Blending highly efficient IEEE802.15.4e Low-Power Mesh Networks into the Internet

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The Internet of Things Stack

- web-like interaction
- Internet Integration
- scheduling
- Low-power reliability
- simple hardware
- CoAP
- UDP
- 6LoWPAN
- "gap"
- IEEE802.15.4e
- IEEE802.15.4
First Challenge: External Interference
Second Challenge: Multipath Fading
Second Challenge: Multipath Fading
Second Challenge: Multipath Fading

0% reliability

100% reliability

ch.11

ch.12
Second Challenge: Multipath Fading
Measure packet performance

- Sensor nodes deployed across entire facility (44 Nodes)
- 2.5 hop average
- Measure performance of:
  - 33 packets (80 bytes) per 15 min per mote
  - 3.6 million packets over 26 days

Path stability = \# packets received \\
\# packets sent
16 Channels on a single path
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
  - Standard published 04/16/2012

- 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
- 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

- Number of slots in a superframe is tunable
- Each cell can be assigned to a pair of motes, in a given direction

16 channel offsets

- e.g. 31 time slots (310ms)
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
  - ...and energy consumption

16 channel offsets

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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
  
  ...and energy consumption

16 channel offsets

e.g. 33 time slots (330ms)
• Cells are assigned according to application requirements
• Tunable trade-off between
  - packets/second
  - latency
  - robustness

...and energy consumption
Example: 30 mote SmartMesh IP network

30 second reporting

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The Internet of Things Stack

- CoAP
- UDP
- 6LoWPAN
- IEEE802.15.4e
- “gap”
- IEEE802.15.4

web-like interaction
Internet Integration
scheduling
Low-power reliability
simple hardware
Why Standardize?

The Internet
Every host on the Internet has a unique Internet Protocol (IP) address
- A packet with an IP header is routed to its destination over the Internet

IP is the narrow waist of the Internet
- “If you speak IP, you are on the Internet”

Evolution of the Internet Protocol
- IPv4 (1981) is currently used
  - 32-bit addresses
  - “third-party toolbox”: ARP, DHCP
- IPv6 (1998) is being deployed
  - “toolbox” integrated
  - 128-bit addresses
IETF 6LoWPAN

MAC | IPv6 | UDP | payload | security
---|---|---|---|---
10B | 40B | 8B | 63B | 6B

127B | IEEE802.15.4
---|---
107B | 6B

MAC | 6LoWPAN | payload | security
---|---|---|---
10B | 4B | 6B
Low-Power Border Router (LBR)

Mesh Network

Internet

compaction

inflation
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
The Internet of Things Stack

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- scheduling
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- simple hardware

CoAP
UDP
6LoWPAN
new! RPL4e*
IEEE802.15.4e
IEEE802.15.4

*tentative name
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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 multihop 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/Linear Technology, 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. Prior to Dust Network, Thomas 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.