http://www.montblanc-project.eu

High Performance Computing Based on Mobile Embedded Technology

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Mont-Blanc project in a glance

2012 2013 2014 2015 2016

Mont-Blanc

Mont-Blanc 2

SEVENTH FRAMEWORK PROGRAMME

HORIZON 2020

To develop an **European** Exascale **approach**
leveraging **commodity** and **embedded** cost-effective technology

Mont-Blanc objectives

2012	2013	2014	2015	2016

Mont-Blanc

- HPC prototype based on current mobile embedded technology
- Learn from the experience, plan for future architecture
- Port real scientific applications

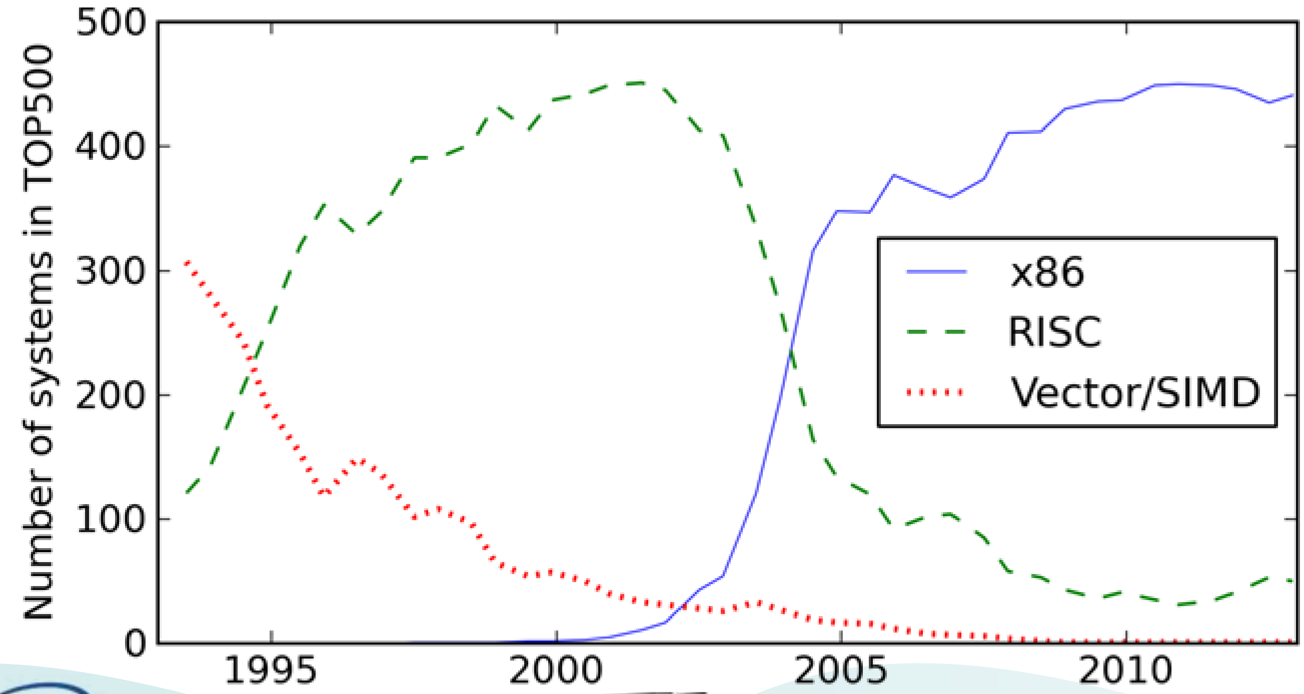
Mont-Blanc 2

Extend
- Set of scientific applications
- OmpSs programming model
- Productivity tools
- Next generation Mont-Blanc architecture

Explore
- ARM 64-bit
- Fault tolerance and resiliency
- Market of ARM-based platforms for mini-clusters

Disseminate: End-User Group

Why are we doing this?

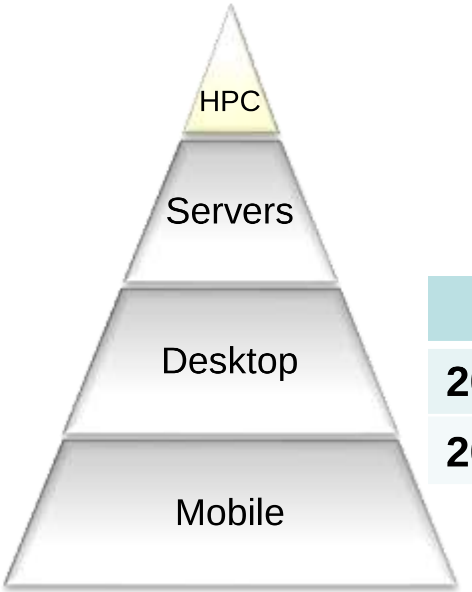


1 teraFLOPS supercomputer
ASCI Red
(Sandia – 1997)
Pentium Pro

1 petaFLOPS supercomputer
Roadrunner
(IBM / Los Alamos NL - 2008)
AMD Opteron + PowerXCell 8i

>10 petaFLOPS supercomputer
Titan
(Cray / Oak Ridge NL - 2012)
AMD Opteron + Nvidia K20

