WG3

IoT Devices: Hardware and Systems

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Grand Challenges

Tweeting TinyCam. A globally-deployable connected camera that can operate on a 1 uW budget, take images, perform scene understanding, and tweet a 160 character of the scene description with which many humans would concur.

State of the Art [1]: Device Hierarchy by Capability

Cloud

PC

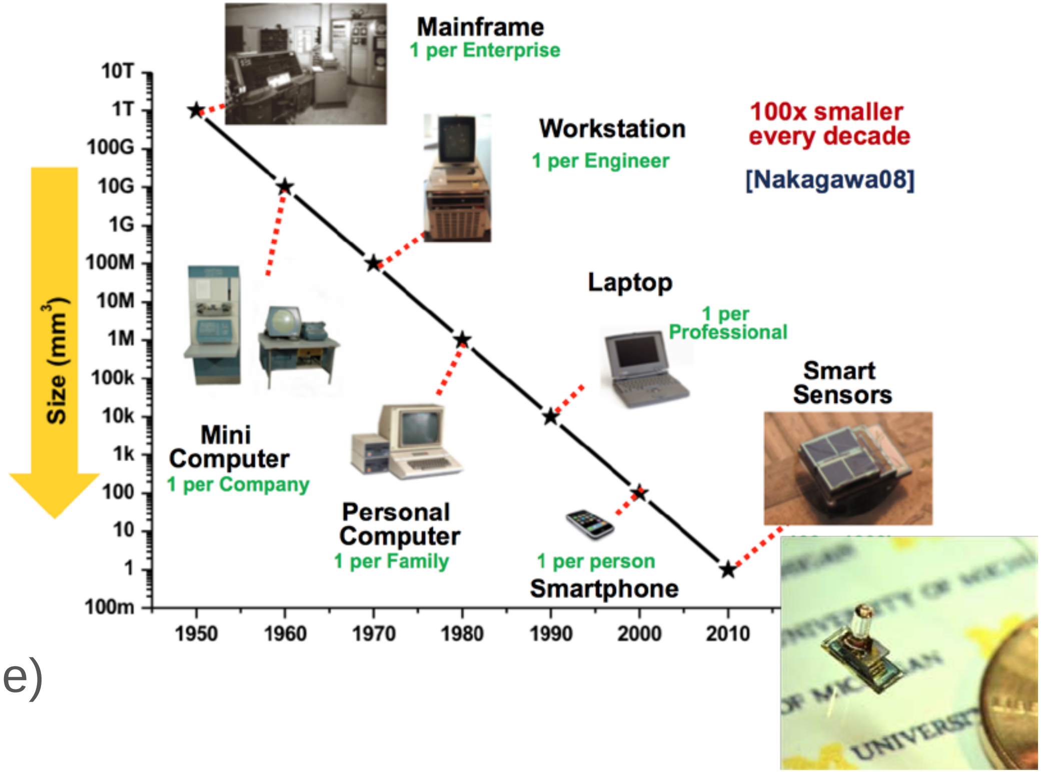
Phone

Arduino / Raspberry PI

CRFID / Energy harvesting devices

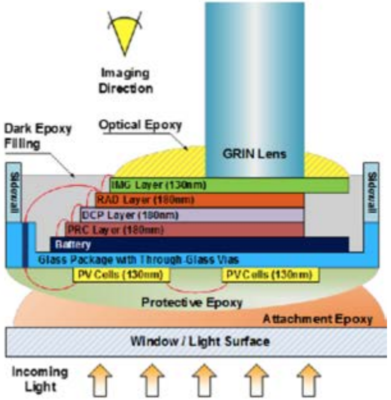
“Smart Dust” (Integrated sensors)

“Dumb tags” (ID-only RFID / barcode)

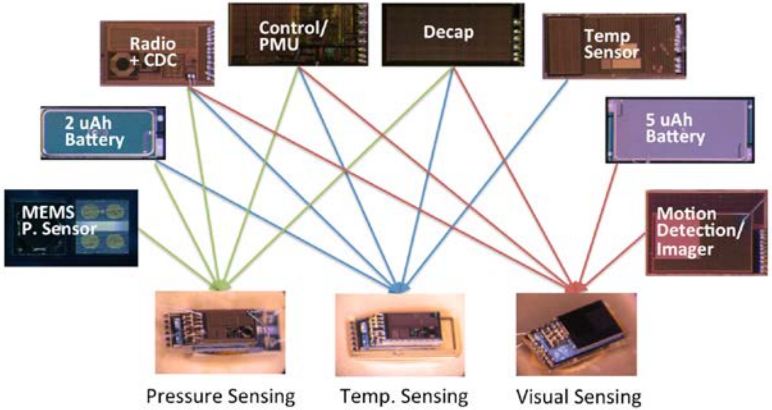


State of the Art [1]: Tweeting TinyCam drill down

- 160x160 imaging and 10x10 motion detection on latest M3 platform
- Includes optics, battery, solar harvesting, and radio in $2x4x3mm^3$
- 203 nW in motion detection mode, 456 nW harvested at 10k lux*

