

Techniques and tools for measuring energy efficiency of scientific software applications

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Techniques in Physics Research*

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1. Why is energy efficiency important on High Throughput Computing (HTC) ?

2. Measuring power consumption

Where is energy used ?

External measurements

Chip monitors

Software based measurements

3. Study case

External measurements

Chip monitors

IgProf for energy measurements

Results: ARM vs Intel comparison

4. Conclusions

1. Why is energy efficiency important on HTC ?



Worldwide LHC computing grid estimated 10 MW of power for 350k x86 cores

only CMS experiment will increase 2-3 orders of magnitude the amount of data in next 15 y.

Future: Scalability, raising costs ?

next: where ?

2.1. Where is the energy used ?

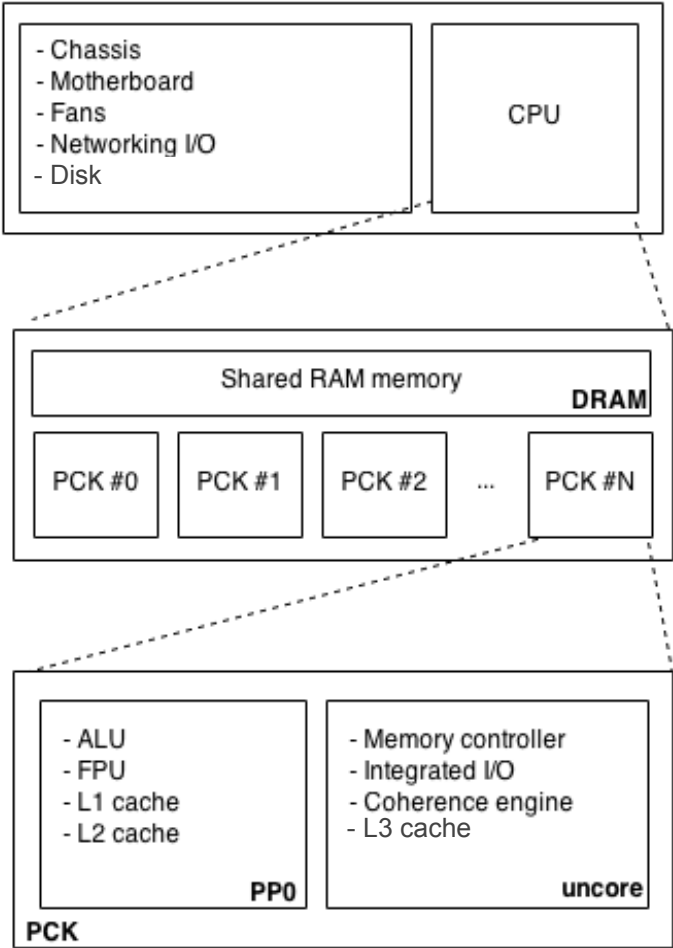
HTC systems are **complex**



Several components

Different **granularities**

CPU can be optimised
more control than other components



2.2. Where is energy used ? > External measurements

Account for the **whole system**

Power consumed without breaking down the system in components

Accuracy: around $\pm 3\%$ for clamps

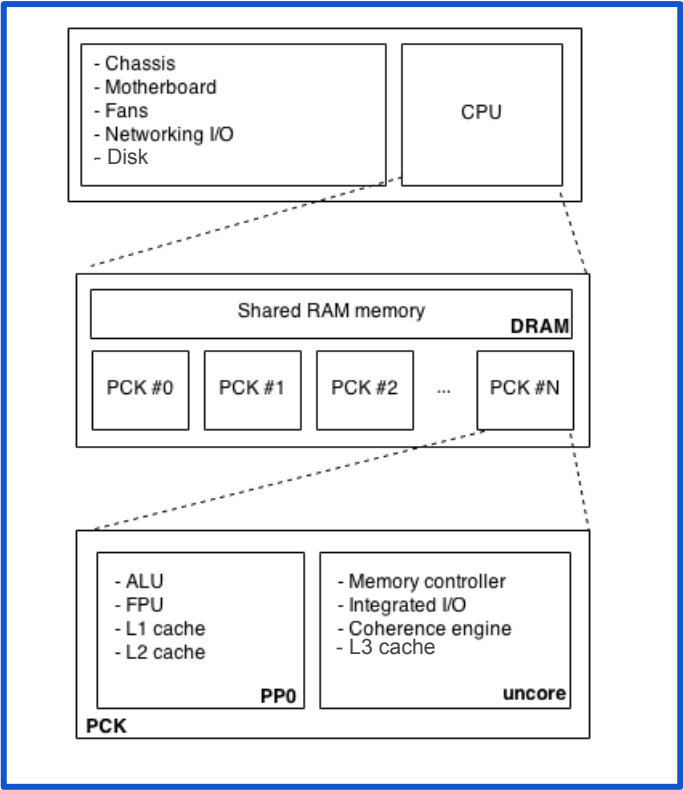
Resolution order of seconds (Hz)



