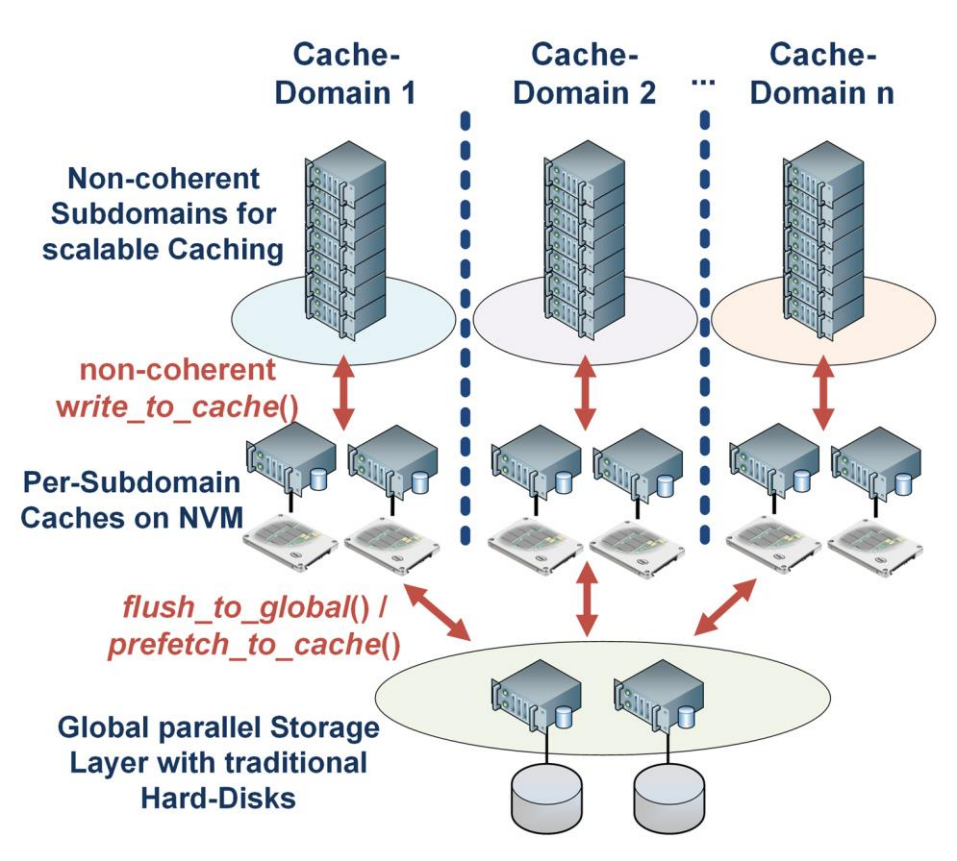
- **Goal: Improve I/O scalability on all usage-levels**
  - BeeGFS leverages architecture and novel memory technologies
  - Extended I/O APIs combine performance with ease of use



