2014

« Advanced Multi Fault Tolerance » in parallel applications : Multi level storage with FTI middleware

Eric Boyer - CINES

Involved Partners

With the support of :

Context (1/3)

Fault tolerance and application resiliency will be a key issue for next multi-petascale and Exascale system as identified by reports including IESP and EESI.

Technological evolution makes this challenge difficult to achieve

Context (2/3)

Checkpointing at system level on multi-petascale and on coming exascale systems is no longer suitable :

100’s GB memory in 2004 top10 HPC

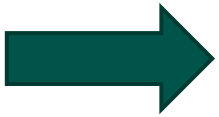
PB of memory in 2014 …

Tiered storage involved (local and global) will not handle such amount and related throughput. Application level, targeting pertinent information is the appropriate option.

Context (3/3)

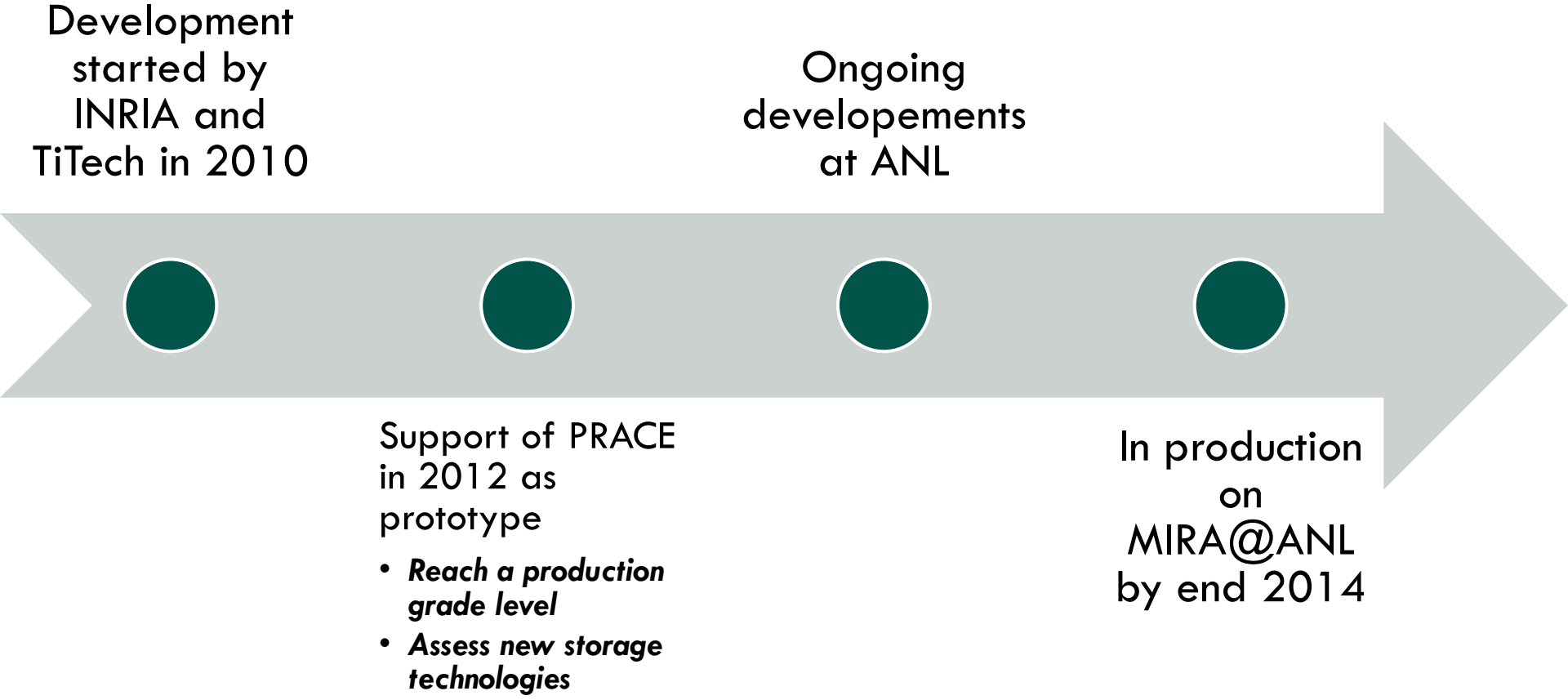
Even at application level, major pitfalls remain !

Increase of hardware component lead to low MTTI, involving increased checkpoint frequency



On exascale systems, this should lead to an unaffordable contribution of checkpoint creation on application execution time.

