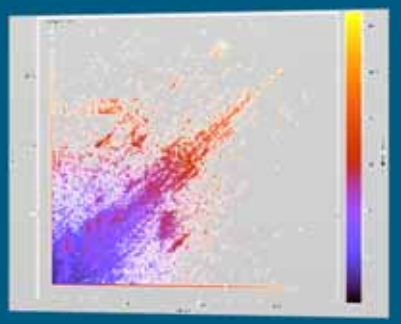
JÜLICH
FORSCHUNGSZENTRUM

I/O Monitoring at JSC, SIONlib & Resiliency

- → Update: I/O Infrastructure @ JSC
- → Update: Monitoring with LLview (I/O, Memory, Load)
- → I/O Workloads on Jureca
- → SIONlib: Task-Local I/O & Buddy Checkpointing



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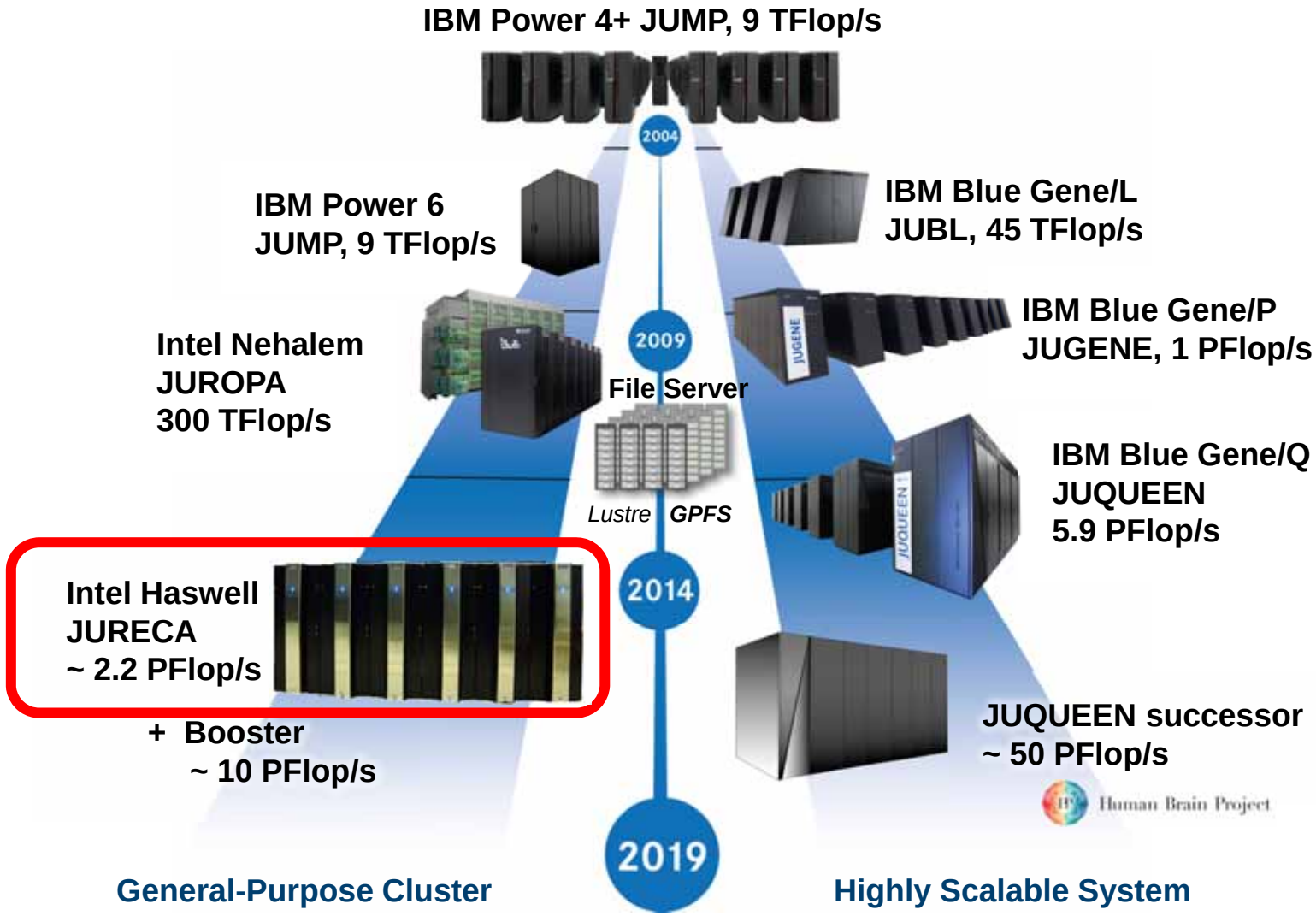
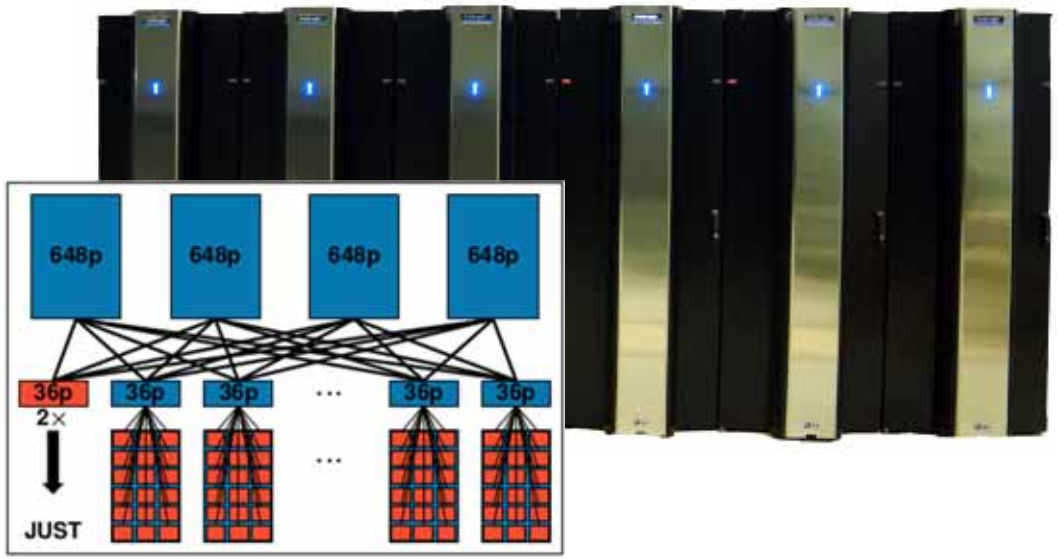
HPC I/O in the Data Center (HPC-IODC), ISC, Frankfurt, June 23th, 2016

HPC Systems @ JSC: Dual Architecture Strategy



JURECA: Jülich Research on Exascale Cluster Architectures

- 2 Intel Haswell 12-core processors, 2.5 GHz, SMT, 128 GB main memory
- **1,884 compute nodes** or 45,216 cores, thereof
  - 75 nodes with 2 K80 NVIDIA graphics cards each and
  - 12 nodes with 512 GB main memory and 2 K40 NVIDIA graphics cards each for visualization
- 2.245 Petaflop/s peak (with K80 graphics cards)
- 1.425 Petaflop/s Linpack from CPUs (out of 1,693 Petaflop/s peak)
- **281 TByte memory**
- Mellanox Infiniband EDR
- Connected to the **GPFS** file system on **JUST** via IB FDR/40GigE gateway switches



Parallel I/O Hardware at JSC (Just4, GSS)

