Deterministic IPv6 over IEEE802.15.4e Timeslotted Channel Hopping (**6TSCH**) **BoF**

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https://bitbucket.org/6tsch/

Administrivia

- Note Well: Be aware of the IPR principles, according to RFC 3979 and its updates

- Blue sheets
- Scribes
- Jabber

Note Well

This summary is only meant to point you in the right direction, and doesn't have all the nuances. The IETF's IPR Policy is set forth in BCP 79; please read it carefully.

The brief summary:

- By participating with the IETF, you agree to follow IETF processes.
- If you are aware that a contribution of yours (something you write, say, or discuss in any IETF context) is covered by patents or patent applications, you need to disclose that fact.
- You understand that meetings might be recorded, broadcast, and publicly archived.

For further information, talk to a chair, ask an Area Director, or review the following:

- BCP 9 (on the Internet Standards Process)
- BCP 25 (on the Working Group processes)
- BCP 78 (on the IETF Trust)
- BCP 79 (on Intellectual Property Rights in the IETF)

Agenda Bashing

Problem statement [40min]

What is IEEE802.15.4e TSCH? (draft-watteyne-6tsch-tsch-lln-context)	[15min]	(Maria Rita Palattella, Thomas Watteyne)
What is missing?	[15min]	(Xavi Vilajosana)
Why is this a problem?	[3min]	(Alfredo Grieco)
Status of 6TSCH group (draft-thubert-6tsch-architecture)	[7min]	(Thomas Watteyne, Pascal Thubert)

Clarifying questions [10min]

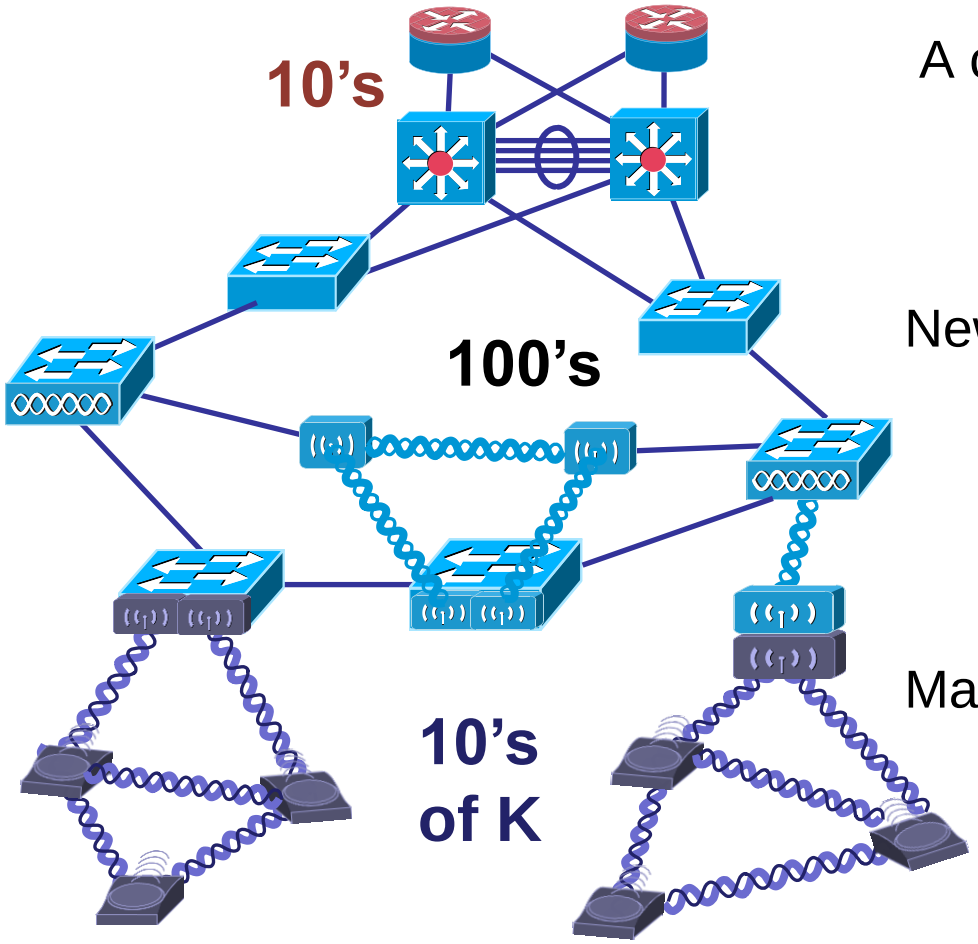
Discussion of the charter [20min]

Introduction	[1min]	(Thomas Watteyne)
Description of the WG	[4min]	(Dominique Barthel)
Work items	[10min]	(Raghuram Sudhaakar)
Non-milestone work items	[2min]	(Pascal Thubert)
External work to other WG	[3min]	(Pascal Thubert)

Open discussion and questions [20min]

Proposed charter: https://bitbucket.org/6tsch/charter-ietf-6tsch/src

IT/OT* Network Convergence



A converged network MUST provide

- High availability, flow isolation, security
- Scalable, **IPv6**-based architecture
- Guaranteed bandwidth, Optimum Capacity

New, Higher-End paradigm

- Reaching more devices, farther, cheaper
- With better guarantees for critical apps
  => **delivery ratio, jitter, latency**
- Optimized power consumption in Low power and Lossy Networks (LLN)

Making Deterministic Happen

- Learn from Industrial, Air and Space
- Replicate and generalize with open standards
- Enable a Multitude of **new** IoT applications

* Information/Operations Technology

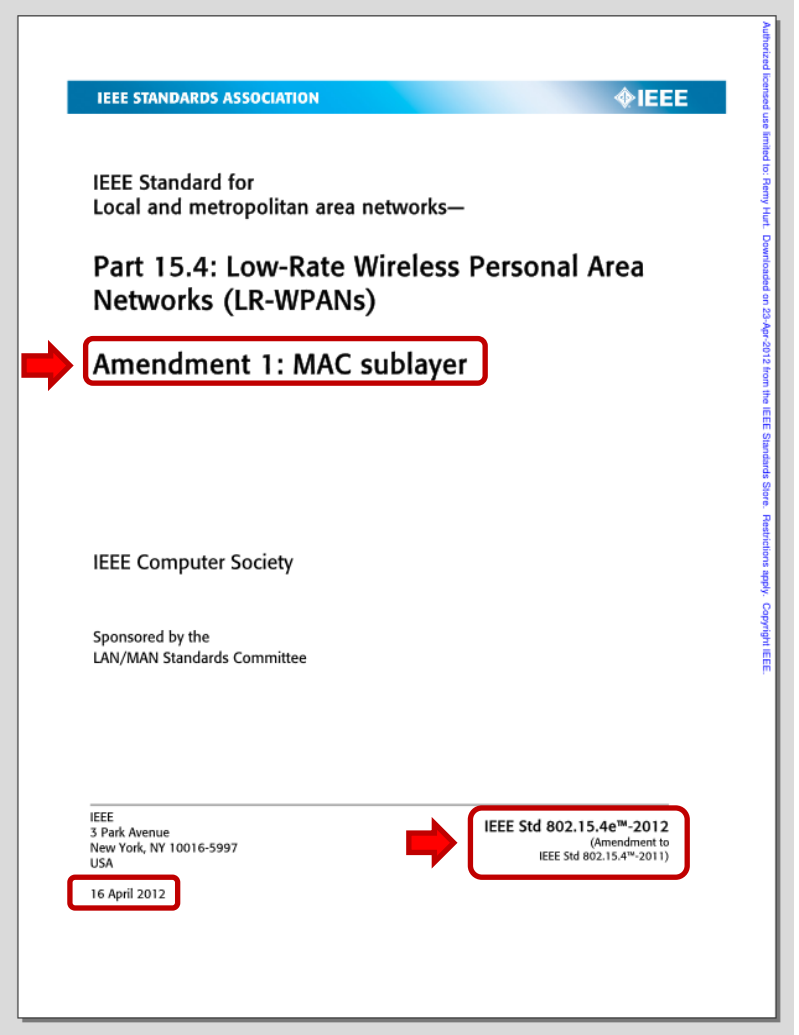
problem statement
• **what is IEEE802.15.4e TSCH?**
• what is missing?
• why is this a problem?
• status of 6TSCH group
discussion of the charter
presentation of remaining drafts

What is IEEE802.15.4e TSCH?

