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## Linux: Understanding Process-Level Power Consumption

Aurélien Bourdon, Adel Noureddine, Romain Rouvoy, Lionel Seinturier

► **To cite this version:**

Aurélien Bourdon, Adel Noureddine, Romain Rouvoy, Lionel Seinturier. Linux: Understanding Process-Level Power Consumption. Green Computing Middleware (GCM'2011), Dec 2011, Lisbonne, Portugal. 2011. hal-00641706

**HAL Id: hal-00641706**

**<https://inria.hal.science/hal-00641706>**

Submitted on 13 Dec 2011

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# Linux: Understanding Process-Level Power Consumption

Aurélien Bourdon

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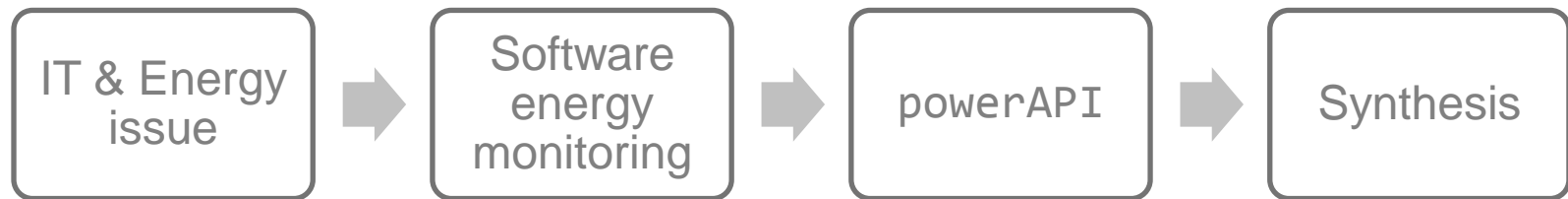
Lionel Seinturier

firstname.lastname@inria.fr

Green Computing Middleware'11

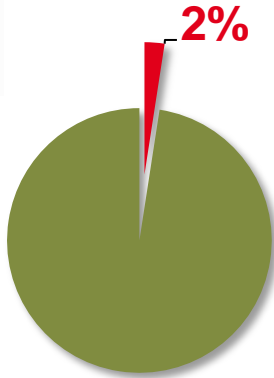
December 12th 2011

# Outline



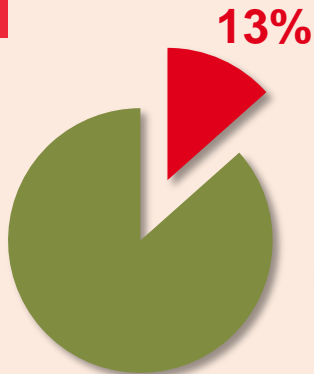
# Information Technologies & Energy issue

