Wireless Sensor Networks for Industrial IoT Applications

Jacky Chen
Field Application Manager
Analog Devices
1) 無線偵測網路和物連網的關連
2) 工業等級無線偵測網路的需求重點
3) DUST 實際應用範例
4) 能源回收的種類和特性
5) 目前既有的解決方案的規格重點
物連網基本架構

Applications

Backhaul

Gateway

Things

MORE DATA ANALYTICS
MORE CONNECTED
MORE COMPUTE
MORE DATA
LTC5800 is the world’s lowest power 802.15.4 system-on-chip
SmartMesh® WirelessHART for industrial process applications
SmartMesh IP™ for 6LoWPAN Industrial IOT applications
>60% of 2025 IoT Value Will Be in Industrial or Automotive Settings

McKinsey Global Institute Study June 2015
To a radio, this...

…is not like this…  ... or this ...

“工業”物連網的環境更嚴峻
無線網路的解決方案

資料量

250k/s

傳輸距離

100m

300m

802.11ac
802.11ad
802.11n

3G

4G LTE

Bluetooth
BLE

RFID
NFC

Dust
802.15.4

ZigBee

Dust
LTC5850

Sub TG
Low power
WAN

802.11a
802.11b
802.11g

Sub 1G
Low power
WAN

802.11n
802.11ac
802.11ad

资料量

250k/s

3G

4G LTE

Dust
LTC5850

Sub TG
Low power
WAN

802.11n
802.11ac
802.11ad

資料量

250k/s
For a homeowner, if this is off by a few degrees we wear a sweater.

For a plant manager, if this is off by a few degrees, we shut down the plant.

Value of Industrial Data is Very High.
Consider:

“99% reliable” = 3.65 days/ year of unplanned downtime

Industrial Applications Require >99.999% Data Reliability
在基本的網路功能之外...

- 資料傳輸可靠度 (data transmit reliability)
- 功耗 (power consumption)
- 保密性 (encryption)
- 安裝簡易程度 (ease of installation)
- 全部的成本 (total cost)
Time synchronized, channel hopping and true mesh for >99.999% reliability
Every mote (by default a router) can run on batteries for 5-10 years
Only active in timeslots where they are scheduled to transmit or receive, typ. DC <1%
90 byte per packet, max 24-36 packets/second through the manager (~2.6kbps)
Built in security and network management
Ultra-Low Power Throughout the Network

30 nodes, 3 hops deep
30 second reporting

1-hop: 47 µA
0.8s latency

2-hops: 35 µA
1.5s latency

3-hops: 23 µA
2.3s latency

1-hop: 88 µA
0.1s latency

2-hops: 52 µA
0.2s latency

3-hops: 23 µA
0.5s latency

30 second reporting

SmartMesh Performance Estimator:
http://www.linear.com/docs/42452

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Proven Reliability in Harsh Environments: Examples

99.999996% data reliability in semiconductor Fab

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Nodes</td>
<td>32</td>
</tr>
<tr>
<td>Mesh Network Depth</td>
<td>3 hops from furthest node to gateway</td>
</tr>
<tr>
<td>Packet Generation Rate</td>
<td>4 data packets / 30 seconds from each node</td>
</tr>
<tr>
<td>Number of Data Packets Sent</td>
<td>26,137,382 over 83 days</td>
</tr>
</tbody>
</table>

100% Reliable at Electronica show with 100's of WiFi networks
Parking Management

Through CY2016:

- 712,956 Hours Saved
- 3,021,964 Miles Saved
- 177,763 Gallons Saved
- 3,142,843 Lbs Saved

(1) Magnetic Sensors Detect Metal of Cars

(2) SmartMesh delivers reliable communication, even with cars overhead

(3) SmartMesh aggregates sensor data locally; need for cellular uplink is reduced
Dual Sensing Technologies
- Passive infrared and accelerometer
- Minimizes false alarms

Wireless Mesh chosen for
- Self-healing and reliability
- Security
- Ease of installation

Reliability and Network Security Come First
Vigilent is the leader in intelligent energy management systems for data centers, telcos and large, commercial buildings.
Internet of Industrial Process Monitoring

Over 8 Billion Hours of SmartMesh-based Operation

700 acre oil refinery using WirelessHART plantwide

Industrial Networks Must Run for 5-15 years; Smart Networks for Smart Things

Tank Farms

Steel Mills

Off-Shore Platforms

Water Treatment

Pipeline Monitoring

Internet of Things Applications

More than 60,000 networks in 120 countries

- Environmental Monitoring
- Parking Management
- Industrial Process
- Data Center Energy Management
Wireless Sensor Networking for Industrial IoT Applications

For Industrial and Commercial applications:

- **Stringent Requirements** – *Missing Data is Costly*
- **Trouble-Free Operation** - *for Many Years is required*
- **Small Networks can Lead to Big Data** – *and Big Returns*
能源採集