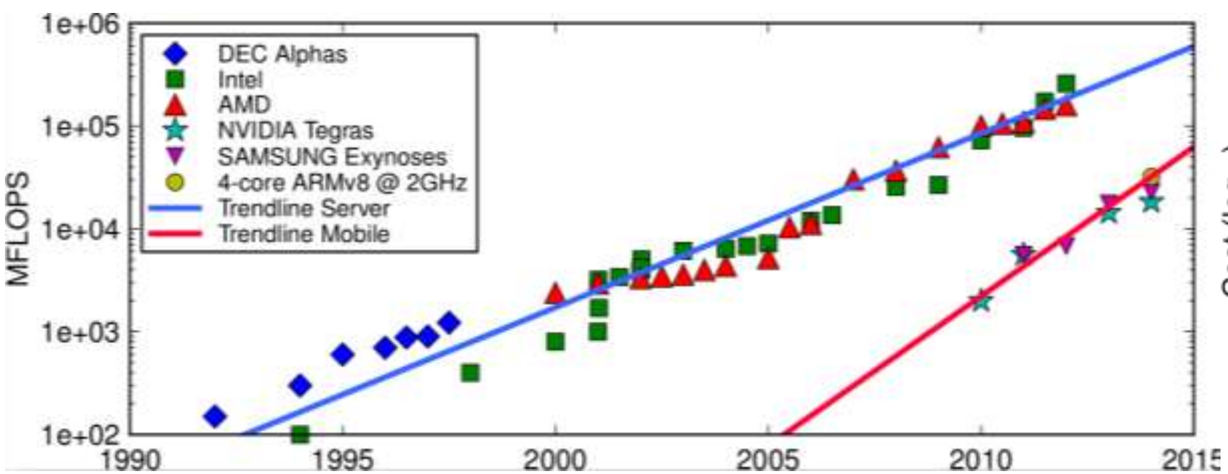
What is commodity nowadays?

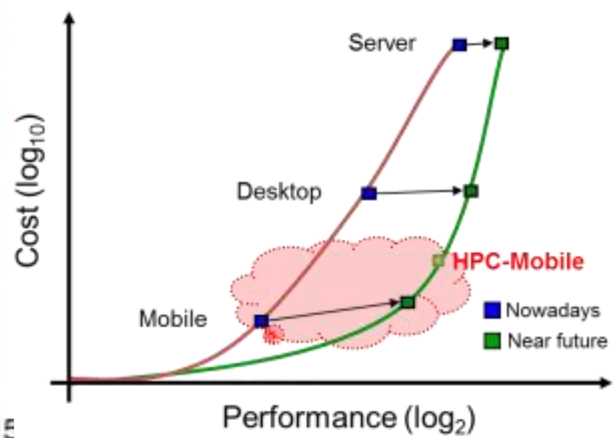


TOP 500 The List. ~23M cores (Nov 2014)

	Servers		PC		Smartphones	
2013	9.0M		316M		1000M	
2014	9.3M	+3%	314M	-1%	1300M	+30%

...and we are still ignoring tablets: >200M





Outline

1. Hardware

- History
- Mont-Blanc prototype
- Limitations

2. Software

- System software
- OmpSs programming model
- Power monitor

3. Applications

- Scalability
- Energy to solution
- End-User Group

4. Conclusions

- Project status
- Mont-Blanc impact
- Remarks

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The Mont-Blanc prototype ecosystem

Tibidabo:
ARM multicore

Carma:
ARM +
external
mobile GPU

Pedraforca:
ARM +
HPC GPU

Arndale:
ARM + embedded GPU

Odroid:
ARM bigLITTLE
In-kernel switcher

Odroid Octa:
ARM bigLITTLE
Heterogeneous
multi-processing

NVIDIA Jetson
ARM 4+1 + K1 GPU

Mont-Blanc protoype:

2011 2012 2013 2014

Prototypes are critical to accelerate software development
System software stack + applications

Mont-Blanc Server-on-Module (SoM)

CPU + GPU + Memory + Local Storage + Network

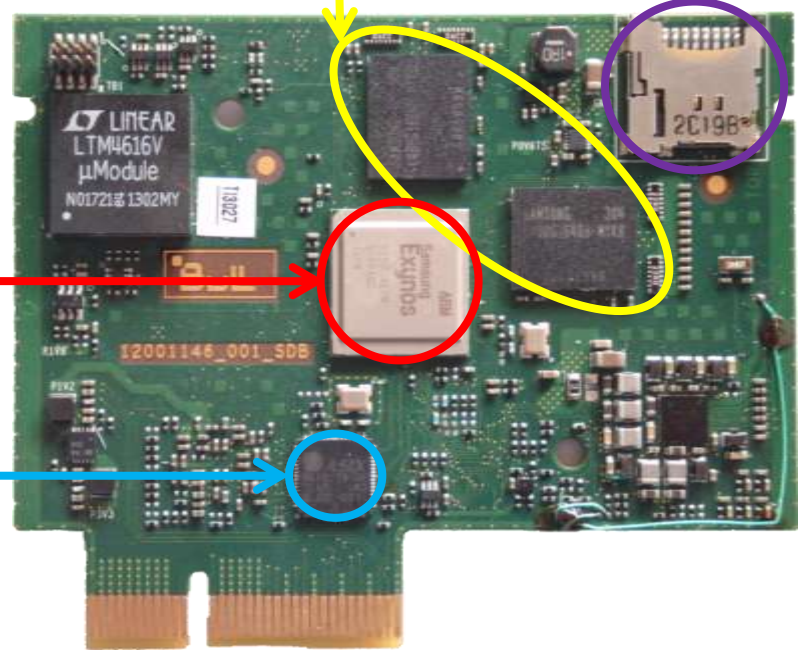
Form factor: 8.5 x 5.6 cm

Memory
4 GB LPDDR3-1600

Local Storage
microSD up to 64 GB

Exynos5 Dual SoC
2x cores ARM Cortex-A15
1x GPU ARM Mali-T604

Network
USB3.0 to 1GbE bridge



The Mont-Blanc prototype

Exynos 5 compute card
2 x Cortex-A15 @ 1.7GHz
1 x Mali T604 GPU
6.8 + 25.5 GFLOPS
15 Watts
2.1 GFLOPS/W

