Toward Zero-Power ICT

European initiative for efficient powering of micro and nanoscale autonomous devices

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GUARDIAN ANGELS Workshop – Helsinki 15-16 Sept 2011
Conclusions

From A. Ionesco’s talk, 15-9-2011

The zero-power platform vision of Guardian Angels is essential to enable the economy of scale and the future success of WSN.

Energy efficiency gain is obtained by:
- Fundamental research into the limits of computation, communication, sensing, energy harvesting.
- …
Toward zero-power ICT

This is part of an ongoing EC (ICT – FET Proactive) effort

- Feb 2010, Brussels. Consultation workshop on "Disruptive Solutions for Energy Efficient ICT"
- Aug.1st 2010 three project started (SiNAPS, GREEN SILICON, NANOPOWER)
- Jan 1st 2011 ZEROPOWER C.A. started
- 26 July 2011 FP7 CALL 8, ICT 9.8 FET Proactive: Minimising Energy Consumption of Computing to the Limit (MINECC) (deadline 17 January 2012)
- 12 Oct 2011 FET Proactive Information Day - Brussels
Toward zero-power ICT

This is NOT the only initiative but shows an interesting peculiarity

1) Addresses the problem of PORTABLE POWER for Autonomous ICT Devices

2) Addresses the problem of ENERGY EFFICIENCY in ICT

To date these two problems we considered independently by different communities
Toward zero-power ICT

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Few hints on these topics…
Heat dissipation in computing devices is a serious problem.

Energy impact of ICT is under discussion

Objectives of the Consultation Workshop (Brussels, 8-9 February 2010): Disruptive Solutions for Energy Efficient ICT

It will be a clear future priority world wide to decrease mankind’s carbon footprint.

According to the SMART2020 study, the share of ICT on the world wide energy consumption today is in the range of 2-5%.

Hence, it becomes more and more important to consider and improve the energy efficiency of ICT.

On the short term, it will be an obvious and practical solution to exploit better the potential of technologies that already exist or are currently in the making. On the long term, new and disruptive ideas will be needed, and we must start to search for those ideas already now.

Fig. 1 ICT impact: The global footprint and the enabling effect

GtCO₂e

2002
2020 BAU
Abatements
2020 with abatements

* For example, avoided deforestation, wind power or biofuels.

There are fundamental physics limits that are relevant

1. Landauer limit to minimum energy for logically irreversible operation
   \[ E_{\text{min}} = kT \log 2 = 10^{-21} \text{ J} \]

2. Quantum limit from Energy/time uncertainty relation
   \[ \Delta t = \frac{\pi \hbar}{2E} \]

Margolus, N. & Levitin, L. B.
The maximum speed of dynamical evolution.

Noise will become increasingly important in ICT

Physical limits of silicon transistors and circuits

Robert W Keyes

IBM Research Division, Yorktown, NY 10598, USA

Received 27 April 2005, in final form 11 August 2005
Published 19 September 2005
Online at stacks.iop.org/RoPP/68/2701

Progressive decrease in supply voltage requires noise tolerance

Universal and reconfigurable logic gates in a compact three-terminal resonant tunneling diode, L. Worschech; F. Hartmann; T. Y. Kim; S. Hofling; M. Kamp; A. Forchel; J. Ahopelto; I. Neri; A. Dari; L. Gammaitoni, APL 96, 042112, (2010)
Future ICT will be characterized by pervasive computing

- Decreases the power demand for ICT devices
- Increases the market for portable micro-to-nano power generators

Guardian Angels (GA’s) are zero-power smart autonomous systems featuring sensing, computation and communication. They can harvest different kinds of energy.

From Florin Udrea presentation at Scientific Session
Sustainable ICT: Micro and Nanoscale Energy Management
Budapest, May 2011
We would like to address all these topics within one unifying frame:

Energy efficiency in micro and nanoscale devices

Coordinating this research effort is the purpose of our C.A. ZEROPOWER (www.zero-power.eu)

4 partners:
NiPS Lab (IT), UAB (Sp), Tyndal (Ir), Univ Glasgow (UK)
0.6 M€, 3 years, lead by NiPS
Key-point in our effort:
A general approach to ICT devices as micro/nano machines

An ICT device is a machine that inputs information and energy (under the form of work), processes both and outputs information and energy (mostly under the form of heat).

Energy efficiency is usually defined as the percentage of energy input to a device that is consumed in useful work and not wasted as useless heat, however ...
... however this definition **does not apply** when we have to deal with processes taking place at nanoscale.