<http://www.p-mastech.com>



<http://www.racksandpower.com>



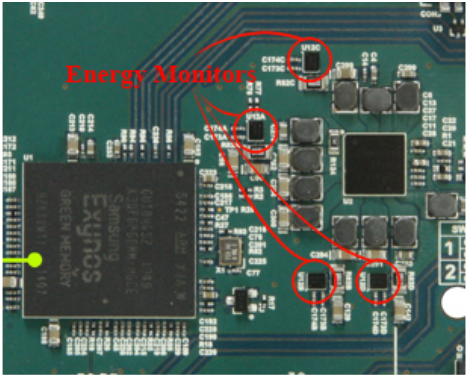
next: internal

2.2. Where is energy used ? > *Chip monitors*

Monitor chips on the motherboard that measure energy consumed by different components of CPU

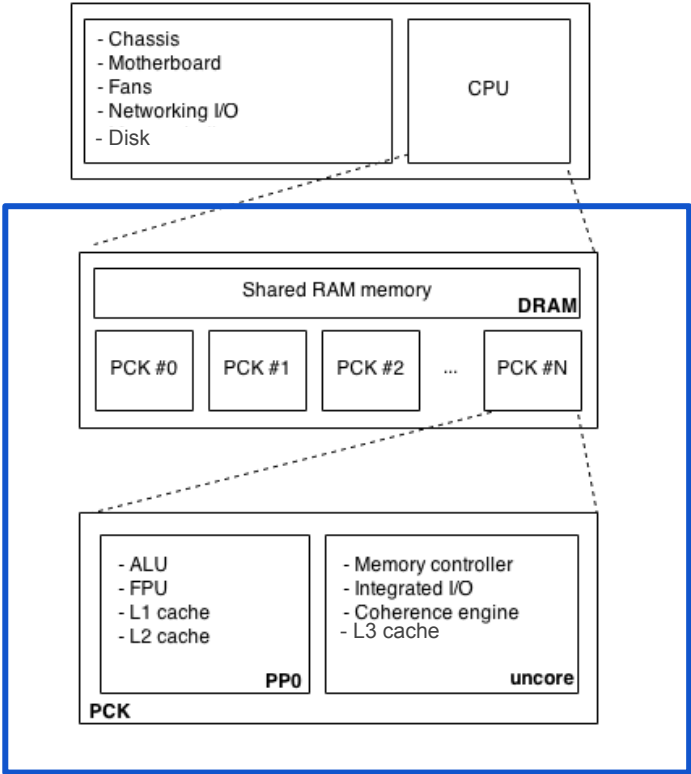
There is no standard solution.

Accuracy: *high* (ex: 0.5% gain error)
Resolution order of microseconds (*kHz*)



Texas Instrument (TI) INA 231 monitoring chip on ODROID XU+E

<http://hardkernel.com>



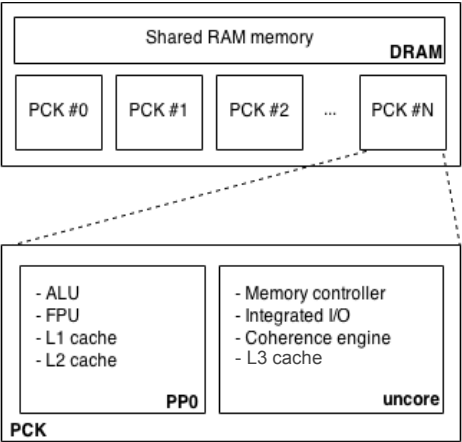
2.2. Where is energy used ? > *Chip monitors* > **RAPL**

Running Average Power Limiting (*RAPL*) by *Intel*

Provides a platform for power monitoring and power limiting of SoC.