需求原因:
- 不在電力網分布範圍
- 佈線有困難
- 不方便使用電池

簡單範例:
鈴噹的聲音判斷海浪的規模。
而鈴噹的動能亦來自海浪。
能源採集的種類

磁場變動 — 線圈感應

震動應力變化 — 壓電陶瓷 (Piezoeffect)

溫差 — 熱電偶 (TEG)

光線 — 光電轉換 (Photovoltaic)

生化能轉換 — 電解液與離子交換 (Galvanic Process)
不同采集种类功率密度比较

![chart showing different types of power density sources including mechanical, thermal, radiant, and biochemical sources with data points for stress-strain, vibration, thermal gradient, sun outside, sun inside, infrared, RF, and biochemistry with references to CEA-Leti]
First think about Your needs
  - Calculate the total energy demand
  - Watch out for peak demands

Then think about Your capabilities
  - Consider the source characteristics
  - Watch out for the stability over time

And then try to match both
  - Choose the right transducer
  - Match it with the right voltage converter
  - If needed consider an energy storage
定義 “工率需求”

量化負載特性:
1. 工作電壓(V)和電流(I)
2. 不同狀態下的耗電
3. 重複的頻率

\[
E_{\text{total}} = \int P(t) \times \Delta t = \sum P_i \times t_i = \sum I_i \times V_i \times t_i
\]

\[
P_{AVG} = \frac{E}{\Delta t}
\]

<table>
<thead>
<tr>
<th>State</th>
<th>ti</th>
<th>Vi</th>
<th>li</th>
<th>Pi</th>
<th>Ei</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversion</td>
<td>0.4ms</td>
<td>2.8V</td>
<td>10mA</td>
<td>28mW</td>
<td>11.2μJ</td>
</tr>
<tr>
<td>Calculation</td>
<td>0.1ms</td>
<td>2.8V</td>
<td>0.5mA</td>
<td>1.4mW</td>
<td>0.14μJ</td>
</tr>
<tr>
<td>Transmition</td>
<td>4.5ms</td>
<td>2.8V</td>
<td>20mA</td>
<td>56mW</td>
<td>252μJ</td>
</tr>
<tr>
<td>Standby</td>
<td>995ms</td>
<td>2.8V</td>
<td>10μA</td>
<td>28μW</td>
<td>27.86μJ</td>
</tr>
<tr>
<td>Summ</td>
<td>1s</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>104μA</td>
<td></td>
<td></td>
<td>291.2μJ</td>
<td></td>
</tr>
</tbody>
</table>

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電源與負載之間的阻抗匹配

阻抗匹配的重點:

1. 輸出功率與阻抗匹配有關
2. 在最佳匹配條件，可以得到最大功率

\[ R_{load} = R_{source} = R \]

\[ R_{load} = \frac{V_{source}^2}{4R} \]
DC/DC 緩衝 “電源” 與 “負載”

- 平均輸出功率 > 平均負載功率
- DC/DC 緩衝輸入電源特性與負載
# Energy Harvest Solutions

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Transducers</th>
<th>LTC Power Management Ics</th>
<th>Typical $P_{OUT}$ @ $V_{OUT} = 3.3\text{V}$</th>
<th>Maximum $P_{OUT}$ @ $V_{OUT} = 3.3\text{V}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Solar (200lux – 1000lux)</td>
<td>Photovoltaic Cells (100cm$^2$)</td>
<td>LTC3105, LTC4071, LTC3129, LTC3459</td>
<td>100uW – 1mW</td>
<td>&gt;100mW</td>
</tr>
<tr>
<td>Outdoor Solar (1000lux – 50000lux)</td>
<td>Photovoltaic Cells (100cm$^2$)</td>
<td>LTC3105, LTC3588, LTC3129</td>
<td>1mW – 100mW</td>
<td>&gt;100mW</td>
</tr>
<tr>
<td>Thermal (10°C – 30°C dT)</td>
<td>TEGs (100cm$^3$)</td>
<td>LTC3108, LTC3109</td>
<td>200uW – 1.4mW</td>
<td>&gt;10mW</td>
</tr>
<tr>
<td>Vibration (Piezo: 0.1g – 1g)</td>
<td>Piezoelectric (30cm$^2$) Electromechanical (200cm$^3$)</td>
<td>LTC3588, LTC3129, LTC3459</td>
<td>50uW – 500uW 500uW – 10mW</td>
<td>&gt;100mW</td>
</tr>
</tbody>
</table>
Energy Harvest Kit

Featuring:

LTC3588 – Piezo Harvesting
LTC3108 – TEG Harvesting
LTC3105 – Diode Drop Supply
LTC3459 – Solar Harvesting
LTC2935 – Supervisor/ULVO

* Formerly known as BCB190-2
Thanks your time!

謝謝！