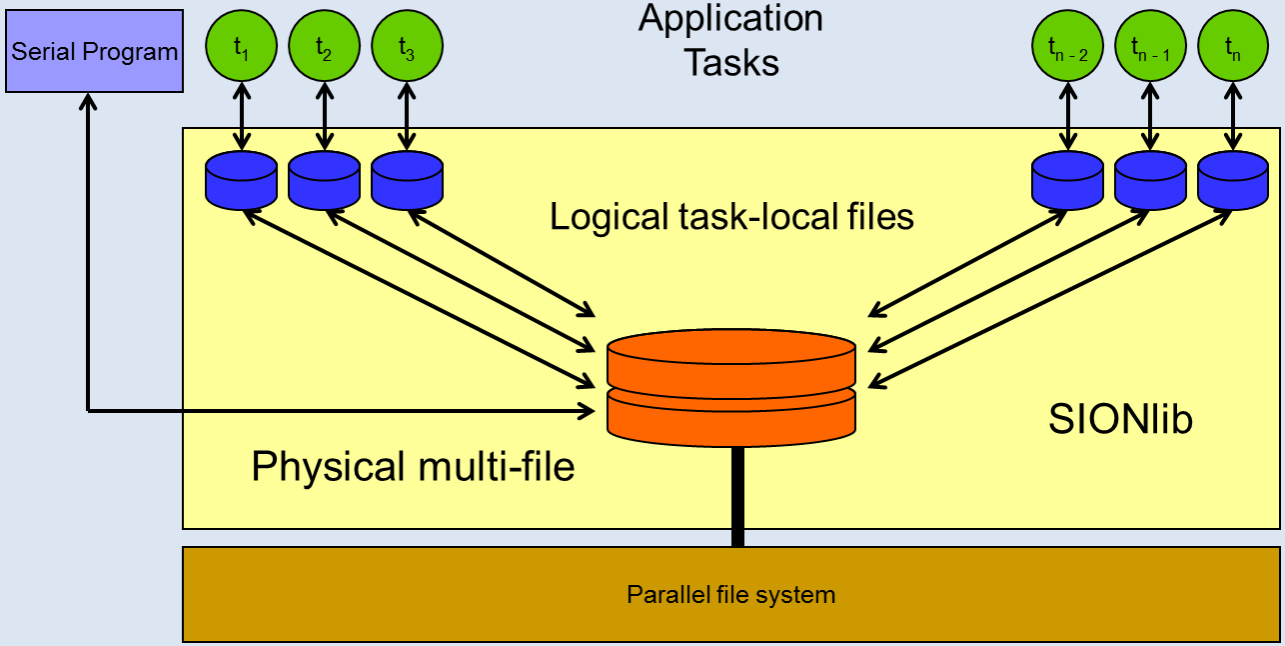
I/O software

BeeGFS® developed by Fraunhofer

- Support underlying hardware
- Two instances:
  - Global FS on HDD server
  - Cache FS on NVM at node
- API for cache domain handling
  - ✓ – Synchronous version implemented
  - WIP – Asynchronous version ongoing
- Functionality to set stripe-size at user-level implemented
  - ✓ – Exploits user knowledge to decide the placement of physical data in the file system
  - ✓ – Co-design request from applications



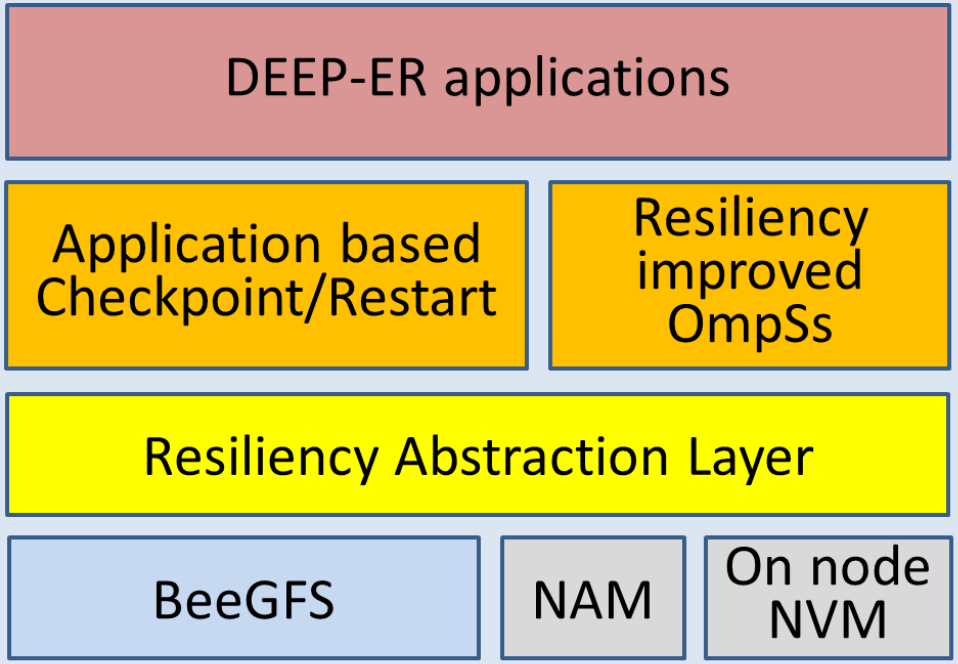
I/O software SIONlib



- Status:
  - ✓ – Restructuration of communication layers
  - ✓ – Used by applications for I/O and checkpointing
  - ✓ – Coordination with SCR for buddy checkpointing
  - WIP – Support BeeGFS cache FS

