Standards-Based Reliable Wireless Sensor Networking

Thomas Watteyne, PhD
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Dust Networks Overview

- Pioneer of reliable, ultra-low power embedded wireless sensor networks (WSN)

Over 10,000 networks in 120 countries
Data centers, oil refineries, museums, mines, chemical plants, city streets, trains, steel mills, pharma plants...and more

- Low power wireless SOC and networking technology leader
- Acquired by Linear Technology, Dec 2011
The Internet of Things Stack

- web-like interaction
- Internet Integration
- Low-power reliability
- simple hardware

CoAP
UDP
6LoWPAN
IEEE802.15.4e
IEEE802.15.4

First Challenge: External Interference

IEEE802.11 (Wi-Fi)
IEEE802.15.1 (Bluetooth)
IEEE802.15.4

Received Signal Power (dBm)
Frequency (GHz)
First Challenge: External Interference

- IEEE 802.11b/g/n
- IEEE 802.11a/n
- IEEE 802.15.4

Second Challenge: Multipath Fading
Second Challenge: Multipath Fading

0% reliability

100% reliability

ch.11

ch.12
Second Challenge: Multipath Fading

Channel Hopping
IEEE802.15.4e - Time Synchronized Channel Hopping

- IEEE802.15 Task Group 4e
  - Amendment to enhance and add functionality to the 802.15.4-2006 MAC to better support the industrial markets

- Time Synchronized Channel Hopping
  - Nodes are synchronized on a common sense of time
  - Nodes send successive packets on different frequencies using a pseudo-random hopping pattern

IEEE802.15.4e - Slotted Structure

- A super-frame repeats over time
  - Number of slots in a superframe is tunable
  - Each cell can be assigned to a pair of motes, in a given direction
IEEE802.15.4e - Slotted Structure

- Cells are assigned according to application requirements
IEEE802.15.4e - Trade-Off

- Cells are assigned according to application requirements
- Tunable trade-off between
  - packets/second
  - latency
  ...and energy consumption

16 channel offsets

e.g. 33 time slots (330ms)
IEEE802.15.4e - Trade-Off

- Cells are assigned according to application requirements
- Tunable trade-off between
  - packets/second
  - latency
  - robustness
  ...and energy consumption

IEEE802.15.4e - Energy Consumption

- "atomic" operations
Dust Networks DN6000 – “Mote-on-chip”

- ARM Cortex-M3 32-bit uC
- IEEE802.15.4 radio

<table>
<thead>
<tr>
<th>Mode</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX @ +8dBm</td>
<td>9.7</td>
</tr>
<tr>
<td>TX @ 0dBm</td>
<td>5.4</td>
</tr>
<tr>
<td>RX</td>
<td>4.5</td>
</tr>
<tr>
<td>Cortex-M3 @ 7.4MHz</td>
<td>2.4</td>
</tr>
<tr>
<td>Doze mode</td>
<td>1.2 uA</td>
</tr>
</tbody>
</table>

IEEE802.15.4e - Energy Consumption

- Example 1: “leaf” node
- Activity:
  - Data publication
    - 80B data payload
    - Published every 30s
    - 80% stability paths to parents
- Consumption:
  - 11uA average
  - 22 years lifetime (2200mAh AA)
IEEE802.15.4e - Energy Consumption

- Example 2: router node, with one child
- Activity:
  - Data publication
  - Provisioning for routing
    - Advertisement sent every 2sec
    - Listening for join requests
    - Forwarding data from child
- Consumption:
  - 31uA average
  - 8 years lifetime (2200mAh AA)

IEEE802.15.4e - Reliability

- 44 nodes, 26 days
- Printing Facility
- >99.999% end-to-end reliability
Why Standardize?

Interoperation - IPSO

- “IP for Smart Objects”
- Alliance of companies
- Promote the use of IP in Smart Objects
- Not a standardization body
- White Papers, interop events...
- www.ipso-alliance.org
Interoperation - IEEE802.15.4e

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Abstract

The Internet of Things revolution is quietly coming, and with it an epochal turnpoint in wireless network design. Major standardization bodies have been looking at how wireless multi-hop networks should operate reliably (WirelessHART, IEEE 802.15.4E, IETF RPL) and how they can integrate within the Internet (IETF 6LoWPAN, CoAP).

This talk will highlight the challenges faced by wireless multi-hop networks, before showing how communication protocols and standards can address these. Numerous use cases, examples and lessons learnt will be taken from open-source and commercial implementations.

Speaker’s Biography

Thomas Watteyne is a Senior Networking Design Engineer at Dust Networks, a company specializing in ultra-low power and highly reliable Wireless Sensor Networking. He designs networking solutions based on a variety of M2M standards and promotes the use of highly reliable standards such as IEEE802.15.4e. In 2009 and 2010, he was a postdoctoral researcher at the University of California, Berkeley, working with Prof. Kristofer Pister. He created Berkeley’s OpenWSN project, an open-source initiative to promote the use of fully standards-based protocol stacks in M2M applications. He obtained his PhD in Computer Science (2008) and MSc in Telecommunications (2005) from INSA Lyon, France.