Different sampling **domains**

package (*PKG*), DRAM, core



Low level measurements package, cores, dram

Resolution according to Intel, sampling frequency up to ~1 kHz

Power capping is also supported by RAPL

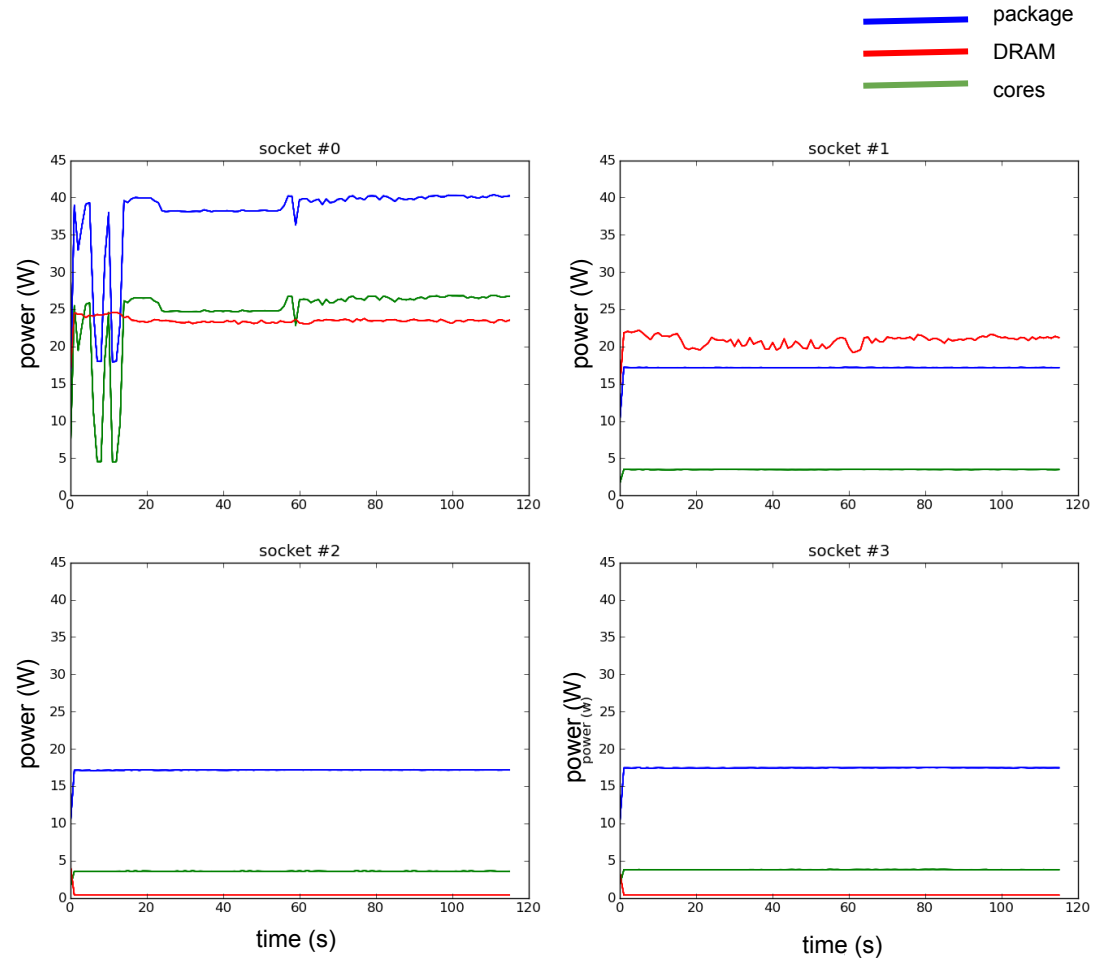
Accuracy high (according to *Intel*)