The well-known laws of heat and work transformation that lie at the base of the classical thermodynamics are going to **need a rethinking**. The very basic mechanism behind energy dissipation requires a new definition when non-equilibrium processes involving only few degrees of freedom are considered.

**CHALLENGE:**

the description of **energy transformation processes at the nanoscale** aimed at unveiling new mechanisms for powering next generations of ICT devices.
European Commission policy toward these issues in FPVII

ICT – FET (Future and Emerging Technologies)

FET proactive initiative: Towards Zero-Power ICT
(http://cordis.europa.eu/fp7/ict/fet-proactive/2zerop_en.html)

Extract from ICT Work programme 2009-2010 - Objective ICT-2009 8.6 – Call 5:
New disruptive directions are needed for energy-harvesting technologies at the nanometre and molecular scale, and their integration with low-power ICT into autonomous nano-scale devices for sensing, processing, actuating and communication.

Three projects have been funded with a budget of 7 M€.
- SINAPS will employ semiconductor nanowires both for energy harvesting of electromagnetic radiation and for (bio-) chemical sensing.
- GREEN SILICON will harvest energy from temperature gradients with zero-, one- and two-dimensional silicon silicon-germanium superlattices.
- NANOPower will investigate the fundamentals of energy harvesting at the nano-scale.

Starting date is 1st of August, 2010, end date 31th July 2013.
Nanoscale energy management for powering ICT devices

www.nanopwr.eu

6 partners:
Wurzburg (Ger), ICN (Sp), VTT (Fi), Univ Geneva (Ch), Unicam (It)
2.6 M€, 3 years, lead by NiPS

NANOPOWER is an EC funded project (Objective ICT-2009 8.6 – Call 5, GA no: 256959) under the FET proactive initiative "Toward Zero-Power ICT" (2zeroP)
The scientific objective of this project is thus to study energy efficiency with the specific aim of identifying new directions for energy-harvesting technologies at the nanometre and molecular scale.

The technological objective of the project is to integrate such technologies into autonomous nanoscale systems to allow new, low-power ICT architectures to find their way into devices.

In a joint effort, the NANOPOWER consortium composed by word leading experts in the fabrication of Si and III-V semiconductor nanodevices, fundamental and applied modelling as well as design and integration of ICT architectures will fabricate, test and evaluate new challenging prototype devices:

✓ Nanomechanical nonlinear oscillators
✓ Phonon rectifiers
✓ Quantum harvesters

addressing applied prototypes and non-equilibrium processes down to the quantum level.
2010 - 2013

- Nanopower classes
- Harvesting from vibrations
- Thermal nonequilibrium
- Quantum harvesting

Harvesting Schemes & Nanopower Roadmap

- Piezoelectric
- Piezoelectric + kinetic storage
- Phonon rectification
- Phonon rectification + Thermoelectric harvesting
- Buttiker Landauer Motor
- Mesoscopic Coulomb drag

Decreasing size: nm

\[ U(x) = \frac{1}{2} k_e x^2 + (A x^2 + B \Delta^2)^{-3/2} \]
**Dissemination activity**

**Scientific Sessions**

“Energy efficient ICT: toward zero-power devices for a greener planet” ICT2010 - 28th September 2010 Brussels


**Newsletter**

A digital newsletter specifically oriented for people interested in nanoscale energy harvesting technology.

[www.zero-power.eu](http://www.zero-power.eu)

**Events**

Micro Energy Day: a public awareness event

[www.microenergyday.eu](http://www.microenergyday.eu)
Educational activity: Summer school

2010

Aug. 1-8 2010

Summer School and
International Workshop

Energy Harvesting at micro and nanoscale
Noise in dynamical systems at the micro and nanoscale

NiPS Laboratory
Noise in Physical Systems
La Tenuta dei Ciclamini
Avigliano Umbro (TR) - Italy

2011

Summer School "Energy Harvesting at micro and nanoscale"
Workshop "Energy management at micro and nanoscale"
Perugia (IT), Aug. 1-6, 2011
Future events

- **ZEROPOWER Workshop**
  Cork, Oct 25-27 2011
  Finalized to build the emerging ICT-Energy related community, at networking existing “energy efficiency” national, regional or international activities/programmes in view of exploiting synergies, maximizing impact and contributing to the definition of international cooperation strategies and/or the development of research collaborations.
  Infos on: [www.zero-power.eu](http://www.zero-power.eu)

River Lee Hotel,
Cork (IR)
Oct. 25-27 2011

[www.zero-power.eu](http://www.zero-power.eu)