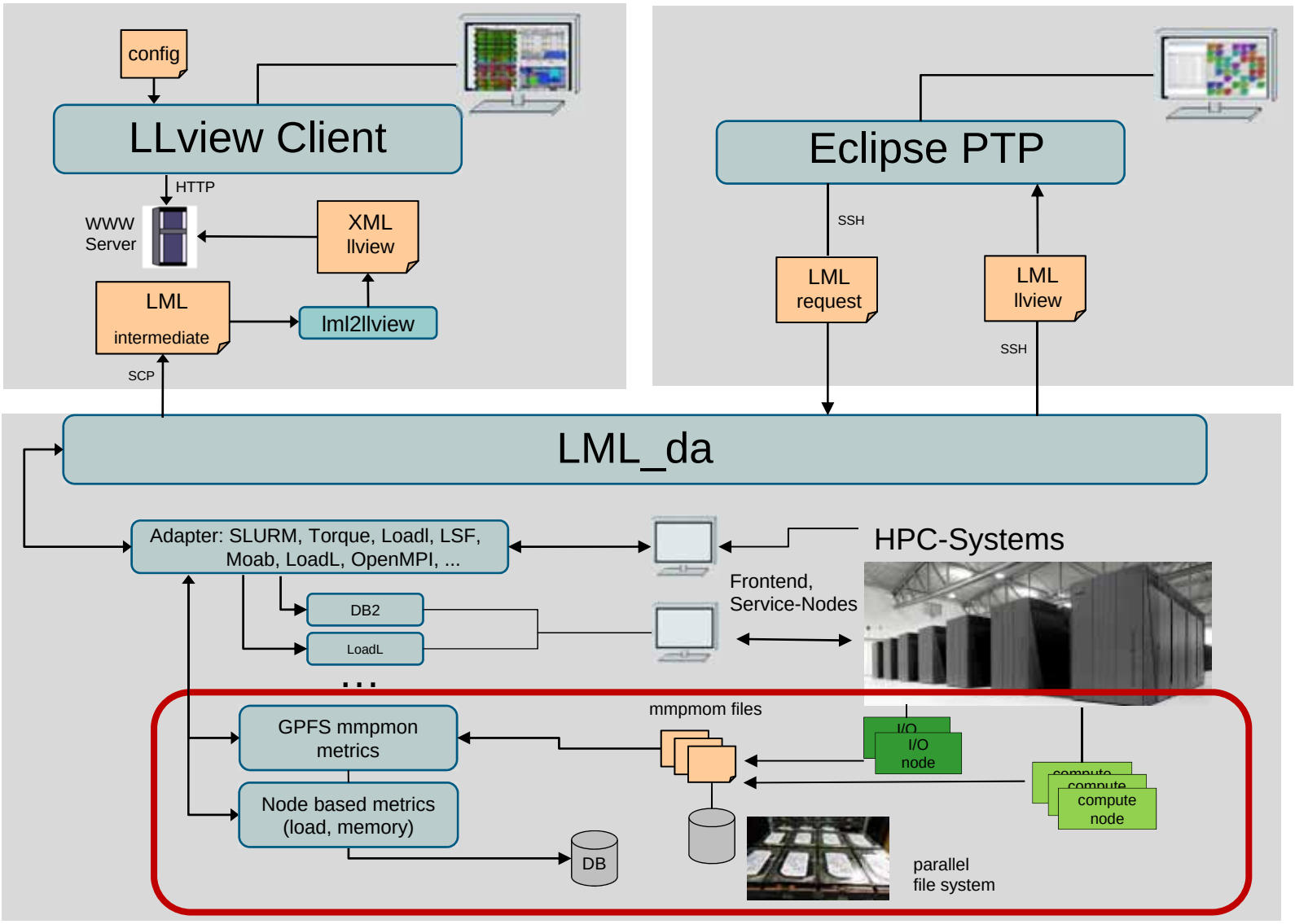
- **Ju**elich **St**orage Cluster (JUST)
  - GPFS Storage Server (GSS/ESS)
  - End-to-End integrity
  - Fast rebuild time on disk replacement
  - GPFS + TSM Backup + HSM
  - → JUQUEEN, JURECA, …
- **Just4-GSS**
  - Capacity: **20.3 Pbyte**
    I/O Bandwidth: up to **220 GB/sec**
  - Hardware: IBM System x® GPFS™ Storage Server solution, GPFS Native RAID
  - 31 Building blocks: each 2 x X3650 M4 server, 232 NL-SAS disks (2TB), 6 SSD

LLview: User-level Monitoring

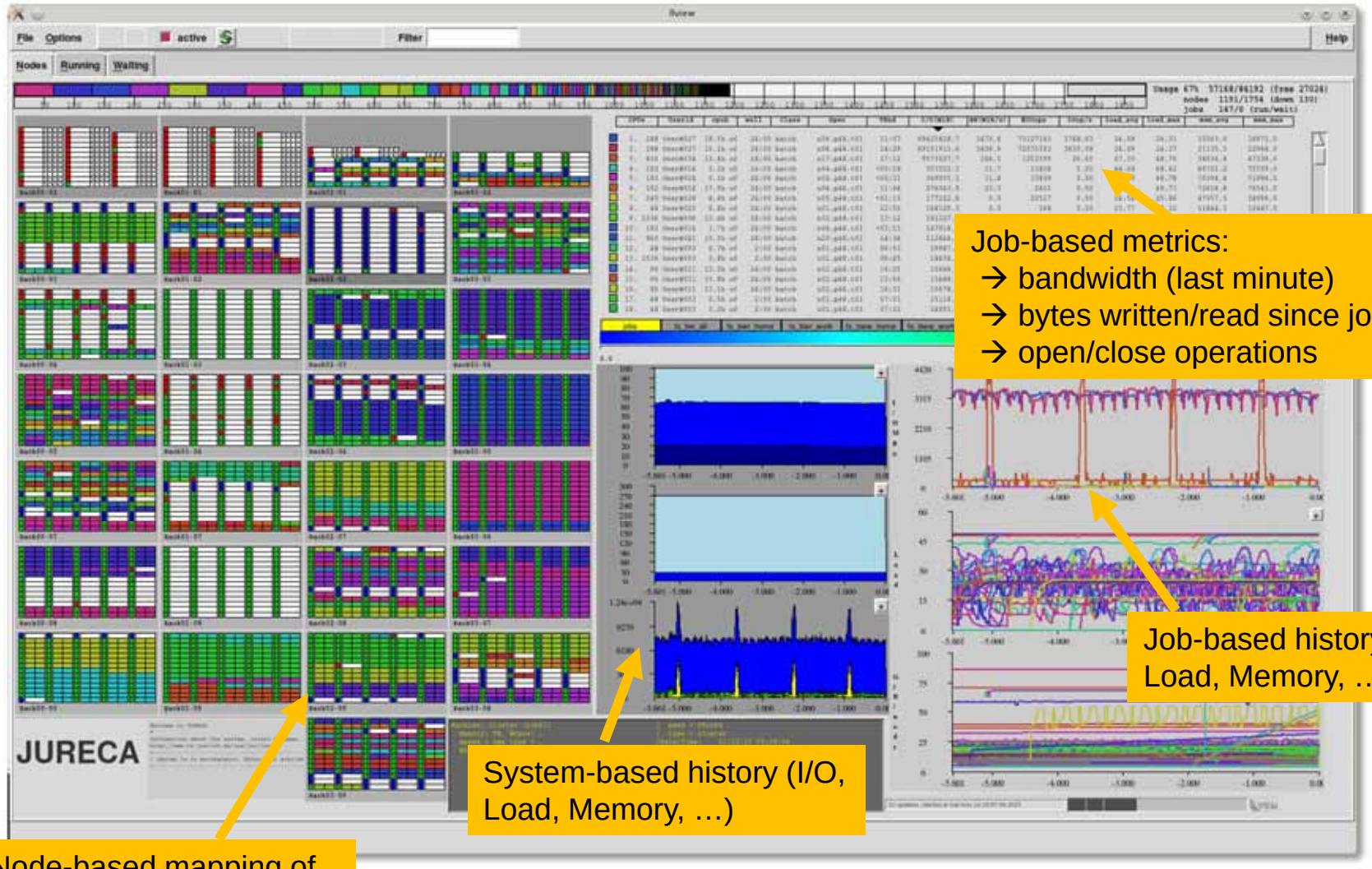
- Efficient supervision of node usage, running jobs, statistics, history
- Prediction of system usage
- Monitoring of energy consumption, load, memory usage, I/O usage
- Interactive and mouse-sensitive
- Main data source: batch scheduler, runtime system
- No interaction with compute nodes
- Fully customizable, fast and portable client-server application
- Integrated into Eclipse/PTP
- Support for various resource manager, incl. LoadLeveler, IBM Blue Gene, Cray ALPS, PBSpro, Torque, SLURM, Grid Engine and LSF

LLview download: (open source)
http://www.fz-juelich.de/jsc/llview

LLview Architecture & I/O monitoring



LLview: Node & File System Metrics



Job-based metrics:
→ bandwidth (last minute)
→ bytes written/read since job start
→ open/close operations

