Determinism in the IoT

The example of 6TiSCH and OpenWSN

Thomas Watteyne

IRTF T2TRG meeting
22 March 2015, Dallas, TX, USA

Goals (and outline)

- Contextualize the work in the 6TiSCH WG
  - Present the base technology: IEEE802.15.4e TSCH
  - Present the *mechanisms* we are defining in 6TiSCH
  - Highlight the different *policies* which can be built using these mechanisms
- Research around 6TiSCH and IoT IETF WG
  - Research needs
  - Research tools, the example of the OpenWSN project
- Highlight the challenges around standards-based research, and the need for an RG around IoT

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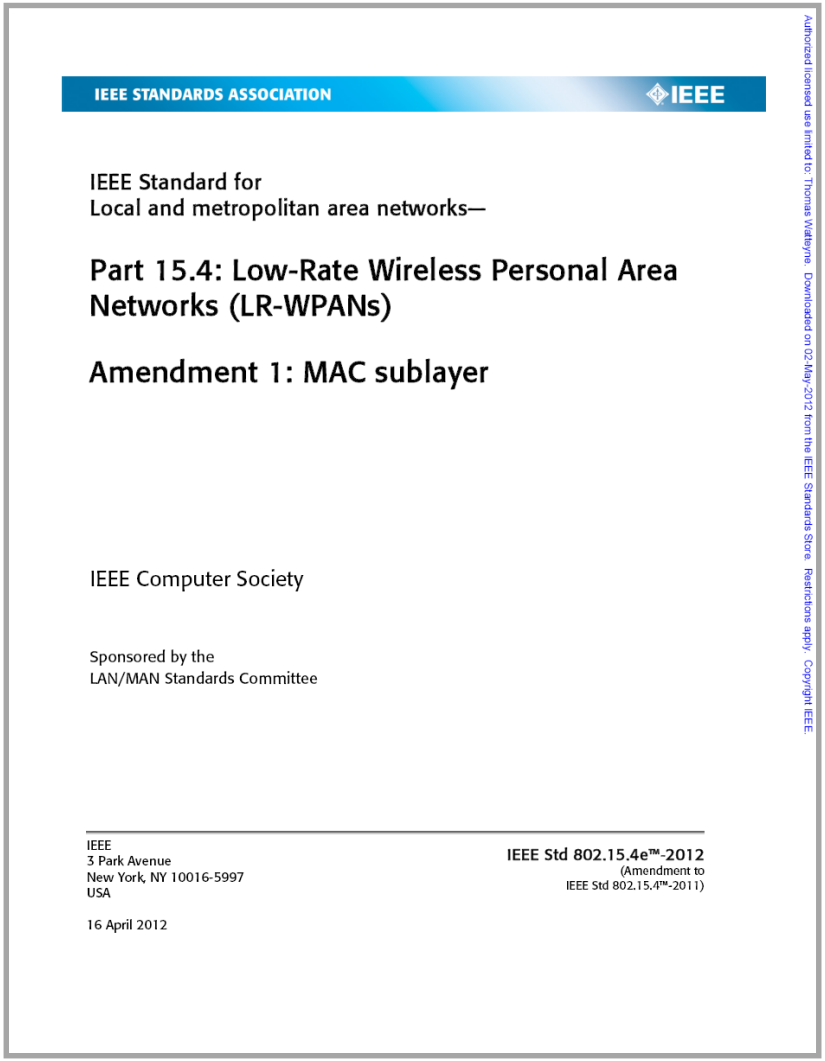
Step 1/3: IEEE802.15.4e and 6TiSCH

IEEE802.15.4e: Status

- Published 16 April 2012
- Only amends MAC layer of IEEE 802.15.4-2011:
  - Does not modify PHY layer
- “Timeslotted Channel Hopping” (TSCH) mode:
  - Ultra low-power operation by synchronizing nodes
  - Ultra high reliability through channel hopping



IEEE STANDARDS ASSOCIATION IEEE

IEEE Standard for
Local and metropolitan area networks—

Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)

Amendment 1: MAC sublayer

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

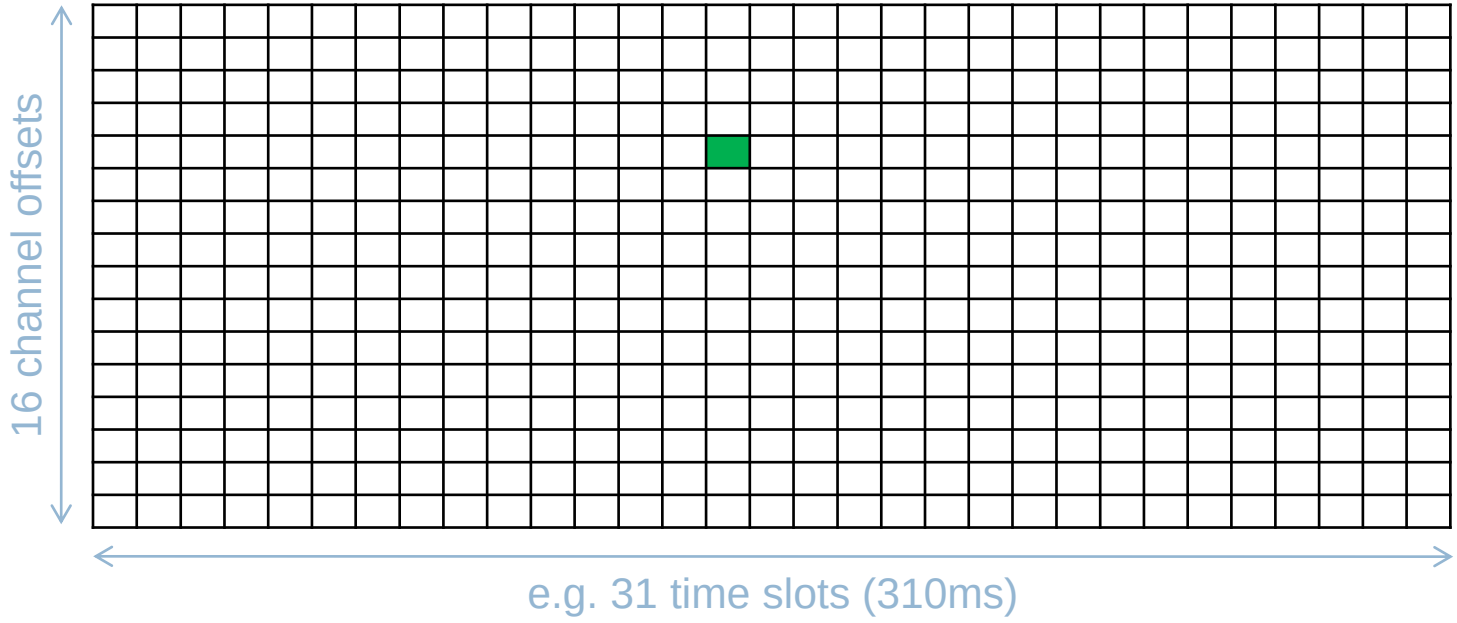
16 April 2012

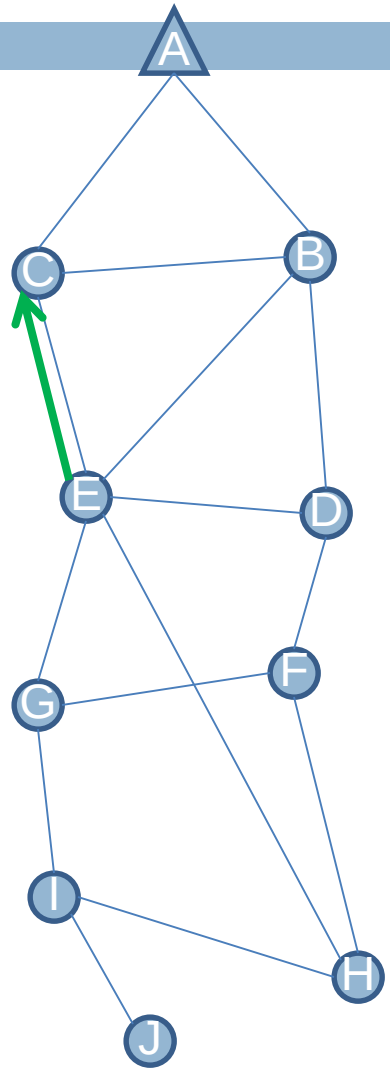
IEEE Std 802.15.4e™-2012
(Amendment to
IEEE Std 802.15.4™-2011)