Maria Rita Palattella

IEEE802.15.4e TSCH

- Task Group within IEEE802.15.4
- Chartered to "*define a **MAC amendment** to enhance and add functionality to better support the industrial markets*"
- Published in April 2012
- "**Timeslotted Channel Hopping**" (TSCH) mode:
  - Low-power operation by **synchronizing nodes**
  - High reliability by **channel hopping**



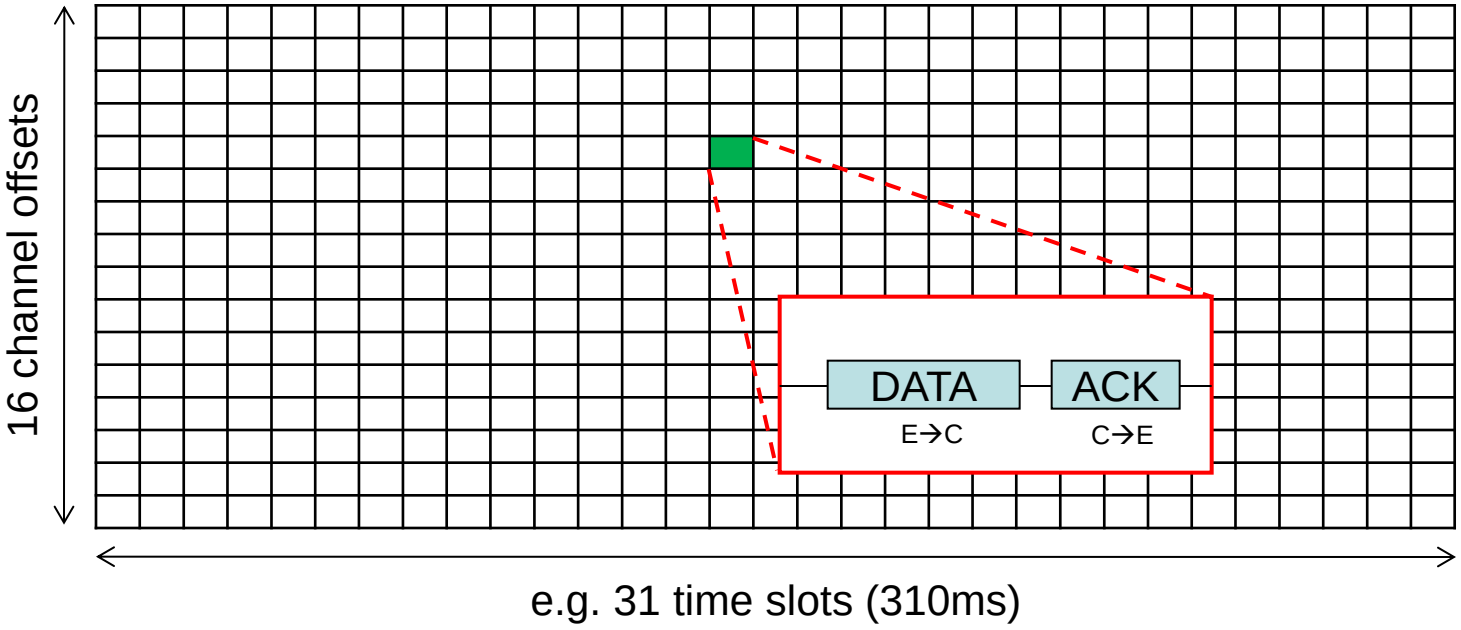
IEEE802.15.4 PHY

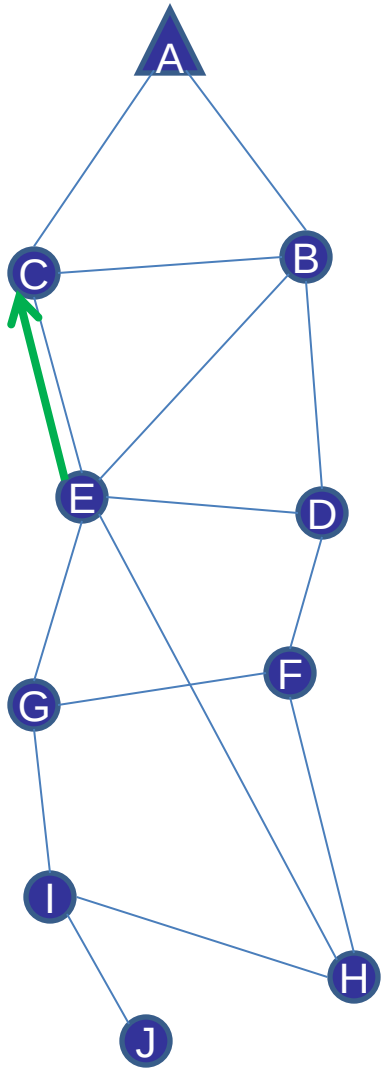
- Versions in 2003, 2006, 2011
- Healthy trade-off between throughput, range, packet length and power consumption.
- Mostly used by low-power battery-powered devices to build Low power and Lossy Networks (LLN)
- **Work by 6LoWPAN, ROLL and CORE WGs define how to fit IPv6 stack on top of IEEE802.15.4.**

Can we build IPv6-enabled LLNs with IEEE802.15.4e TSCH as a foundation?

TSCH Schedule [1/2]

- All nodes in a TSCH network always keep **synchronized**.
- Time is divided in slots, grouped in a ***slotframe***, which continuously repeats over time (slotframe length tunable).
- A TSCH schedule indicates what to do in each **cell**:
  - transmit to a neighbor
  - receive from a neighbor
  - sleep (i.e. radio off)





