Enjeux et défis scientifiques pour un déploiement durable de l’IoT : état de l’art de solutions d’optimisation énergétique

Alain Pegatoquet – Maître de Conférences, LEAT
Internet of Things is a buzzy phrase...

IoT is not easy to define...

Internet of Things definitions

- "A network of items each embedded with sensors which are connected to the Internet." IEEE Institute. March 2014

- "Cyber physical systems (CPS) involve connecting smart devices and systems in diverse sectors like transportation, energy, manufacturing and healthcare in fundamentally new ways." NIST
- **IoT ↔ Human + Physical Objects** (sensors, controllers, actuators, devices, computing, storages) + **Internet**

- **P2P** ↔ People to People
- **M2P** ↔ Machine to People
- **M2M** ↔ Machine to Machine

[Farhan 2018]
IoT ↔ **Sensors/Actuators** (Application dependent) + **Gateway** (Access Point) + **Internet** + **Services**

Wireless Sensors Networks (WSNs) is one of the key underlying enabling technology for IoT
**Current Trends**
- More functionality per area
- Greater HW/SW requirements
- Longer Battery lifetime

**Biggest Challenges**
- Energy storage (capacity)
- Energy consumption
- Energy harvesting
- Smart devices
- Miniaturization
A typical IoT device

Different application use cases

- Drowsiness Detection
- Fall Detection
- Activity Tracking

Constraints:
- Computations
- Memory
- Battery
**IoT Challenges**

- **Business**: Silos vs. Horizontal, Application Domains, The revenue (per device, connectivity, Data), *New business model*...

- **Societal**: Privacy, Data Ownership, Security, Easiness of Use, Social Cooperation

- **Technical**: complexity, communication, Data, Software platforms, *energy consumption*...
▪ Size of the **IoT market worldwide** from 2017 to 2025 (in billion U.S. dollars)

The global IoT market is expected to grow to **$212 billion by the end of 2019**. The technology reached 100 billion dollars in market revenue for the first time in 2017, and forecasts suggest that this figure will grow to around 1.6 trillion by 2025.
What about the Overall Energy Consumption?

- IoT: **75 billions** of connected objects in **2025**...

![Bar graph showing the increase in billions of connected objects from 2015 to 2025, with a significant jump in 2025.]

Sources: [Lucero 2016] [Rioual 2019]
Optimize Energy Everywhere!
Optimizing Energy Everywhere!

- **IoT Devices Power Management** (Node level)
  - Optimize **Components** power consumption (DPM, Power/Clock gating, DFVS, etc.)
    - [Ben Ameur 2018] [Mbarek 2013]
  - Optimize **communications** (RF activities)
    - [Rault 2014] [Castagnetti 2014] [Le 2016] [Maitra 2016] [Kim 2015] [Huang 2013] [Sentieys 2013] [Ait Aoudia 2017]
  - Optimize **activities** (task scheduling)
    - [Arcaya 2019]

- **Autonomous IoT Devices**
  - Energy harvesting [Vullers 2010]
  - Power management [Kansal 2007] [Castagnetti 2012]

- **Network-level Optimizations**

- **IA-based approach**
Routing protocols (multi-hop)

Cooperative networks
- The nodes work together to improve the communication or the energy consumption of the overall network (e.g. cluster head) [Liang 2010] [Chen 2016]

Edge Computing...
- Process data as close as possible from the nodes to minimize the transmission, reduce the latency and optimize the bandwidth utilization...
Edge Computing & IA based approach
IA has already been widely used to optimize performance/energy for embedded systems.

- All types of learning approaches
  - Supervised, unsupervised, reinforcement
  - Bio-inspired

- For all kinds of problematic
  - Communications (MAC, Routing, Self-learning radios, Cooperative networks, Rate control...)
  - Tasks scheduling
  - Power management
  - Energy Harvesting

- A new paradigm for embedded architectures

Neuroscience
Spiking Neural Networks (SNN) motivations

- Accuracy ✓
- Hardware implementation
  - Powerful computer (CPU/GPU) ✓
  - Embedded systems (FPGA/ASIC) ✗
Spiking versus Formal Neural Networks

**FNN neuron**
- Multiplication + Addition
- Non-linear activation function

**SNN neuron:**
- Addition
- No more Multiplication!
- Comparison

**Integrate-and-Fire**

---

[Abderrahmne 2020]
- Results with MNIST classification

### SNN vs. FNN hardware cost and accuracy

<table>
<thead>
<tr>
<th>ANN Model</th>
<th>FNN</th>
<th>SNN</th>
<th>SNN Gain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy (%)</strong></td>
<td>95.73</td>
<td>95.37</td>
<td>-0.38</td>
</tr>
<tr>
<td><strong>Total power (mW)</strong></td>
<td>52.22</td>
<td>28.46</td>
<td><strong>45.37</strong></td>
</tr>
<tr>
<td><strong>Total area (mm²)</strong></td>
<td>1.888</td>
<td>0.869</td>
<td><strong>53.98</strong></td>
</tr>
</tbody>
</table>

- For almost the same accuracy, SNN is around \(~50\%\) more efficient in terms of **power / area**
References


[Eggimann 2019] Manuel Eggimann, Stefan Mach, Michele Magno and Luca Benini, A RISC-V Based Open Hardware Platform for Always-On Wearable Smart Sensing, IEEE 8th International Workshop on Advances in Sensors and Interfaces (IWASI), 2019

[Farhan 2018] Laith Farhan et. al, A Concise Review on Internet of Things (IoT) - Problems, Challenges and Opportunities. 11th International Symposium on Communication Systems, Networks, and Digital Signal Processing (CSNDSP 2018), Budapest, Hungary, 2018


References


Thank you for your attention!