IoT for precision agriculture: trends and challenges

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Outline

• Introduction:
  – Requirements: How to feed increasing world population in the next coming year and preserve our planet?
  – Current practices in smart farming

• IoT core technology:
  – Panorama of IoT technology
  – IoT node hardware
    • State-of-the-art of IoT Node
    • Trend and challenges
    • Low Power Wide Area network:

• Use cases: SIS and CAPTOR H2020 project

• Open research issues

• Conclusion
Introduction: Requirements and motivations

- Observations: World population increase to 9 or 10 billion in 2050 [1]
  - Improve yield crop and quality, and minimize production cost by using less fertilizer, pesticide, water and human intervention: limited resource (smarter planet)
  - Different technologies are carried out: genetic, pesticide, monitoring equipment, etc.
  - More knowledge are need to understand the plant behavior in interaction with its environment (temperature, air and soil humidity, light intensity etc.), diseases and pest.
  - In general the plant development is studied in small scale (in the lab or small cultivated field) but the investigation of real world large scale condition is still a big lack! (environment of each cultivated field is different from the other ones).
Introduction: Motivations

• Precision Agriculture is a way to “apply the right treatment amount in the right place at the right time” (Gebbers and Adamchuk, 2010).

• Two approaches:
  – Remote sensing: satellite (Weekly to monthly – 1 to 50m) and UAV ‘Unmanned Aerial Vehicles’ (Weekly to daily - <0.5m)
    • large scale cultivated field environment data may be sampled and analyzed
  – Proximal (close range and contact): data logger or smartphone, embedded or buried sensors (wire or wireless ‘IoT’)
    • Small scale cultivated field environment data may be sampled and analyzed in real-time to be able to react early, locally and appropriately.
Multi-scalar IoT for smart farming

Scalar IoT: temperature, humidity, soil moisture etc.
Multimedia: low cost CMOS image (plant disease and pest)
Multi-scalar: scalar + multimedia

- Trend: Fusion of the remote data (satellite and/or UAV) with local data (IoT) to deal with large scale cultivated field in real-time (POC ‘Proof of Concept’).

Strawberry white spot (disease)

whitefly on tomato (pest)
Multi-j Scalar IoT for smart farming

Scalar IoT: temperature, humidity, soil moisture etc. (e.g., smart irrigation system)

Multimedia: low cost CMOS camera (plant disease and pest)

Multi-j Scalar: scalar + multimedia

• Trend: Fusion of the remote data (satellite and/or UAV) with local data (IoT) to deal with large scale cultivated field.
Panorama of IoT cloud-based platforms

- Big ICT players: IBM (Bluemix), Microsoft (Azure), SAP (HANA) … provide the IoT cloud-based platforms containing three main layers:
  - Back-end: Integration and Services, decision support system
  - Middleware: connect and collect.
  - Front-end: IoT nodes
- The front-end layer is open for diverse players to develop their specific physical devices for specific application (LPWA: NB-IoT (MNO), Sigfox, LoRa (ISM), IEEE802.15.4, …)

Figure 2: IBM Bluemix IoT based platform
Key components of IoT core technology

- IoT Node
- HW
- Operating system
- Protocol Stack
- Middleware
- Applications

Radio Radius: 100  |  Fieldsize X: 500  |  Fieldsize Y: 500  |  Node Number: 50  |  Minimum Intersection Nodes: 1  |  Optimum Intersection Nodes: 2

Master: 13(26%)  
Lost: 0(0%)  
Slave: 37(74%)  
Bridge: 15(30%)  
Slave without Intersection: 22(44%)

Simulator

Internet

= 

Applications
Middleware
Protocol Stack
Operating system
IoT Node HW

EFITA'2017 - 2-6 July Montpellier, FRANCE
IoT node - Basic Hardware

• Key features of a IoT Node

- Processor
- Memory: RAM & ROM
- Peripheral Devices: ADC, UART, SPI, I²C, GPIO, VGA
- Signal conditioner
- Power supply
- Antenna
- Wireless Access medium
- Energy harvesting & Power management Unit

Sensor

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IoT Core Technology
Use case
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Conclusion
# Low Power Wide Area network ‘LPWA’