FTI : Fault Tolerance Interface

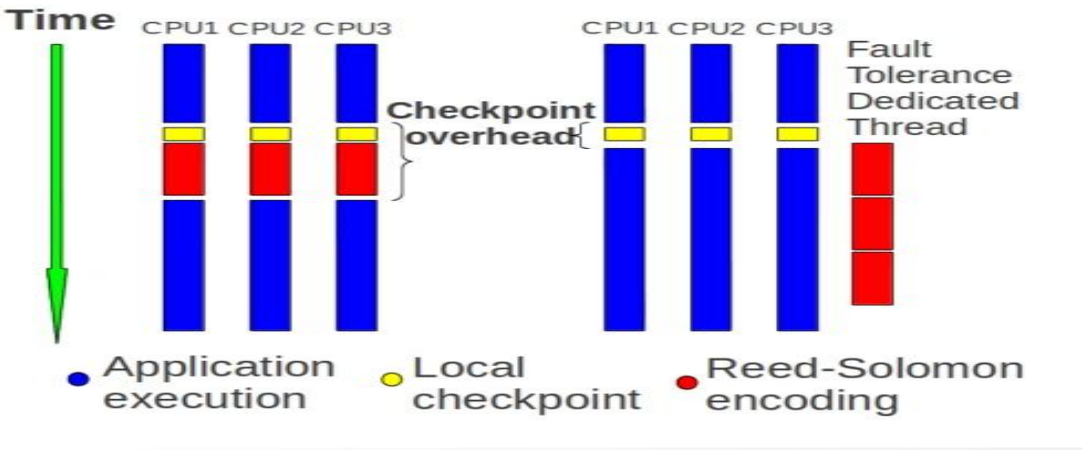


FTI : Fault Tolerance Interface

- Suitable at application level
  - Easy to implement on already checkpointed applications
  - The application integration focuses on « what »
  - FTI handles « how » and takes the best advantage of the HPC platform
  - Embedded added value by FTI hardly integrable by application implementation

FTI : Fault Tolerance Interface

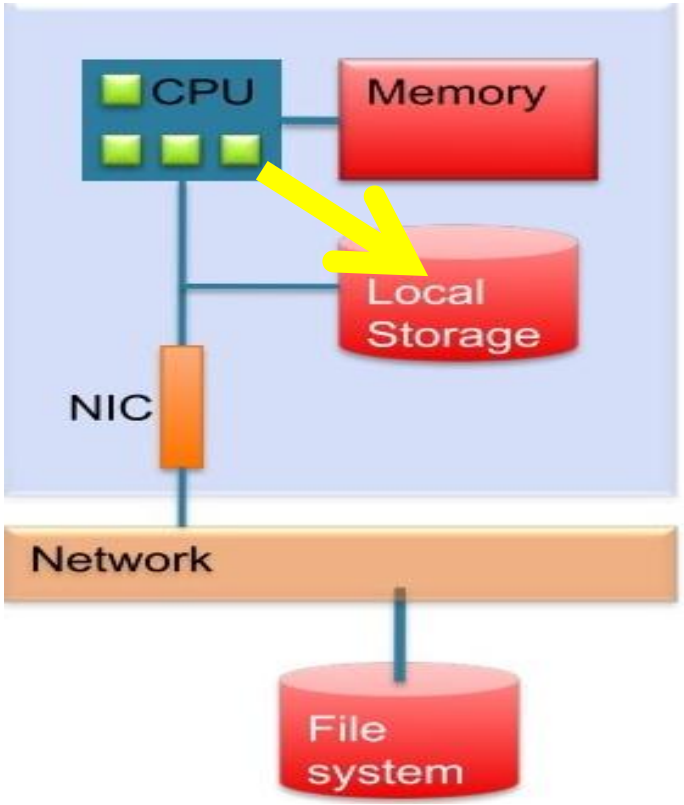
- Introduces asynchronous processus for checkpoint