Carrier blade
15 x Compute cards
485 GFLOPS
1 GbE to 10 GbE
300 Watts
1.6 GFLOPS/W

Blade chassis 7U
9 x Carrier blade
135 x Compute cards
4.3 TFLOPS
2.7 kWatts
1.6 GFLOPS/W

Rack
8 BullX chassis
72 Compute blades
1080 Compute cards
2160 CPUs
1080 GPUs
4.3 TB of DRAM
17.2 TB of Flash

35 TFLOPS
24 kWatt

	Mont-Blanc [GFLOPS/W]	Green500 [GFLOPS/W]
Nov 2011	0.15	2.0
Nov 2014	1.5	5.2

Limitations of commodity mobile technology

- 32-bit memory controller
  - Even if ARM Cortex-A15 offers 40-bit address space
- No ECC protection in memory
  - But surprisingly enough this is not affecting badly scalability (so far)
- No standard server I/O interfaces
  - No native Ethernet or PCI Express
  - Provide USB 3.0 and SATA (required for tablets)
- No network protocol off-load engine
  - TCP/IP, OpenMX, USB protocol stacks run on the CPU
- Thermal package not designed for sustained full-power operation

Implementation decisions, not unsolvable problems

The only need is a business case to justify the cost
of including the new features (e.g. the HPC and server markets)

Wait for next SoC producer ⟷ Design a new HPC SoC

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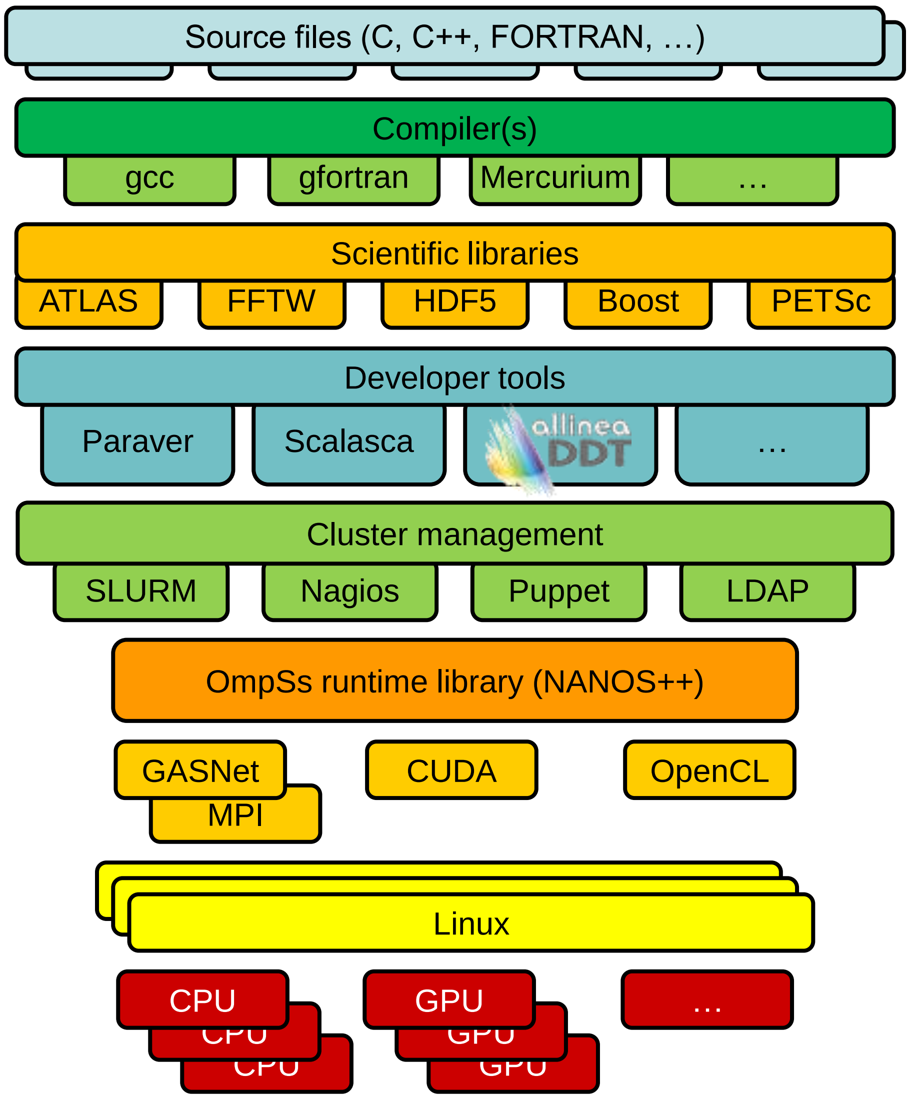
System software stack

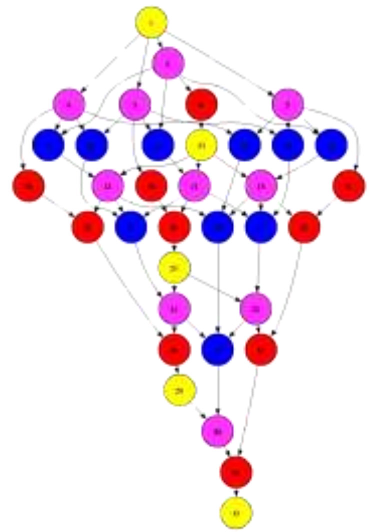


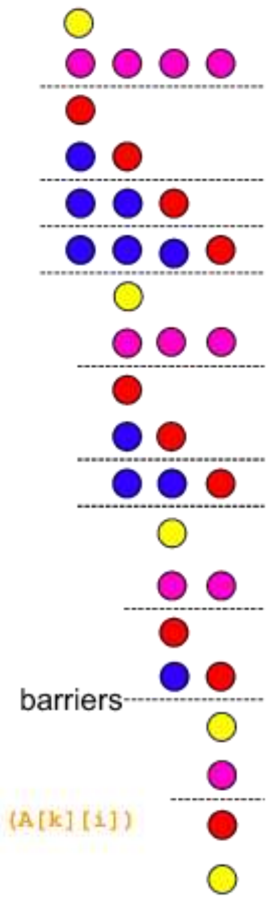
- Open source system software
  - Ubuntu/Debian Linux OS
  - GNU compilers
  - JDK
  - Scientific libraries
  - Cluster management
- Runtime libraries
  - MPICH2, CUDA, OpenCL, OmpSs
- Productivity tools
  - Perf
  - Paraver, Scalasca
  - Allinea DDT debugger