Resiliency

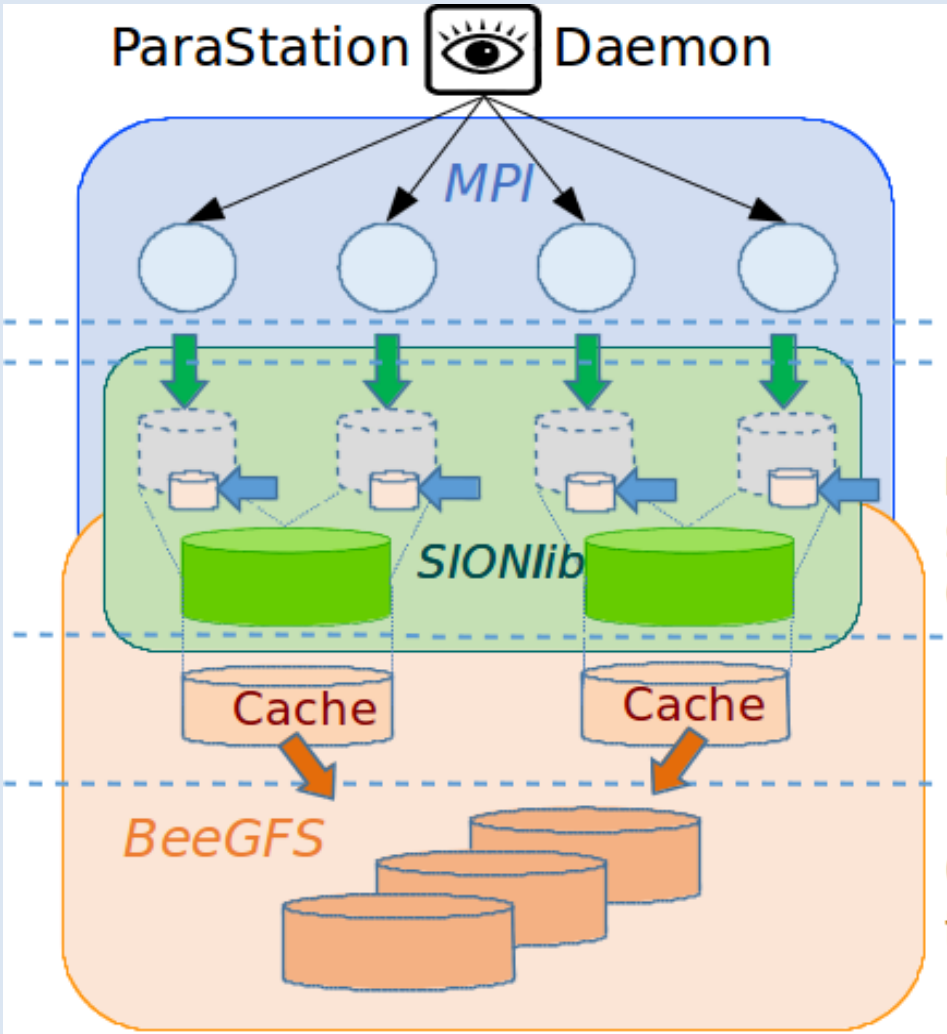
- **Hierarchical, distributed checkpoint/restart scheme**
  - Multi-level checkpointing/restart: NVM, NAM, HDD storage
  - OmpSs extensions for automatic task resiliency