- Relies on multi-level storage technologies

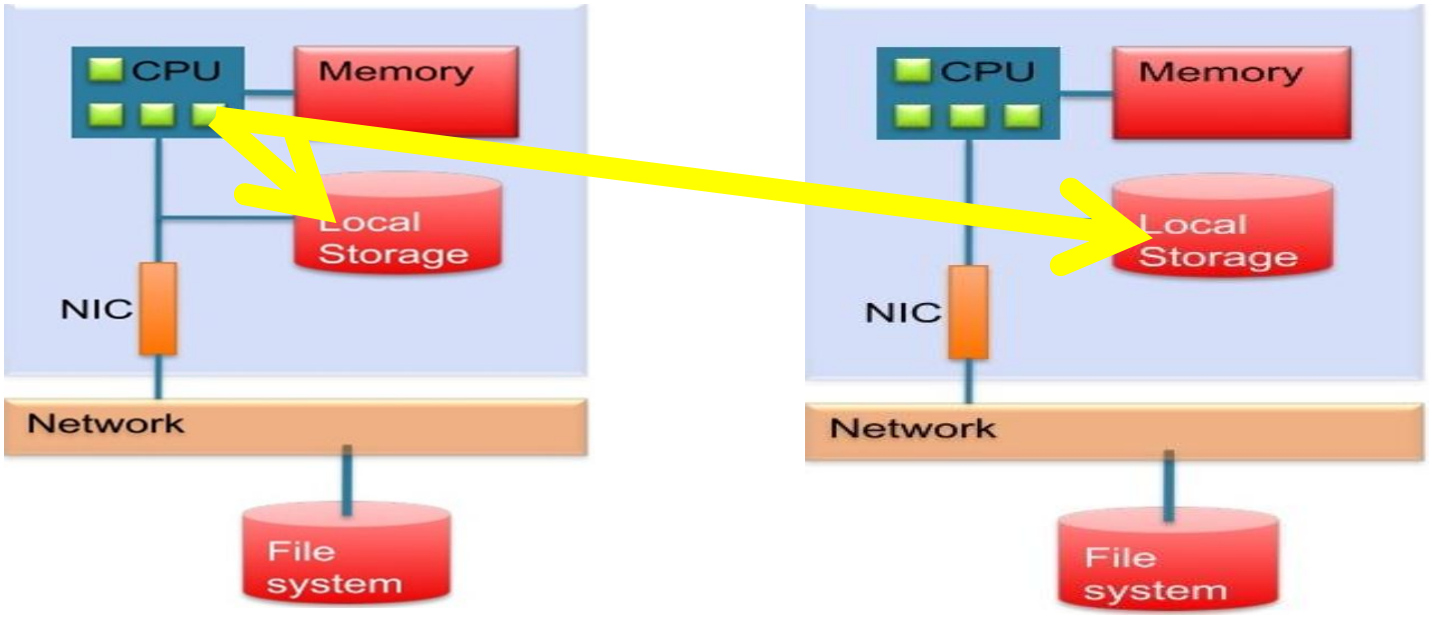
FTI : Protection levels

- **L1** : FTI performs checkpointing on local storage without any concern to resist a failure of this support.



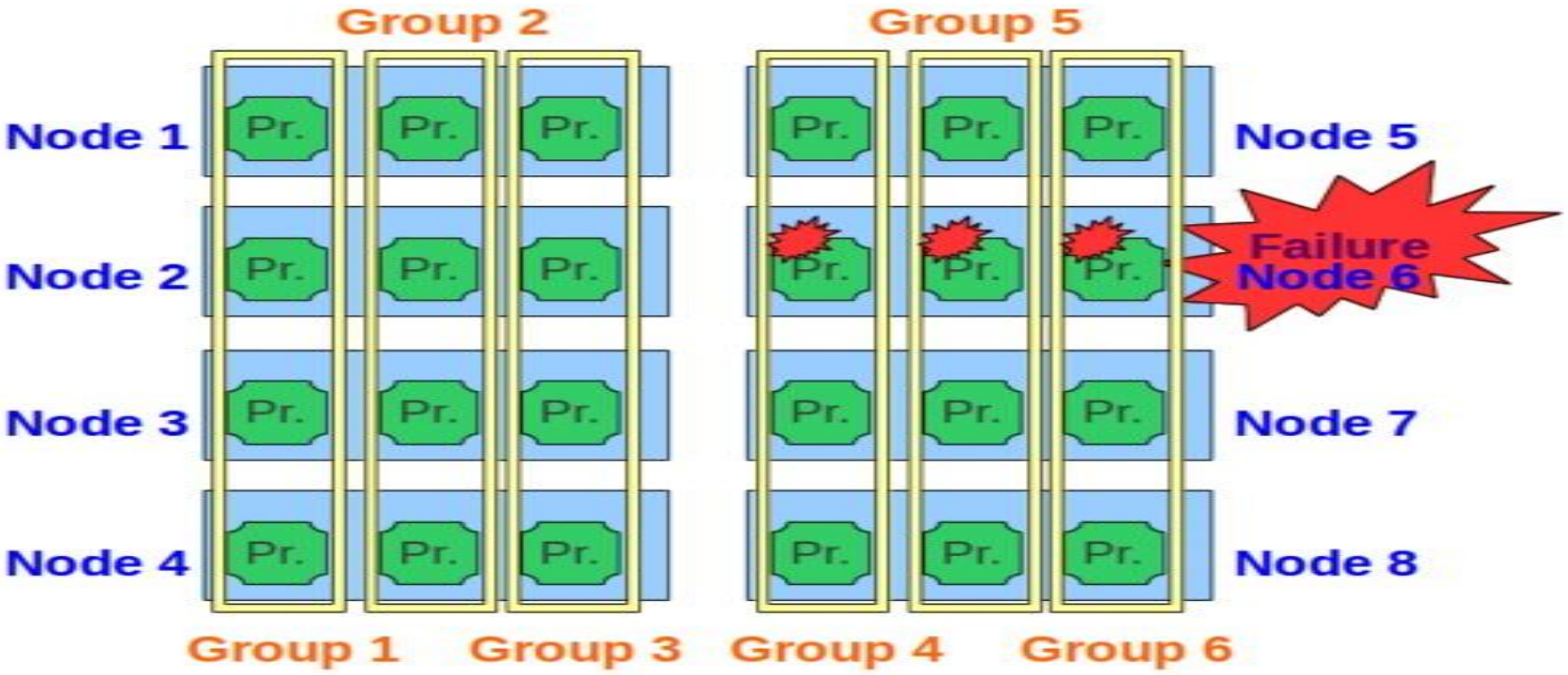
FTI : Protection levels

- **L2** : FTI does a local checkpoint and duplicates to a partner node. This mode allows an application to resume from any failure involving one node in each partnership.