IEEE802.15.4e: Communication Schedule

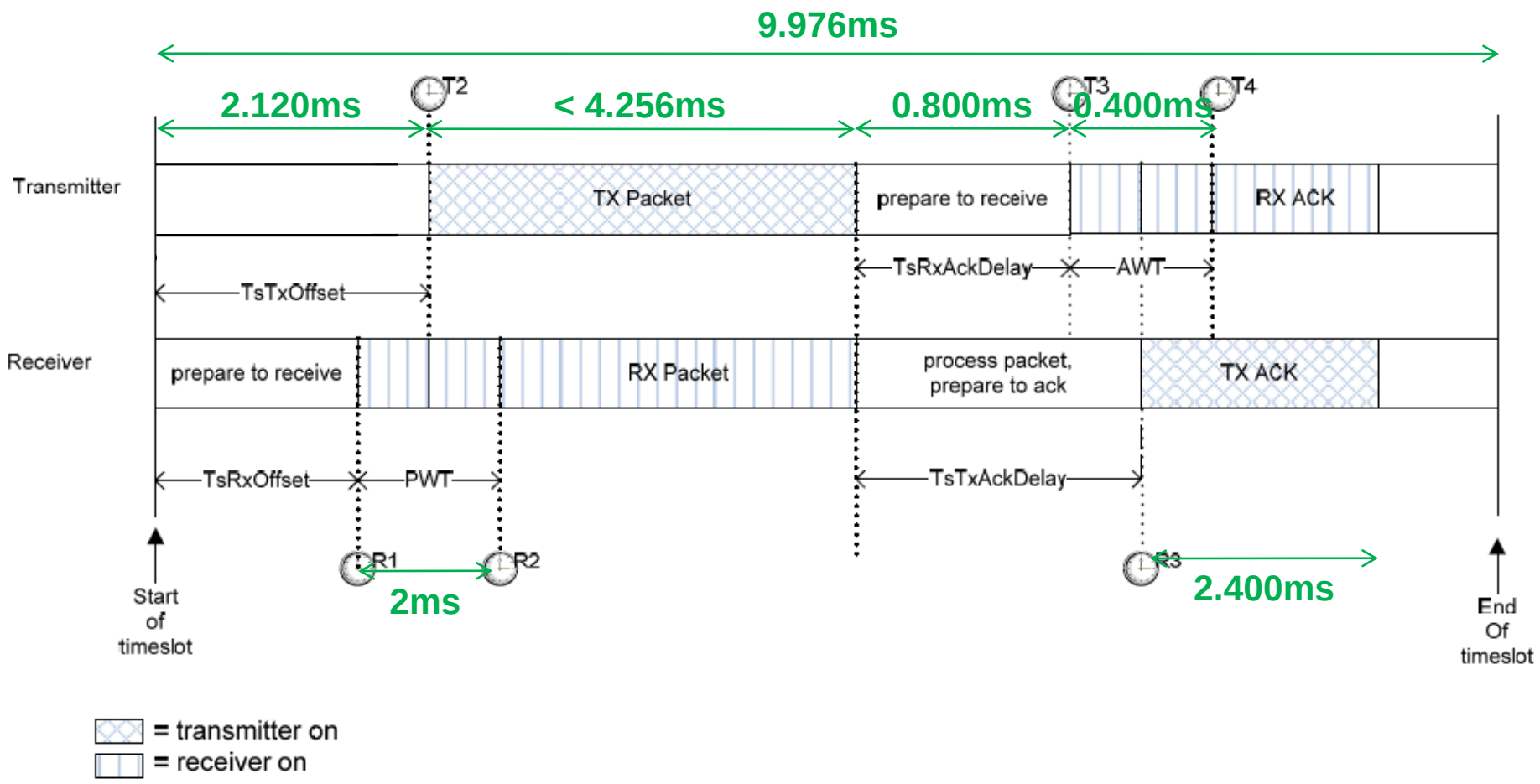
A super-frame repeats over time

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



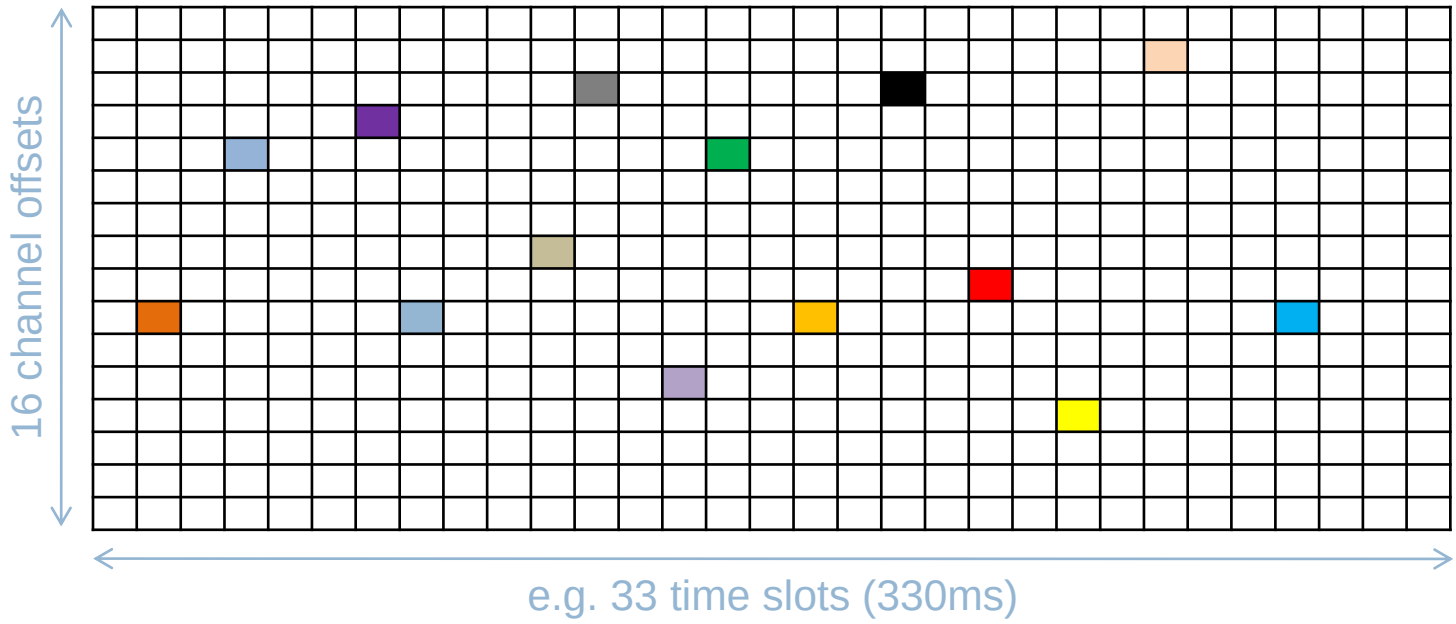


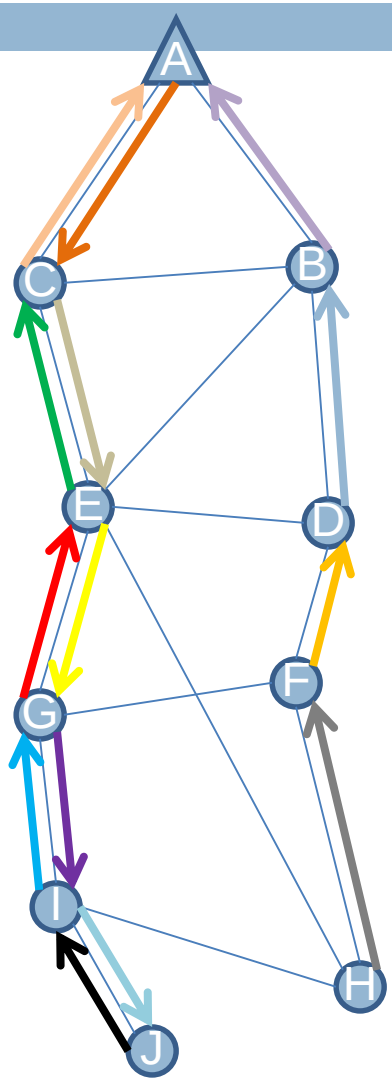
IEEE802.15.4e : a Slot



IEEE802.15.4e - Slotted Structure

- Cells are assigned according to application requirements

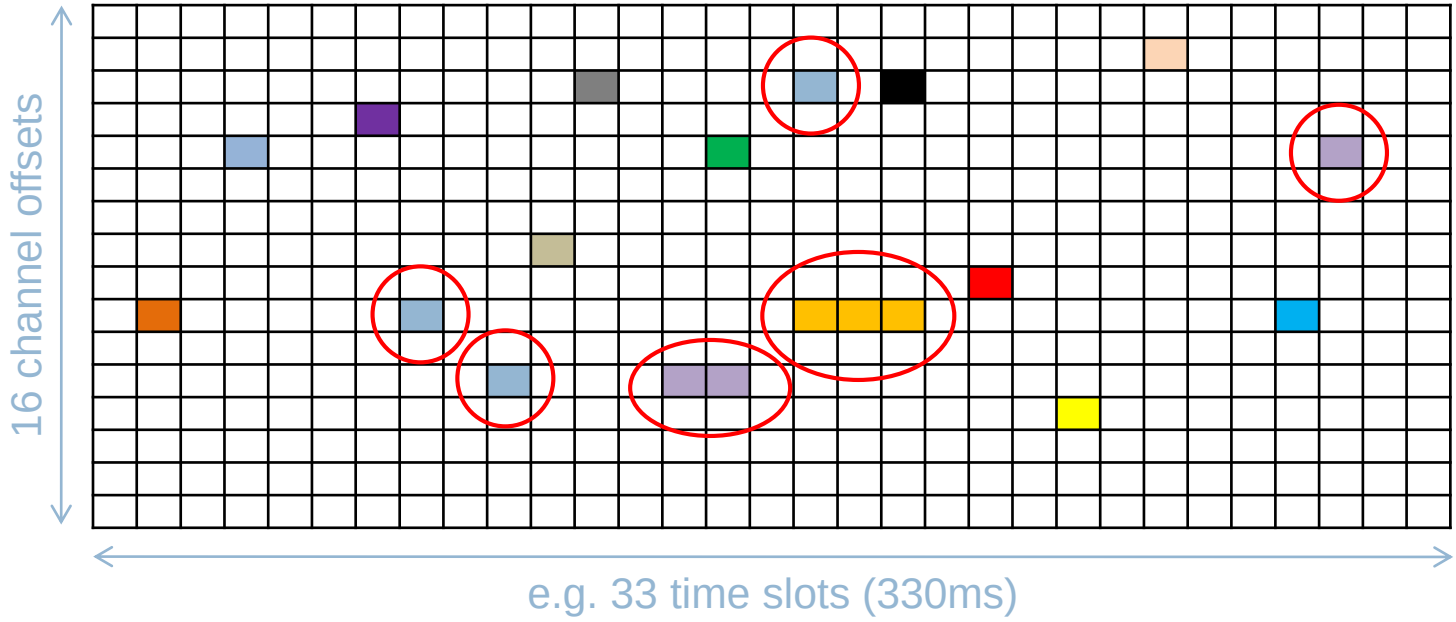


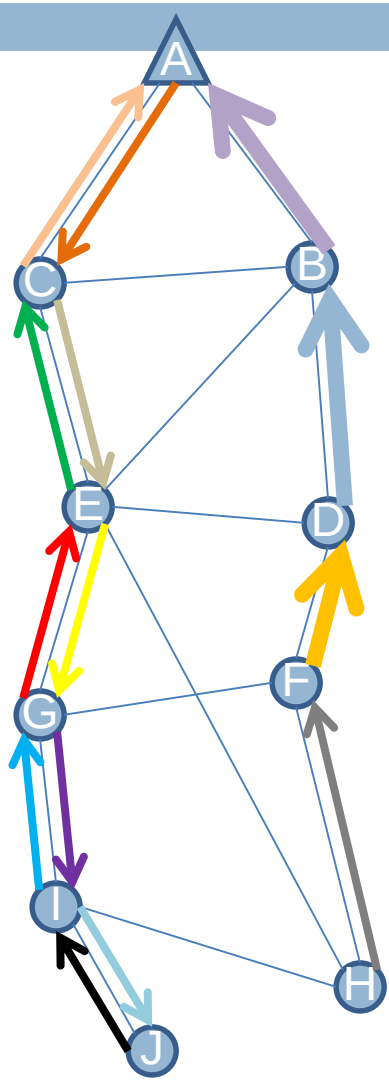


IEEE802.15.4e - Slotted Structure

- Cells are assigned according to application requirements
- Tunable trade-off between
  - packets/second