2.2. Where is energy used ? > *Chip monitors* > **RAPL**

Example of RAPL

System with 4 sockets
Sockets #0 and #1 working
Sockets #2 and #3 idle

Possible to understand how
packages, cores & dram consume
energy



2.2. Where is energy used ?

Recap

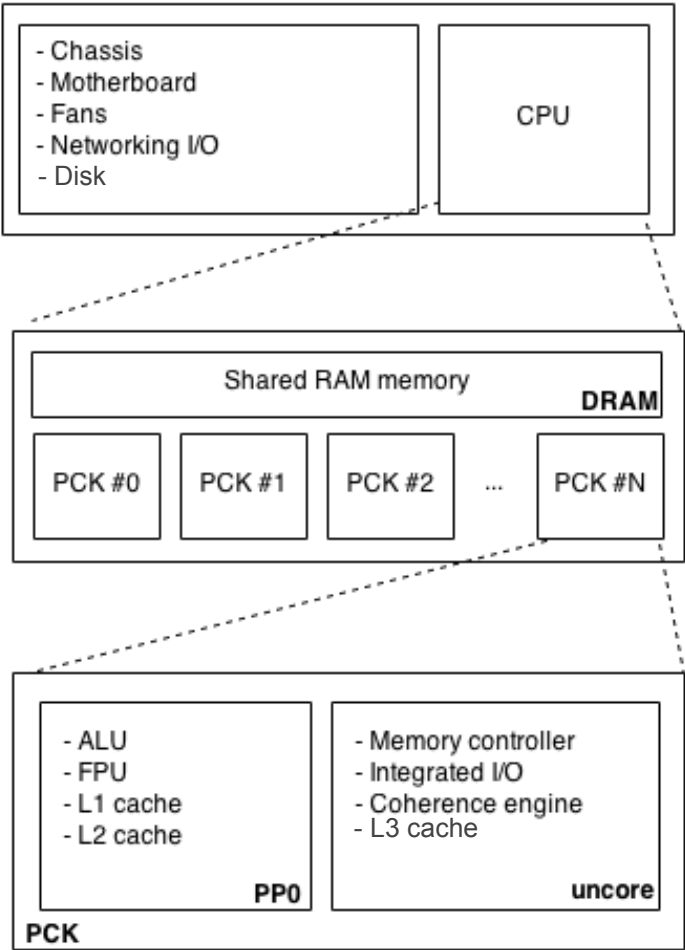
Energy consumption in HTC is an issue

HTC systems are complex

Different tools for different granularities and components:

External measurements

Chip monitors



2.2. Where is energy drained ? > Software-based> IgProf

IgProf

application profiler developed at CERN by the CMS software team

general purpose. open source. not experiment specific

measures performance (time spent in functions) and memory usage at *runtime*

allows developer to understand:

- bottlenecks

- where code needs to be optimised

cross platform: recently ported to 64-bit ARM, also supports 32-bit ARM, Intel x86 and x86-64

2.2. Where is energy drained ? > Software-based> IgProf

IgProf & energy profiling

Uses RAPL and PAPI to measure energy consumed.

Map functions and low level operations with **energy consumption**

more info (strategies, results, examples)

paper and <http://igprof.org/>

3. Study case

Comparison ARMv7 vs Intel XEON

32bit ARMv7 is used on smartphones. comparison with Intel XEON

measurements

Internal

RAPL for *Intel*

cross platform *chip monitor* integrated (TI INA 231) for ARMv7

External

workload

ParFullCMS

Multithreaded

Geant4 benchmark application

Uses the CMS geometry

3. Study case

ARMv7 Exynos5 Octa Cortex™
4x A15 @ 1.6Ghz and/or A7 cores (big.LITTLE technology)
2 GB RAM
ARMv7/32bit
development board

Intel 32x Intel™ Xeon™ CPU E5-2650 @ 2.00GHz
252 GB RAM
system on a rack



3. Study case

What to expect

ARMv7 performs better (energy efficiency perspective)

Both ARM and Intel do not perform better when overcommitted (*more threads than number cores*)