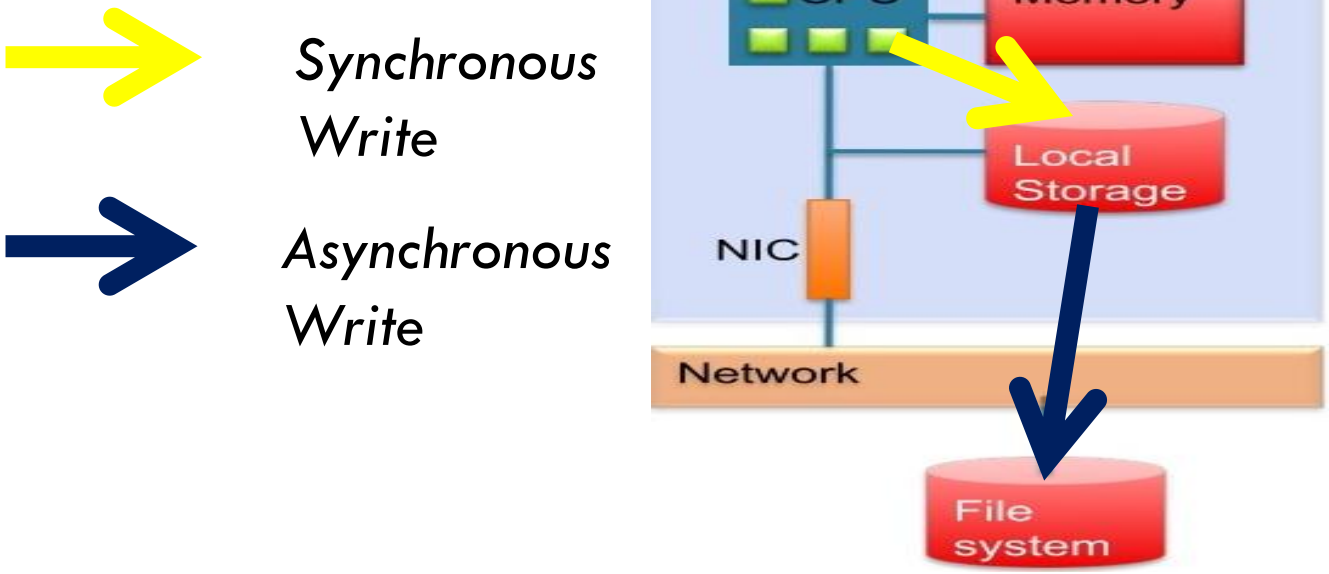
FTI : Protection levels

- **L3** :FTI dispatches checkpoints to a group of multiple nodes. The backup is encoded with other processes using a Reed-Solomon algorithm.

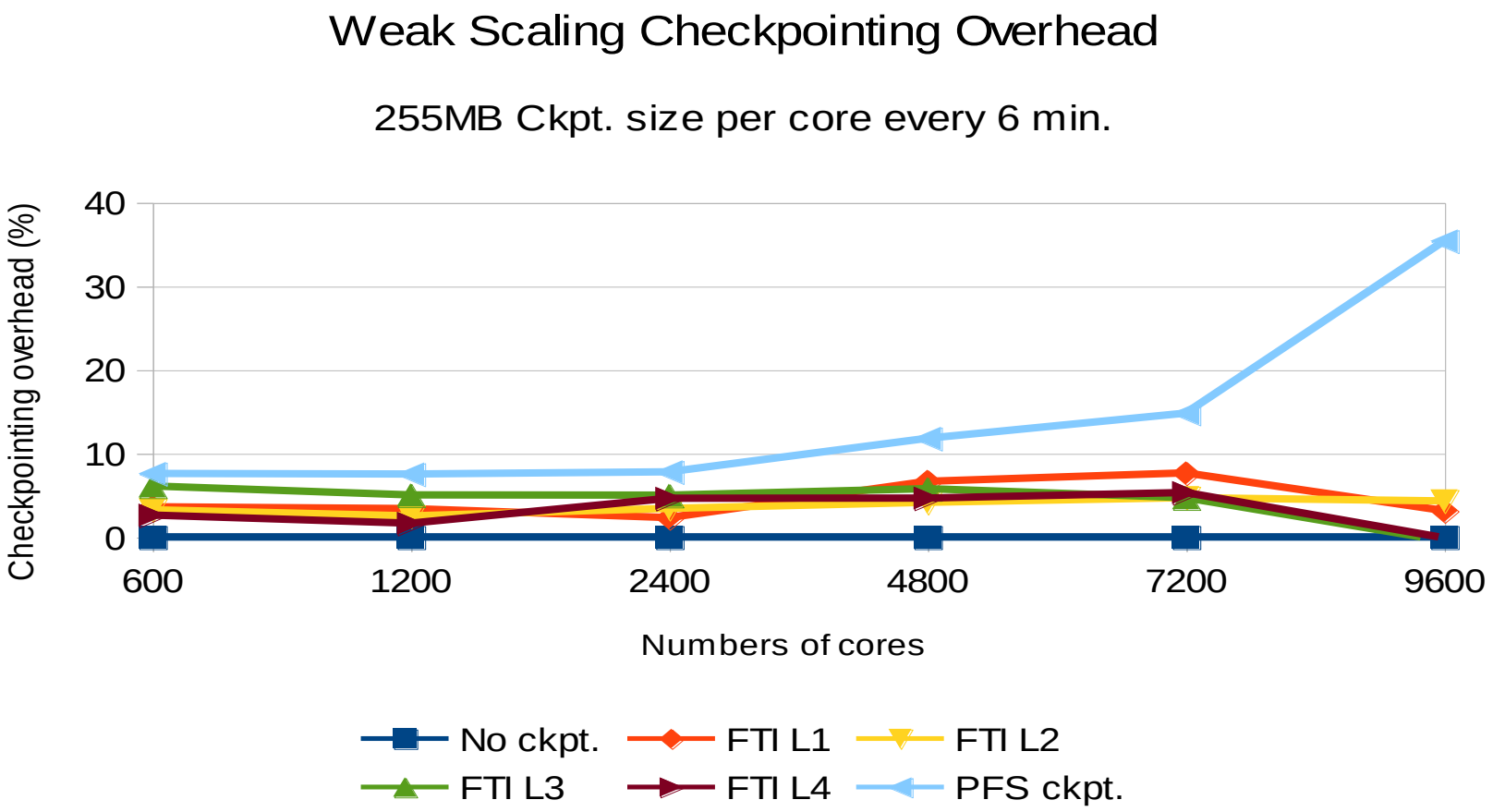


FTI : Protection levels

- **L4** : FTI writes the checkpoint on the parallel file system (PFS). To hide the cost of the backup level, the local storage system is used as a buffer to write the data on PFS asynchronously.