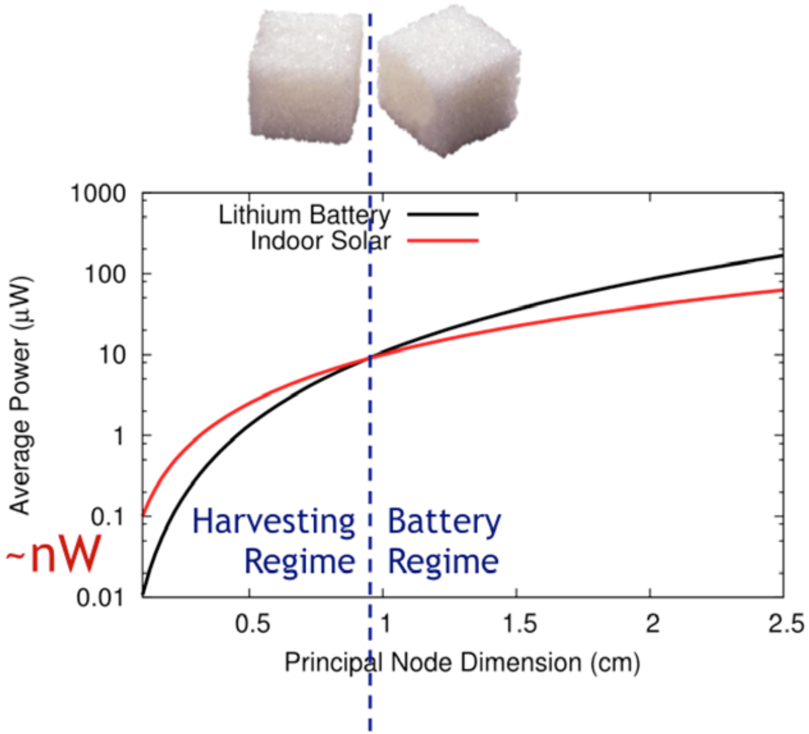


* 10k lux ⇔ full daylight (but not direct sun)