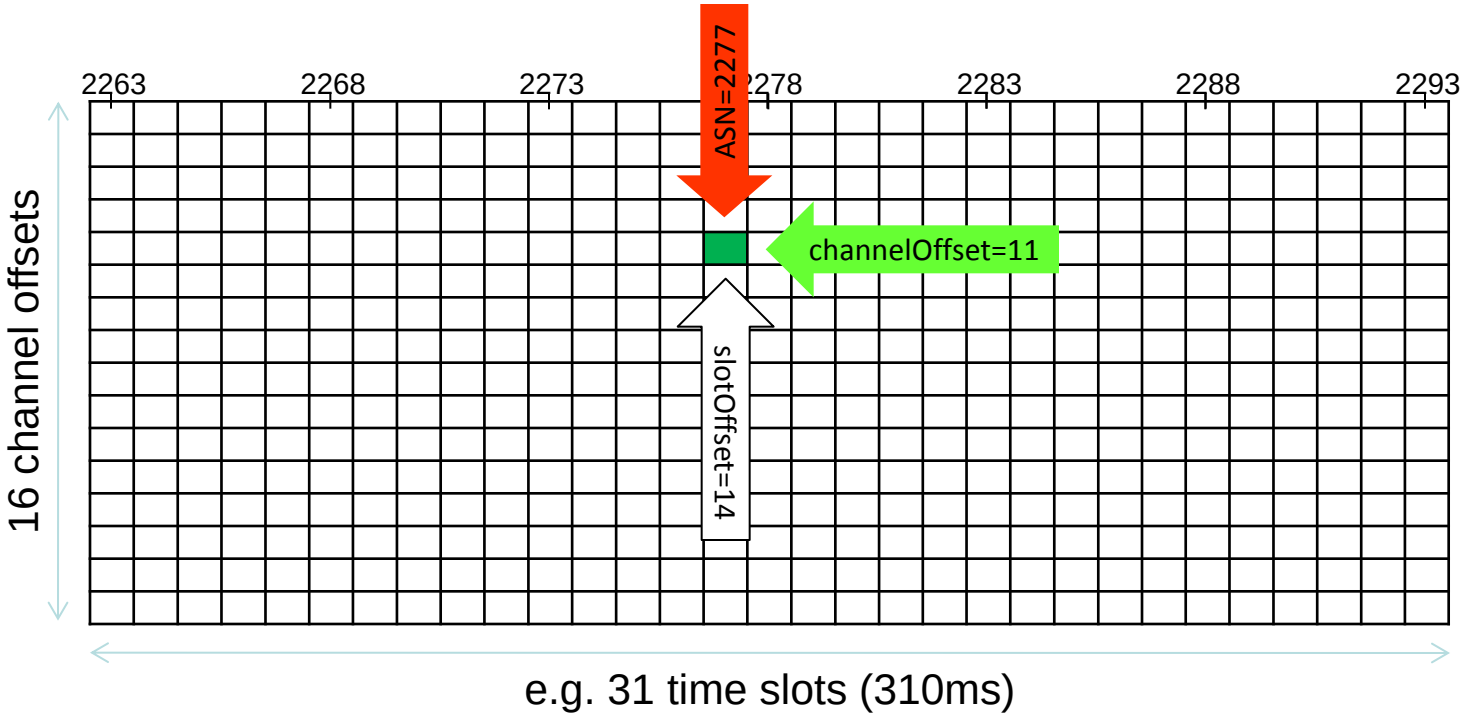
Time Synchronization*

- Clocks drift
- **Each time** two neighbor nodes communicate, they have the opportunity to resynchronize
- **Timestamping** the arrival time of the data packet, and indicating timing error in ACK
- Several methods to force resynchronization if no data traffic. **Overhead extremely low**.

* See draft-watteyne-6tsch-tsch-lln-context-02.

Channel Hopping

- **Translation function** used to turn channel offset into frequency.
- At each iteration of slotframe, **different frequency for same cell**.
- Channel hopping does **NOT** require a modification of schedule.



Now:
Ch. 11 (**2.405GHz**)

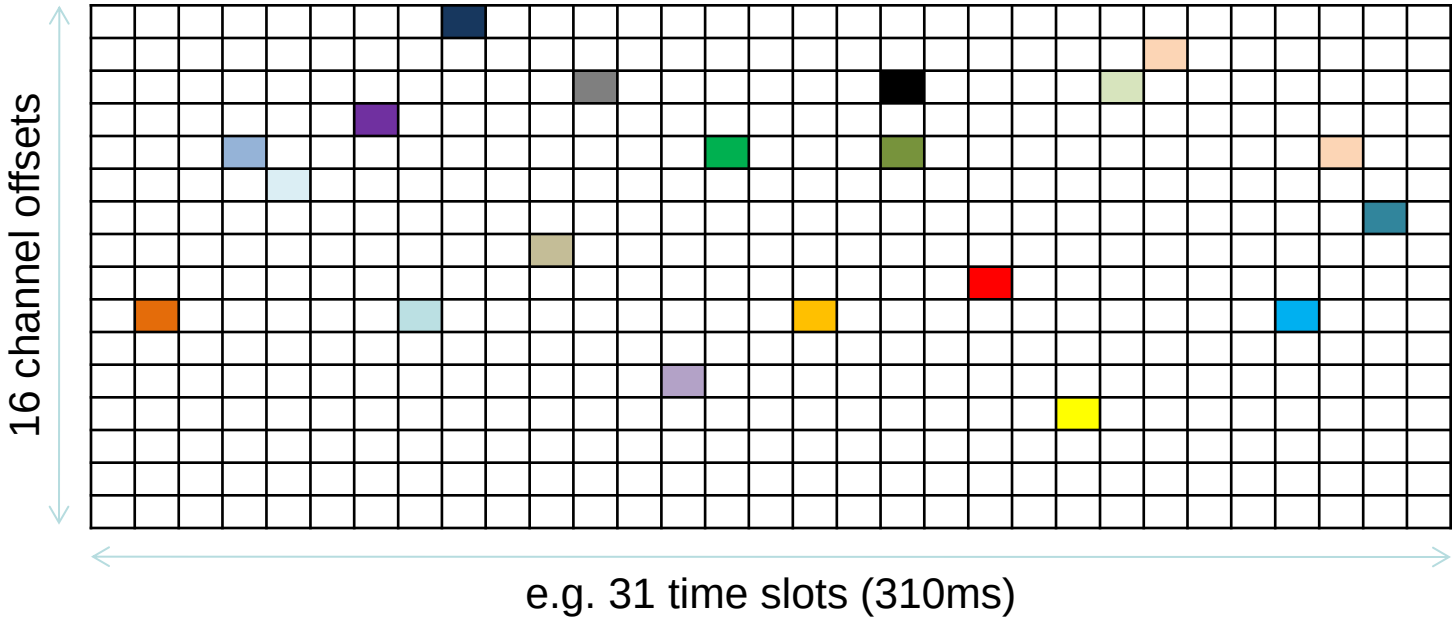
Next slotframe:
Ch. 26 (**2.480GHz**)

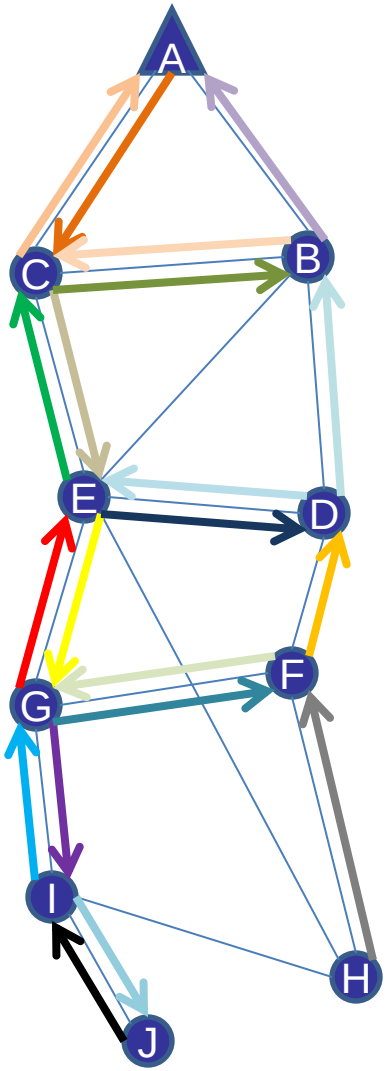
frequencyChannel=(channelOffset+ASN)%16+11

TSCH Schedule [2/2]

- This schedule allows for a direct **trade-off** between
  - throughput
  - latency
  - redundancy

  … and energy consumption.
- A **collision-free** communication schedule is typical.