# IT & Energy



World wide carbon emission

Gartner group report



French electricity consumption

French ministries. IT & Sustainable Development report

8<sub>x</sub>



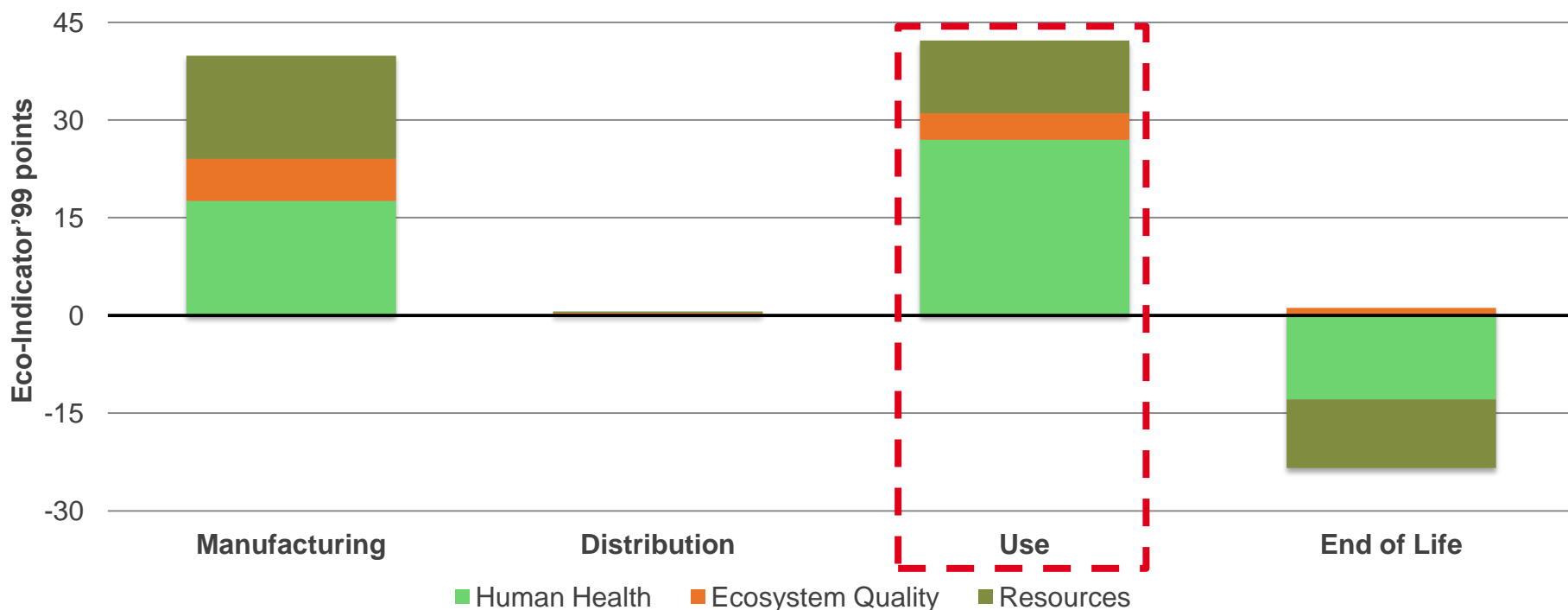
8<sub>x</sub>



**10% increase by year, over the past 10 years**

# IT: Where is the energy consumed?

Life Cycle Assessment (LCA) for a common PC



Duan & al. Life cycle assessment study of a Chinese desktop personal computer

# IT & Energy: Towards a software concern

Hardware optimizations... but not software

Energy intelligence software is... out of software

Software is not energy aware by design

**Software has to be energy aware**

**Tools which could help developers to visualize energy consumption**

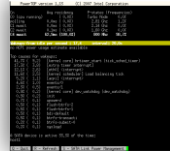
**Discover new green development methodologies**