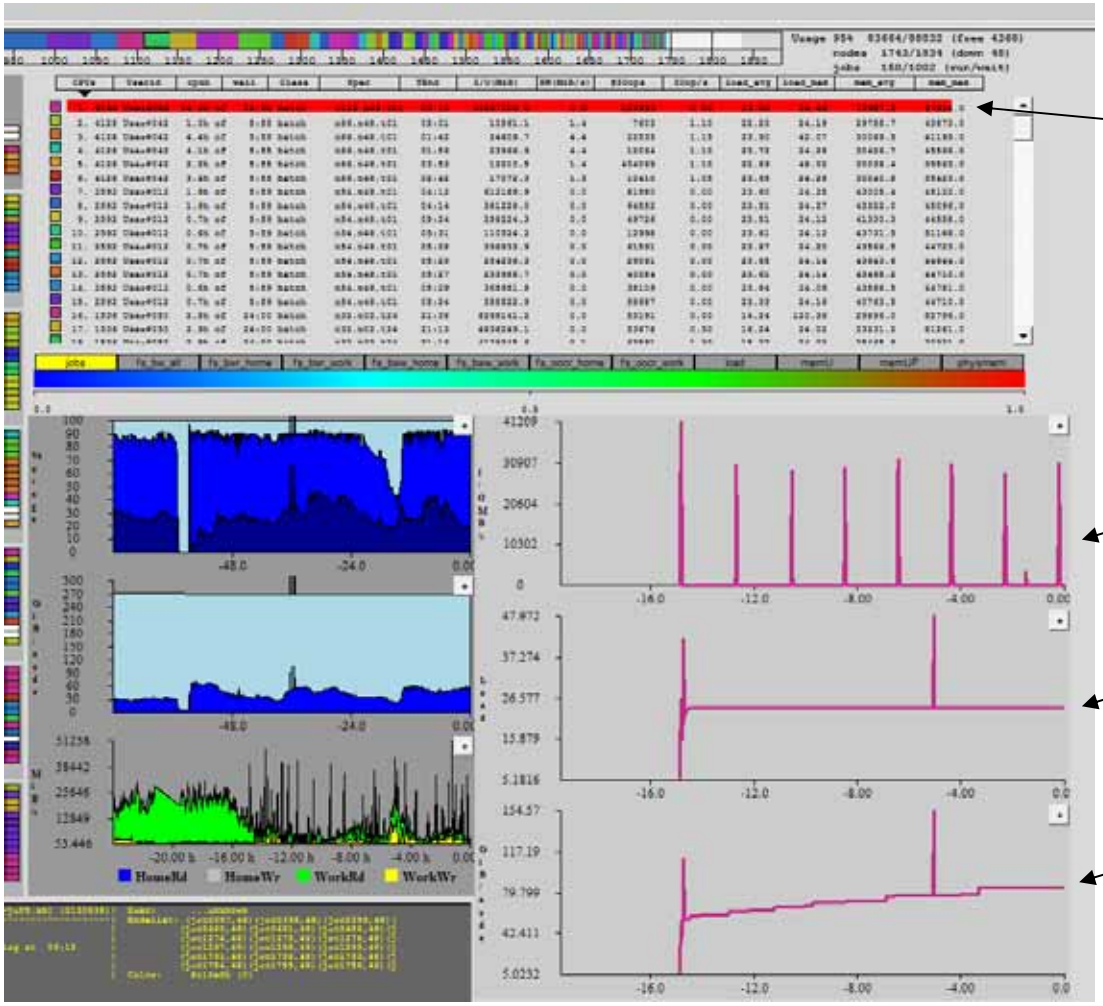
Job-based history (I/O, Load, Memory, …)

System-based history (I/O, Load, Memory, …)

Node-based mapping of I/O load (color-coded)

LLview: Node & File System Metrics

- Job-based monitoring



selected job:
- using 86 nodes
- transferring ~ 31 TiB

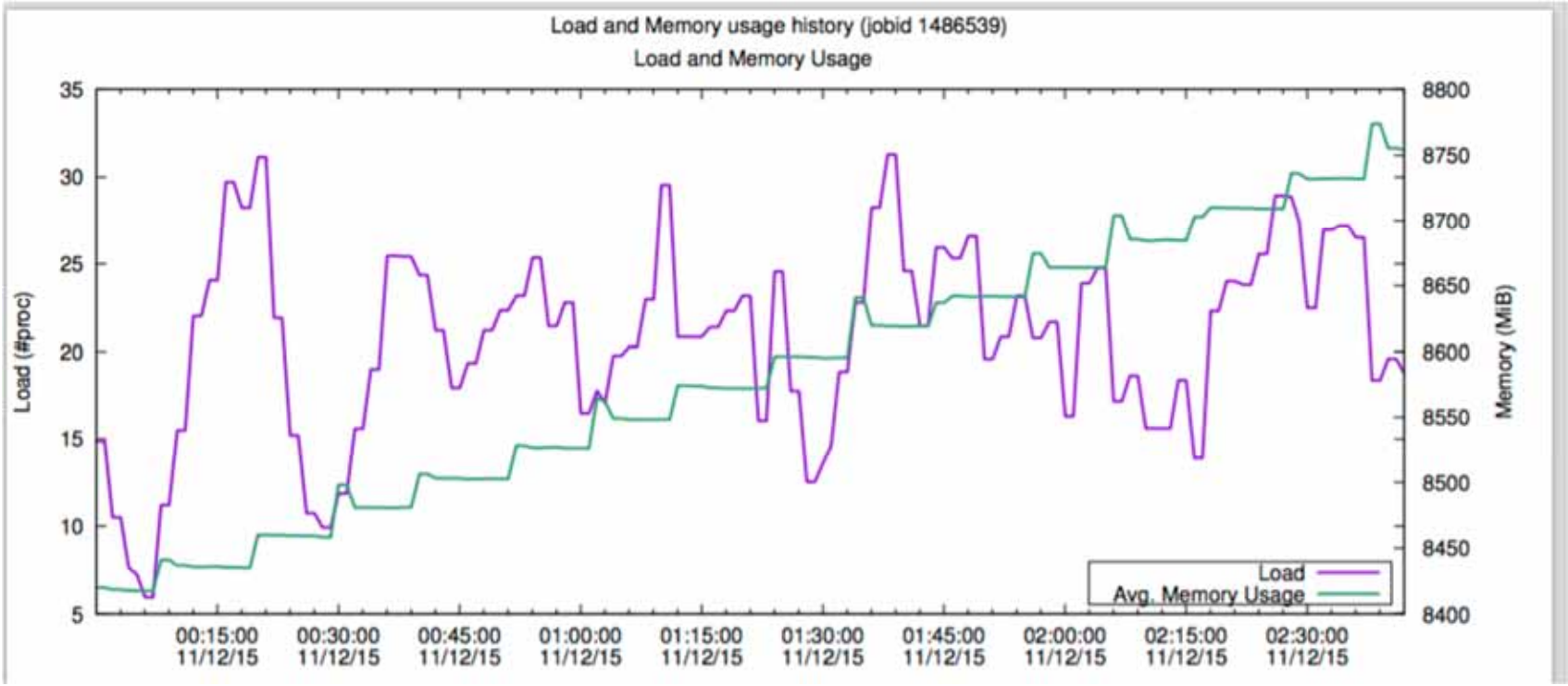
I/O activity of application

avg. load per node

avg. memory usage per node

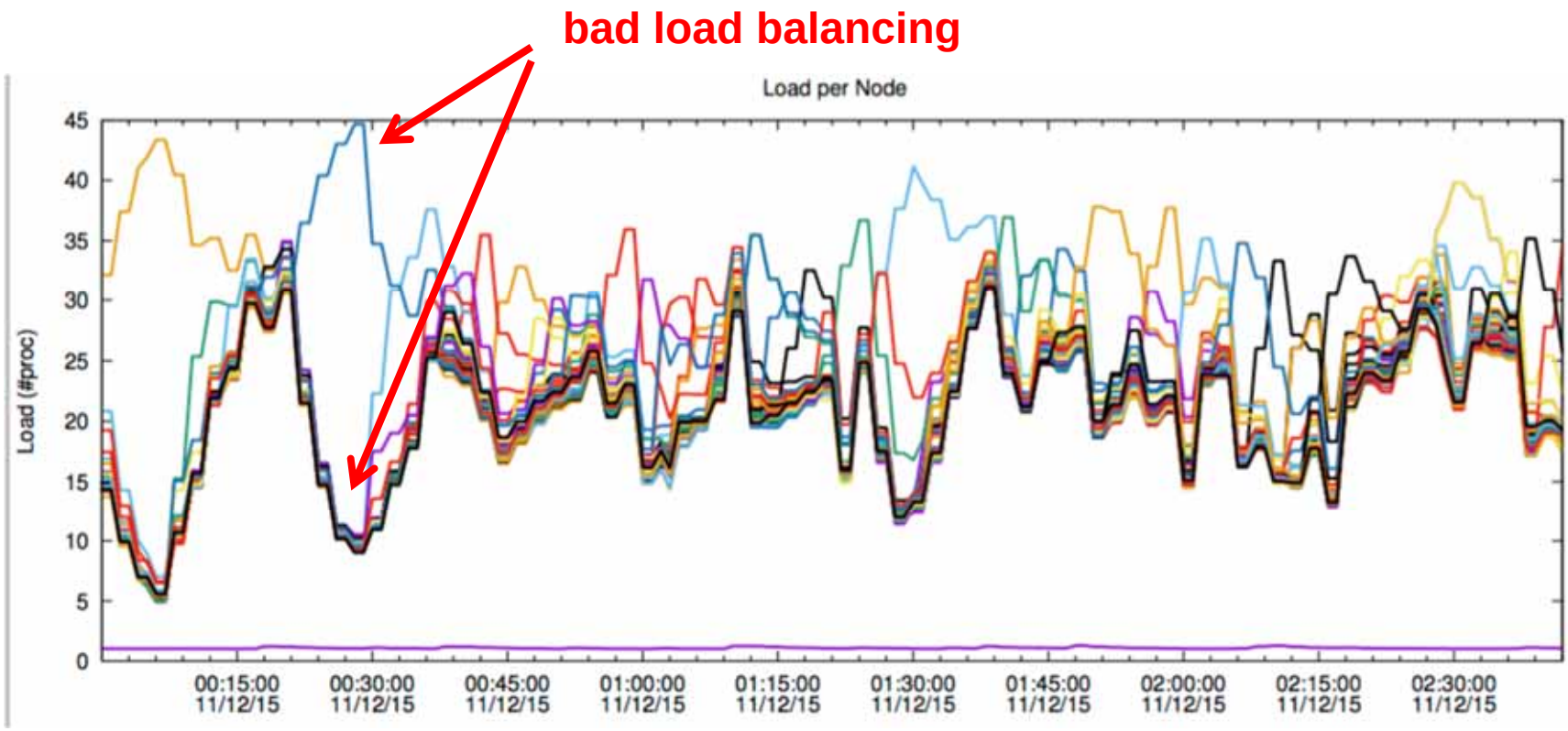
LLview: Offline Analysis
Accumulated Information – load & mem

Slight increase over time -> memory leak?
Load fluctuates -> why?