…and energy consumption

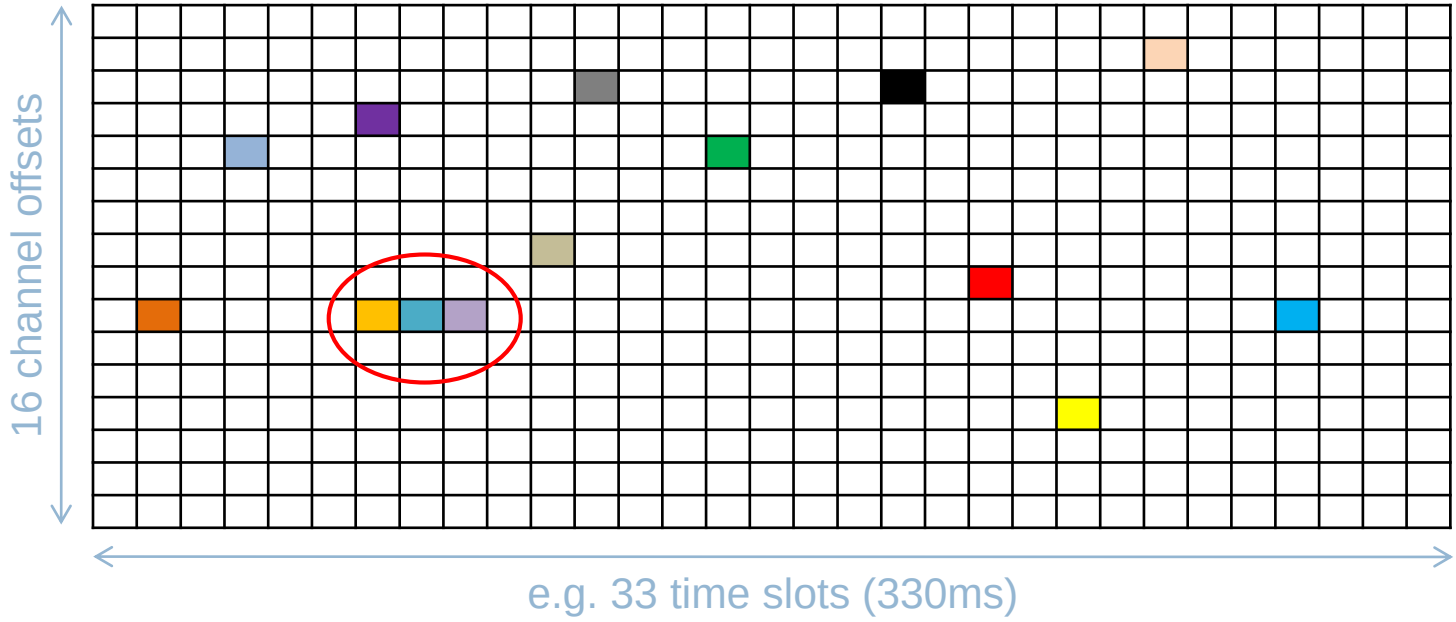


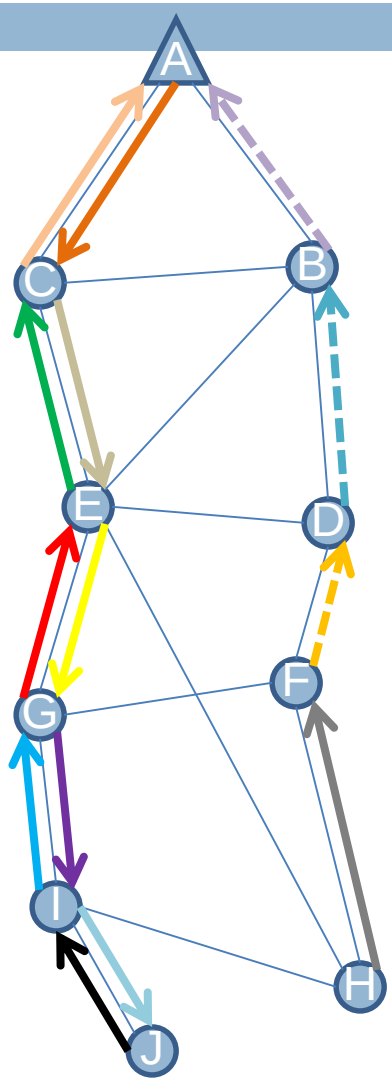


IEEE802.15.4e - Slotted Structure

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

…and energy consumption

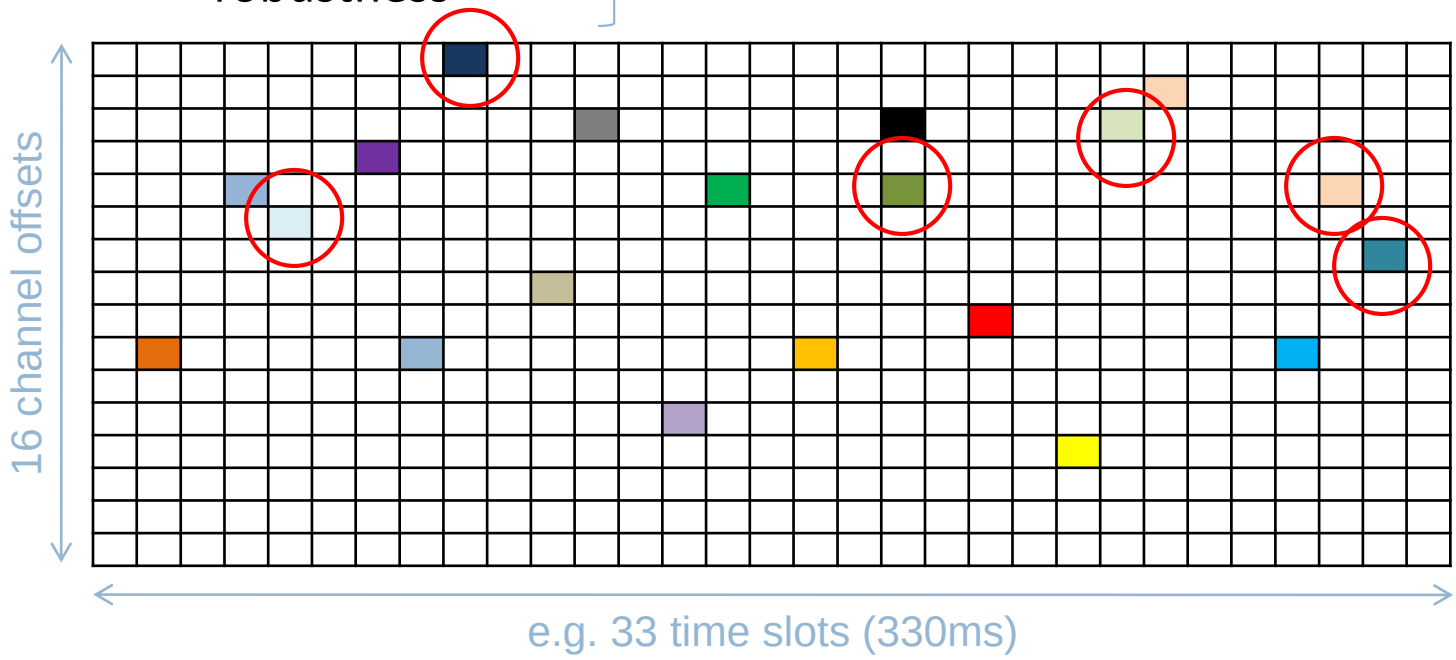


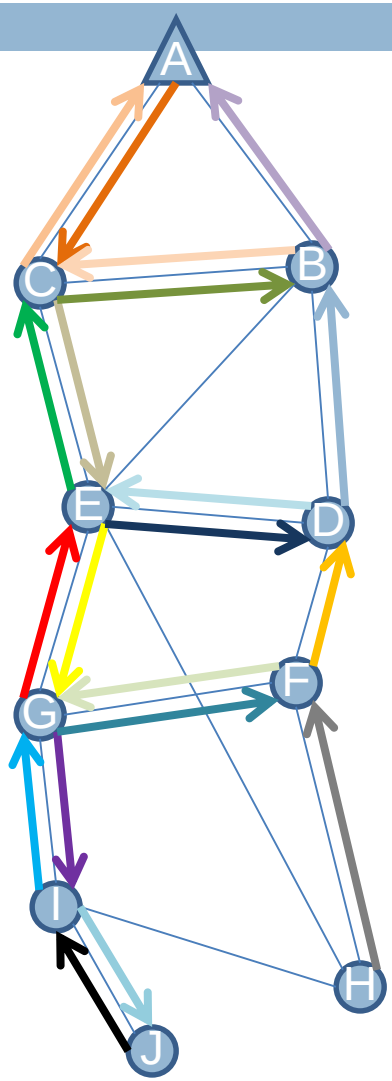


IEEE802.15.4e - Slotted Structure

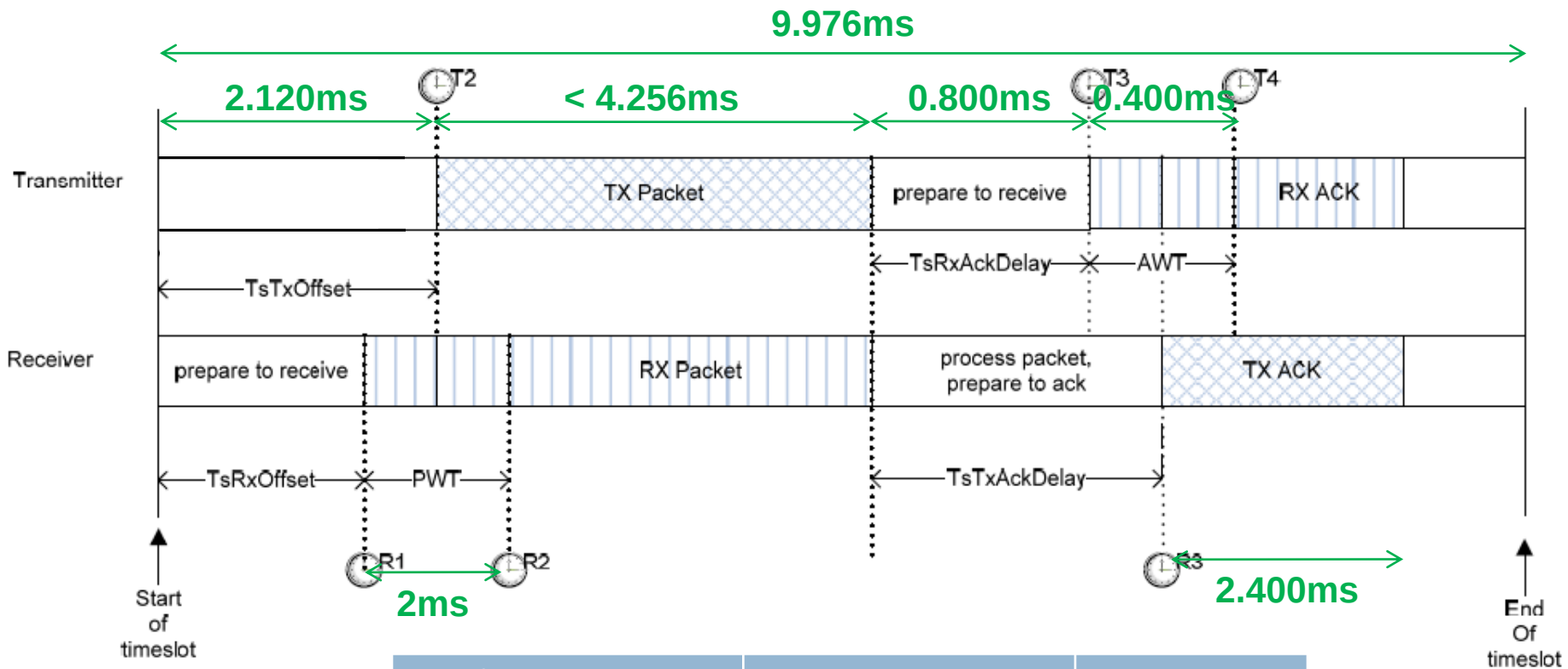