<table>
<thead>
<tr>
<th>Items</th>
<th>LoRaWAN</th>
<th>Sigfox</th>
<th>LTE Cat-1 2016 (Rel-8)</th>
<th>LTE Cat-M1 2017 (Rel13)</th>
<th>LTE Cat-M2 NB-IoT 2018 Rel13+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency bands</td>
<td>433 / 470 / 780 / 868 / 915 MHz ISM</td>
<td>868 / 915 MHz ISM</td>
<td>License (700 MHz-2.5GHz)</td>
<td>License (700 MHz-2.5GHz)</td>
<td>License (700 MHz-2.5GHz)</td>
</tr>
<tr>
<td>Modulation</td>
<td>DSS with Chirp</td>
<td>UNB / GFSK - BPSK</td>
<td>OFDMA</td>
<td>OFDMA</td>
<td>OFDMA</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>125 - 500 KHz</td>
<td>100 Hz (EU) / 600 Hz (NAM)</td>
<td>20 MHz</td>
<td>1.4 MHz</td>
<td>200 KHz</td>
</tr>
<tr>
<td>Data Rate max.</td>
<td>250B (max)</td>
<td>8B Max</td>
<td>10 Mbps</td>
<td>380 Kbps</td>
<td>~250 Kbps DL</td>
</tr>
<tr>
<td></td>
<td>293 - 50K bps</td>
<td>100 bps (EU) / 600 bps (NAM) 6 12 /</td>
<td>1.4 MHz</td>
<td>200 Kb/d</td>
<td>22 kbps UL</td>
</tr>
<tr>
<td>Number of sending messages/day</td>
<td>unlimited</td>
<td>UL: 140 msgs/d</td>
<td>unlimited, 200 Kb/d</td>
<td>NC</td>
<td>NC</td>
</tr>
<tr>
<td>Operation mode</td>
<td>Public or private</td>
<td>Public (MNO)</td>
<td>Public (MNO)</td>
<td>Public (MNO)</td>
<td>Public (MNO)</td>
</tr>
<tr>
<td>Power max</td>
<td>14-30 dBm</td>
<td>14-22 dBm</td>
<td>46 dBm</td>
<td>23 dBm</td>
<td>20 dBm</td>
</tr>
<tr>
<td>Energy efficient</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

LPWA: increase communication robustness, easy to deploy (star of star topology) and decrease simple scalar IoT node battery-less cost but it’s not appropriate for all environment sensor types (e.g., CMOS camera)
Key components of IoT core technology

LPWA gateway → LPWA
new paradigm: one hop
energy efficient and
reliable large scale IoT
node deployment

$LQI_{E2E} = PDR^h$  where $PDR$ is Packet Delivery
Ratio and $h$ is hop number; $LQI_{E2E} = 0.9^{10} \approx 0.35$
Energy consumption $\geq 10$ time

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IoT Node HW: State-of-the-art and design trend

- Two main development and design trends: Commercial Off-The-Shelf ‘COTS’ and System on Chip ‘SoC’
- COTS: platform for test and validation, real world experimentation
- SoC: Ultimate goal to achieve the implementation of long lifetime (battery-less), low cost and invisible IoT node integrated and embedded into environment or object.
- **Trend:** Asymmetric ON/OFF multicore architecture and battery-less (https://www.enocean.com/en/): energy harvesting circuits (solar panel, wind, vibration, heat ...)

[Image of CMS solar panel and Supercapacitor]
The WiseNET™ Chip – A True SoC

- TSMC 0.18μm
- 3.6 x 3.3 mm²
- 1.7M transistors
- 1906 resistors
- 341 capacitors
- 8 inductors

- Power management
- CoolRISC ℜcontroller
- Sensor interface

Rx / Tx

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- Mote: CrossBow
  - Integration: Low
  - Power: highest
  - Volume: 45 cm³

- Mote: Michigan Uni Prototype
  - Integration: Medium
  - Power: Lowest
  - Volume: few cm³

- Mote: Pico-Mote, Uni of Berkeley
  - Integration: high
  - Power: Low
  - Volume: few mm³