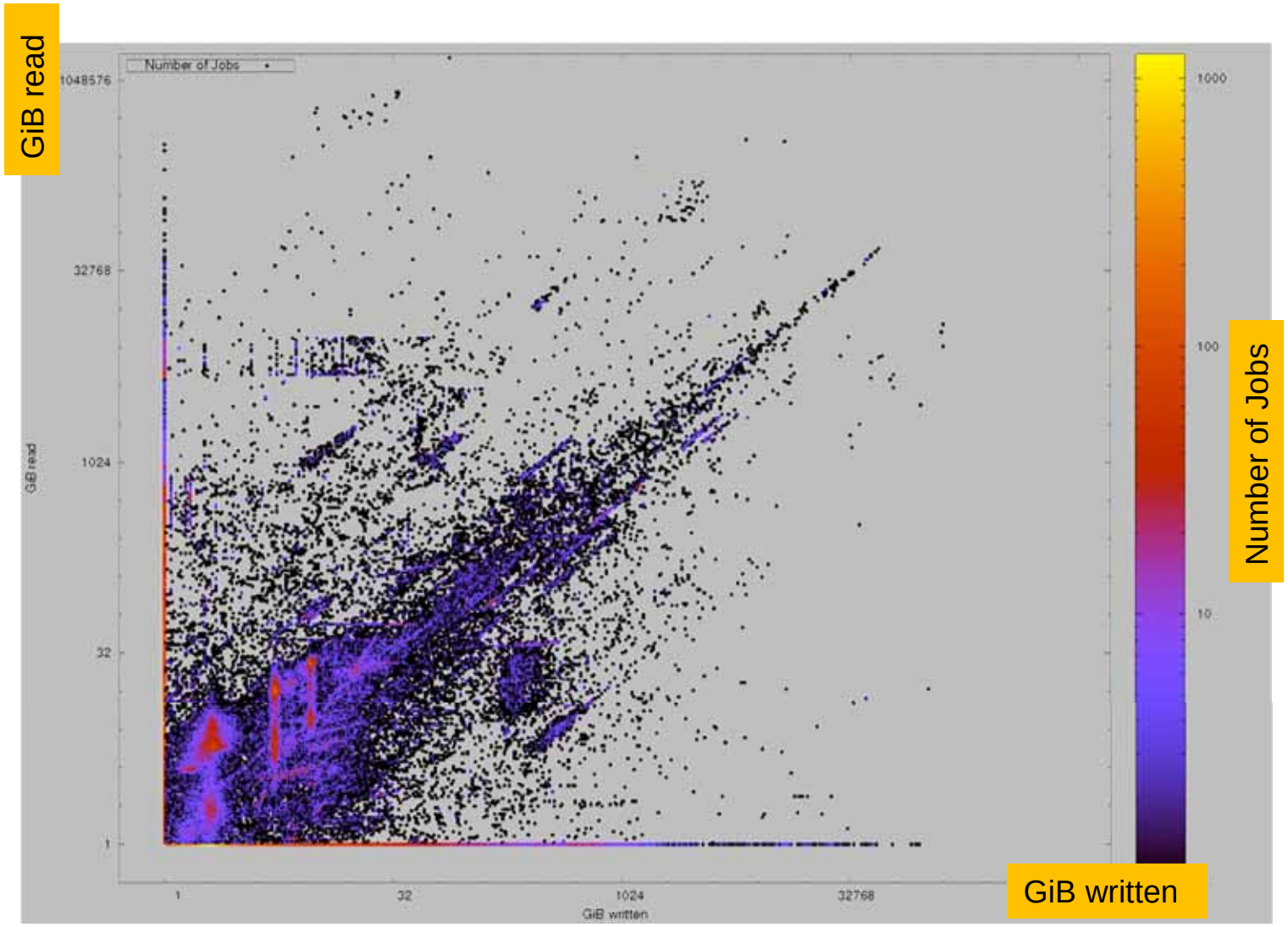
ODE for ~20.000 components , rhs distributed over 64 nodes

LLview: Offline Analysis
Node-specific information - load



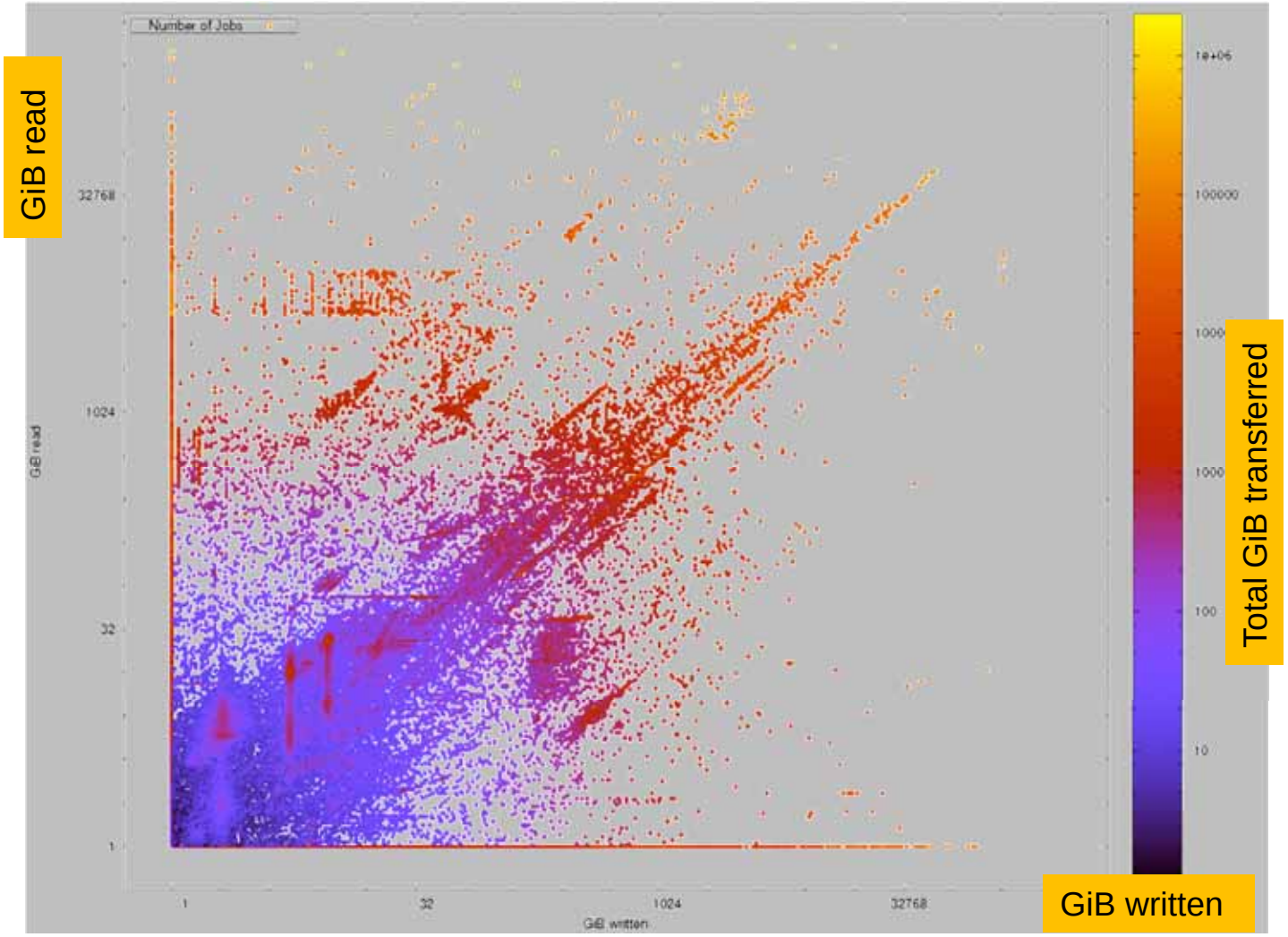
ODE for ~20.000 components , rhs distributed over 64 nodes