# Software energy monitoring



# State-of-the-art

PowerTop



JouleMeter

pTop



EnergyChecker

There are not reusable libraries

Not easy to support platform interoperability

Development is over

Manual calibration

Requires external device

# Our solution: powerAPI

# Architecture overview

Energy module

=

Process(es) energy profiler through a specific hardware component

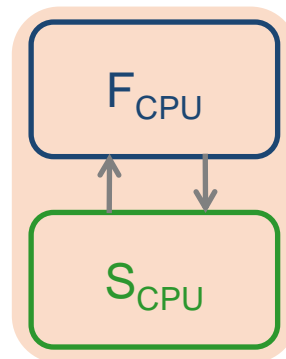
Energy module



Formula

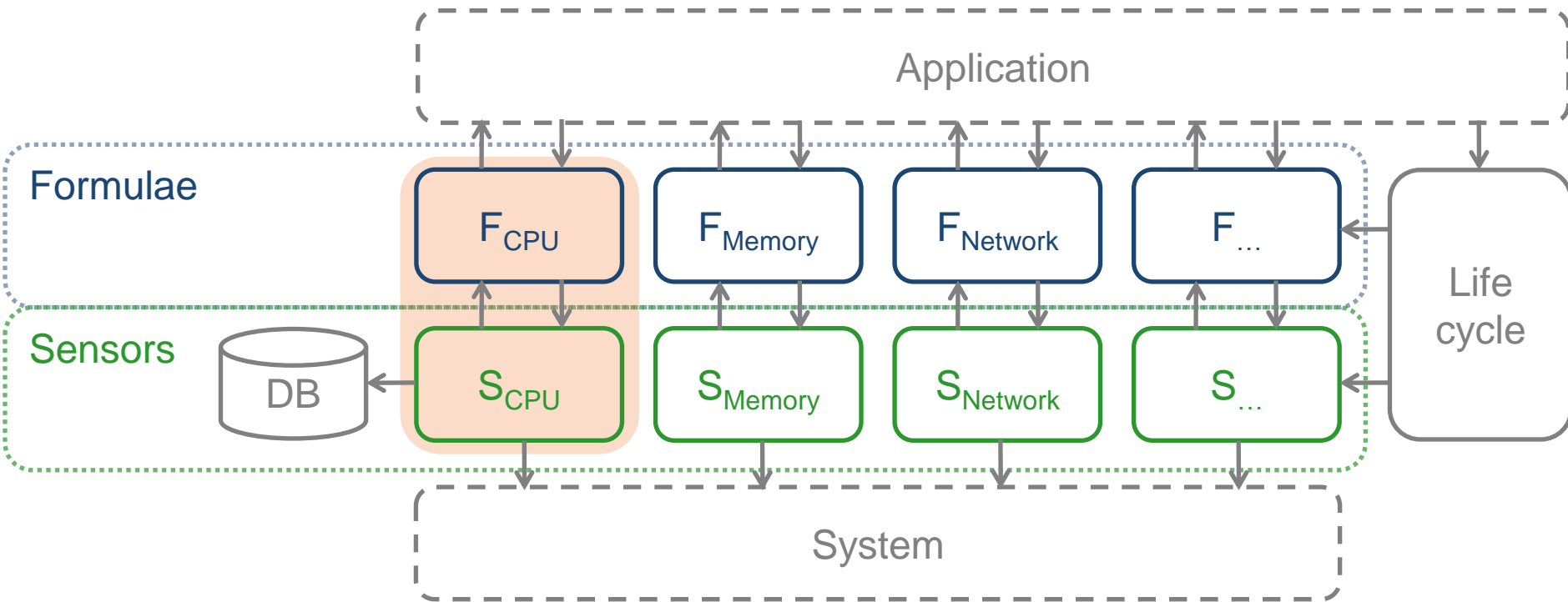


Sensor



As many sensors as there are specific environments

# Architecture overview



# Architecture benefits

Modular approach, easy to extend

Interoperability

Adaptation to the execution platform, auto-calibration

Adaptation to the application needs

# How does it work?

## CPU case study, Linux system

# How does it work? CPU case study



$$P_{CPU}^{PID}(d) = P_{CPU}(d) \times U_{CPU}^{PID}(d)$$

Process CPU  
power

Global CPU  
power

Process CPU  
usage

Global CPU Power

Process CPU Usage

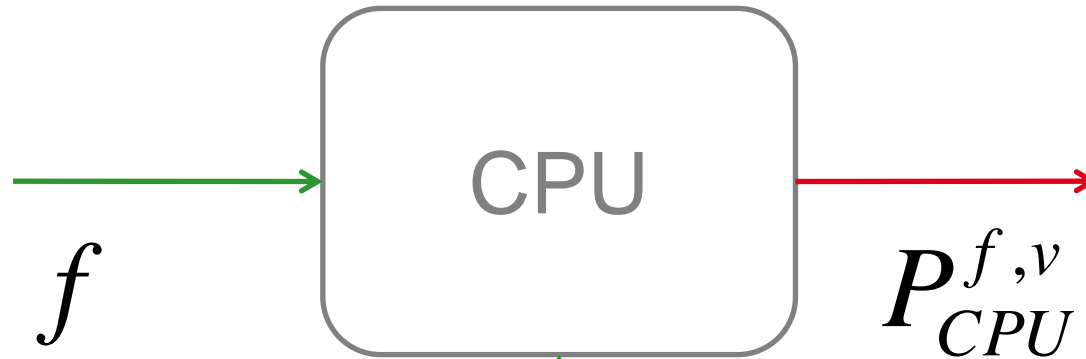
Static part

Dynamic part

Process CPU time

Global CPU time

# How does it work? CPU case study



$$\underbrace{C}_{\text{Static part}} \times \underbrace{\quad \times \quad}_{\text{Dynamic part}} \times v^2 = \quad [1]$$

[1] Ge & al. Improvement of Power-Performance Efficiency for High-End Computing

Global CPU Power



Process CPU Usage

Static part

Dynamic part

Process CPU time

Global CPU time



# How does it work? CPU case study

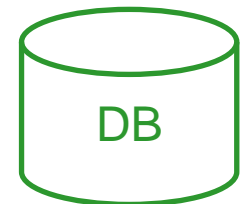
Static part is made up of several constants hard to find out...