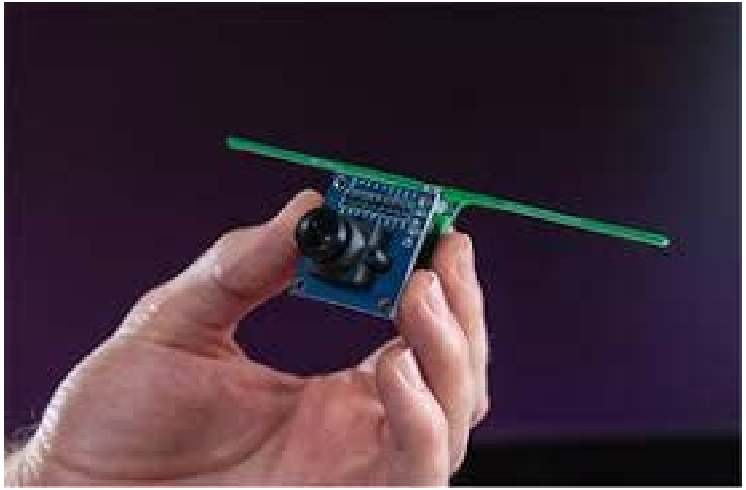


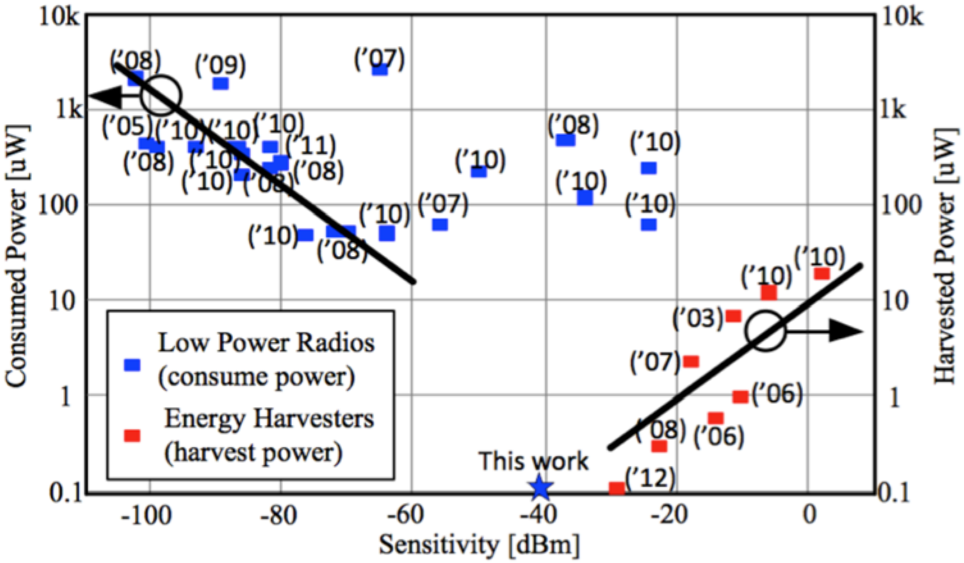
"IoT Design Space Challenges: Circuits and Systems," David Blaauw, Dennis Sylvester, Prabal Dutta, Yoonmyung Lee, Inhee Lee, Sechang Bang, Yejoong Kim, Gyouho Kim, Pat Pannuto, Ye-Sheng Kuo, Dongmin Yoon, Wanyeong Jung, Zhi Yoong Foo, Yen-Po Chen, Seok Hyeon Jeong, and Myungjoon Choi, In *Proceedings of the 2014 IEEE Symposium on VLSI Technology* (VLSI'14), Honolulu, HI, Jun. 11-13, 2014.

State of the Art [2]: Energy Harvesting



State of the Art [3]: Talking with the Sensors?





N. E. Roberts and D. D. Wentzloff,
"A 98nW Wake-up Radio for Wireless Body Area Networks",
IEEE Radio Frequency Integrated Circuits Symposium (RFIC), June 2012

What Was Discussed [1]

Prototyping cost, time, “cost of a mistake” - why is chip design so hard?

Why can’t we fabricate a chip of some sort as easily as getting a PCB built?

What tools can we develop to make learning and deploying faster and lower cost?

Shifting thinking from probabilistic to deterministic sensing / devices

Open Problems Identified [1]

What applications justify special-purpose hw vs. Swiss army knife (smart phone)?
Will it ever be economical to deploy large numbers of sensors in a home?

Where is “the Edge”? A moving boundary?

Indoor localization still isn’t “solved” / ubiquitous

Backscatter enables near-zero energy cost *transmission* - but what about *receiving* (beyond an envelope detector)?

Low cost/fast silicon (+novel computational materials) prototyping

Printable / flowable computing materials

Open Problems Identified [2]

Sensors that don’t scale down in size

Scaling up capabilities (mm^3 as an example)

New ways to fabricate circuits / systems in small volume, large areas, etc.

Energy storage technologies with better cycle life,

Ultra-stable (ppm, ppb, ppt), ultralow-power time bases (uA, nA, pA)

Solid-state laser rangefinder

Top Three+ Problems

Effective integration of components into systems (with tool help)

“cloning Steve Hodges problem”

Fusion of rich computing and deep storage with emerging sensors

Global connectivity (160 bytes) at low cost, size, and power

Going from discrete sensors to area sensors to paint-on sensors

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Diminished Reality Contact Lens. A contact lens that knows your health goals and augments reality in real-time by editing out things you should avoid (biscuits, candy, and cigarettes, for example)

Mind-reading Baseball Cap. An fNIR-like cap that costs as much as a baseball cap and can read your mind.

Call to Action/Next Steps [1]

Better tools for rapid prototyping

Power, performance, and computational infusion into sensing

Wireless power solutions for wearables, nearables

Integrating backscatter into cellular standards (+dedicating spectrum for power)

Open experimental platforms (for wearables, CRFID, smart dust, displays)

Transition from deterministic to statistical thinking with sensor data

Embracing intermittency, unreliability, and variability in all layers of system stack

Call to Action/Next Steps [2]

Sensing: drive down power and integrate computation into sensors

Store vast amounts of data locally and access that data inexpensively

Efficiently store, convert, and use ambient energy

Communication has to get vastly better in bits/J/m/$

Need specialized accelerators for doing computation (DSPs, DNNs, FFTs)

Need better ways to interface with pervasive sensors

Mechanisms to get researchers to attack these problems in a cohesive way