I/O Workload Analysis: number of jobs



Example: number of jobs

I/O Workload Analysis: transfer size



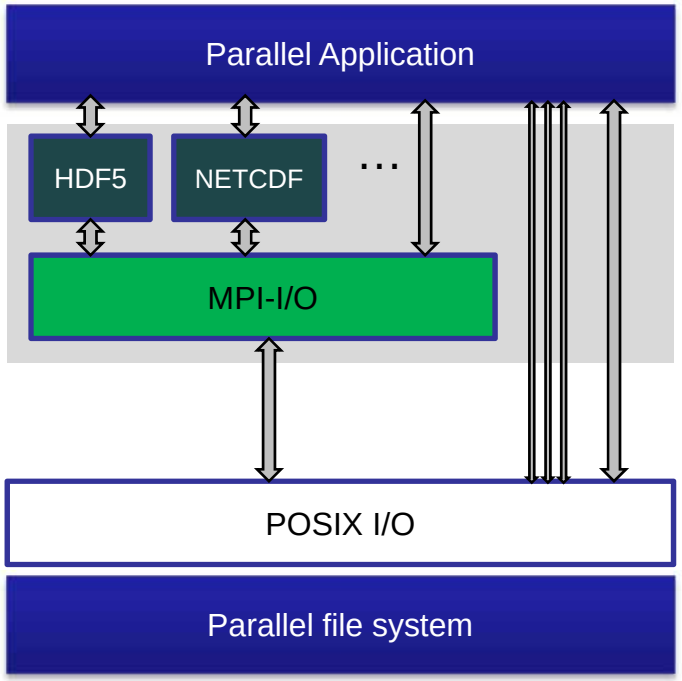
Example: transfer size

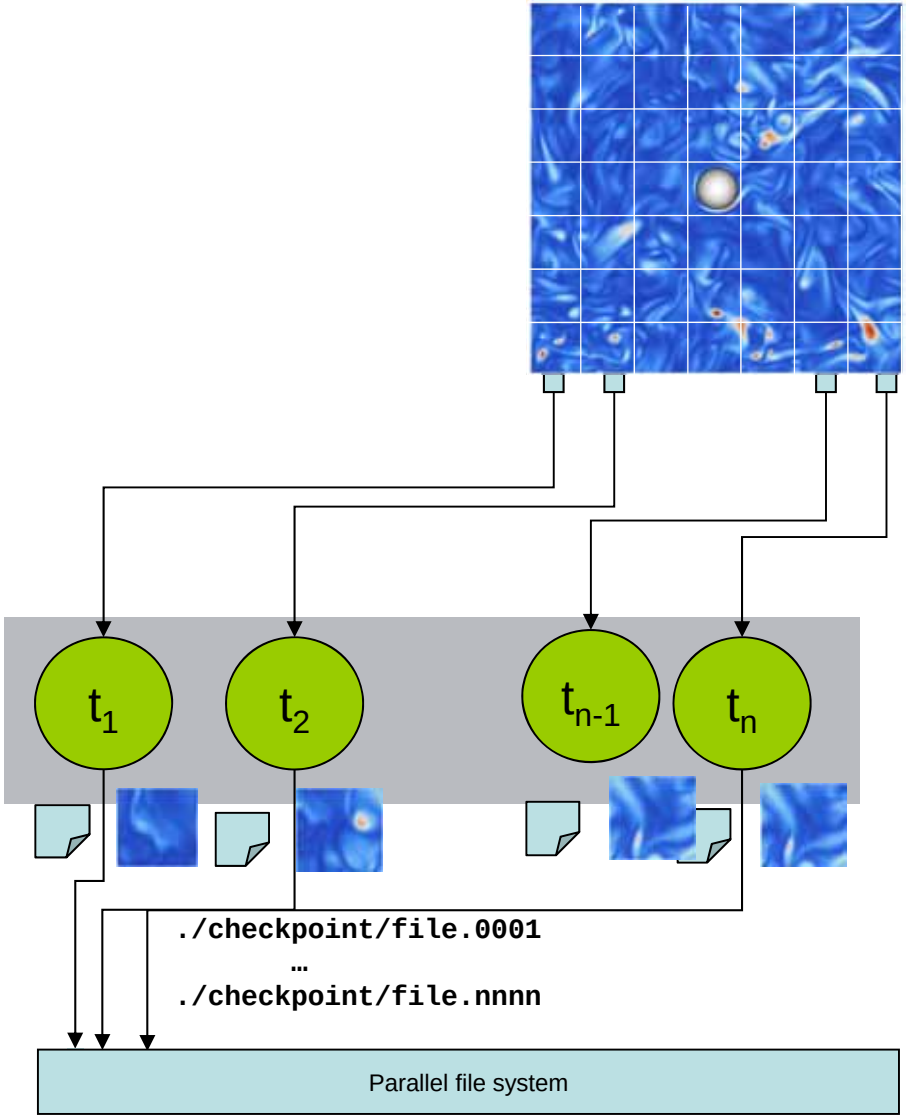
I/O Workload Analysis: Next steps

- Classification (e.g. research topic, group, account)
- Additional metrics
  - Bandwidth
  - Open/Close calls
  - Type of I/O: continuous, burst, ..
  - Parallel I/O or one writer/reader, …
  - More?

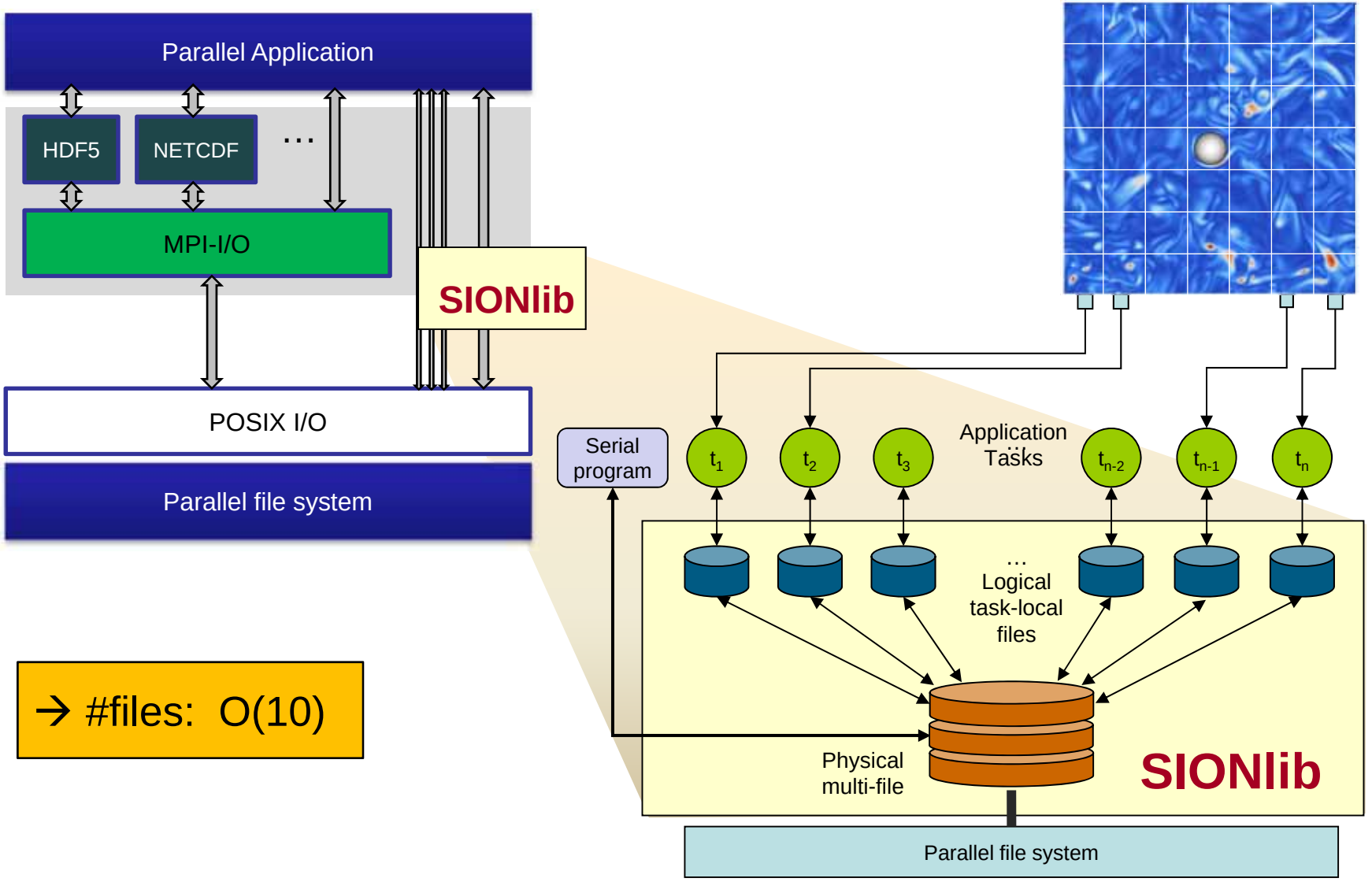
- Report at job end, containing information and timelines for
  - I/O activity
  - Memory usage
  - Load