That's why we used constructor's Thermal Dissipation Power value

$$P_{CPU}^{f_{TDP}, v_{TDP}} = TDP \times 0.7$$

Rivoire & al. JouleSort: A Balanced Energy-Efficiency Benchmark

$$C = \frac{P_{CPU}^{f_{TDP}, v_{TDP}}}{f_{TDP} \times v_{TDP}^2}$$



Global CPU Power



Static part



Dynamic part

Process CPU Usage

Process CPU time

Global CPU time

# How does it work? CPU case study

We need to have

All frequencies used by CPU during the  $d$  period

Correspondance table between a frequency and its voltage

Global CPU Power



Static part ✓

Dynamic part



Process CPU Usage

Process CPU time

Global CPU time

# How does it work? CPU case study

Frequencies used by CPU during d period

cpu-freq-utils tool

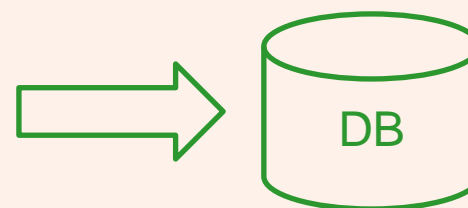
```
/sys/devices/system/cpu/  
|_ cpu[0-n]/  
|_ cpufreq/time_in_state
```

2,8 GHz	70722 ms
1,599 GHz	4477 ms
...	...

Correspondance table between frequency and voltage

Constructor's data

2,8 GHz	1.5 V
1,599 GHz	0.8 V
...	...



Global CPU Power



Static part ✓

Dynamic part



Process CPU Usage

Process CPU time

Global CPU time

# How does it work? CPU case study



$$P_{CPU}(d)$$

Global CPU  
power

×

$$U_{CPU}^{PID}(d)$$

Process CPU  
usage

Global CPU Power ✓

Static part ✓

Dynamic part ✓

Process CPU Usage

Process CPU time

Global CPU time

# How does it work? CPU case study



$$U_{CPU}^{PID}(d) = t_{CPU}^{PID}(d) / t_{CPU}(d)$$

Process CPU  
usage

Process CPU  
time

Global CPU  
time

Global CPU Power ✓

Process CPU Usage ⚠

Static part ✓

Dynamic part ✓

Process CPU time

Global CPU time

# How does it work? CPU case study

Process CPU time

Global CPU time

procfs virtual file system

/proc/[pid]/stat file

/proc/stat file

Sum of all kind of times (usertime, systemtime, blockingiotime...)

Global CPU Power ✓

Static part ✓

Dynamic part ✓

Process CPU Usage ⚠

Process CPU time ⚠

Global CPU time ⚠

# How does it work? CPU case study



$$P_{CPU}^{PID}(d) = P_{CPU}(d) \times U_{CPU}^{PID}(d)$$

Process CPU  
power

Global CPU  
power

Process CPU  
usage

Global CPU Power ✓

Process CPU Usage ✓

Static part ✓

Dynamic part ✓

Process CPU time ✓

Global CPU time ✓

# Does it work?

## Validation



# Validation



Dell Precision T3400



Ubuntu 11.10 generic  
(kernel version 3.0.4)