Deterministic Networking

TDM + Synchronization + Slotframe(s)

Adapted to deterministic traffic (known a priori)

- A time slot is a **unit of throughput** allocated to a deterministic flow (!= CSMA/CA)

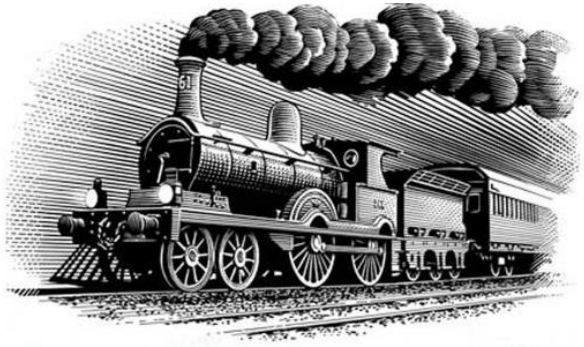
Adapted to several isolated flows (Traffic Engineering)

- Optimized path and track per single flow

Network synchronization and

Timely transmission

- No hot potato forwarding / pile up
- No exponential backoff
- No collision and virtually no jitter



Proven Technology

- The *concept* of Timeslotted Channel Hopping is present in:
  - WirelessHART (2007)
  - ISA100.11a (2008)
- Commercial products available, tens of thousands of networks running today
- But not based on IEEE802.15.4e TSCH

New Applications

- *Control loops* in a wireless process control network, in which **high reliability** and a fully **deterministic** behavior are required.
- *Umbrella networks* transporting data from different independent clients, and for which an operator needs **flow isolation** and **traffic shaping**.
- *Energy harvesting* networks, which require an extremely **low and predictable average power** consumption.
- *Widespread monitoring* such as corrosion monitoring or pipe leak detection, which requires a large number of sensors slow periodic reporting rates and open loop operation.

Summary

- IEEE802.15.4e MAC amendment, TSCH mode:
  - **Low-power** through time synchronization
  - **High reliability** through channel hopping
- IEEE802.15.4e TSCH allows for **deterministic** behavior:
  - Flow isolation
  - Traffic engineering
  - Predictable power consumption
- **Proven** technology
- New **applications**
- IT/OT* Convergence if coupled with IPv6

* Information/Operations Technology

problem statement
• what is IEEE802.15.4e TSCH?
• **what is missing?**
• why is this a problem?
• status of 6TSCH group
discussion of the charter
presentation of remaining drafts

What is missing?

Xavi Vilajosana

What is our objective?

- Enable Operational Technologies (OT) integration to the Internet architecture that is based on open standards.
  - Use existing blocks.
  - Define the missing ones.

- Missing IETF architecture and related protocol adjustement/specification.

Building blocks

- Most building blocks already exist:
  - Not all within IETF
  - Not all with IPv6 in mind
- It is matter of defining how these blocks integrate together into the IPv6 architecture.

Out of scope in IEEE 802.15.4e (1/2)

- draft-watteyne-6tsch-tsch-lln-context-02
  - Network Formation:
    - EBs IEs, etc..
  - Network Maintenance:
    - Time sources, join priority, etc..
  - Multi-Hop Topology:
    - Match multihop routes and tracks
  - Resource Management:
    - Schedule maintenance, SlotFrame maintenance
  - Dataflow Control:
    - Queues length, priorities and retransmissions

Out of scope in IEEE 802.15.4e (2/2)

- draft-watteyne-6tsch-tsch-lln-context-02
  - Deterministic Behavior:
    - Ensure timely delivery
  - Path Computation Engine
    - [I-D.phinney-roll-rpl-industrial-applicability]
    - BW allocation from an external PCE
  - Secure Communication
    - Distribution of keying material and authentication

Where the blocks come from

- IETF work done by 6LoWPAN, ROLL and CORE WGs → No deterministic MAC
- Other TSCH based std. → not inter-operable. (double OPEX)
  - Own version of IETF building blocks (PCE/P,ICMP,DHCP,PANA,DTLS)
  - Don't support IETF (RPL,ND,CoAP) → Missing Distributed Routing

WirelessHART

ISA100Wireless

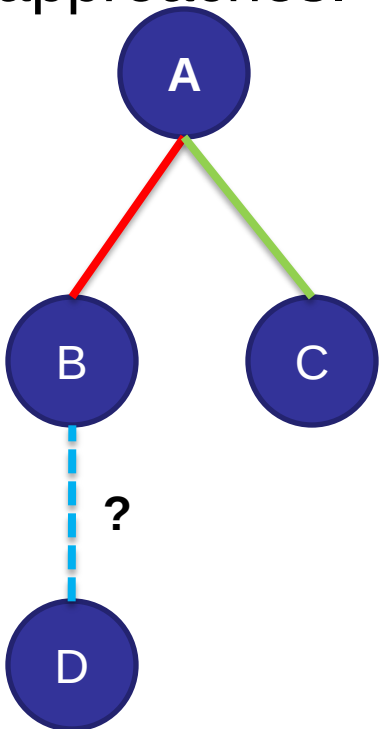
ZigBee Energy

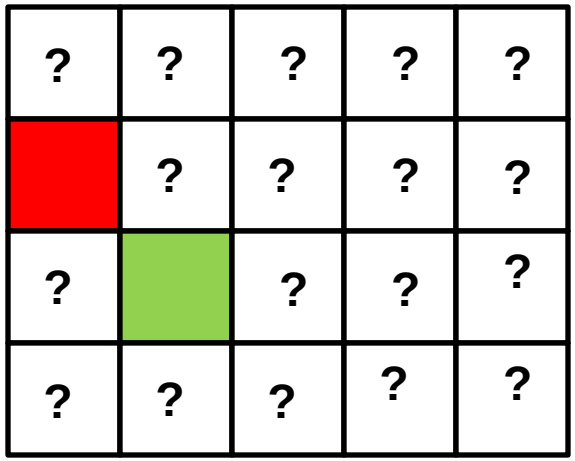
Missing Blocks (1/3)

- Schedule computation
  - Centralized & Distributed
- Schedule distribution
  - PCE to nodes
  - Along track
- A global picture
  - Architecture definition
  - Backbone integration

Schedule Computation

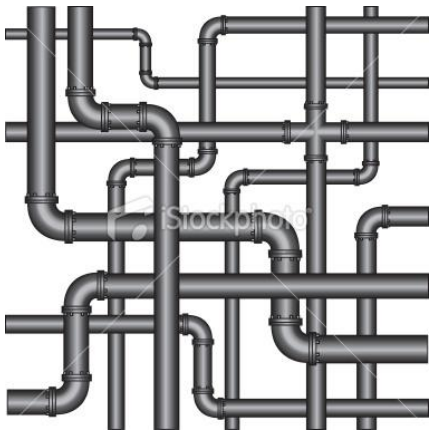
- Blocks to build and manage schedule information exist but they have not been put together to manage TSCH schedules.
  - PCE/P, RSVP, NSIS, etc…
- Missing guidelines for centralized and distributed approaches.