Application-based C/R

- More efficient than transparent system-wide strategies
  - Based on SCR (library developed at LLNL)
- Checkpoint/Restart (C/R) layer will
  - Give application hints on when and where to checkpoint
    - Event-driven Monte Carlo failure model + analytical closed formula
  - Hide meta-data handling from user
- Combine local and global strategies
  - High frequency of local checkpoints
  - Intermediate frequency of buddy checkpoints → use SIONlib and BeeGFS
  - Low frequency of global FS checkpoint → use SIONlib and BeeGFS
- Explore the use of new memory technologies (NAM)

Checkpointing
Integration SCR/SIONlib/BeeGFS



Compute Nodes

CP-Framework API

SIONlib / sion_fwrite()
(node-local I/O view)

Local Buddy Checkpoints

Shared SIONlib Files
(one per BeeGFS Cache Domain)

Non-coherent write()

BeeGFS Cache Domains

BeeGFS API / flush()

Global Storage with traditional Hard-disks

Task-based C/R

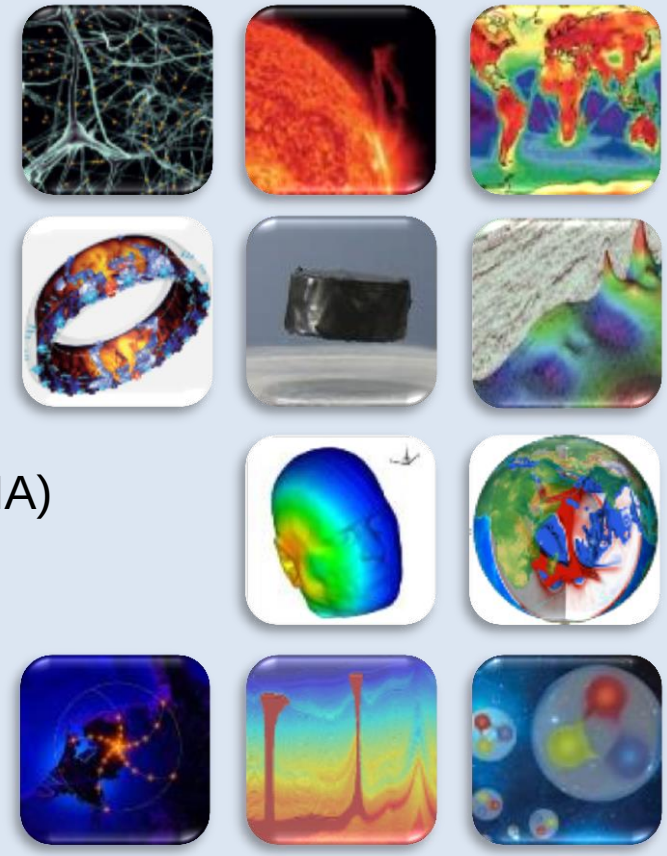
Implemented on:

- Straightforward idea:
  - Save the inputs of the task before running it
  - In case of failure, re-execute the task with the original inputs
- Task-based resiliency provides:
  - A **transparent, fine grained** and **lightweight** protection against **transient errors**
  - Recovers from remote task offloads
- Status:
  - ✓ Design completed
  - WIP – Implementation ongoing
  - WIP – Investigation ongoing on integration with both ParaStation MPI and SCR

Applications

DEEP + DEEP-ER applications

- Brain simulation (EPFL)
- Space weather simulation (KULeuven)
- Climate simulation (CYI)
- Computational fluid engineering (CERFACS)
- High temperature superconductivity (CINECA)
- Seismic imaging (CGG)
- Human exposure to electromagnetic fields (INRIA)
- Geoscience (BADW-LRZ)
- Radio astronomy (Astron)
- Oil exploration (BSC)
- Lattice QCD (UREG)



Goals

- Gather requirements for co-design
- Evaluation of DEEP/-ER architecture and programmability