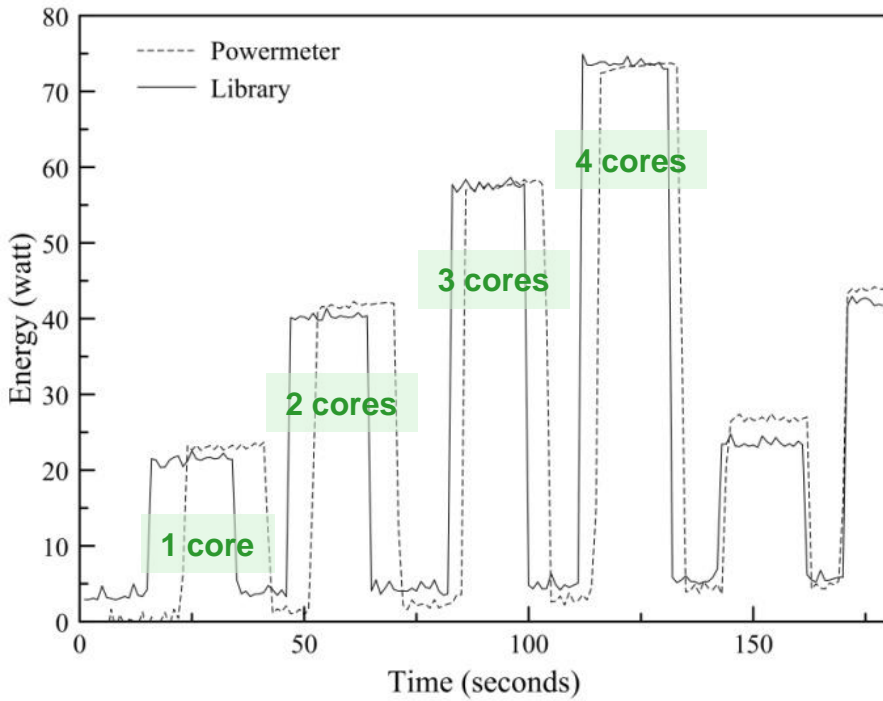
Intel Core 2 Quad Q6600  
(2.4 GHz)