- Cells are assigned according to application requirements
- Tunable trade-off between
  - packets/second
  - latency
  - robustness

…and energy consumption





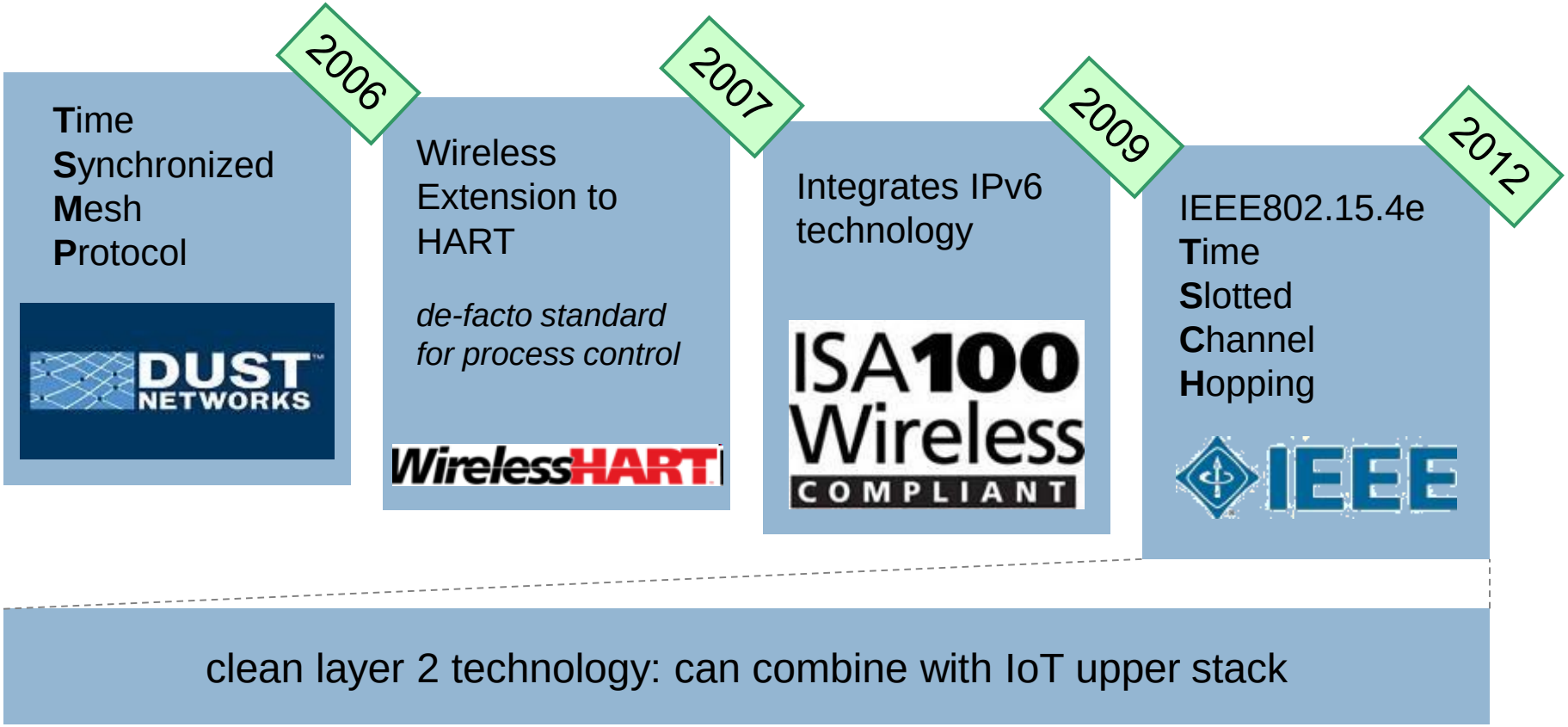
IEEE802.15.4e - Energy Consumption



Type of slot	Transmitter	Receiver
"OFF"	-	-
transmission w. ACK	6.856ms	7.656ms
Transmission w.o. ACK	4.256ms	5.256ms
Listening w.o. reception	-	2.000ms

