OpenWSN: Open-Source Standards-Based Protocol Stacks for Wireless Mesh Networks

Thomas Watteyne
Berkeley Sensor and Actuator Center
University of California, Berkeley

What We Want

• Develop a 7-layer OSI stack basis
  — Open-Source
  — On a variety of hardware/software platforms
• Using the cutting-edge technologies
  — IEEE802.15.4-2006 radio chips
  — Protocols being standardized at the MAC, routing, transport and application layers
• Towards Smart Energy Management
  — Residential, commercial and industrial facilities
  — On the distribution grid
Protocol Integration

Reliability

Reliability is challenged by:
- external interference
- multi-path fading
First Challenge: External Interference

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

IEEE802.11b/g/n
IEEE802.11a/n

868 MHz
433 MHz

2.4 GHz

5 GHz

IEEE802.15.4

OpenWSN
Second Challenge: Multipath Fading

ch. 11
Second Challenge: Multipath Fading

IEEE802.15.4e - Status

- **IEEE802.15 Task Group 4e**
  - Amendment to enhance and add functionality to the 802.15.4-2006 MAC to better support the industrial markets
  - Revision 6 dated 03/10/2010

- **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 – Channel Hopping

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 – A Slot

IEEE802.15.4e – Energy Consumption
IEEE802.15.4e – Slotted Structure

- Cells are assigned according to application requirements

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
  - ...and energy consumption
IEEE802.15.4e – Trade-off

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

16 channel offsets

e.g. 33 time slots (330ms)

OpenWSN
IEEE802.15.4e – Synchronization

- Clocks drift (10ppm typical)
- Periodic realignment (within a clock tick)
- Resynchronization every 100s needed (every 30s in practice)

IEEE802.15.4e – Lifetime

- Assumptions
  - 2400mAh (AA battery)
  - 14mA when radio on (AT86RF231)

- If my radio is on all the time
  - 171 hours of time budget (7 days of lifetime)

- If I only want to keep synchronization (theoretical lower limit)
  - 7.656ms from a time budget of 171 hours → I can resync. 80x10^6 times
  - 76 years of lifetime (≈ battery shelf-life)

- A duty cycle of 1% → 2 years of lifetime
• Looking at node D
  – “normal” case
    • 1 reception, 1 transmission (15ms) every 3.3 seconds
    • .45% duty cycle → 4 years lifetime

• Looking at node D
  – “normal” case
  – Triple data rate
    • 3 receptions, 3 transmissions (45ms) every 3.3 seconds
    • 1.36% duty cycle → 17 months lifetime
IEEE802.15.4e – Lifetime

- Looking at node D
  - “normal” case
  - Triple data rate
  - Double every link
    - 2 receptions, 2 transmissions (30ms) every 3.3 seconds
    - .9% duty cycle → 2 years lifetime

---

IETF 6LoWPAN - IPv4 vs. IPv6

IPv6
2^32 addresses
(RFC 2460, 1998)

IPv4
2^16 addresses
(RFC 791, 1981)

RFC 675
2^16 host addresses
2^14 net addresses
(1974)

Thomas Watteyne @ WCNC 2010
IETF 6LoWPAN - IP headers

IPv4 header [RFC791], 1981

IPv6 header [RFC791], 1998

IETF 6LoWPAN - Header Compaction

RFC4944

Not compacted

Well-known value

Value inferred from IEEE802.15.4 header

Thomas Watteyne @ WCNC 2010

OpenWSN
IETF RPL - Status

- IETF WG “Routing Over Low power and Lossy networks”
  - Design a routing protocol for Wireless Mesh Network
  - Revision 7 dated 03/10/2010

- Gradient Routing
  - Nodes acquire a “rank” based on the distance to the collecting node
  - Message follow the gradient of ranks
OpenADR - Motivation

OpenADR - Overview

- [http://openadr.lbl.gov/](http://openadr.lbl.gov/)
  - CEC OpenADR-Version 1.0, April 2009
- OpenADR specification requires:
  - OpenADR server to generate DR message
  - Compliant XML messaging over secure TCP/IP connection
  - Client processor and software framework that decodes and acts upon server messages
- Thanks to IP-enabled mesh networks
OpenADR - Architecture

OpenWSN

OpenWSN - Motivation

TelosB  GINA  JN5148
OpenWSN – Vizualization Tools

OpenWSN

OpenWSN – Open Source

- [http://openwsn.berkeley.edu/](http://openwsn.berkeley.edu/)
- Source code repository: Subversion with public check out
- Documentation: wiki
- Project management: Timeline & Roadmap
- Bug reporting: ticketing system

Thank you.