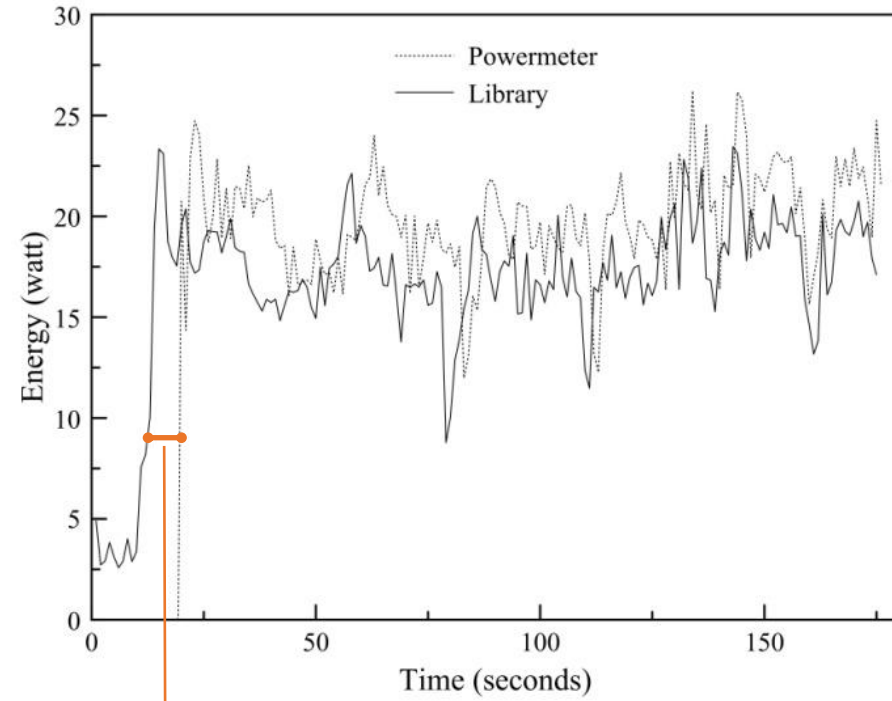
PowerSpy powermeter

# Validation

Stress CPU stressor



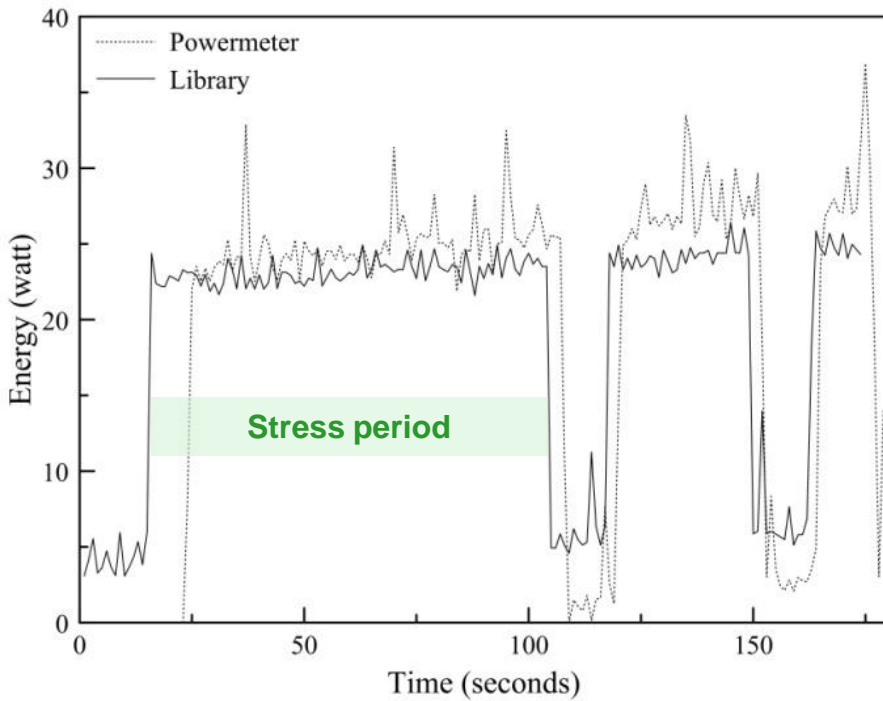
Mp1ayer movie player



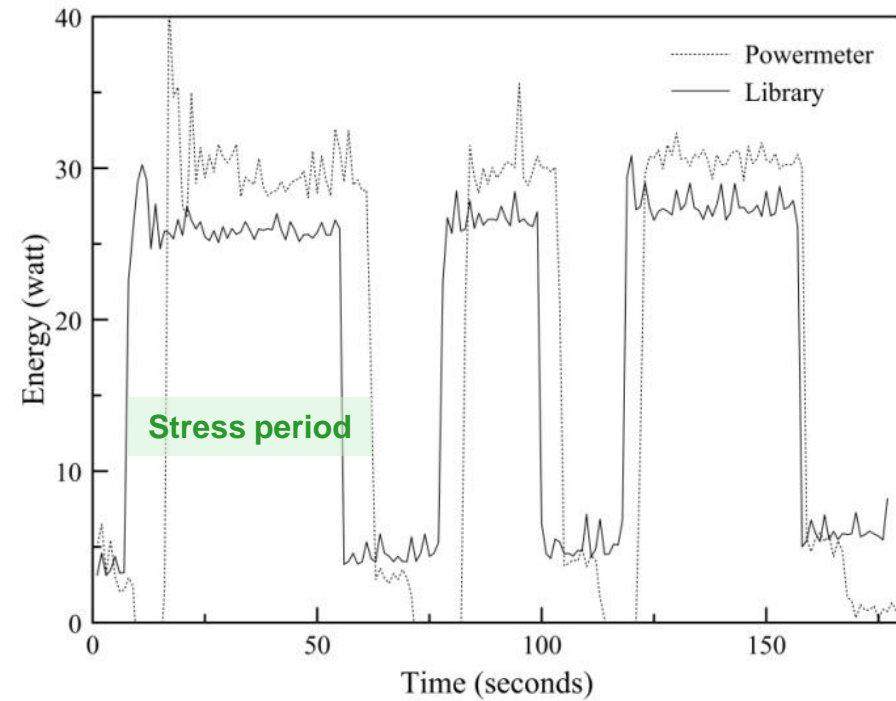
Time lag due to different refresh times  
between powermeter and powerAPI

# Validation

Tomcat web server



Jetty web server



# Conclusion & Perspectives

# Synthesis

Need tools which could help developer to monitor software energy consumption

Some libraries already exist but integration and evolution are difficult

powerAPI = Process-level energy sensor library with a modular and adaptive architecture

We are working on new modules development (memory, disk...)