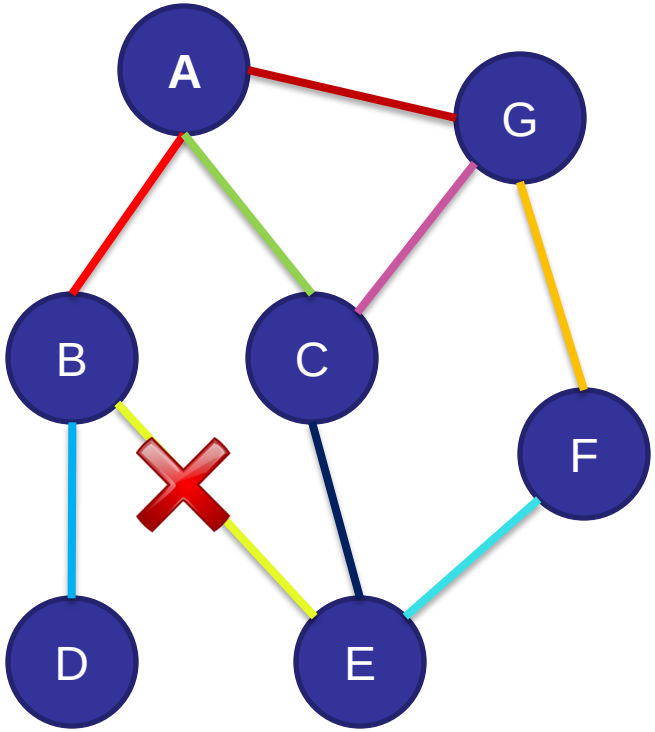


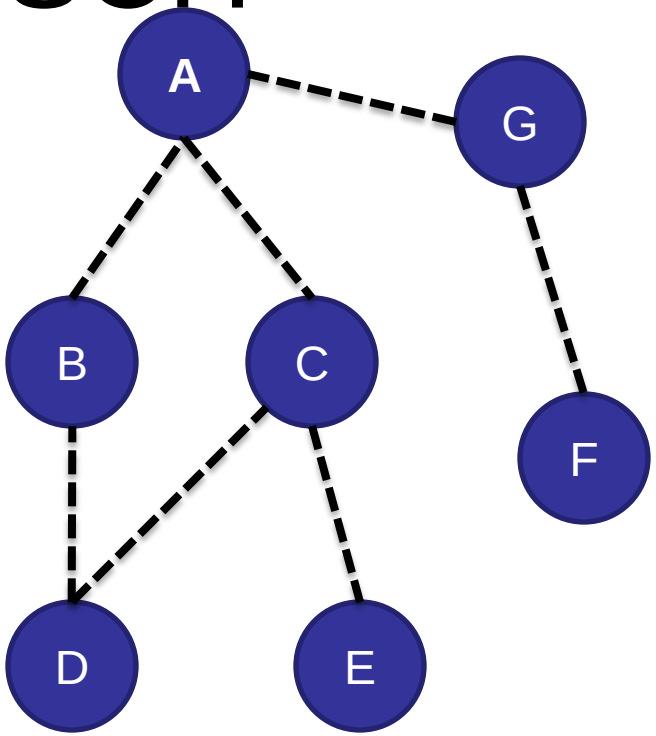
Missing blocks (2/3)

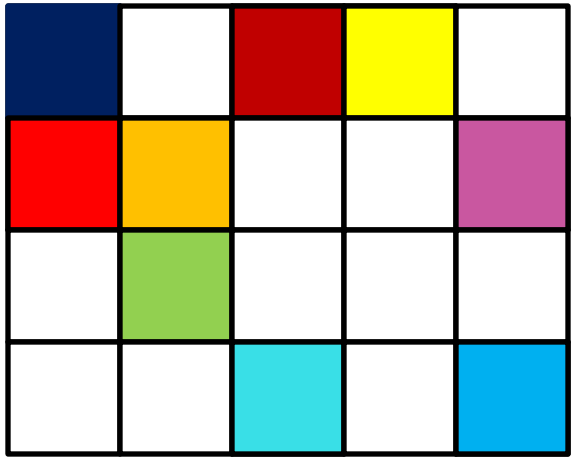
- QoS enforcement, monitoring and taking advantage of deterministic L2
- RPL on TSCH, metrics, matching DODAGs to Schedules
  - Matching of RPL OF to TSCH slotted nature
  - Matching of RPL routes to TSCH links
  - RPL best effort routes vs deterministic paths
    - Fast commissioning
- Traffic classes, Queues and priorities. Differentiated services.



RPL on TSCH

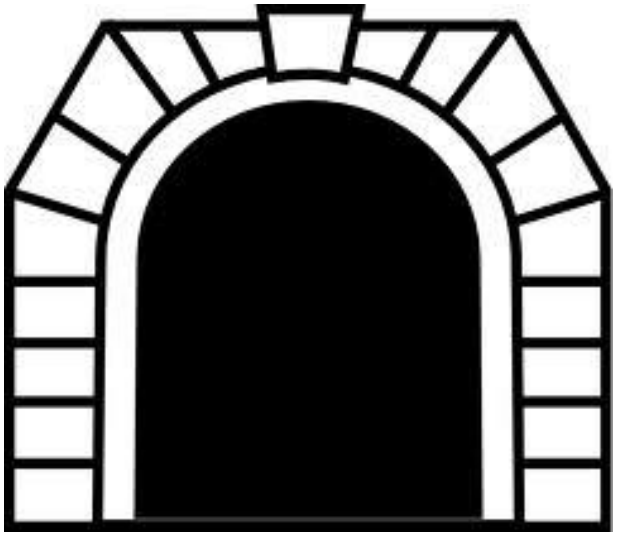






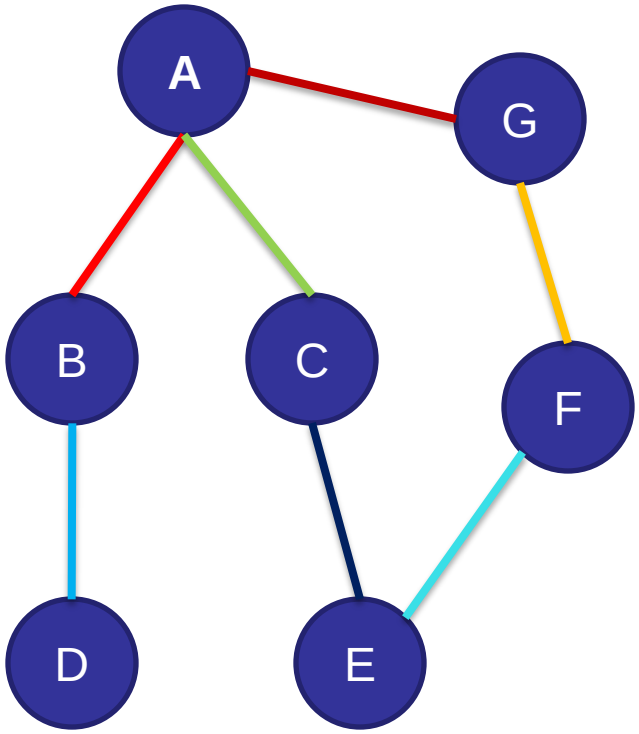
-RPL on TSCH, routes and best effort vs deterministic tracks: support for mobility and fast commissioning

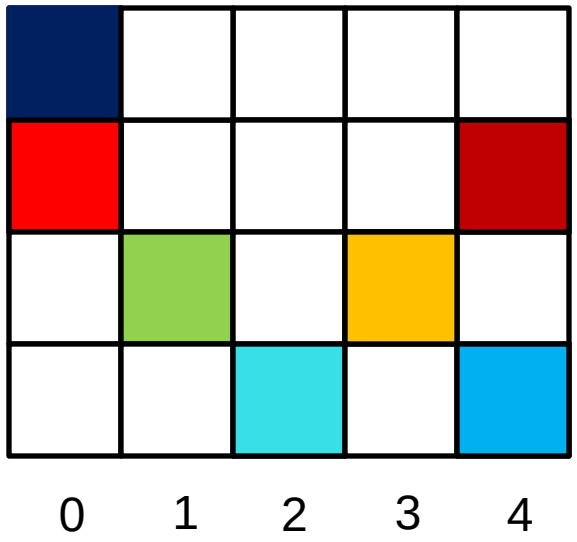
Missing blocks (3/3)



