Internet of Things: What’s in it for the microelectronics industry

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IoT and VLSI circuits – challenge and opportunity

- IoT overview
- Short, medium and long range opportunities
  - End units
  - Cloud, servers
  - Communication
- VLSI design with other technologies
  - Sensors and actuators for IoT
  - Flexible electronics, printed electronics
- Summary
  - Application specific IoT (ASIT)
**IoT levels**

- Generic IoT device that can operate via the Internet (IoT) or an Integrated private mesh (IPM)
- Will replace smartphones in “things” interface where cost & power or security is an issue

Cloud, Fog, mesh, grid: big data

An application specific integrated circuit – processing, memory, communication

Sensors & actuators

Power supply
“Internet of Things” paradigm as a result of the convergence of different visions

L. Atzori et al. / Computer Networks 54 (2010) 2787–2805
Internet of Things: Interactions among the physical, digital, virtual worlds

IOT end units

**Autonomous units**
- Wearable
- RFID

**Non autonomous/Embedded units**
Powered by the mother system
Will become integral part of every item: cars, kitchen items, house items etc.

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**The Internet of Things Landscape**

![Image of the Internet of Things landscape](source-goldman-sachs-global-investment-research-hbr.org)
**IoT and our daily life**
## IoT application space

<table>
<thead>
<tr>
<th>Sensor Property</th>
<th>Sub categories</th>
<th>Range of values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensing / Actuation Modality</td>
<td>Type</td>
<td>Pressure, temperature, strain, chemical, imaging, sound, etc.</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>Continuous ↔ Infrequent, on-demand</td>
<td></td>
</tr>
<tr>
<td>Trigger</td>
<td>Timer based (accuracy?); event in monitored value; external trigger (wakeup radio, battery condition, etc.)</td>
<td></td>
</tr>
<tr>
<td>Computational Performance</td>
<td></td>
<td>Sub-kHz ↔ 100’s of MHz</td>
</tr>
<tr>
<td>Form Factor / Size</td>
<td></td>
<td>Submillimeter ↔ tens of centimeter scale</td>
</tr>
<tr>
<td>Energy Source / Life Time</td>
<td></td>
<td>Wired (permanently, intermittently); battery (primary, secondary); energy scavenging (continuous or as available); lifetime of hrs, days, years</td>
</tr>
<tr>
<td>Communication Connectivity</td>
<td>Type</td>
<td>Wired vs. wireless (communication distance, communication standard)</td>
</tr>
<tr>
<td>Data Rate / Packet Size</td>
<td>kbps ↔ Gbps; Bytes ↔ MBytes</td>
<td></td>
</tr>
<tr>
<td>Communication Interval</td>
<td>Continuous ↔ Infrequent; triggered by monitored event or external request</td>
<td></td>
</tr>
</tbody>
</table>

D. Blaauw et. al, 2014 Symposium on VLSI Technology Digest of Technical Papers
IoT challenge: 50B systems in 2010
IoT and VLSI circuits – challenge and opportunity

Major issues – end units

- Power supply, energy → autonomous vs. non autonomous systems
- Design for cost, design for power
- Design for “hostile environment” –
  - High noise,
  - Limited computation capability,
  - Limited bandwidth
  - Not standard interfaces to sensors and actuators
IoT and VLSI circuits – challenge and opportunity

**Major issues – cloud servers**
- Memory
- CPU
- DSPs
- More...

**Major issues – communication**
- Wireless
- Algorithms
  - Metadata, compression, security, etc.

Those are standard observations, what are the challenges?
VLSI design for IoT & more

Flexible electronics

Flexible Electrodes

Nano-bio sensors

Si CMOS ICs: VLSI, ASIC etc.