"atomic" operations

Time Synchronized Channel Hopping



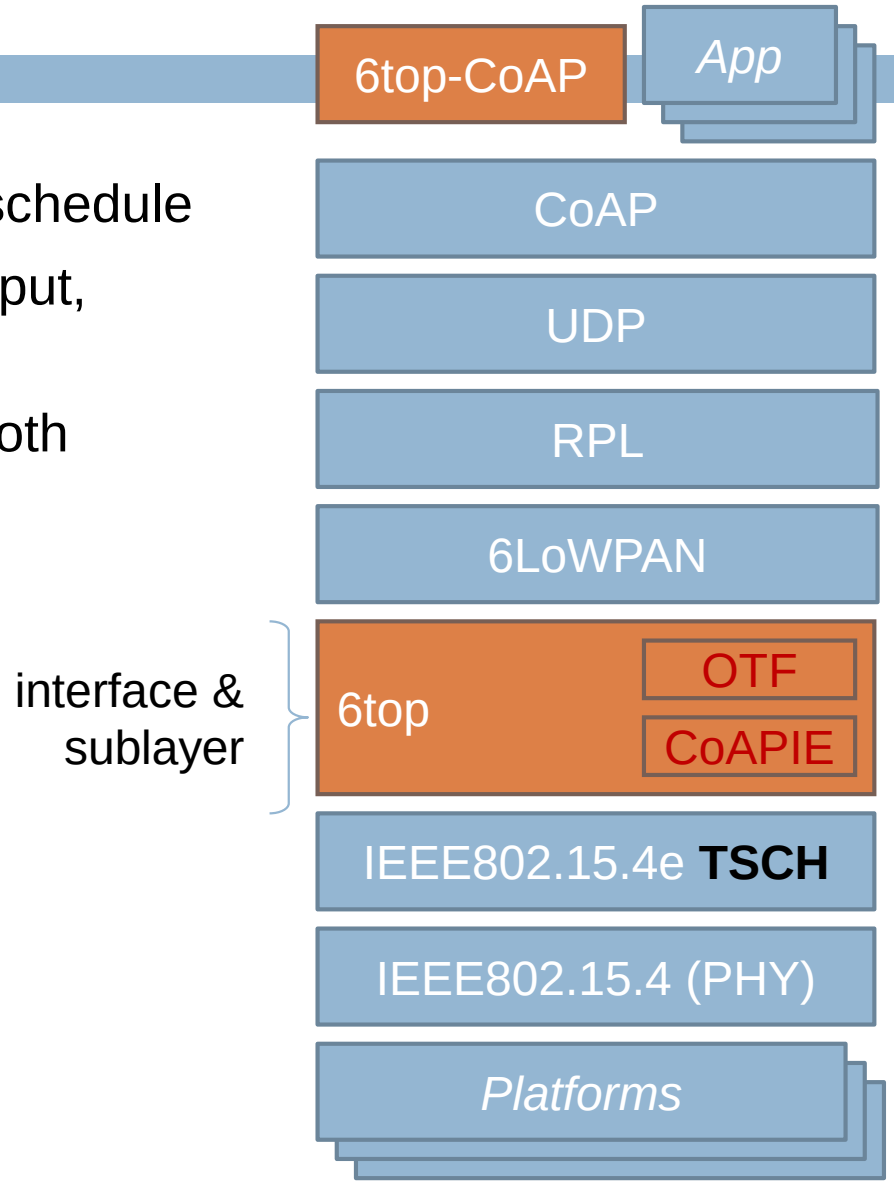
Complementarity between commercial, standardization, open-source implementations and large-scale testbeds

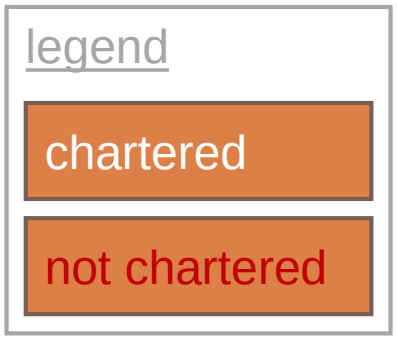
IETF 6TiSCH

- created October 2013
- ***IPv6 over the TSCH mode of IEEE 802.15.4e***
- 304 members (mix between academic and non-academics)
- Face-to-face meetings at IETF86, IETF87, IETF88, IETF89, IETF90, IETF91, IETF92
- Over 100 meetings (incl. telcos)
- Plugfest March 2014, July 2014
- Plugtest July 2015, Nov. 2015

IETF 6TiSCH

- Goal: management of the TSCH schedule
- Introduce determinism in: throughput, latency, reliability
- Provide mechanisms to support both centralized and distributed …
- … in a secure manner.





Step 2/3: Research around 6TiSCH with OpenWSN

Mechanisms vs. Policy

Mechanisms

- Packet formats
- Interaction models between entities
- APIs

Policy

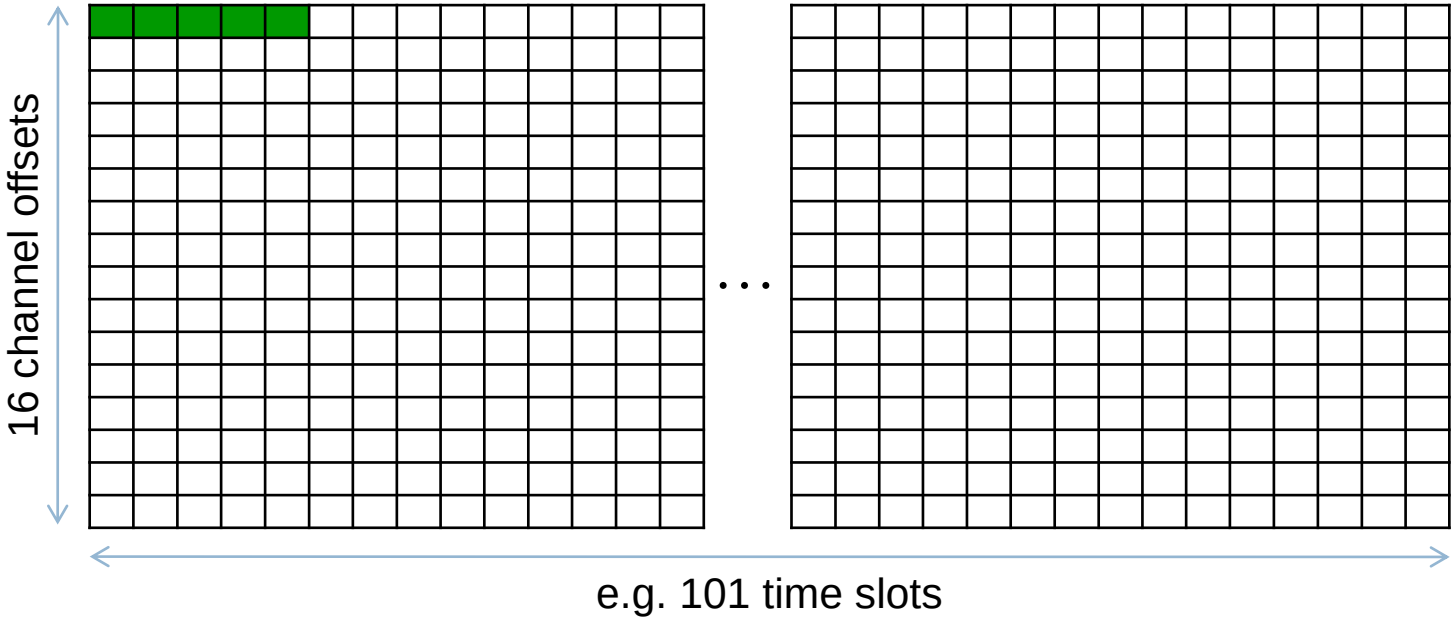
- Different scheduling “paradigms”
- Identify limits
- Which one to use when

IETF

“research”
(not per se IRTF?)