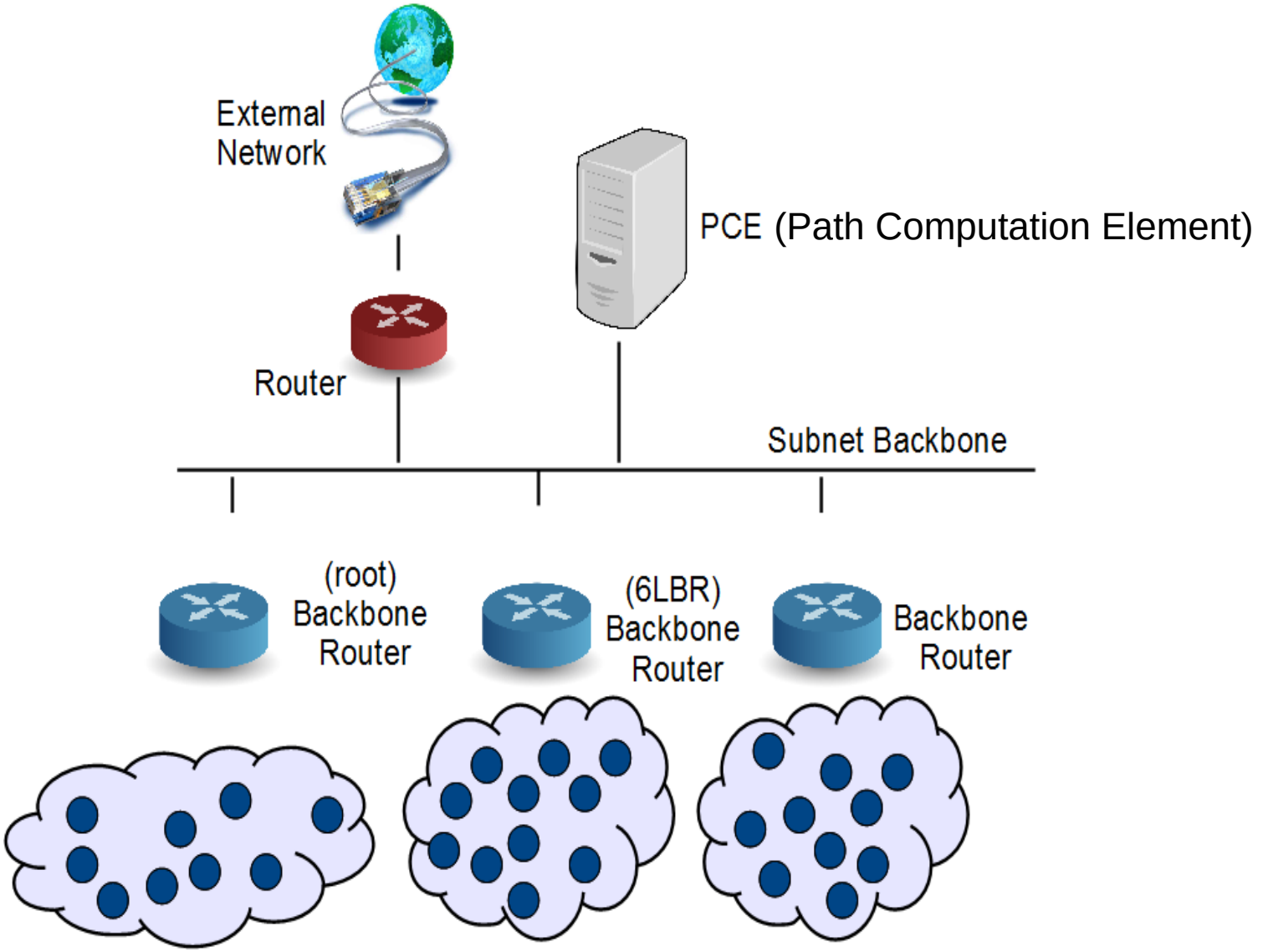
- Security
  - Keying distribution
  - Commissioning and joining
  - Authentication
- Tunneling
  - Packet switching
  - Tunneling other technologies on IEEE802.15.4e
- Backbone operation, ND, mobility

Tunneling and QoS





Backbone operation



problem statement
• what is IEEE802.15.4e TSCH?
• what is missing?
• **why is this a problem?**
• status of 6TSCH group
discussion of the charter
presentation of remaining drafts

Why is this a problem?

Alfredo Grieco

Why are missing blocks needed?

- Customer dissatisfaction with competing stds
  -> no device interop, double opex
  -> lack of common network management
- Deterministic-only will not allow Mobility
- Distributed-only will not optimize
- Missing IETF architecture hinders the adoption of IETF blocks by other standards
- Open standard/source needed for new usages

BoF question

Is this a topic that the IETF should address?

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Status of 6TSCH group

Thomas Watteyne

Status of the 6TSCH group [1/3]

- Mailing list
  - created 24 January 2013
  - Today 159 members
- Weekly calls
  - Each Friday, 5-6pm CEST
  - 21 calls total
  - Attendance (min/avg/max)=(8/11.2/15)
- 2 meetings in IETF86 Orlando (1.5h each)

Status of the 6TSCH group [2/3]

- Homepage at https://bitbucket.org/6tsch/
  - Git repositories
  - wiki and issue tracking
- Contents:
  - Meetings:
    - Agenda, minutes, attendance, webex recordings
  - Drafts:
    - Versioning and issue tracking
  - Source code:
    - Simulator *(note: other open-source/vendor implementations)*
  - Draft charter

Status of the 6TSCH group [3/3]

- Drafts (6):
  - draft-watteyne-6tsch-tsch-lln-context-02
  - draft-thubert-6tsch-architecture-02
  - draft-palattella-6tsch-terminology-01
  - draft-wang-6tsch-6top-00
  - draft-vilajosana-6tsch-basic-01
  - draft-ohba-6tsch-security-01

- Authors (13):
  - Alfredo Grieco, Alper Yegin, Kris Pister, Maria Rita Palattella, Pascal Thubert, Qin Wang, Rafa Marin-Lopez, Robert Assimiti, Subir Das, Stephen Chasko, Thomas Watteyne, Xavi Vilajosana, Yoshihiro Ohba.