Power consumed ratio external/internal is bigger on Intel (*rack vs dev. board*)

Chip monitors and external measurement techniques in action

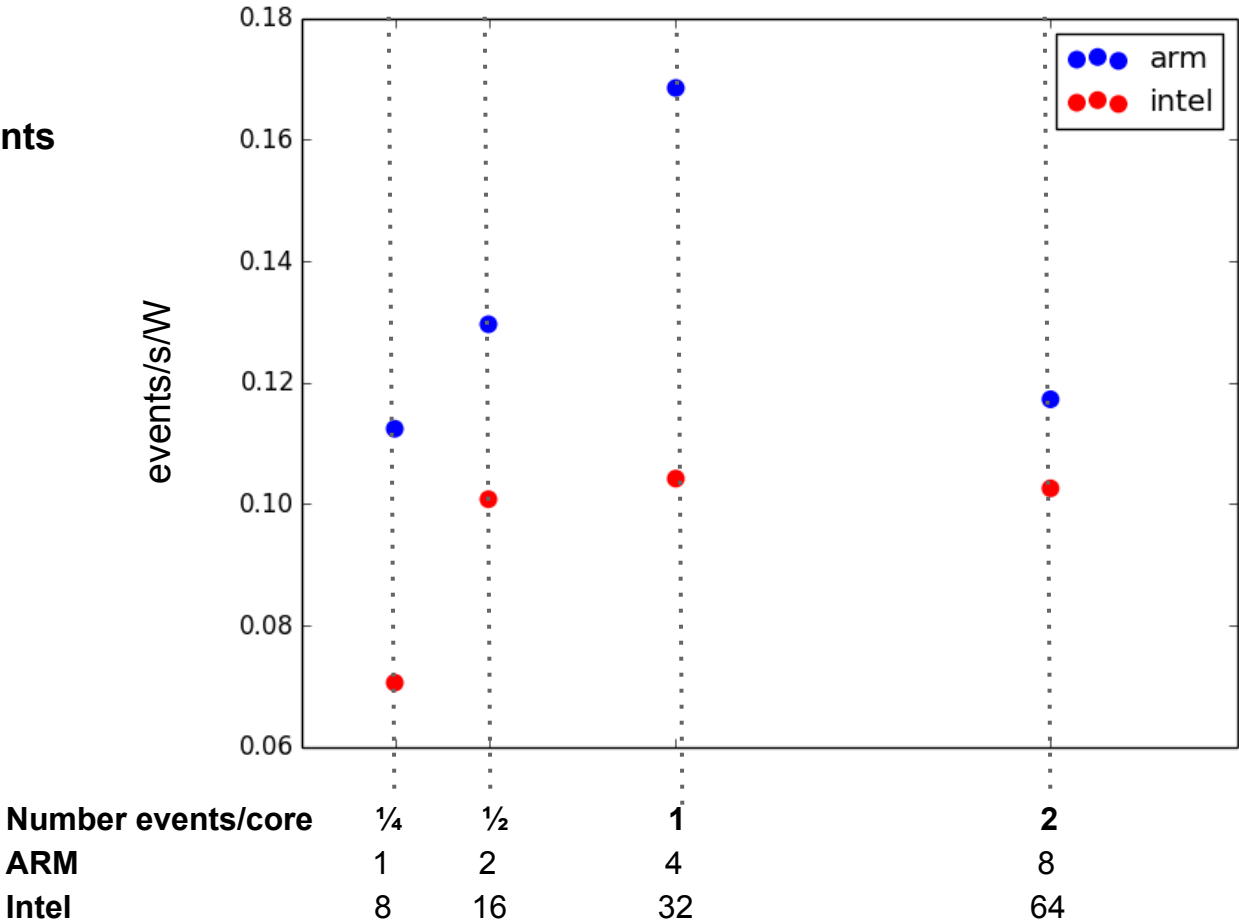
Chip monitors measurements

TI INA 231

- core + dram

RAPL

- core + dram

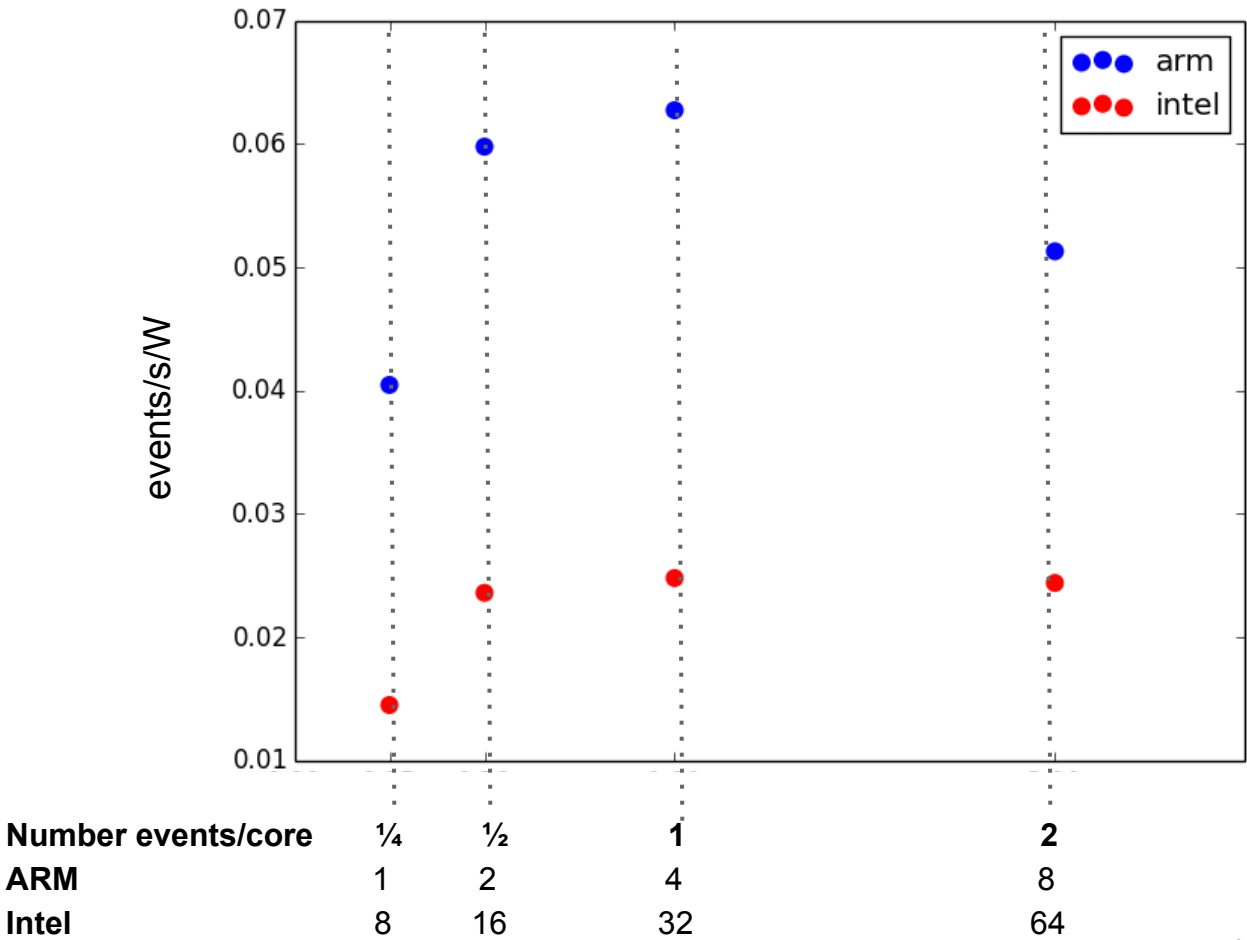


3. Study case > External measurements

External measurements

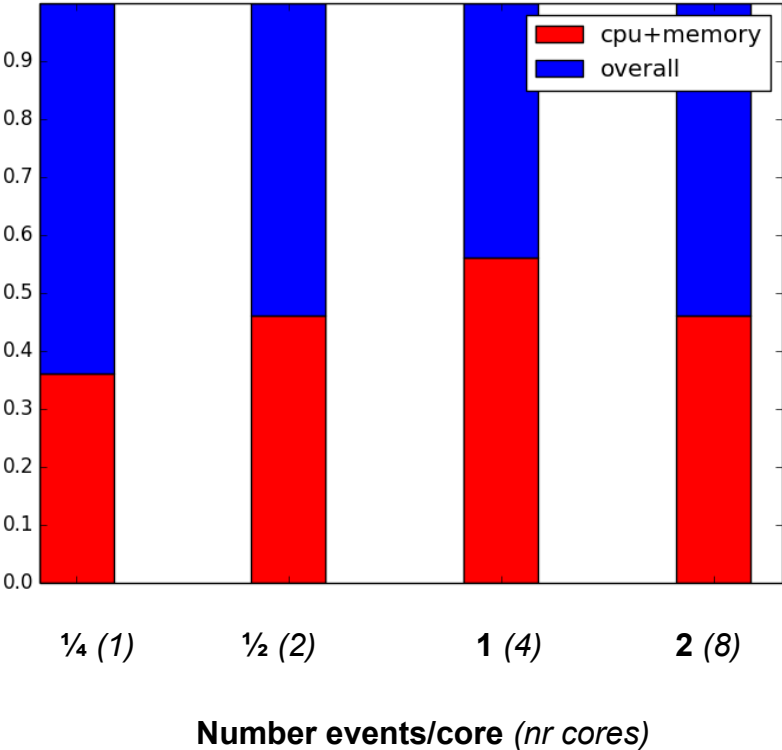
External power monitor