# Applications

Some applications already exist

Process-level energy consumption visualizations

Monitoring and profiling Java applications at runtime  
(eSurgeon)

# Thank you!

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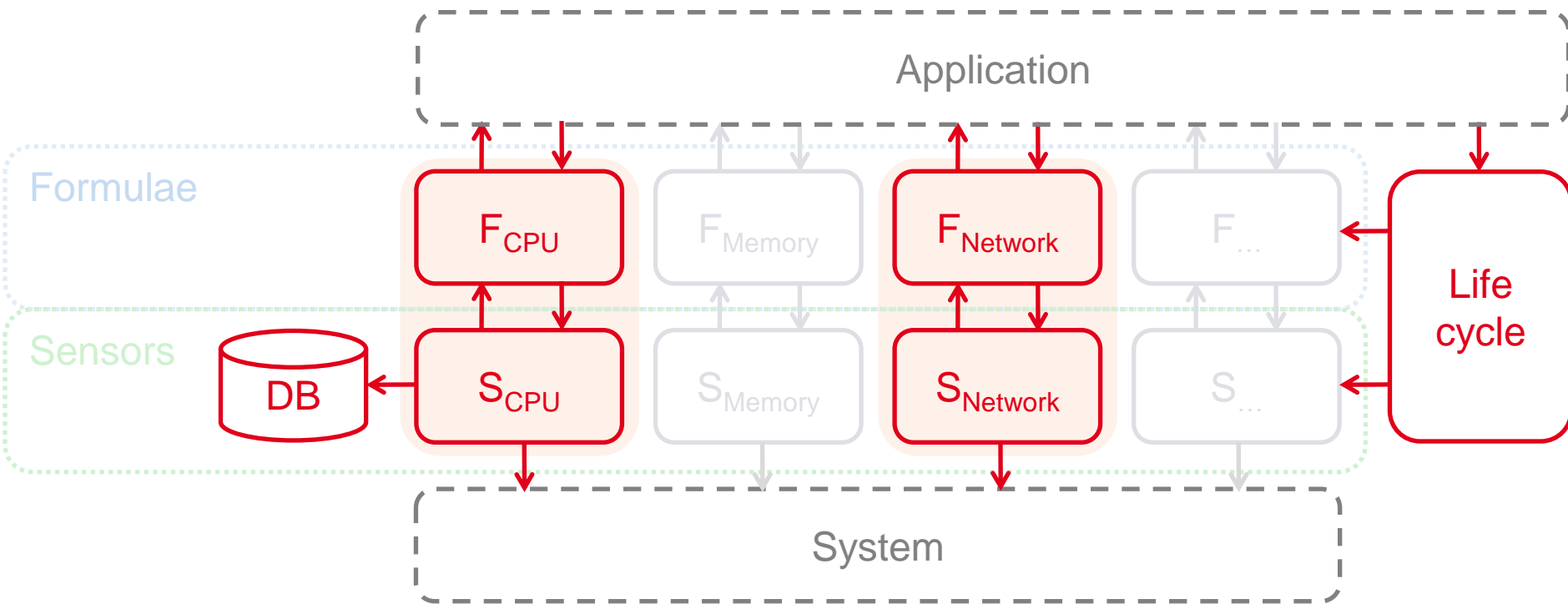
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# Backup slides



# Architecture overview, current state



# CPU power consumption formula

$$P_{CPU}^{f,v} = C \times f \times v^2$$

$$P_{CPU}^{f_{TDP},v_{TDP}} = TDP \times 0.7$$

$$TDP \times 0.7 = C \times f_{TDP} \times v_{TDP}^2$$

$$C = \frac{TDP \times 0.7}{f_{TDP} \times v_{TDP}^2}$$

# Technical details

C++

Qt

SOF

CMake