draft-thubert-6tsch-architecture

Pascal Thubert

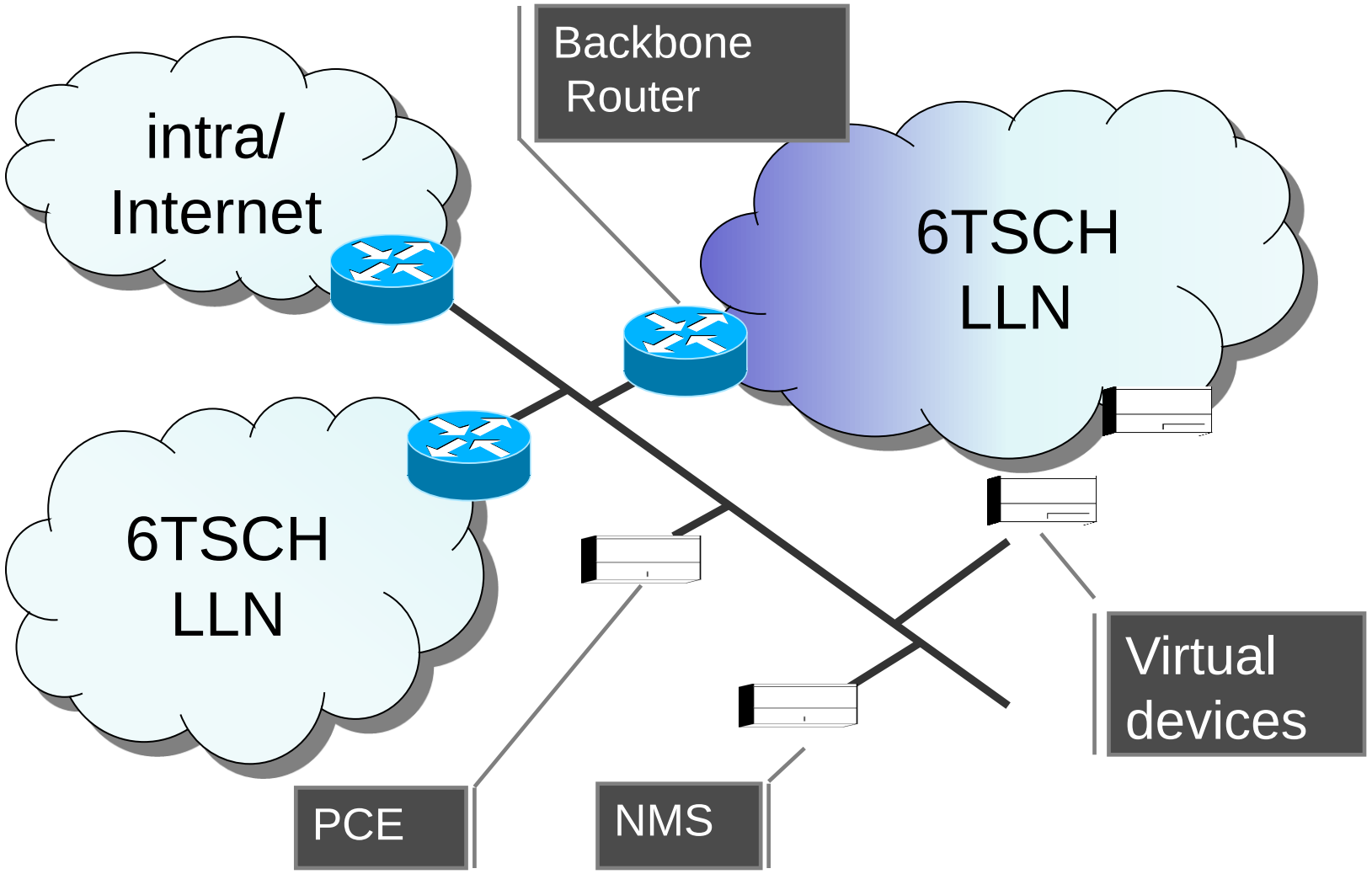
Goal of this document

- Informational
- Up to date repo following WG decision
- Position blocks and protocols
- Overview / entry point for newcomer

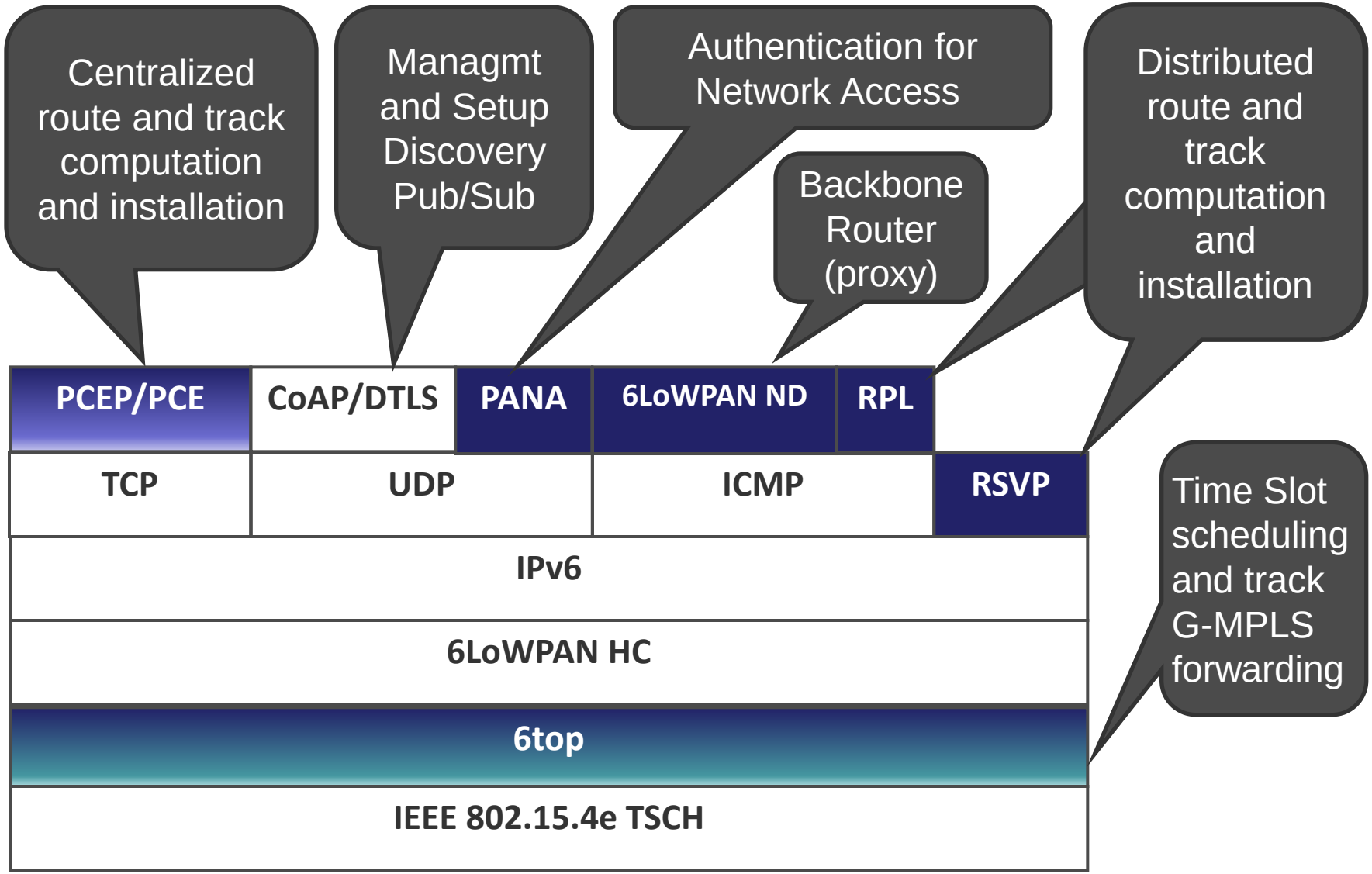
Requirements

- Wireless Process Control
- Smartcities / IoT infrastructure and SP
- Building Automation
- Vehicular Automation
- Commercial Automation
- Home Automation

Architecture scope



6TSCH: Architecture



Centralized vs. Distributed routing

Centralized

God's view optimization

Multipath redundancy

Deterministic (optimized)