SIONlib: Shared Files for Task-local Data



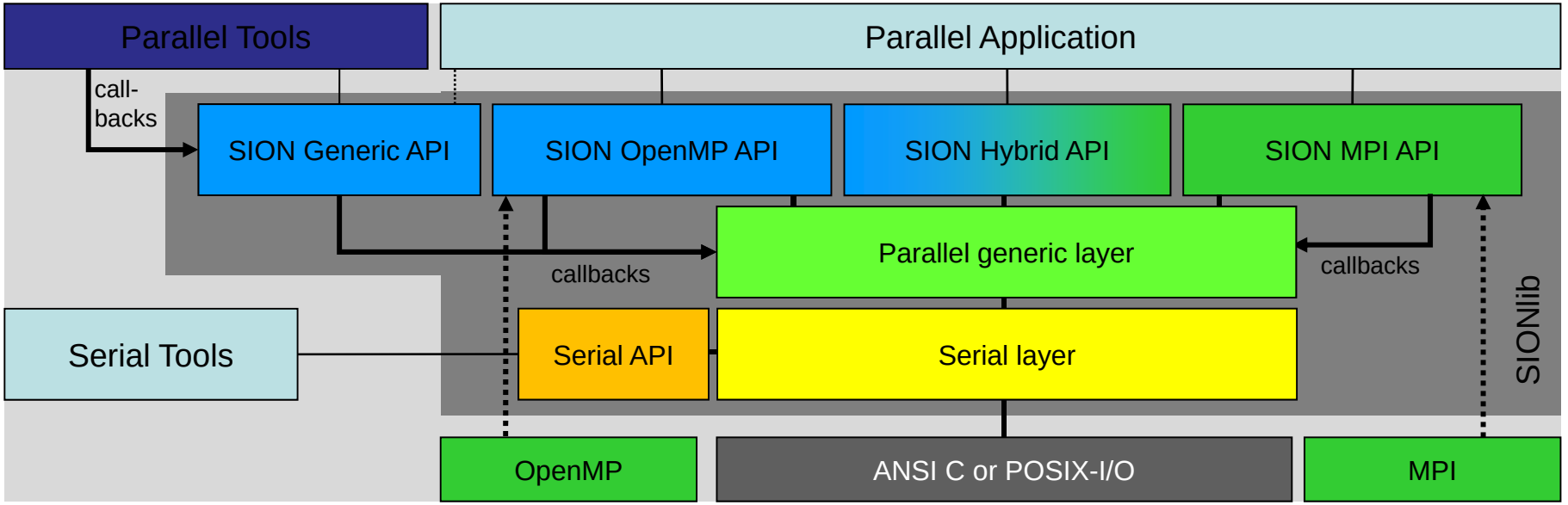


SIONlib: Shared Files for Task-local Data



→ #files: O(10)

SIONlib: Architecture & Example



- Extension of I/O-API (ANSI C or POSIX)
- C and Fortran bindings, implementation language C
- Current versions: 1.6.2
- Open source license: http://www.fz-juelich.de/jsc/sionlib

```
/* fopen() → */
sid=sion_paropen_mpi( filename , “bw“,
                      &numfiles, &chunksize,
                      gcom, &lcom, &fileptr, ...);

/* fwrite(bindata,1,nbytes, fileptr) → */
sion_fwrite(bindata,1,nbytes, sid);

/* fclose() → */
sion_parclose_mpi(sid)
```

DEEP-ER: The Project

- **DEEP – Extended Reach**: EU-funded Exascale research project

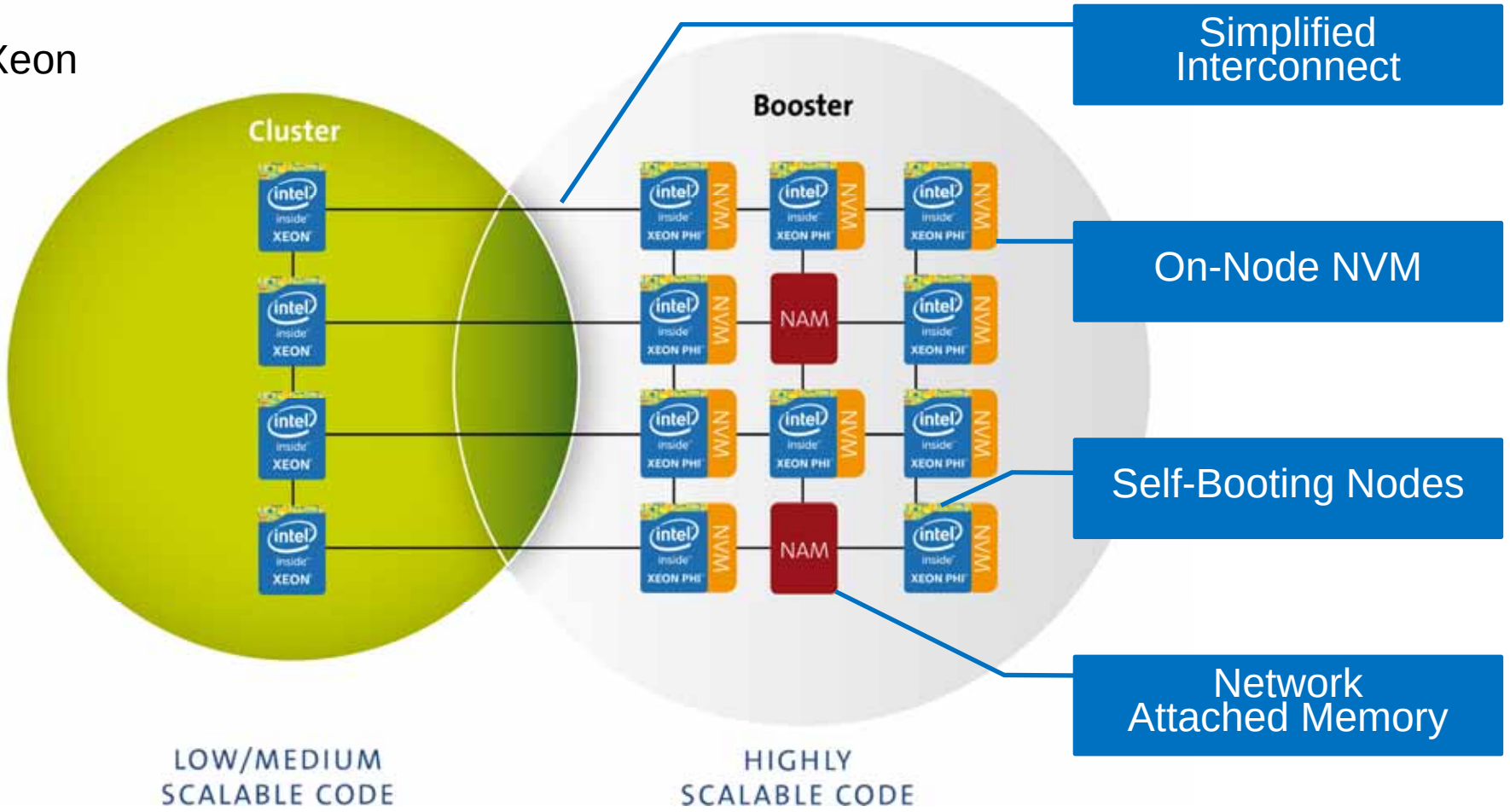
- **Budget:** 10M €
  - ✓ EU-funding: 6,4 M €
  - ✓ Start: Oct'13
  - ✓ Duration: 42 months

- The DEEP-ER **Consortium**
  - ✓ Coordinator: JSC*
  - ✓ 14 Partners
    - *3 PRACE hosting members*
    - *4 industry partners*
  - 7 European countries