+ Server software stack
(LAMP, Hadoop, OpenStack)

OmpSs programming model

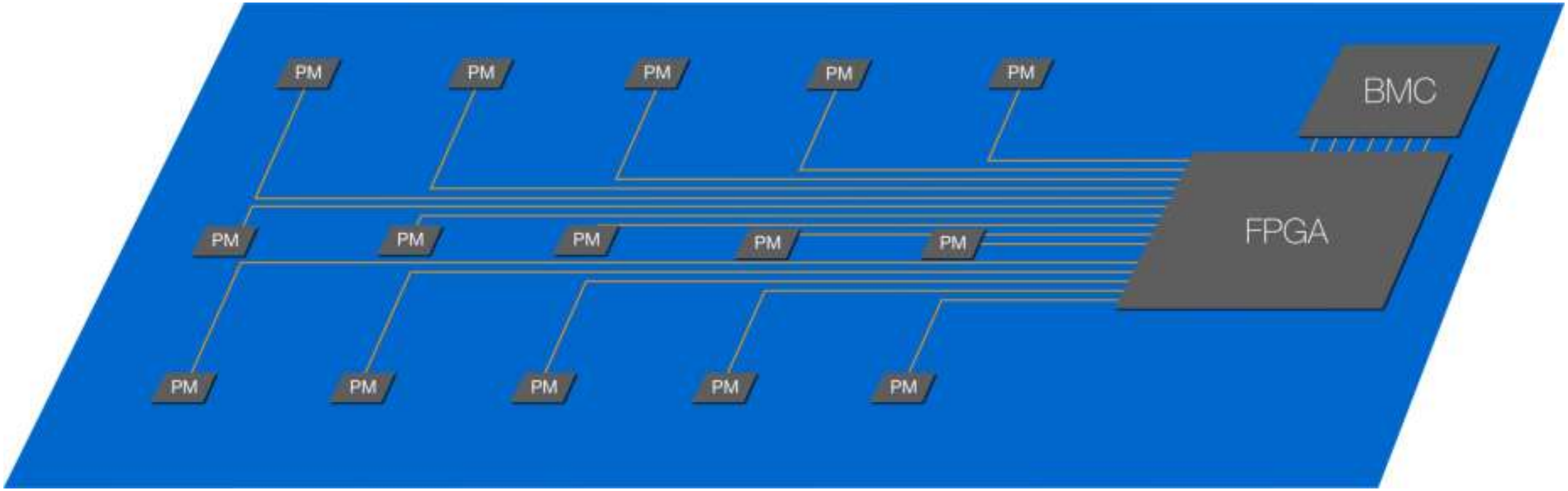
- Programmer exposed to a simple architecture
  - Tasks
  - Data dependencies
  - Target devices (heterogeneity)
- Task graph provides look ahead
  - Exploit knowledge about the future
  - Allows exploration of scheduling policies
- It helps handling limitations of the hardware
  - Heterogeneity
  - Multiple address spaces
  - Low interconnect bandwidth
  - Synchronization





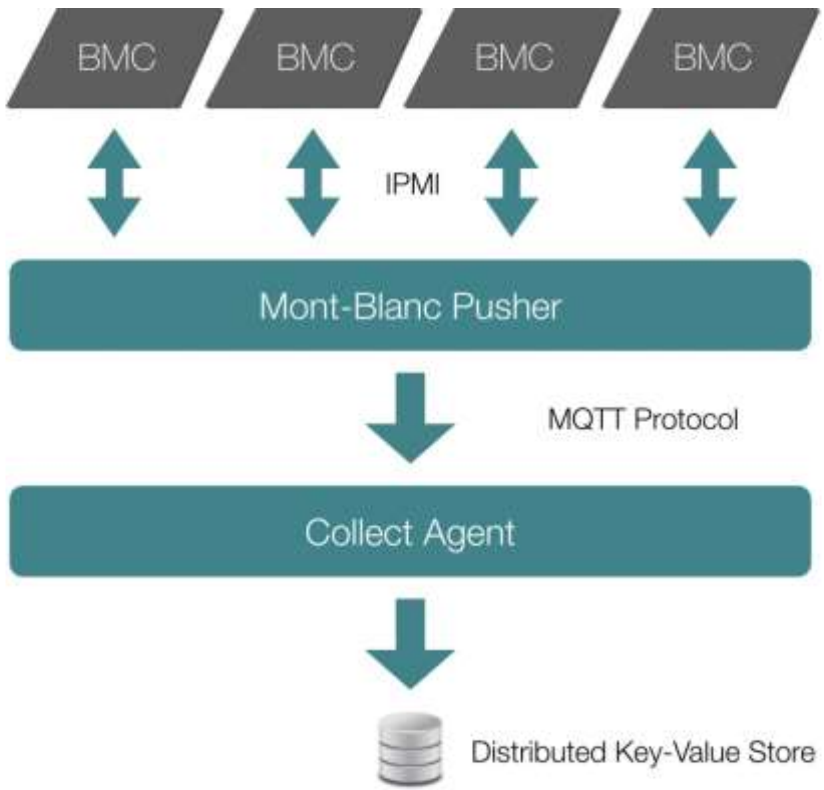

```
void Cholesky( float *A[NT][NT] ) {
int i, j, k;
for (k=0; k<NT; k++) {
   #pragma omp task inout (A[k][k])
   spotrf (A[k][k]) ;
   for (i=k+1; i<NT; i++) {
      #pragma omp task in (A[k][k]) inout (A[k][i])
      strsm (A[k][k], A[k][i]);
   }
   for (i=k+1; i<NT; i++) {
      for (j=k+1; j<i; j++) {
         #pragma omp task in (A[k][i], A[k][j]) inout (A[j][i])
         sgemm( A[k][i], A[k][j], A[j][i]);
      }
      #pragma omp task in (A[k][i]) inout (A[i][i])
      ssyrk (A[k][i], A[i][i]);
   }
}
```