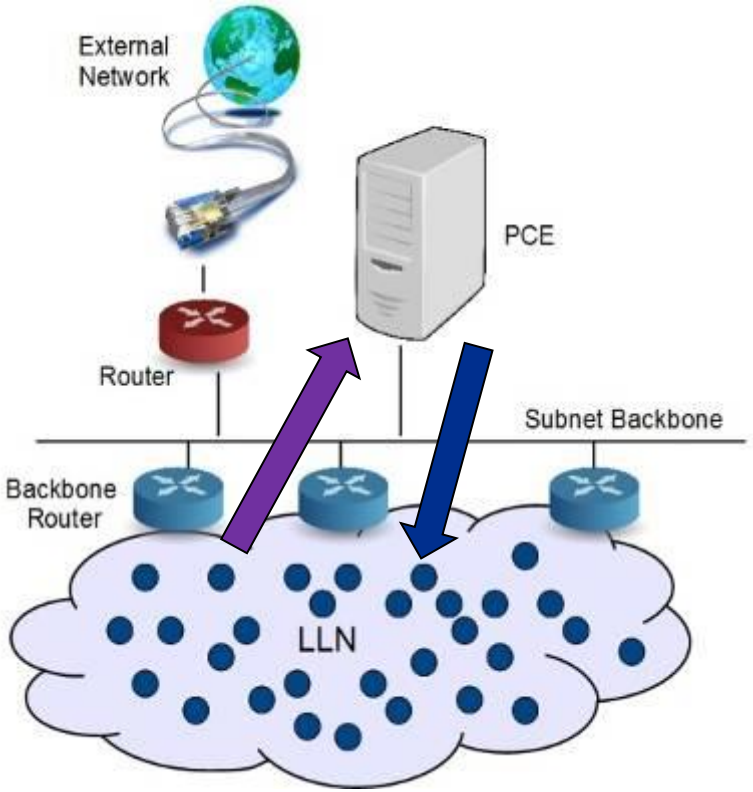
6TiSCH: Static Schedule

- "Minimal" approach
  - draft-ietf-6tisch-minimal
  - Static schedule, slotted-Aloha access
  - **Questions**: energy/latency/throughput limits?



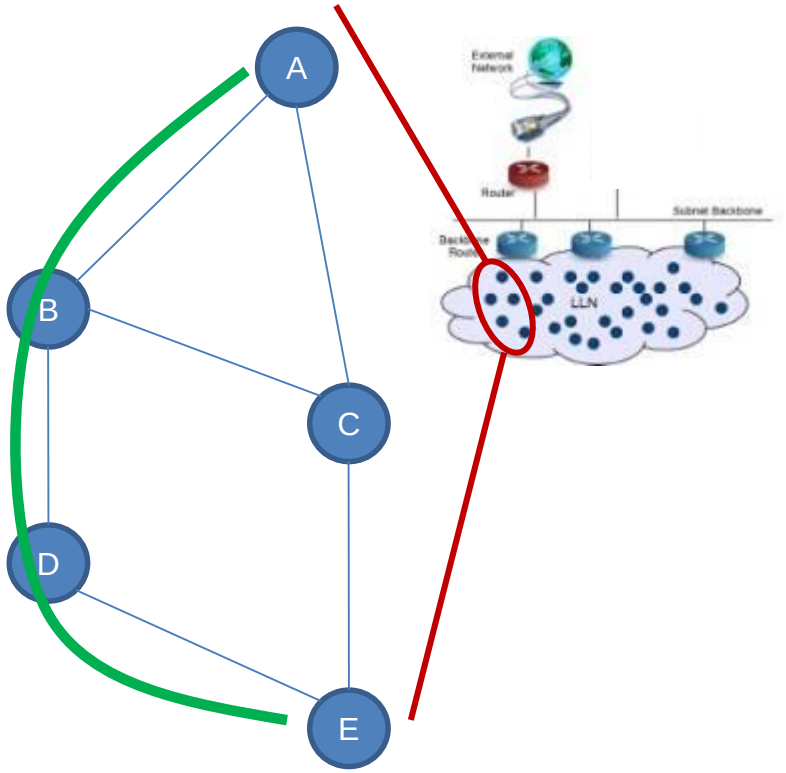
6TiSCH: Dynamic Scheduling

Centralized



vs.

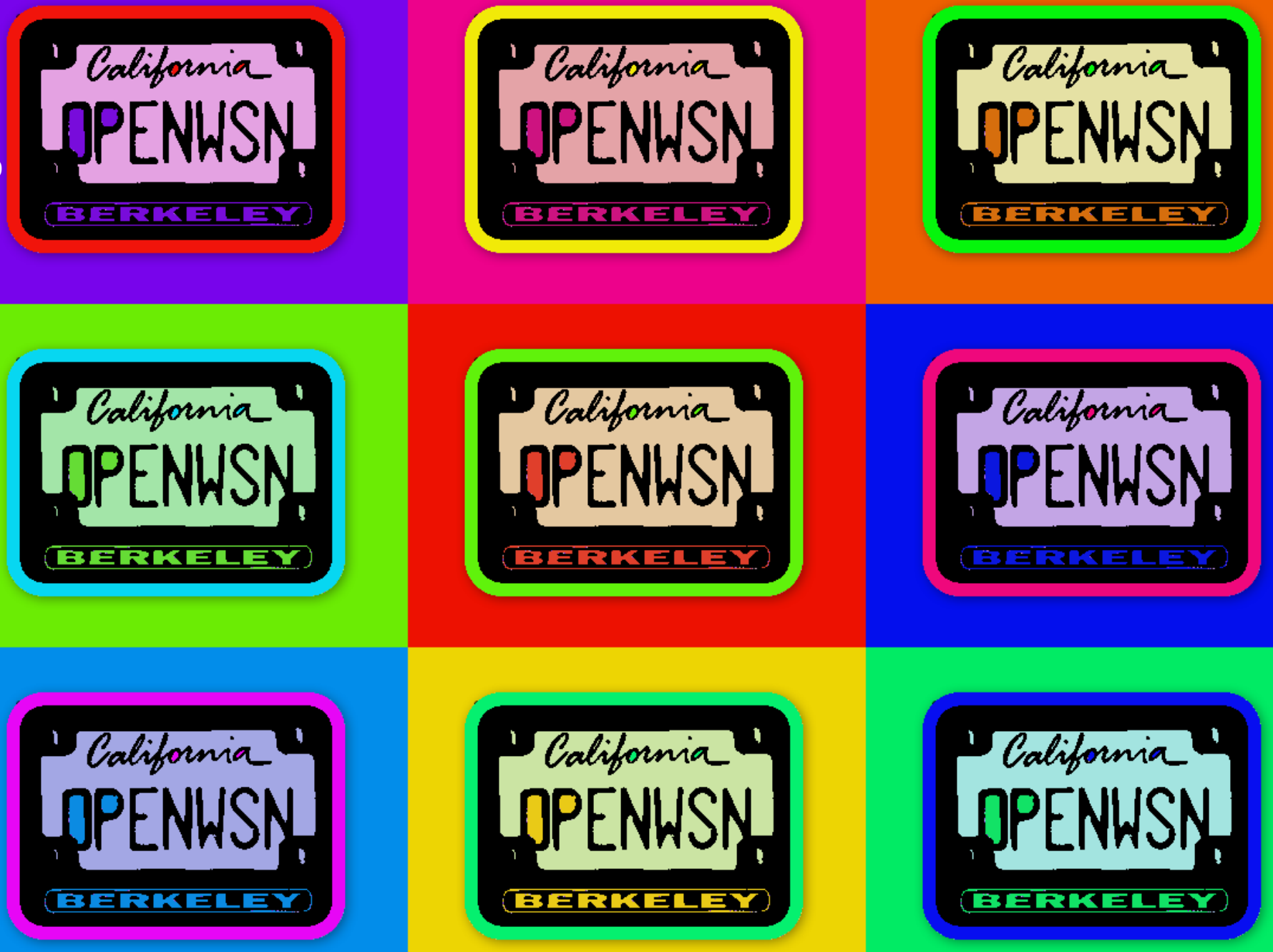
Distributed



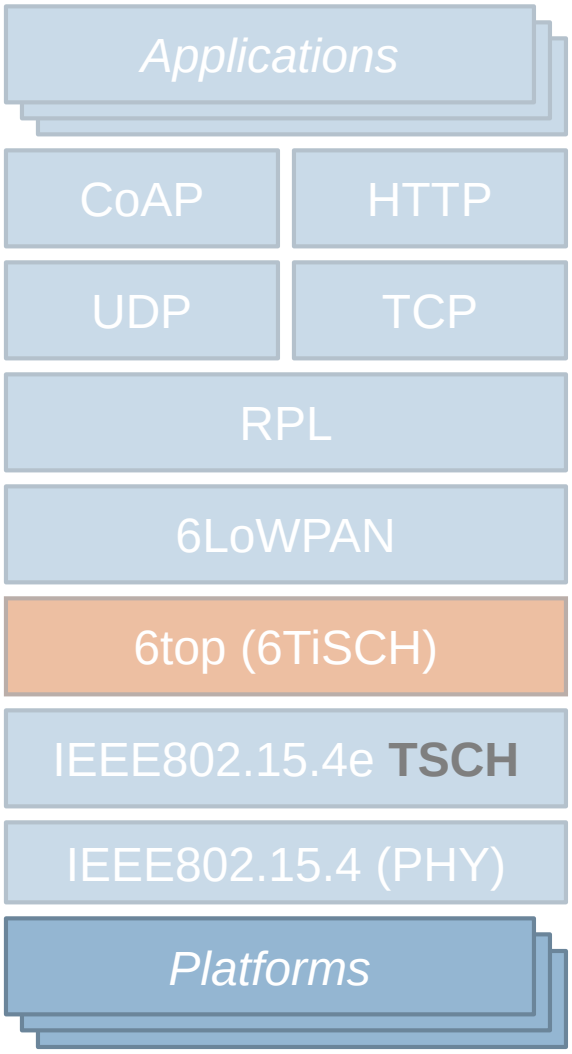
- **questions**: scalability, reactivity?

e.g. "On-The-Fly" scheduling
draft-dujovne-6tisch-on-the-fly-02.txt

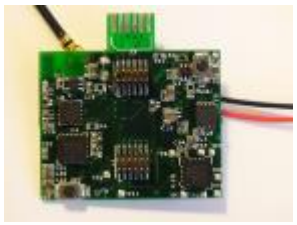
- **questions**: reactivity, performance?