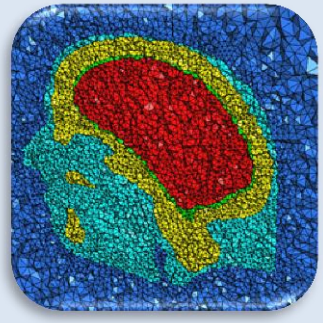
Inria

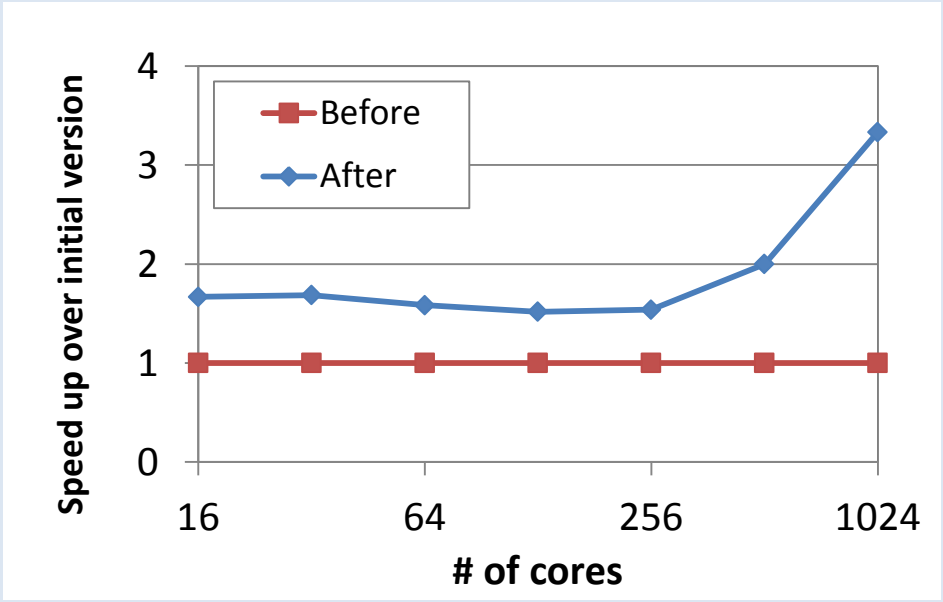
Results will be presented at PARCO2015*

Improvements applied below:

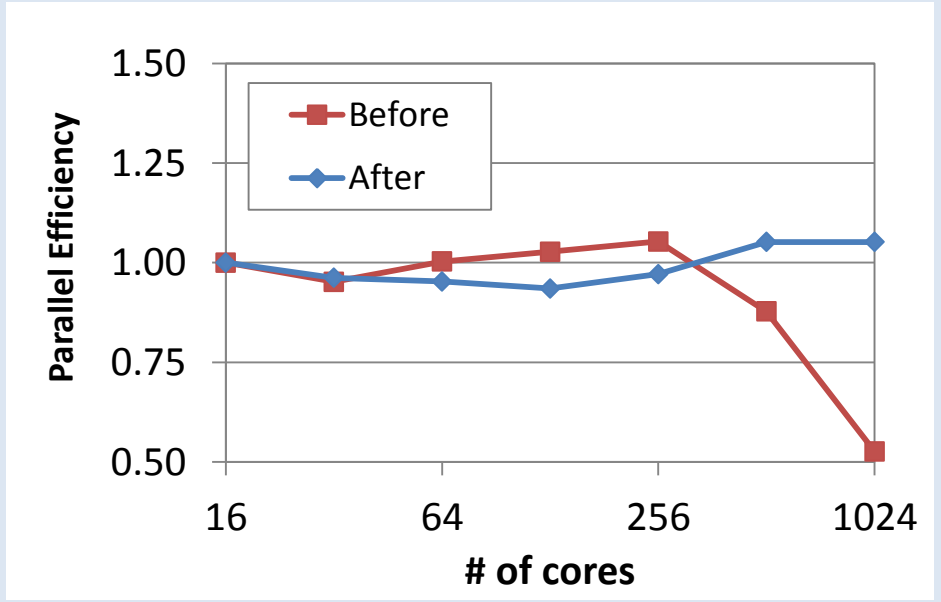
- Non-blocking communication
- Renumbering scheme
- Vectorisation and locality

Setup:
- Human head
- DEEP Cluster
- Mesh: 1.8 million cells
- 16 processes per node
- Pure MPI.
- P1 approximation.