* Jülich Supercomputing Centre

DEEP-ER: Architecture Innovation

Xeon



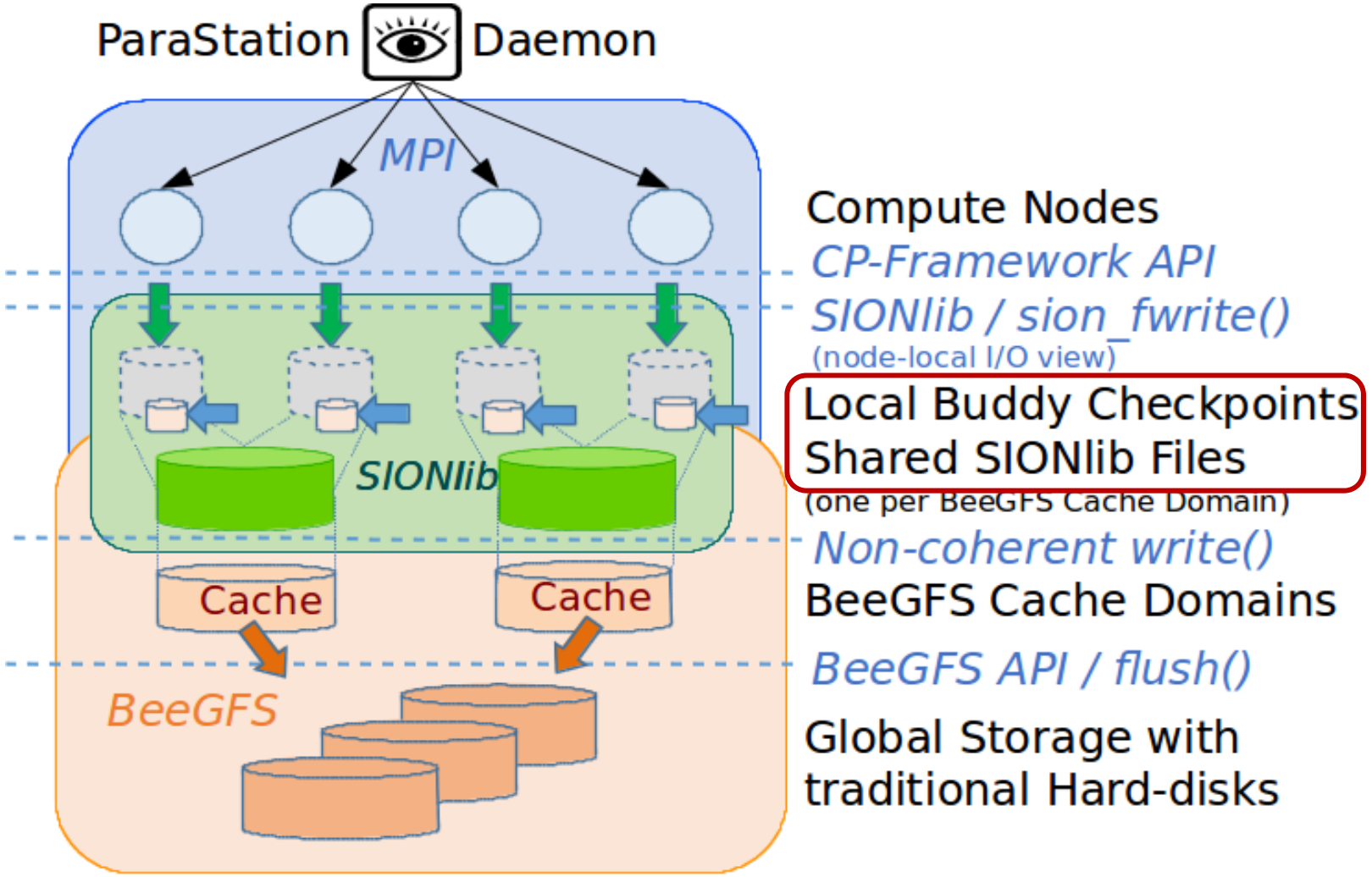
Simplified Interconnect

On-Node NVM

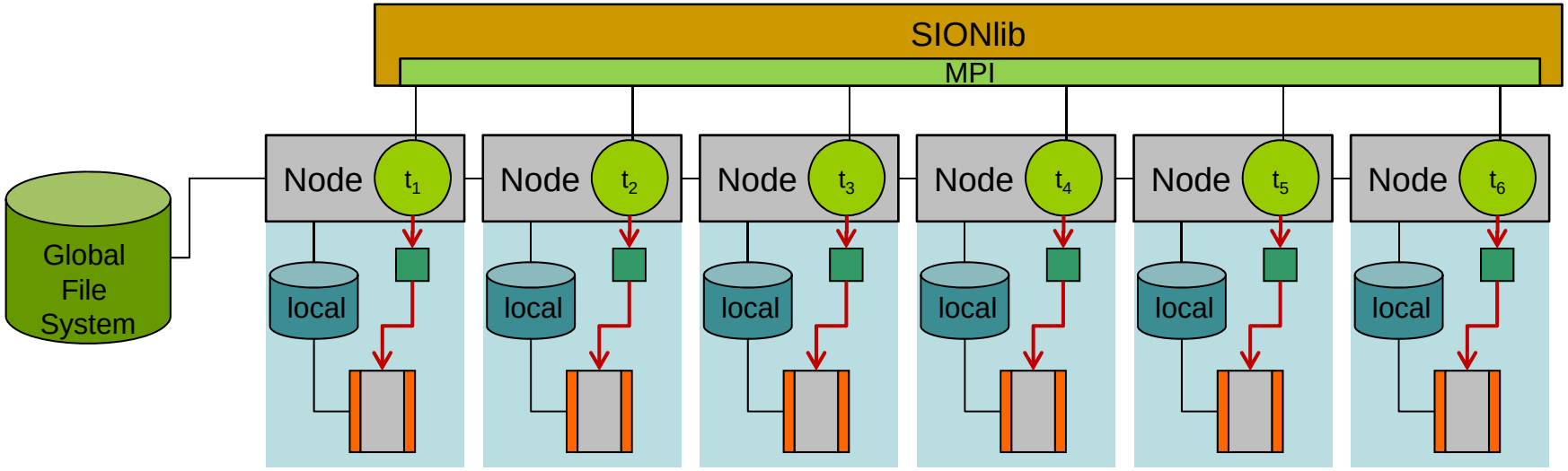
Self-Booting Nodes

Network Attached Memory

DEEP-ER: Resiliency Integration SCR/SIONlib/BeeGFS

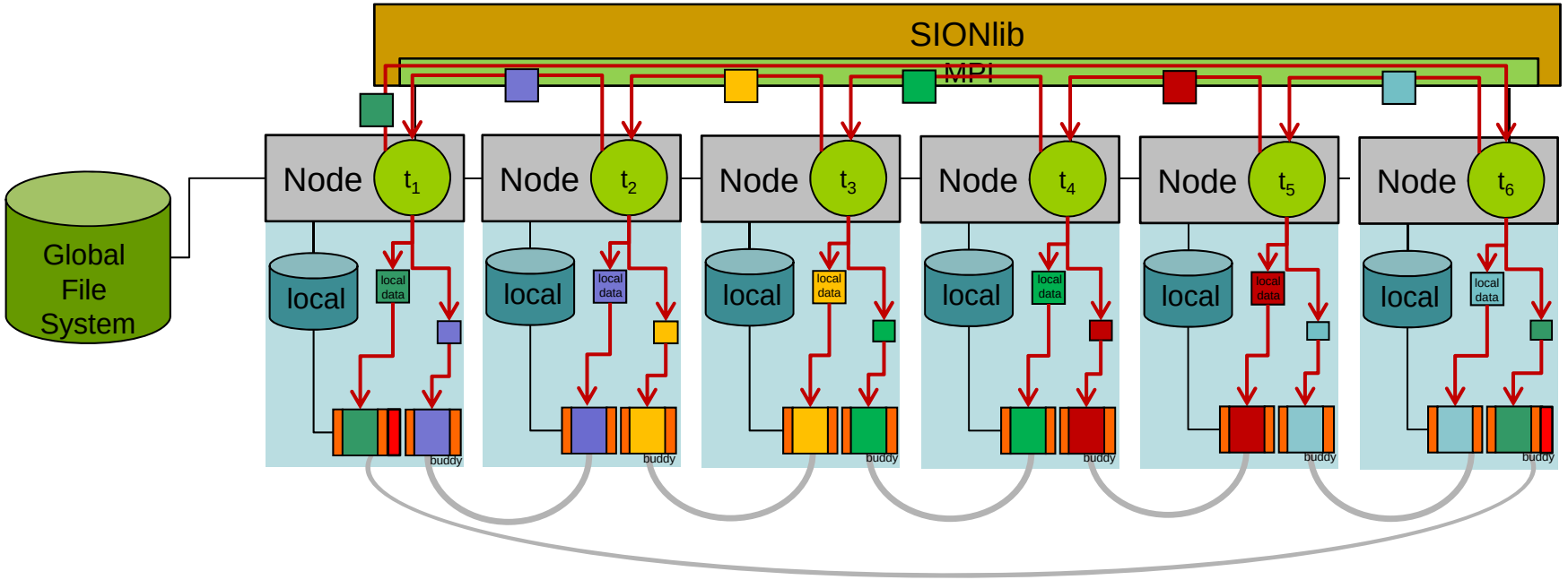


SIONlib: Local checkpointing



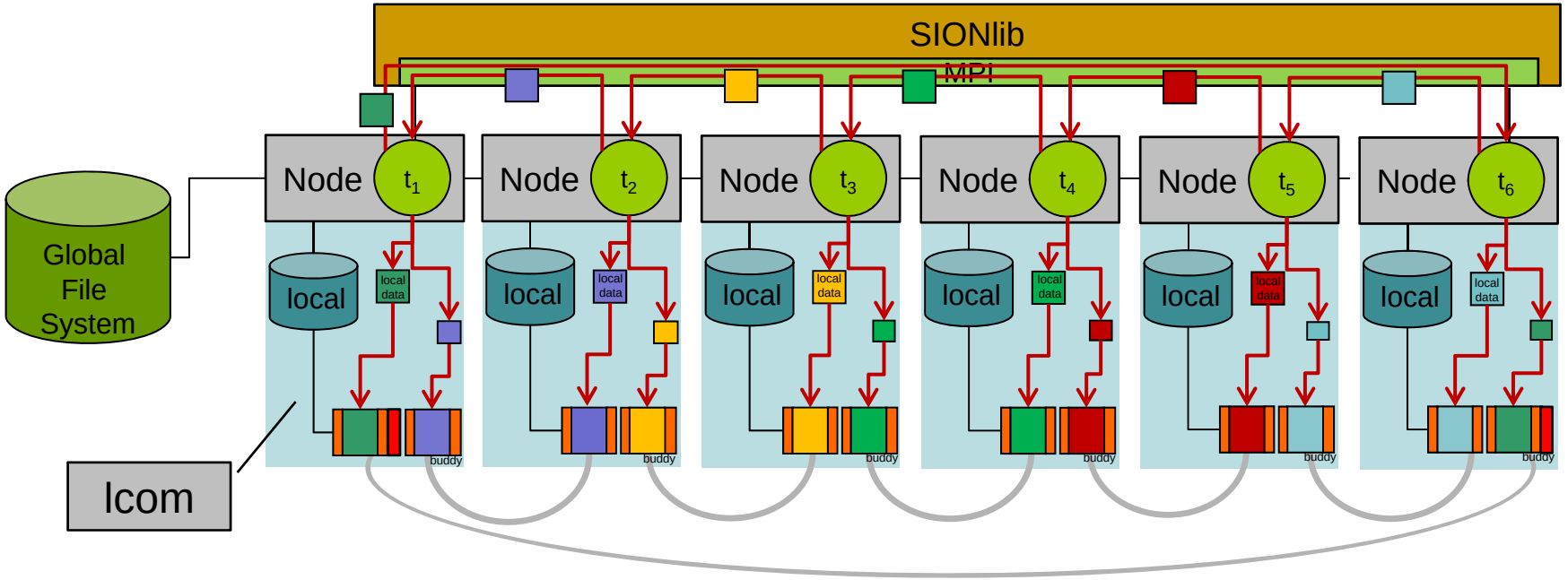
- Mapping: task writes to local storage
- Transparent access to data from application
  → when files migrated to global storage