California
OPENWSN
BERKELEY

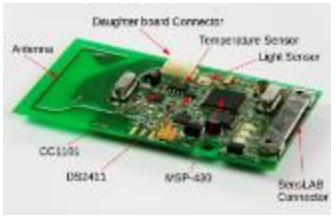
OpenWSN.berkeley.edu



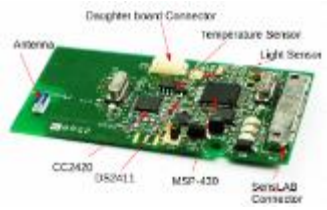
OpenMote-CC2538



GINA



WSN430v13b



WSN430v14

Z1

TelosB

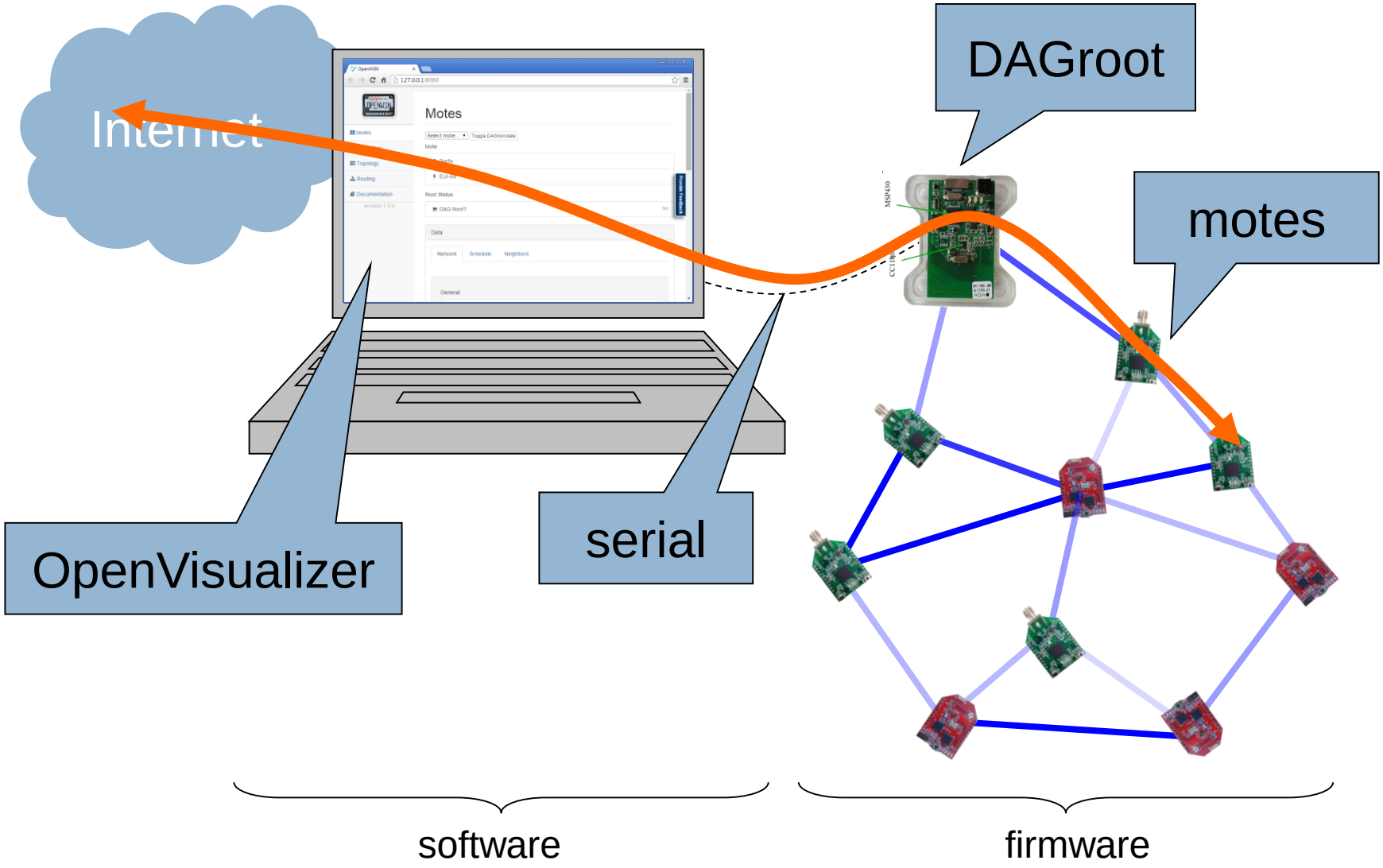
OpenMoteSTM

SAM R21

IoT-LAB_M3

AgileFox

Architecture

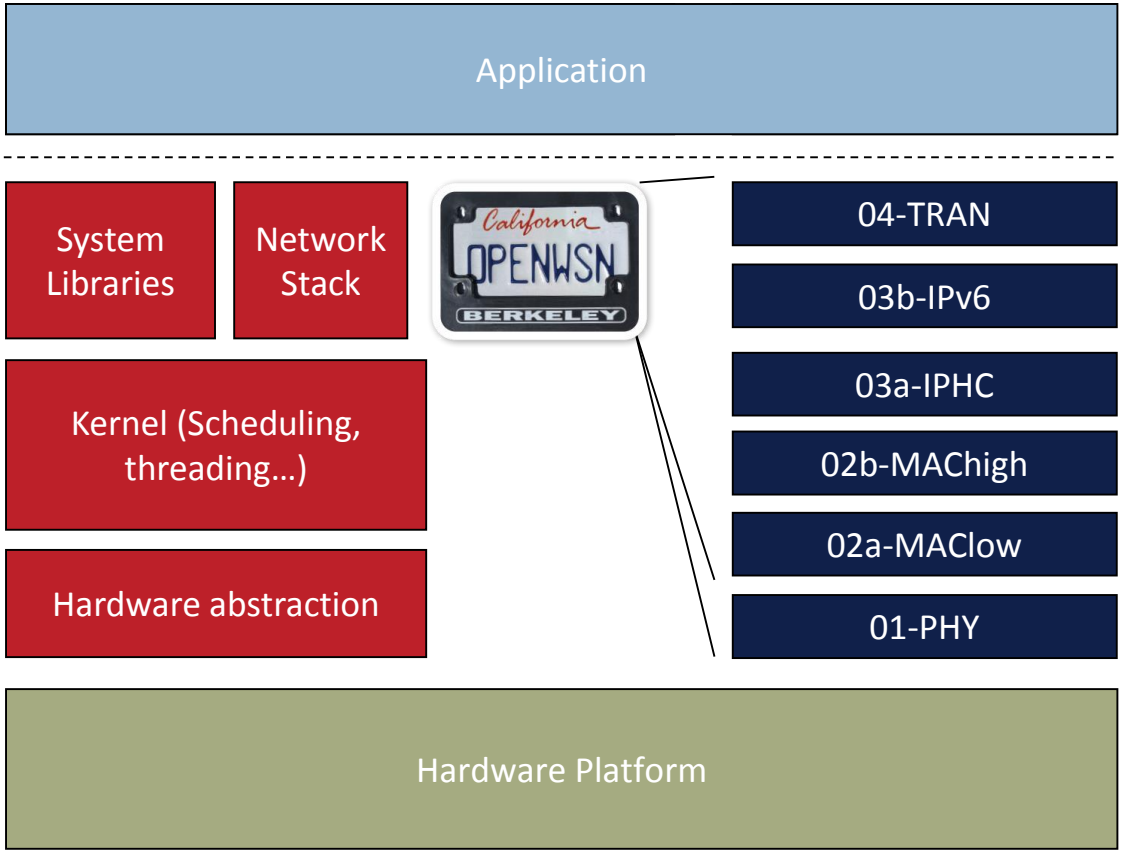


RIOT integration



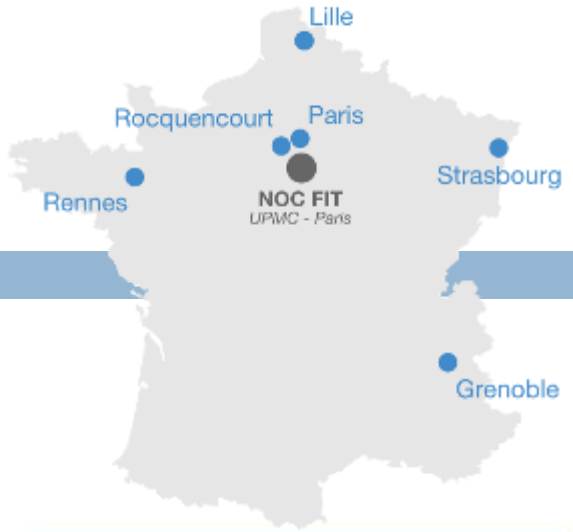
Thomas Eichinger Oliver Hahm Emmanuel Baccelli