Power monitor – HW infrastructure

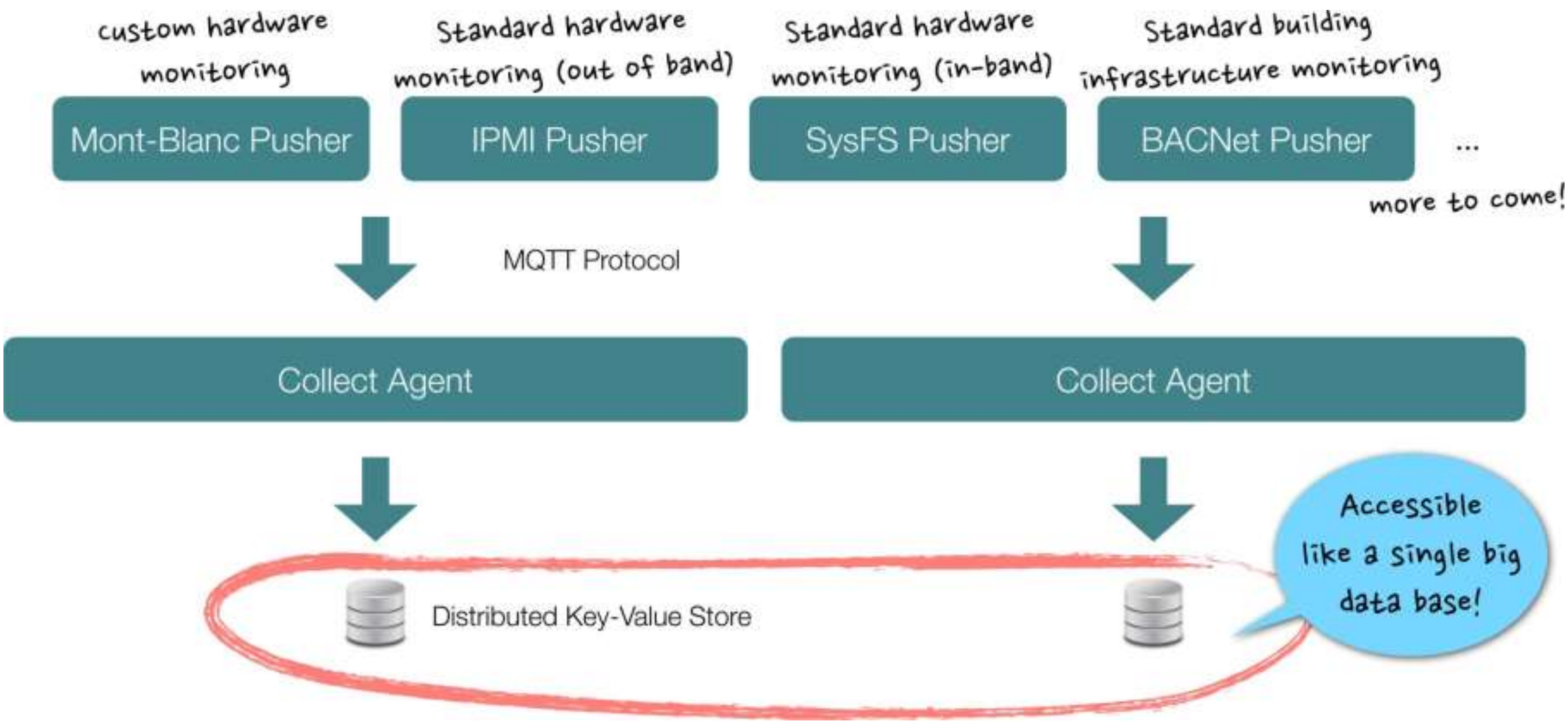


Power monitor – HW / SW interface

- Field Programmable Gate Array (FPGA)
  - Collects power consumption data from all 15 power measurement / sample interval: 70ms
- Board Management Controller (BMC)
  - Collects 1s averaged data from FPGA
  - Stores measurement samples in FIFO
- Mont-Blanc Pusher
  - Collects measurement data from multiple BMCs using custom IPMI commands
  - Forwards data using MQTT protocol through Collect Agent into key-value store