SIONlib: Buddy-CP, Logical mapping



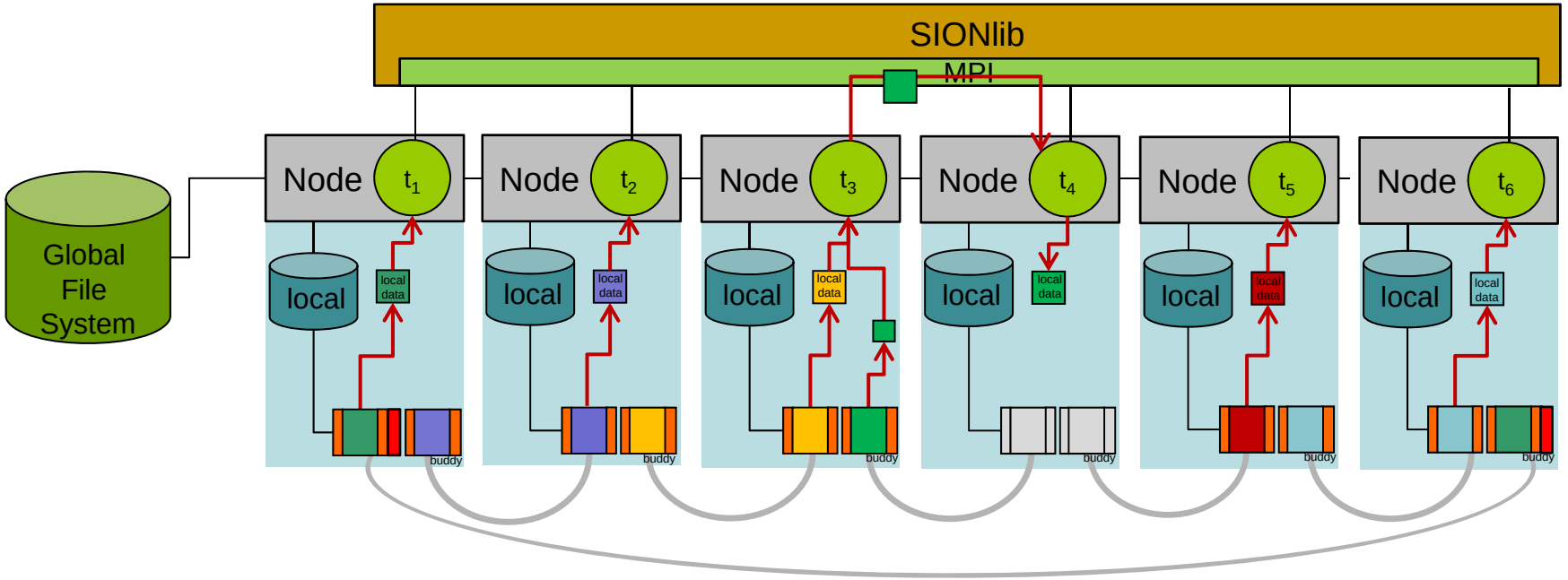
- Mapping: 1:1 task writes to local storage and storage of buddy node
  1:x task writes to local storage and storage of x buddy nodes
- Data exchange to buddy node is done via SIONlib MPI/OpenMP layer
- Collective checkpoint calls required

SIONlib: Write buddy checkpoint



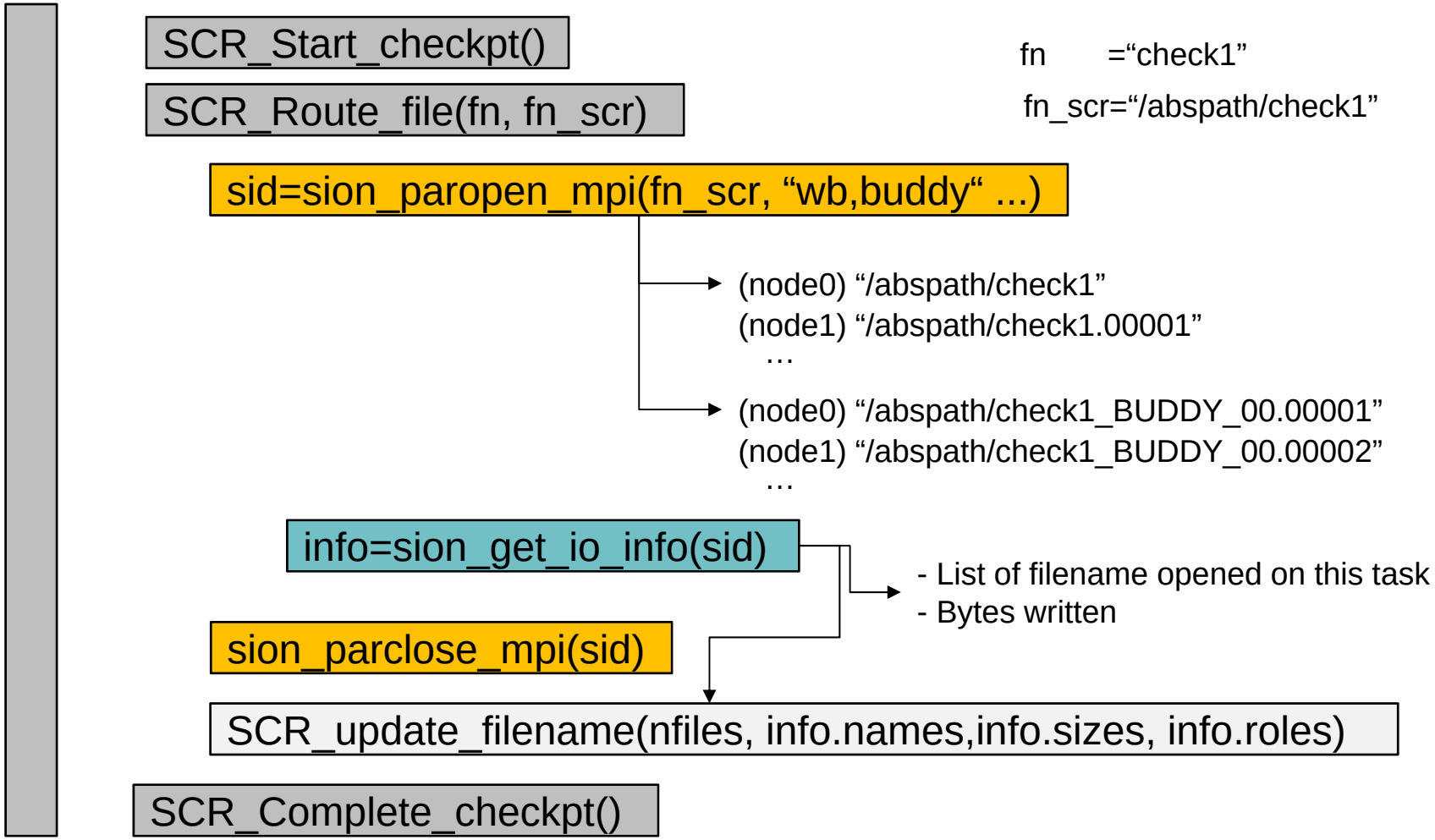
- Open: `sid=sion_paropen_mpi(…,"bw,buddy",MPI_COMM_WORLD, lcom, … )`
- Write: `sion_coll_write_mpi(data,size,n,sid)`
- Close: `sion_parclose(sid)`
- Write-Call will write data first to local chunk, and then sent it to the associated buddy which writes the data to a second file

Restore checkpoint after failure



- Open: `sid=sion_paropen_mpi(…,"br,buddy",MPI_COMM_WORLD, lcom, … )`
  - *First tries normal open and falls back to buddy data if first open fails*
- Read: `sion_coll_read_mpi(data,size,n,sid)`
- Close: `sion_parclose(sid)`

SIONlib and SCR: example



Conclusion

I/O monitoring, combination of information from different sources

- → LLview + GPFS mmpmon
- → On-line and off-line analysis

- I/O Workload analysis
  - → concepts for analysis of job-based mmpmon data
  - → Automatic job reports after job end

- DEEP-ER project: SIONlib support for resiliency
  - → Multi-version buddy checkpointing
  - → Support for multi-level checkpointing with SCR