- Goal: combine the RIOT preemptive scheduler with the OpenWSN protocol stack

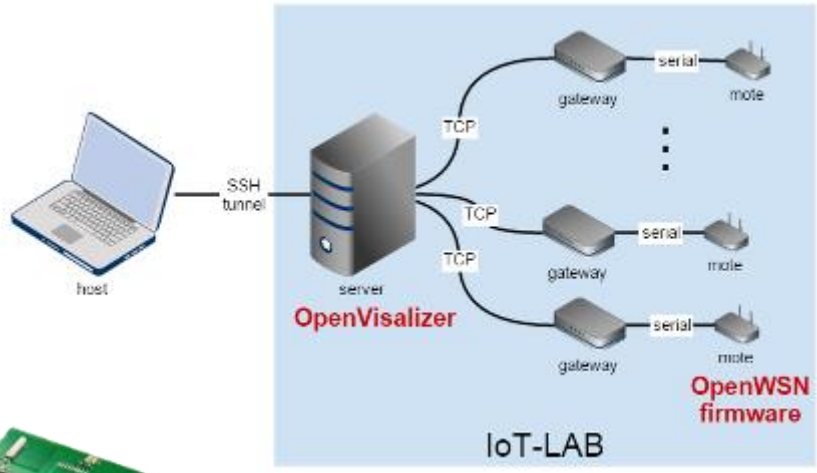


Demonstrated during 6TiSCH plugfest at IETF90, Toronto, July 2014.

FIT IoT-lab



- 2728 wireless sensor nodes
- 6 deployment sites across France
- web interface to:
  - reserve nodes for an experiment
  - upload binary images
- free for academic use
- officially launched this morning
- Full OpenWSN support



MSP430f1611
CC2420

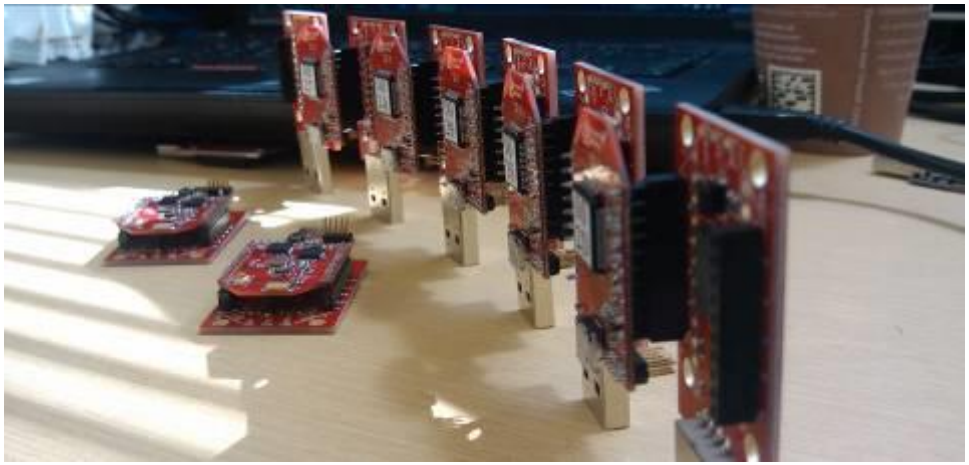
STM32F (Cortex)
AT86RF231

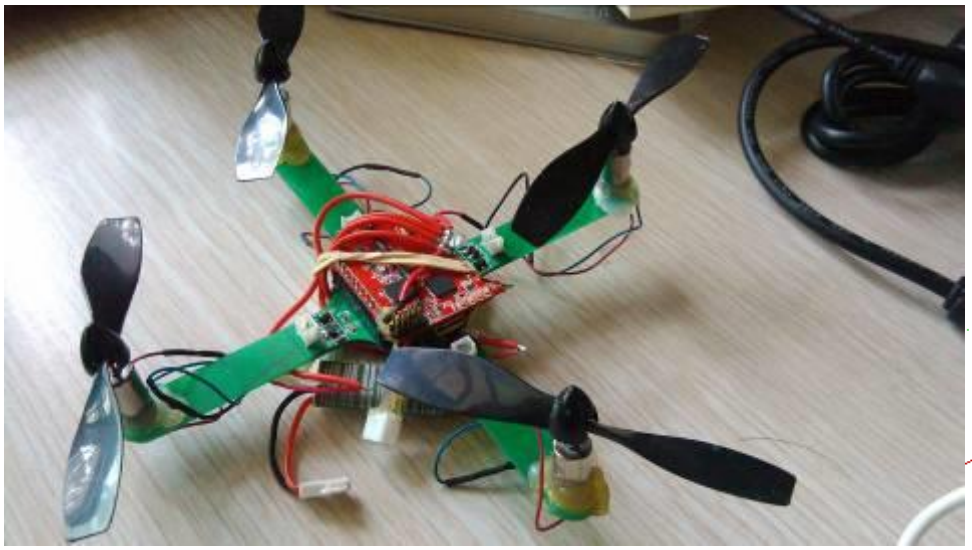
Cortex-A8
(Linux)

OpenMote-STM

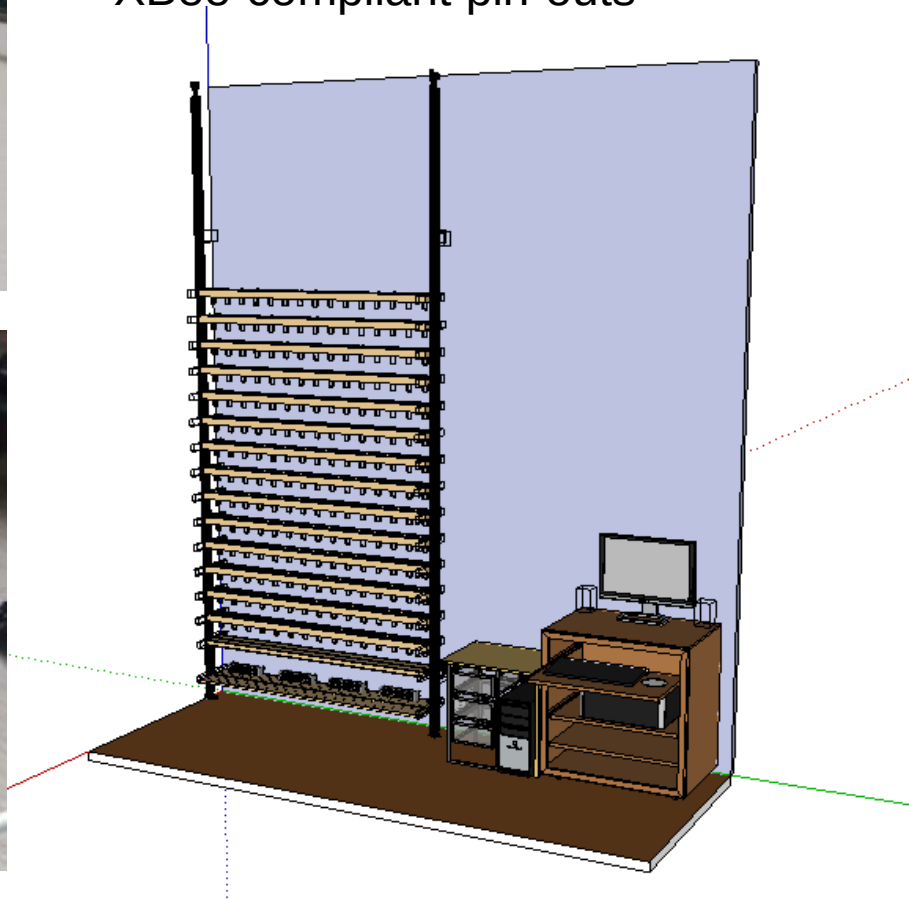

Tengfei Chang Qin Wang

University of Science & Technology Beijing, China





- STM32 micro-controller, Atmel AT86RF231 radio
- XBee-compliant pin-outs



OpenMote

Open hardware for the Internet of Things.

Xavi Vilajosana

Pere Tuset

- An easy-to-use ecosystem of IoT hardware
- Centered about the OpenMote-CC2538

OpenMote	**OpenBase**	**OpenBattery**
TI CC2538 SoC	Ethernet PHY+MAC	Temp./Humd.
(Cortex M3 + radio)	USB-to-UART port	Acceleration
4 LEDs, 2 Buttons	10-pin ARM JTAG	Light
2 antennas		2xAAA batteries

www.openmote.com

6TiSCH plugfests

IETF89, London, March 2014

IETF90, Toronto, July 2014

Step 3/3: Challenges of standards-based research

Challenges

- 6TiSCH-related
  - Limits of TSCH
  - centralized vs. distributed approach
  - IRTF? **Probably not**: too specific & addressed by research community
- IoT-related
  - Putting together the “building blocks” for management:
    - publish detailed description
    - evaluate overhead
    - reference implementations and tools
  - Ditto for “security”:
    - *same points as above*
- More general
  - Challenge of “putting it all together”
    - e.g. RPL and IP-in-IP
  - How to stress importance of “running code”
  - How to ask research community of input
    - Maintain list of research challenges?
  - How to get feedback from research into standardization activities
    - performance studies
    - research challenges?