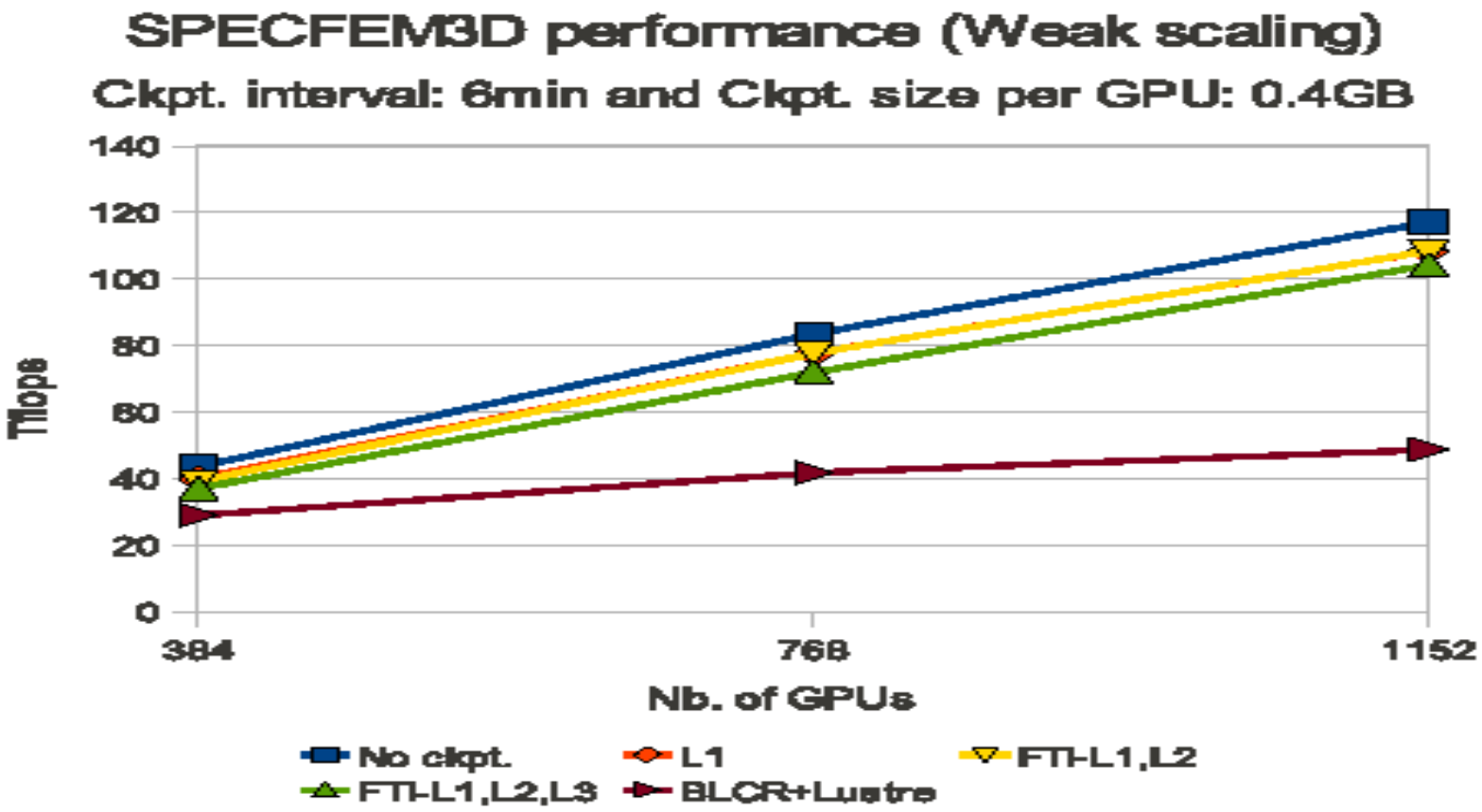


FTI : HYDRO



CURIE – TGCC / Performed by CINES

FTI : SPECFEM3D

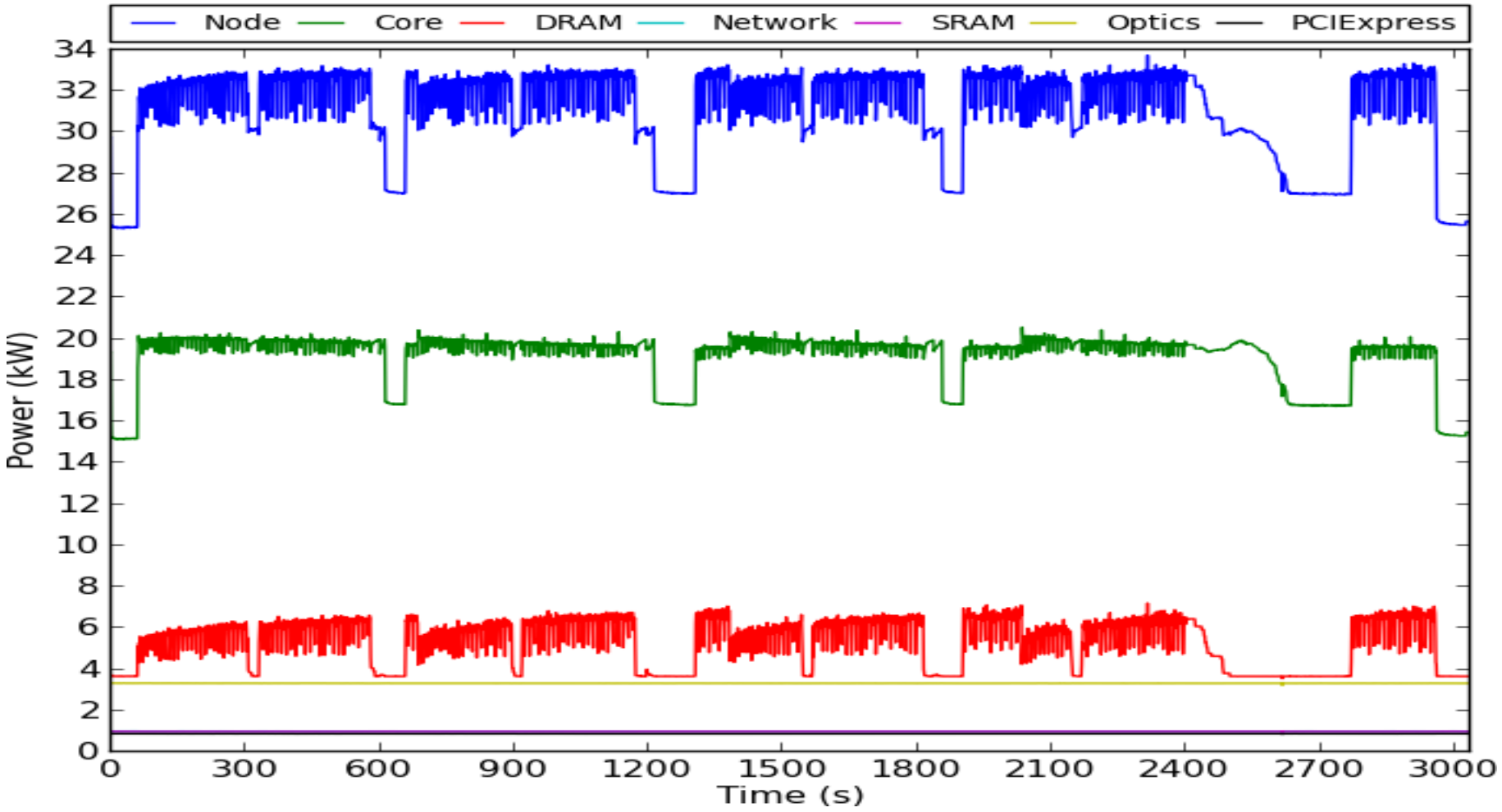


TSUBAME 2.0 / TiTech

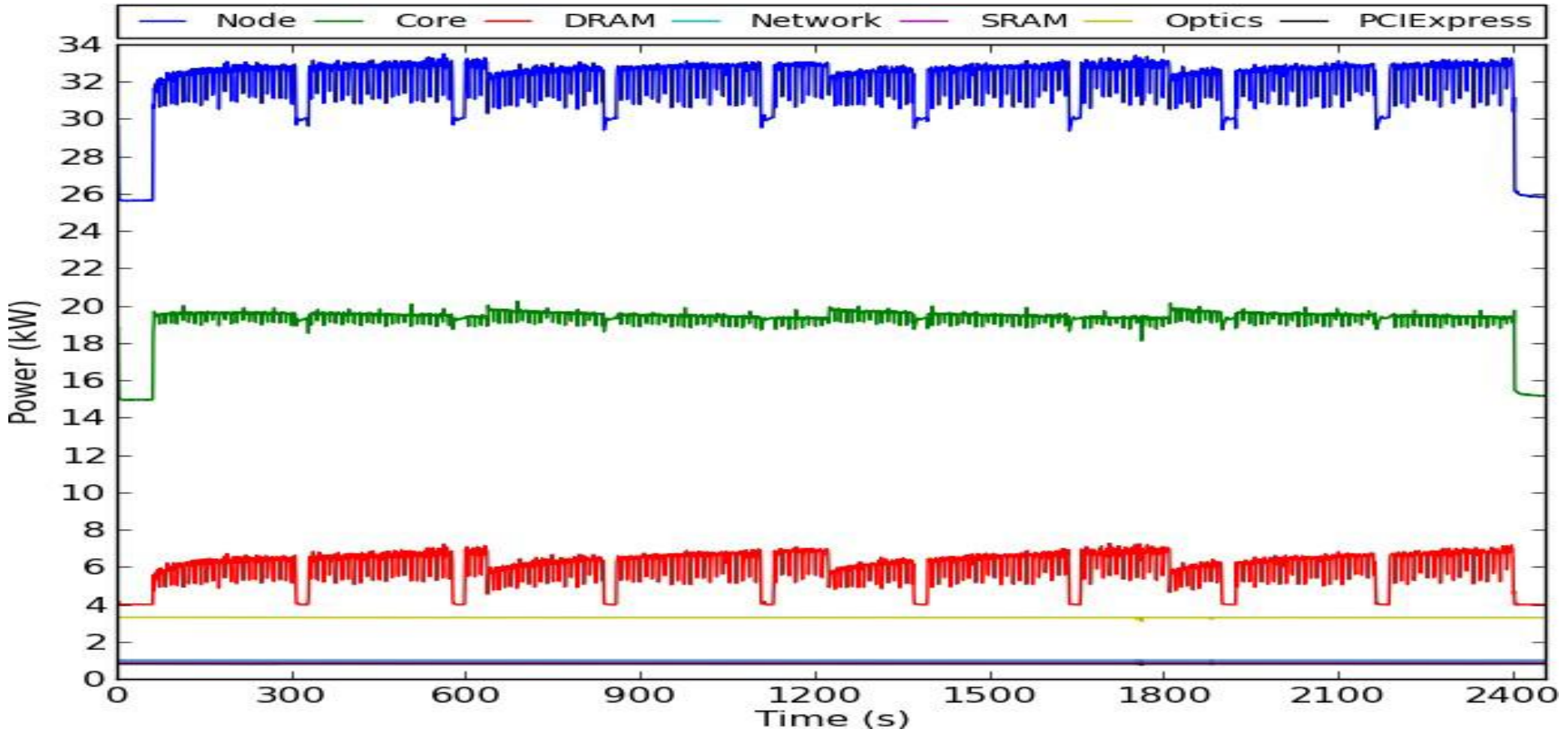
FTI : LAMMPS

- Integrated LAMMPS with FTI
- Lennard-Jones simulation
- 1.3 billion particles
- 32,678 MPI ranks on MIRA (BG/Q)
- Ckpt. interval : L1:4, L2:8, L3:16, L4:32
- Ckpt. pattern : 1-2-1-3-1-2-1-4

FTI : LAMMPS – Synchronous mode



FTI : LAMMPS – Asynchronous mode



Speedup 1,2 / Synchronous mode

FTI : GYSELA5D

- Contribution of « Maison de la Simulation »
- Work in progress …
- Test bed for enhancements and future developments :

➔ Towards a production grade solution (DONE)

- Introduction of a Fortran API
- Removal of the dependency on python
- Clean-up of the API (no more use of global variables, ...)
- Support for a forced checkpoint at last iteration for multi-job runs
- Support of a degraded mode with no dedicated FTI process
- FTI errors can not stop the application anymore

➔ Performance evaluation in a production code (WIP)