Power monitor – Block diagram



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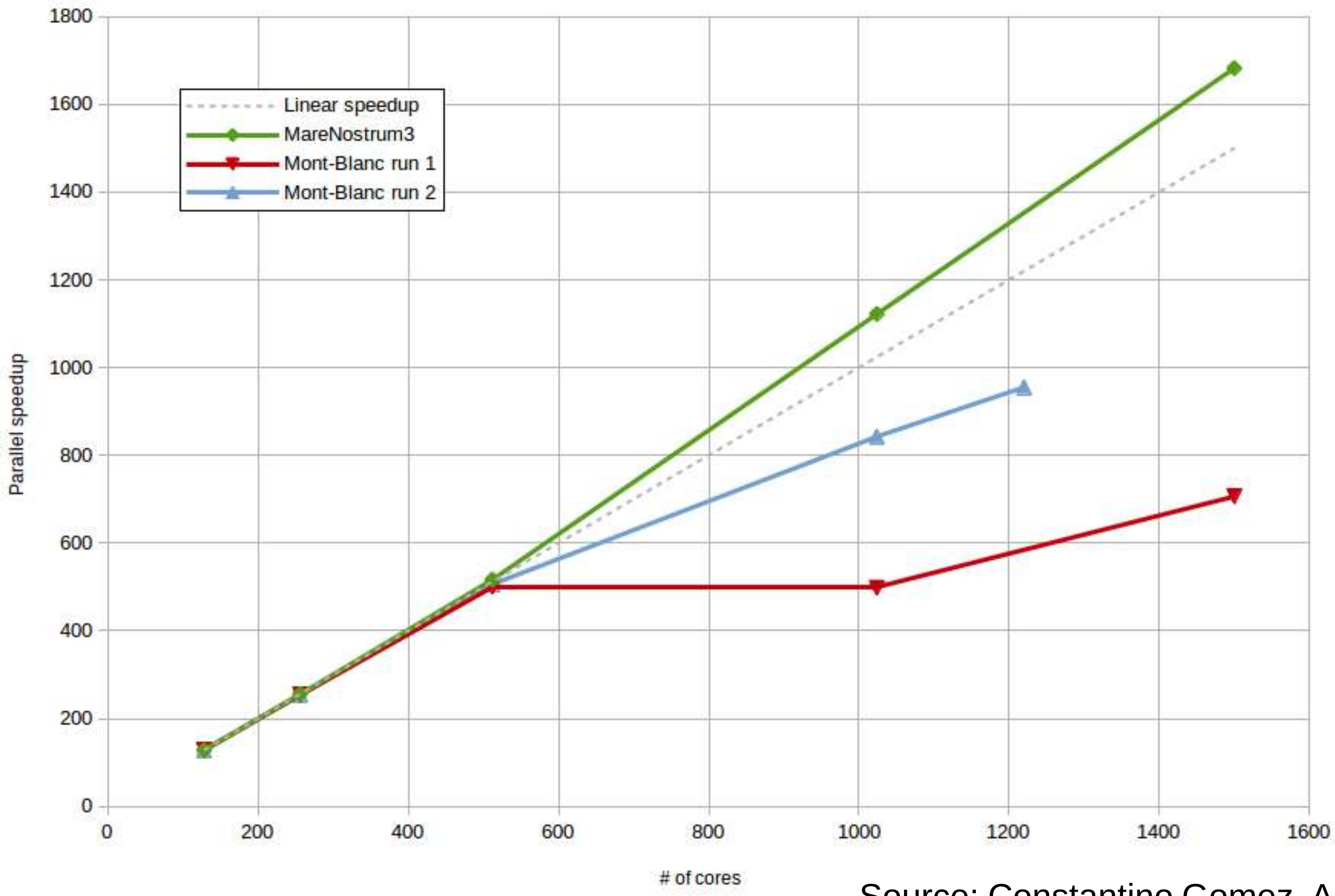
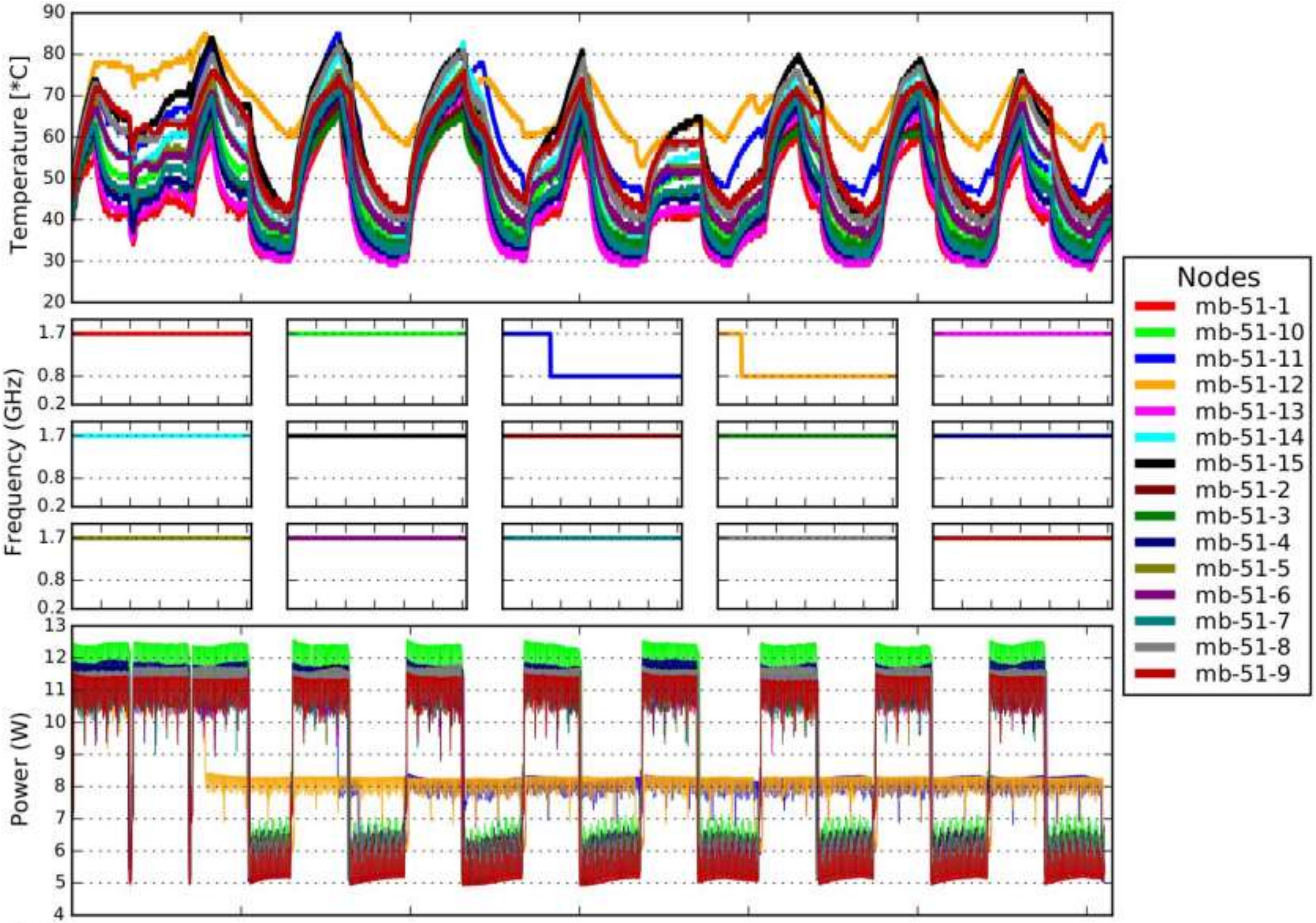
One application running: Alya RED