Printed electronics
Printed electronics - forecast

market volume (Billion EUR)

Silicon IC’s

Printed Electronics
Moore’s law and more
Conventional CMOS IC → Next generation technologies

Wearables 1.0

IRONMAN

Wearables 2.0

INVISIBLE MAN
IoT & design challenges

System architecture
• IoT module
  – Connectivity
  – Data processing
  – Sensing & actuating
• Many components and standards already exist: Bluetooth, Bluetooth low energy, ZigBee, WiFi and Near Field Communication (NFC).
ASIT: Application Specific IoT

• Application or field of use
• Sensors specific to the application
• Specific End units and mid-units
• Application specific: power, security, cost
• Total hardware/software immersion
• Internet Connectivity
• Specific metadata algorithms
IoT power vs. lifetime

Average power draw constraint as a function of lifetime and battery size

D. Blaauw et. al,
2014 Symposium on VLSI Technology Digest of Technical Papers
Common protocols used for wireless sensor applications
**IoT needs**

- IoT processing capability
- More memory: HDD, SLC, MLC, TLC etc.
- More information closer to the node
- Performance tailored to application
- Reduce latency
- Good controller and server performance
- Bandwidth monitoring & control allowing maximum connectivity
IoT security main issues
S. Sicari et al. / Computer Networks 76 (2015) 146–164
Sensing

Sensor cloud architecture

IoT challenge: latency
M2M technology

(NICT, Japan)
IoT M2M technology (Beecham Research, 2015)
A Vision of the Future

Emergence of Ambient Intelligence:
Sense/monitor, communicate and react to the environment
→ Ultra-low-power, robust computing technology required!
A conceptual model of a conventional mechatronic system.
New technologies:
Thin film transistor (TFT) IC + sensors on plastic;
flexible electrics IoTs.

Advantage: extremely low cost
Challenge: only $10^4$-$10^5$ transistors.
The challenge

Differentiation is created in software
- Common hardware platform, multiple Applications
- Memory requirements:
  - Low power with Instant-On
  - Small Silicon Footprint
  - Programmable, non-volatile code storage
  - Highly Secure to Protect S/W IP and Prevent Hacking

(Linh Hong, Flash summit 2014)
Extreme low power technologies

• Spintronics

Comparison of logic-LSI architectures; (a) conventional, (b) nonvolatile logic-in-memory.


Nonvolatile TCAM cell layouts; (a) 6T-2MTJ twin-cell, (b) complementary 5T-4MTJ cell.
Extreme low power technologies

• Nano Watts amplifier

Block diagram of proposed AMP.

Memory for IoT

- **Voltage Range**
  - Wide VCC to Maximise Battery Voltage Range

- **Power**
  - Reduce R/W Energy Consumption

- **Features**
  - How MCU Accesses Memory for Energy Savings

- **What’s Next?**
  - Authenticated Access (Security)
  - New Lower Power / High Speed I/F
  - Enhanced Cached R/W Operations

- **Improved Security**
  - Improved Security Features
  - MCU SoC
  - Serial NVM

- **New Interfaces & Features**
  - XiP Serial NVM

Paul Hill, Director of Product Marketing  Adesto Technologies, Flash Summit 2014
**Example: Sensor integration for food tracking**

- Cartasense Inc., Israel
- Tel Aviv university: sensor R&D
  - Gas sensor: O$_2$, CO$_2$, Ethanol, Ethylene glycol, ethylene, ammonia etc.
  - Fluid sensors: pathogens, toxic materials
  - Physical sensors: Humidity, Temperature, pressure, position, velocity, acceleration etc.
- The challenge: adapt sensor to the application in very short time, low cost
- Method: Generic platform
The CartaSense Offering

Complete suite of hardware and software aimed to collect data to support business decisions and increased profitability.

Wireless Sensors  Gateways  Comm. Server software  Web application
The Only Complete IoT Logistics Solution

Always-on, Real-time Visibility

Product in the Field

Product in Storage

Product in Transport

Internet of Things

Cloud-based Services

SMS & Email Alerts

Cold-Chain Quality Control
Advanced Agricultural Monitoring

Temperature & Humidity
Soil Moisture
Solar Radiation
Safety & Security
Some general thoughts

• Few major factors:
  • Most advanced technologies fail; that is inevitable and not unhealthy.(R. Landauer 1990)
  • Integrated systems may reach their downscaling limits by 2025; maybe
• Israel has a wide base of Ultra Large Scale integration (ULSI) circuit design.
• Therefore, IoT is an opportunity
  • Application Specific IoT
  • Standard sensor & actuator interface
  • Circuit design on silicon & flexible substrates
"On the Internet, nobody knows you're a dog."