Speck (2003)
## Low performance multimedia IoT Nodes

<table>
<thead>
<tr>
<th>Platform</th>
<th>Processor</th>
<th>RAM</th>
<th>Flash</th>
<th>Radio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyclops</td>
<td>8-bit ATmega128L MCU + CPLD</td>
<td>64 KB</td>
<td>512 KB</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>FireFly Mosaic</td>
<td>60MHz 32-bit LPC2106ARM7TD MI MCU</td>
<td>64 KB</td>
<td>128 KB</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>eCam</td>
<td>OV 528 serial-bridge controller JPEG compression only</td>
<td>4 KB (Eco)</td>
<td>-</td>
<td>RF 2.4 GHz 1Mbps</td>
</tr>
<tr>
<td>MeshEye</td>
<td>55 MHz 32-bit ARM7TDMI based on ATMEL AT91SAM7S</td>
<td>64 KB</td>
<td>256 KB</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>WiCa</td>
<td>84 MHz Xetal SIMD Processor +8051 ATMEL MCU</td>
<td>1.79 MB +128KB DPRAM</td>
<td>64 KB</td>
<td>IEEE 802.15.4</td>
</tr>
<tr>
<td>MicrelEye</td>
<td>8-bit ATMEL FPSLIC (includes 40k Gate FPGA)</td>
<td>36 KB + 1 MB external SRAM</td>
<td>-</td>
<td>Bluetooth</td>
</tr>
<tr>
<td>CMUcam3</td>
<td>60 MHz 32-bit ARM7TDMI based on NXP LPC2106</td>
<td>64 KB</td>
<td>128 KB</td>
<td>-</td>
</tr>
</tbody>
</table>
uSu-Mx: low cost Multi-scalar IoT node

- Raspberry-Pi 3:
  - 1 GB main memory
  - WiFi et BLE
  - 4 cores 1 GHz

- The key features of uSu-Edu are:
  - Power supply 9-Volt Alkaline Battery or Lithium-ion Battery
  - IEEE802.15.4
  - 1 3-axis Accelerometer
  - 1 3-axis Gyroscope
  - 1 3-axis Compass
  - 1 barometric pressure
  - 1 Air Temperature Sensor
  - 1 Light Sensor
  - 1 RS232/USB Slave Port
  - 1 Extend Port enables to connect with Arduino Shield
  - 1 Port enables to directly connect with Raspberry Pi board.
Use cases: Smart irrigation System and CAPTOR H2020 projects

• http://edss.isima.fr/sites/smir/site

iLive sensor (scalar IoT node) deployed at Montoldre in cooperation with IRTSEA since 2013
RAPTOR deployment in Jardin Lecoq ATMO Auvergne, Clermont-Ferrand, France
Deployment of Raptor nodes in Vienna by Global2000

User: gbaustria01
Group: Raptor_3G_03
Node ID: 000100001866AC27
Caption: Raptor_N90
RAPTOR deployment in Palau Reial by CSIC, Barcelona Spain

IoT Core Technology
Open research issues

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User: upcspain01
Group: Raptor_3G_01
Node ID: 0001000018671537
Caption: Raptor_N70
Open research issues

• EU survey on ICT adoption (2013):
  - COST effective: 47%
  - Not appropriate for farm size: 28%
  - Complexity: 27%

• How to implement heterogeneous, interoperable and context aware, Low cost, Robust, easy to maintenance and to deploy, IoT Cloud platform dedicated to smart farming?

• How to evaluate objectively the global impact of IoT cloud platform in the field of smart farming?
• Low cost, robust and user friendly Cloud IoT-based platform is a key issue for smart farming to increase yield and quality of crop with minimize impact on environment (sustainable development for smarter planet)

• The IoT will revolutionize (big bang) the ICT and continue to push ahead the current trend: Big data centers and smart tiny data centers (trillion?) in order to meet the requirements divers applications.

• The IoT will drive new research fields, and uncountable and unimaginable applications (services).

• The economic and social impact of IoT is an open question, but one thing is sure that IoT will change the way of our every day living and goods productions (e.g. crop ...).
References


8. Claudia Dierke and Ulrike Werban, Relationships between gamma-ray data and soil properties at an agricultural test site, Geoderma Volume 199, May 2013, Pages 90-98, Elsevier

Acknowledgments

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