- Evaluation on multiple real-life crash scenarii
- Comparison with the use of local memory rather than local storage
- Analysis of the impact of the dedicated process without dedicated core

FTI : Implementation

FTI is a collection of few simple functions to call within the application :

•int FTI_Init (char _configFile, MPI_Comm globalComm);
this function will initialize FTI.

•int FTI_Protect (int id, void _ptr, long size);
It stores a pointer to a variable that needs to be protected.

•int FTI_Snapshot ();
*this function t*akes an FTI snapshot or recover the data if it is a restart.

•int FTI_Finalize ();
this function closes FTI properly on the application processes.

FTI : Implementation

- **FTI_Init:**
  - Read configuration file
  - Creates checkpoint directories
  - Detect topology of the system
  - Regenerate data upon recovery

FTI : Implementation

- **FTI_Protect:**
  - Stores metadata concerning the variable to protect

FTI : Implementation

- **FTI_Snapshot:**
  - Test if it is time for a checkpoint
  - If it is, it checks which level of ckpt.
  - It saves the checkpoint as requested
  - It loads the checkpoint upon recovery

FTI : Implementation

- **FTI_Finalize:**
  - Frees the allocated memory
  - Informs it is over to dedicated threads
  - Clean checkpoints and metadata

FTI : How to implement ?

At application level :

- Selection of data to protect to initiate a restart in case of failure

At submission time :

- Set up in « config.fti » file
  - Storage locations for checkpointed data
  - Levels / combination
  - Async / sync
  - Frequency or period

FTI : Next steps ?

- Silent data corruption handling

Behavioral-based SDC detection

- Spacial analysis
- Temporal analysis
- Approximate computing

- Checkpoint data compression

Credits

- Leonardo Bautista Gomez (ANL)
- Julien Bigot (Maison de la Simulation)
- Franck Capello (ANL)
- Guillaume Colin de Verdière (CEA)
- Stéphane Requena (GENCI)
- Adèle Villermet (Student@ENSEIRB-MATMECA)

REFERENCE

FTI is Open Source under LGPL

http://leobago.com/projects/fti

leobago@mcs.anl.gov

QUESTIONS ?