rack PDU power monitor

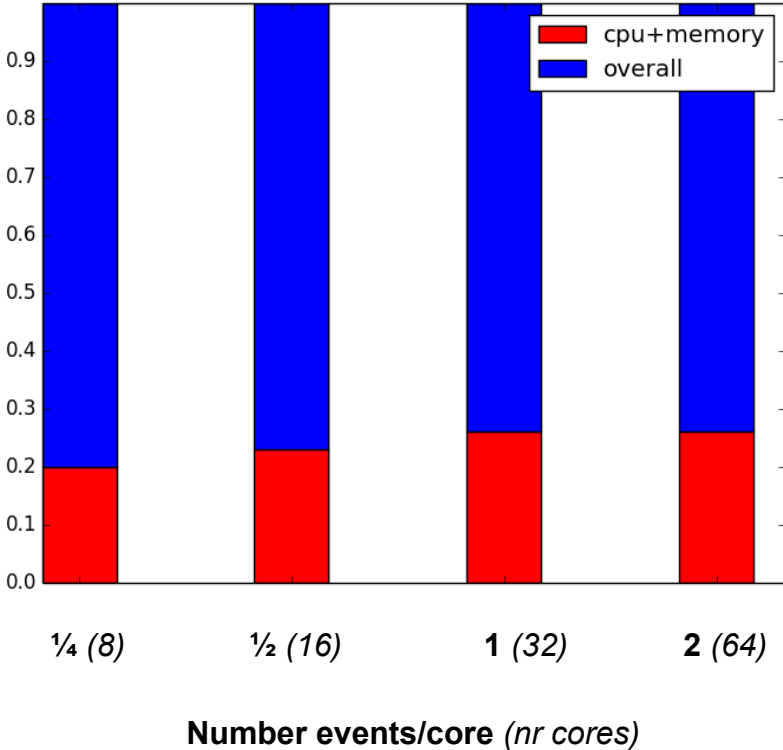


3. Study case > External measurements

ARM ratio *CPU+mem* vs overall



Intel ratio *CPU+mem* vs overall



3. Study case > Comparison ARM vs Intel

32bit ARMv7 with interesting results.

Different system's components → different tools for measurement

External, ***chip monitors*** and **software-based** measurements give good picture of the system's energy consumption at different levels.

4. Wrapping up

Energy efficiency is a major concern of HTC

Important to be aware of where and how energy is consumed on a HTC system

There are **tools and techniques** that account for the different system's components

Recently, **IgProf** was ported for ARM 64 bit and got power profiling capabilities.

ARM keeps showing potential for efficient HTC



Q & A

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