Performance improvement up to 3.3x

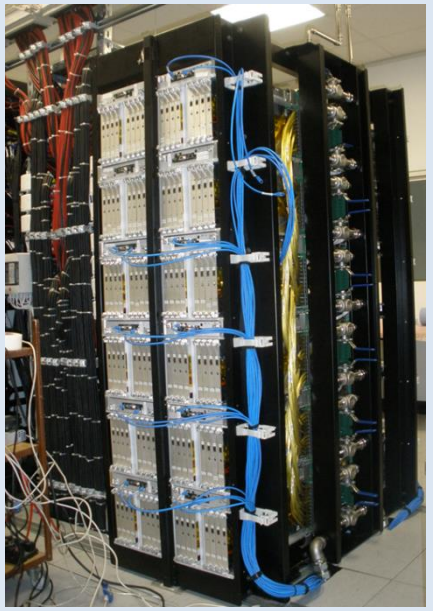


Almost perfect parallel efficiency now

*Leger R., Alvarez Mallon D., Duran A., Lanteri S., "Assessing the DEEP-ER Cluster/Booster Architecture with a fine-element type solver for bioelectromagnetics", Submitted to PARCO2015, Contribution ID: 25. www.parco2015.org

DEEP Status (M42)

- **Hardware status:**
  - DEEP Cluster (@JSC) → Applications work
  - Full Booster (384 KNCs) → in bring-up
  - Energy Efficiency Evaluator (16 KNCs) (@LRZ)
  - ASIC Evaluator (32 KNCs)→ under installation
- **Software status:**
  - Development completed
  - Installation on first Booster Chassis done
  - Tuning and optimization ongoing
- **Scientific Applications:**
  - Optimised and benchmarked in several platforms
  - Demonstration on DEEP Booster will start now



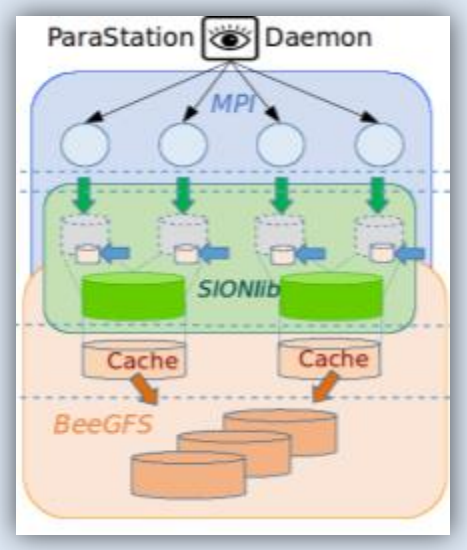
Booster

ASIC Evaluator

DEEP-ER Status (M18)

- **Hardware status:**
  - Overall design finished
  - Prototype under development
  - NAM in development
  - NVM good performance with applications
- **Software status:**
  - Programming environment from DEEP
  - Being extended for I/O and resiliency
    - I/O: BeeGFS, SIONlib, Exascale10
    - SCR, task-based resiliency, failure model
- **Scientific Applications:**
  - Applications analysed, various optimisations done
  - I/O and checkpointing strategies identified

On-node NVM
(Intel DC P3700)



Buddy checkpointing

Take-aways

- **DEEP**: Develop the Cluster-Booster architecture
  - Handles heterogeneity in an innovate way
  - Maps application (scalability) characteristics onto hardware
  - Easy-to-use and familiar programming environment
- **DEEP-ER**: addresses I/O and resiliency
  - Explores new memory technologies
  - Develops scalable I/O strategies
  - Resiliency strategies:
    - Multi-level checkpoint/restart
    - Task-based resiliency
- Using a high variety of applications for co-design and demonstration

Want to know more?

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The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n° 287530 and n° 610476

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