- Electro mechanics of the heart (of a rabbit)
- 10 steps measuring the parallel region of the code (MPI only)

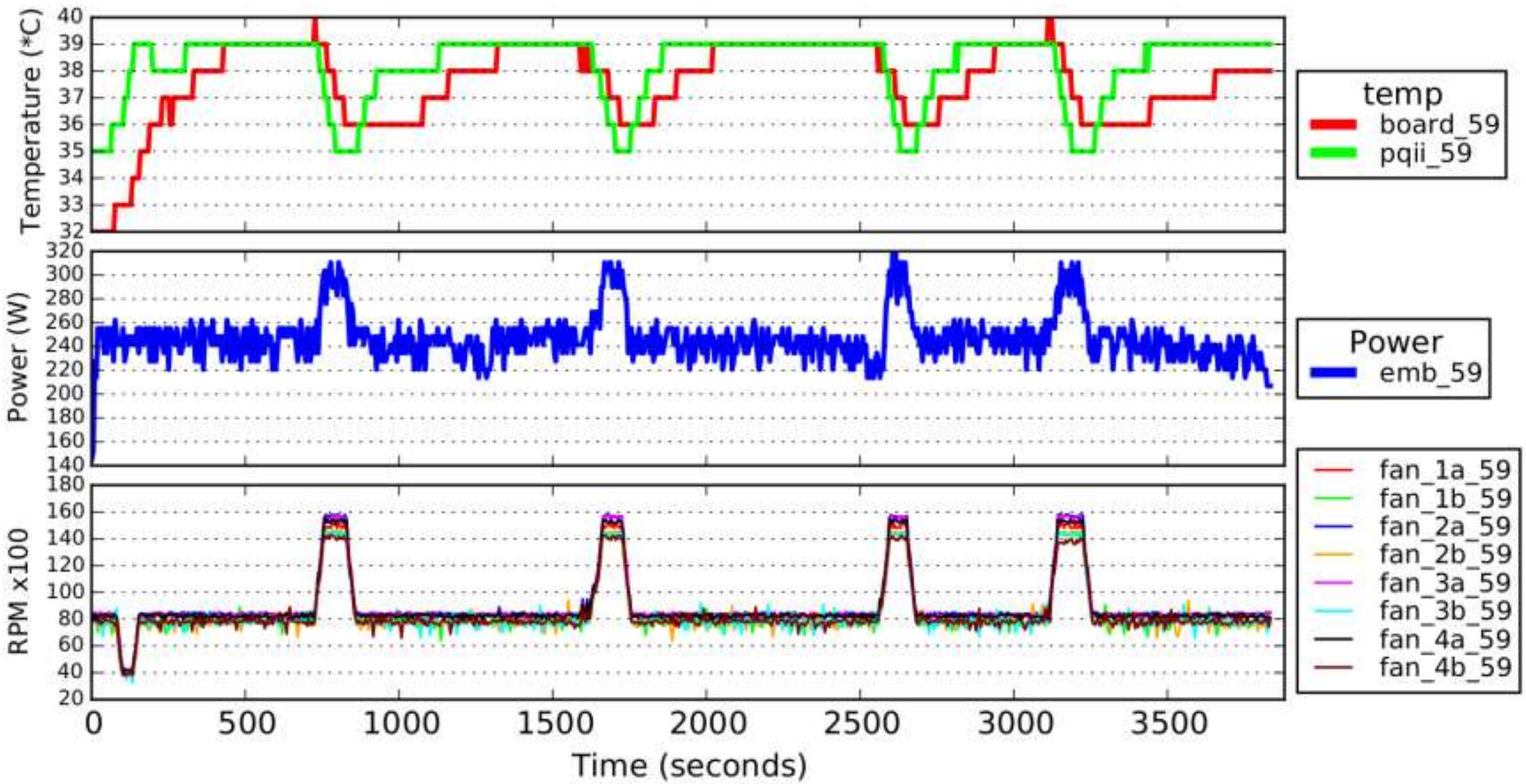


Source: Constantino Gomez, Alejandro Rico

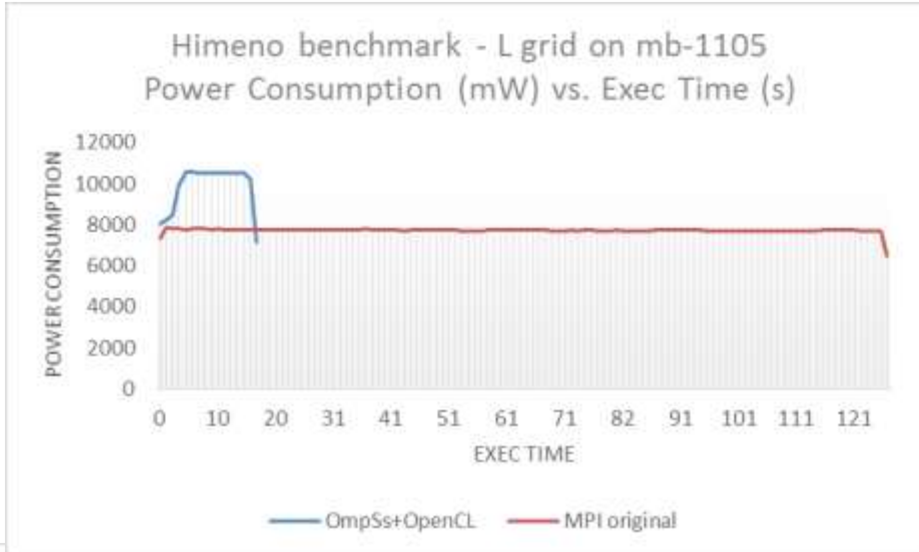
Understanding… at node level

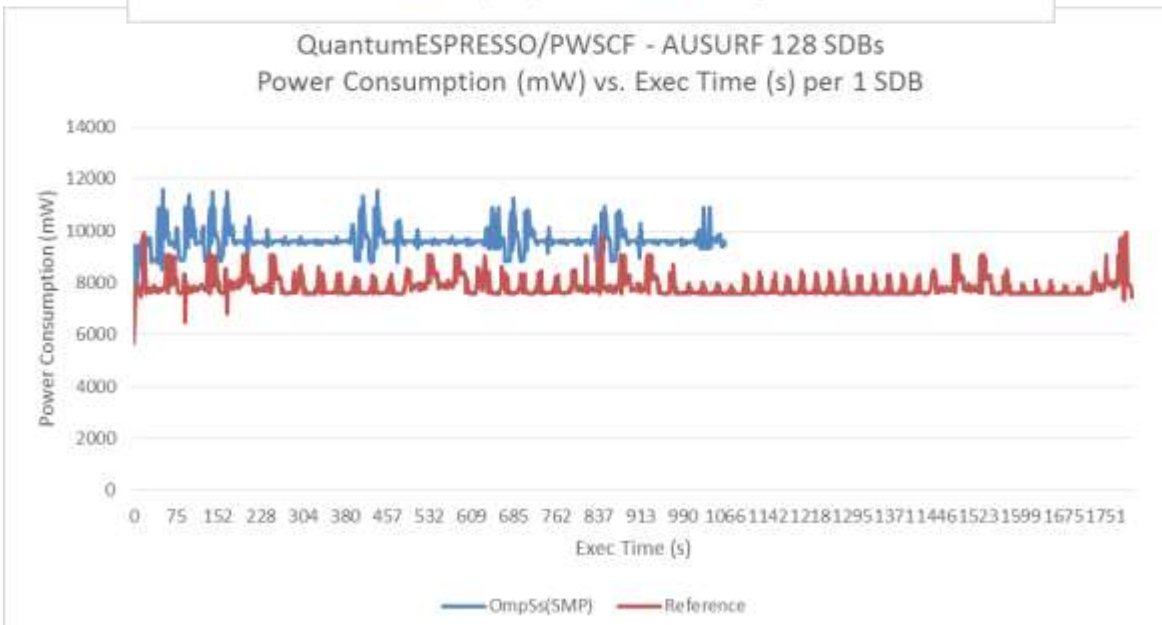


Understanding… at blade level



Energy to solution





End-User Group

- Develops a synergy among industry, research centers and partners of the project
- Validates the novel HPC technologies produced by the project
- Provides feedback to the project

Mont-Blanc provides EUG members with:

- Remote access to Mont-Blanc prototype platforms
- Support in platform evaluation and performance analysis
- Invitation to the Mont-Blanc training program

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Mont-Blanc project status

DONE!

- Prototype: design, development, deployment, monitor
- Deployment of HPC software stack on ARM
- Porting of HPC kernels and applications
- Test of non-HPC workload (Hadoop, OpenStack)

ON GOING…

- Next-generation architecture modelling
- ARM 64-bit exploration (mobile and server market)
- Porting of new applications
- Programming model enhancement
- Monitoring prototype for fault tolerant techniques

Mont-Blanc impact

MONT-BLANC

Lower cost

Higher cost

Cheap computing
- Industrial applications
- Small labs
- Small datacenters

New HPC node architecture
- Modular (IP)
- Requires industry involvement
- European architecture

Mobile technology
- Cheap due to volumes
- Fast evolution
- Constrained by mobile requirements
- More aggressive

Automotive
- Sensor fusion
- Autonomous driving
- Hybrid fuel
- …

Server technology
- Expensive
- Slower evolution
- More oriented to HPC (?)
- More conservative

Student Cluster Competition – ISC'15

Visit us @ booth #422

- First team participating with ARM-based cluster
- First Spanish team
- 3 kW power budget
- 5+ applications
  - HPCC
  - LAMMPS
  - PyFR
  - Octopus
  - Some "secret" applications
- 3 awards
  - Highest HPL
  - Fan favorite
  - 1st, 2nd, 3rd overall places

Conclusions

- Mont-Blanc project explores the use of mobile embedded technology for scientific computing
- Hardware contributions
  - Several ARM-based prototypes have been developed
  - Companies and research institutions (EUG) can test MB prototypes
- Software contributions
  - System software + Power monitor
  - Programming model
  - Applications
- Even with “cheap” hardware it is possible to perform “decent” scientific computing

> “The secret is to win going as slowly as possible.”
> Niki Lauda

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