Backup Slides

- IESP¨: International Exascale Software Project : http://www.exascale.org/iesp/IESP
- EESI : European Exascale Sotware Initiative : http://www.eesi-project.eu
- MTTI : Mean Time To Interrupt

Backup Slide : Tera to Exa / systems

System attributes	2010	"2015"		"2018"		Difference Today & 2018
System peak	2 Pflop/s	200 Pflop/s		1 Eflop/sec		O(1000)
Power	6 MW	15 MW		~20 MW		
System memory	0.3 PB	5 PB		32-64 PB		O(100)
Node performance	125 GF	0.5 TF	7 TF	1 TF	10 TF	O(10) – O(100)
Node memory BW	25 GB/s	0.1 TB/sec	1 TB/sec	0.4 TB/sec	4 TB/sec	O(100)
Node concurrency	12	O(100)	O(1,000)	O(1,000)	O(10,000)	O(100) – O(1000)
Total Concurrency	225,000	$O(10^8)$		$O(10^9)$		O(10,000)
Total Node Interconnect BW	1.5 GB/s	20 GB/sec		200 GB/sec		O(100)
MTTI	days	O(1day)		O(1 day)		- O(10)

Backup slide : Tera to Exa /software

- **Steepness of the ascent from terascale to petascale to exascale**
- Extreme parallelism and hybrid design
  - Preparing for million/billion way parallelism
- Tightening memory/bandwidth bottleneck
  - Limits on power/clock speed implication on multicore
  - Reducing communication will become much more intense
  - Memory per core changes, byte-to-flop ratio will change
- Necessary Fault Tolerance
  - MTTF will drop
  - Checkpoint/restart has limitations

Backup Slide : FTI screen shot in HYDRO

```
  //pre-allocate memory before entering in loop
  //For godunov scheme
  start = cclock();
  start = cclock();
  allocate_work_space(H.nxyt, H, &Hw_godunov, &Hvw_godunov);
  compute_deltat_init_mem(H, &Hw_deltat, &Hvw_deltat);
  end = cclock();
#ifdef MPI
#if FTI==1
  FTI_Protect(0,functim, TIM_END,FTI_DBLE);
  FTI_Protect(1,&nvtk,1,FTI_INTG);
  FTI_Protect(2,&next_output_time,1,FTI_DBLE);
  FTI_Protect(3,&dt,1,FTI_DBLE);
  FTI_Protect(4,&MflopsSUM,1,FTI_DBLE);
  FTI_Protect(5,&nbFLOPS,1,FTI_LONG);
  FTI_Protect(6,&(H.nstep),1,FTI_INTG);
  FTI_Protect(7,&(H.t),1,FTI_DBLE);
  FTI_Protect(8,Hv.uold,H.nvar * H.nxt * H.nyt,FTI_DBLE);
#endif
#endif
  if (H.mype == 0) fprintf(stdout, "Hydro: init mem %lfs\n", ccelaps(start, end));
  // we start timings here to avoid the cost of initial memory allocation
  start_time = dcclock();

  while ((H.t < H.tend) && (H.nstep < H.nstepmax)) {
    // reset perf counter for this iteration
    flopsAri = flopsSqr = flopsMin = flopsTra = 0;
    start_iter = dcclock();
    outnum[0] = 0;
    if ((H.nstep % 2) == 0) {
      dt = 0;
```

Backup Slide : FTI screen shot in HYDRO

```
    if (H.mype == 0) {
      fprintf(stdout, "--> step=%4d, %12.5e, %10.5e %s\n", H.nstep, H.t, dt, outnum);
      fflush(stdout);
    }
#ifdef MPI
#if FTI==1
    // FTI snapshot
    FTI_Snapshot();
#endif
#endif
  } // while
  end_time = dcclock();

  // Deallocate work spaces
  deallocate_work_space(H.nxyt, H, &Hw_godunov, &Hvw_godunov);
  compute_deltat_clean_mem(H, &Hw_deltat, &Hvw_deltat);

  hydro_finish(H, &Hv);
  elaps = (double) (end_time - start_time);
```

FTI : What else ?

ADIOS ORNL	Multi purpose I/O	Data structure oriented	No restart integrated
FTI ANL	CPR	Data structure oriented	Integrated restart
SCR Scalable C/R LLNL	CPR	File oriented	Integrated restart

Centre Informatique National de l'Enseignement Supérieur

The national computer center of french higher education

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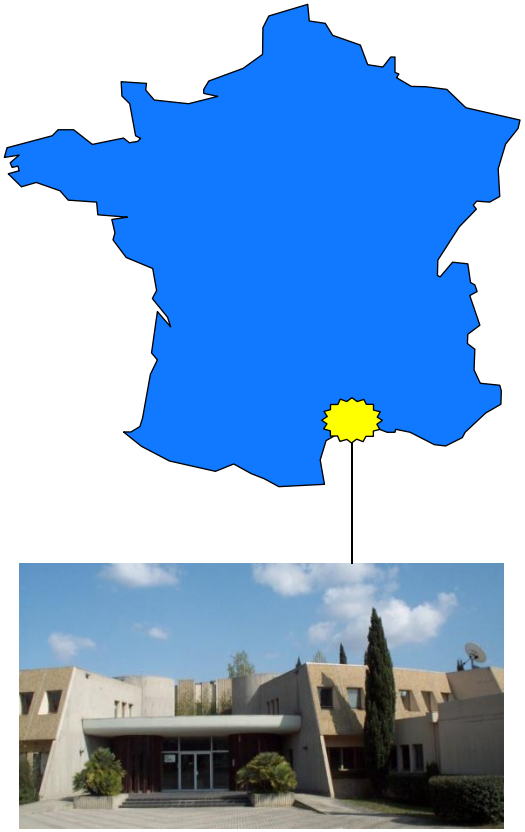
CINES is located in Montpellier (South of France)



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