Energy hunter-gatherer sensors: small power the next Big Thing

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KETs (Key enabling technologies)

Unlocking potential
... by way of artefacts
KETs (Key enabling technologies)

Mind / Solution prov.

Unlocking potential
... by way of artefacts

ICT

Ciber-Physical Systems
and/or

Smart Systems
CPS & SS

(miniaturised) systems that connect the digital to the physical world

Collect info / Process info / Act or help to decide

From the ‘cloud’ to the ‘ground’

... becoming part of global problems solutions
ICT today...

**ICT** (computation & communication)

Human dimension: Social Networks
... Internet of Souls

You will never walk alone
ICT tomorrow... Internet of Things

‘friendly’ cooperative objects acting on the background of human activity

ICT tomorrow... Trillion Sensors

Inter-net net-work

Capture & exchange

Sensors

Wireless Sensors Networks

2007 – 10 mil sensors
2013 – 10 bil sensors
...
Trillions sensors in the next decade?
ICT tomorrow... **Trillion Sensors**

**Internet**

Capture & exchange

Sensors

Wireless Sensors Networks

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Figure 3. Exponential technologies promise growth of goods and services to match global demand for them within one generation, enabling Abundance.
ICT tomorrow... **Smart Everywhere**

- Smart mobility
- Smart health
- Smart energy
- Smart production
- Smart cities
...
ICT tomorrow... *Smart Everywhere*
Sensors... **better small**

If a network of so many... better small

less material and energy consumption – more applications
Sensors... better autonomous

As elements of Smart Systems:

- Functional autonomy
- Energy autonomy
Energy hunter-gatherer Sensors

For off grid applications batteries are OK but...
Batteries get depleted, and need replacement or recharge

What if sensors are deployed in remote locations or in harsh places?
- Battery replacement is not practical

What if sensors are so ‘many’?
- Battery replacement is not practical
Energy hunter-gatherer Sensors

Energy autonomy in off grid long term applications?

Energy harvesting

Heat
Shock & vibrations
Electromagnetic waves
...

Get the energy or replenish the battery from the environment
If small ... will it provide enough?

Energy sources for harvesting are low intensity and intermittent. Harvesters are to be small if sensors are small.

A small harvester gets a small portion of a low intensity source... Will it be enough for energy autonomy of a micronode?

At current SoA, a harvester may power a sensor but not account for the power surge needed for the wireless communication... but it may recharge a ‘battery’ and enable a moderate duty cycle operation.
If small ... let it be ‘dense’

Exploit the beneficial evolution of surface to volume ratios when going small...

High density 3D features for the harvester architecture and nanostructured materials will increase the power performance...
If small and dense... let it be silicon

Which materials to use?
Why not silicon (and its ‘merry’ friends)? It’s the material of reference of micro-nano-technologies

Abundant
Mature and enabling technology
Cost effectiveness and economy of scale
Miniaturized systems and dense architectures
SiNERGY

Silicon Friendly Materials and Device Solutions for Microenergy Applications

www.sinergy-project.eu

- 3D microstructures + bottom-up SiNWs

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Closing the talk...

• Without an ‘install and forget’ approach IoT / TS may not happen → (micro)energy autonomy is required

• Battery-free self powered devices are the ultimate goal. EH is an option but there is still a gap between generation (µW) and consumption (mW) → secondary batteries still needed

• Energy/power does not (down)scale well → high density features (3D architectures and nanomaterials) need to be handled

• Let’s try do harvesters/batteries with the same technologies already used for fabricating sensors reliably, cost-effectively and in high numbers → Si µn-technologies (and materials)

• Si technology enables ‘smaller is better’ and ‘smaller is cheaper’ scenarios
... and the loop: CROSS KETS
• KETs (Key enabling technologies)
• CPS & SS
• ICT today...
  ... Internet of Souls
• ICT tomorrow...
  ... Internet of Things
  ... Trillion Sensors
  ... Smart Everywhere
• Sensors... small & autonomous
• Energy hunter-gatherer Sensors
• If small ... Let it be ‘dense’
• If small and dense... Let it be silicon
• Closing the talk and .. and the loop: CROSS KETS