Virtualization

Distributed

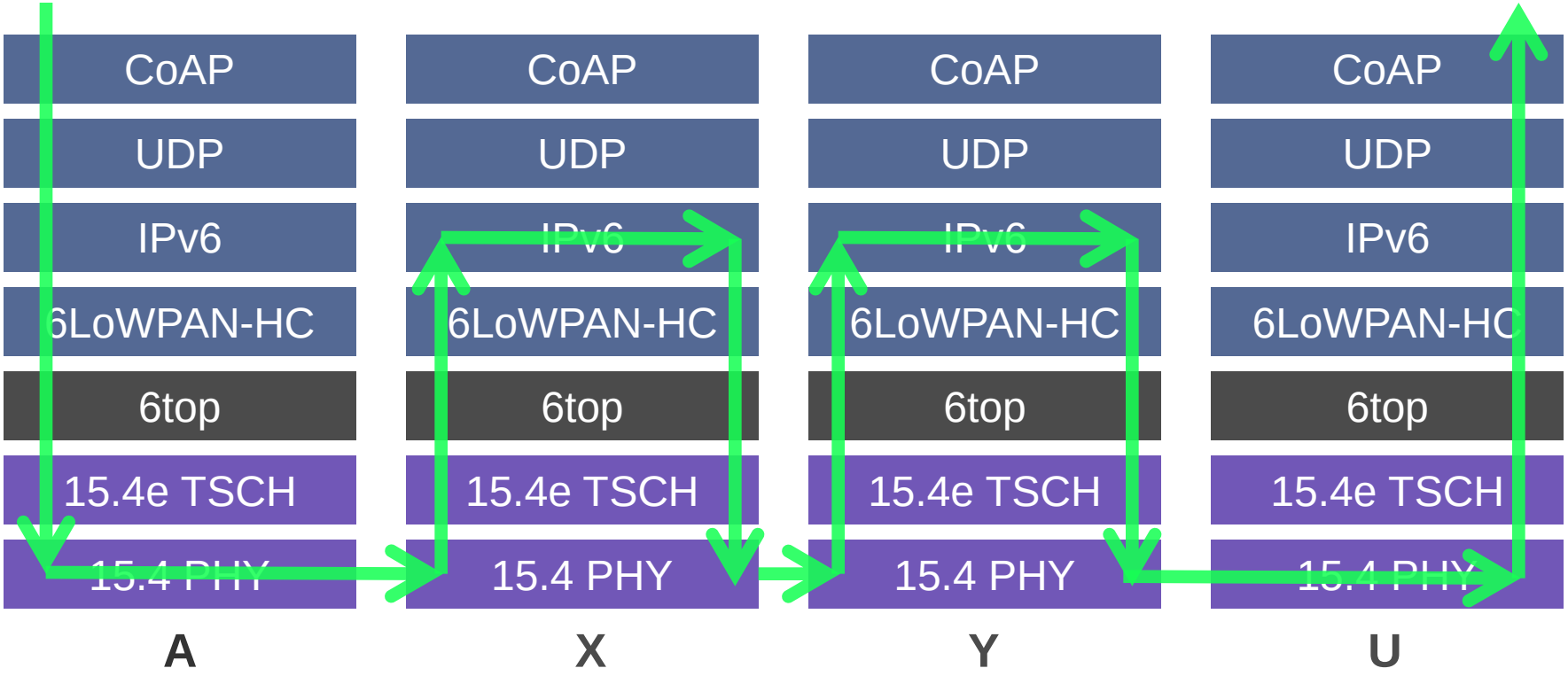
Autonomic & Mobile

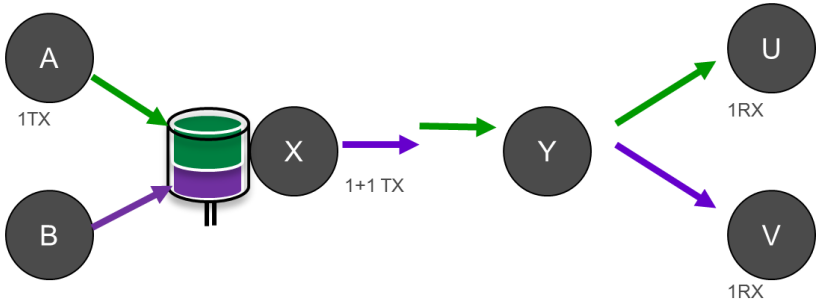
Highly available (DARPA)

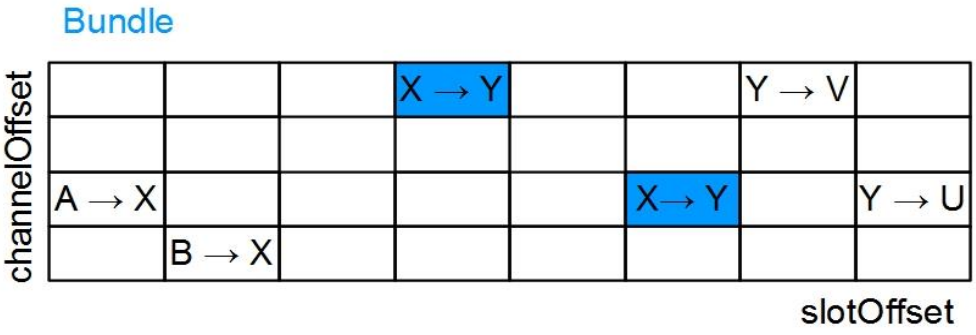
Deterministic

Scalability

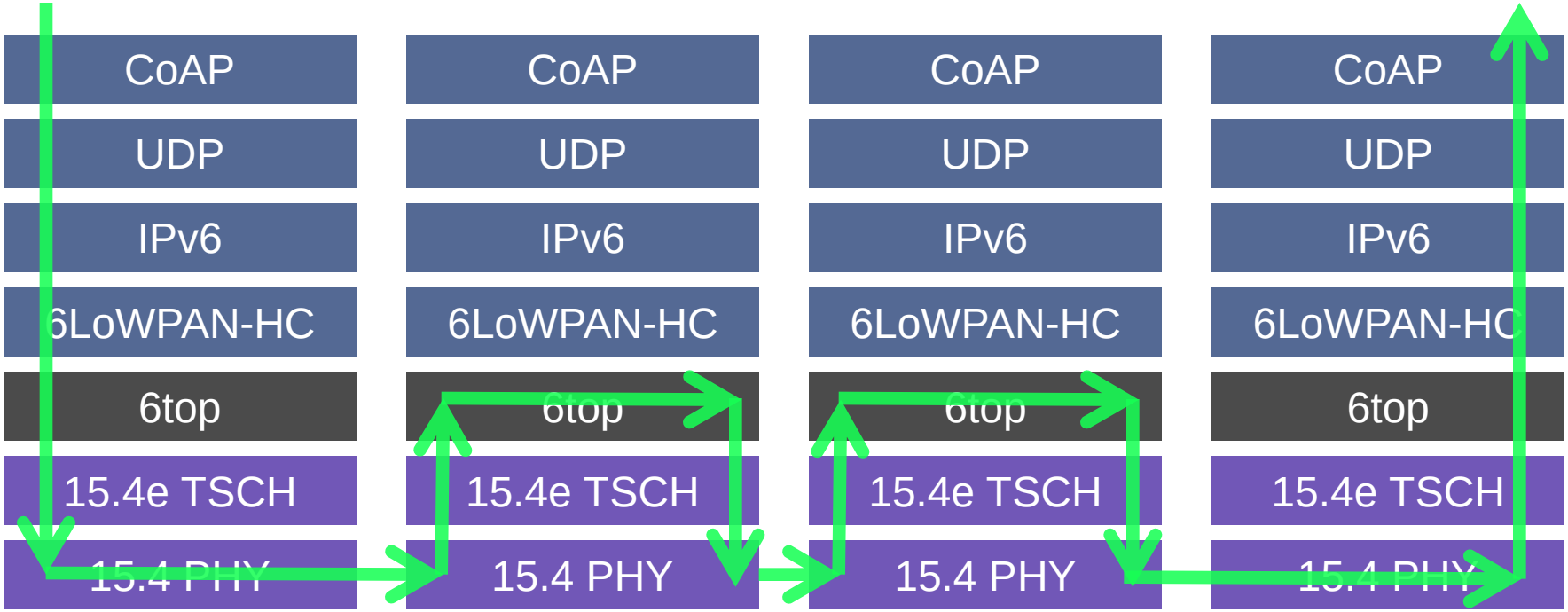
Best effort routing

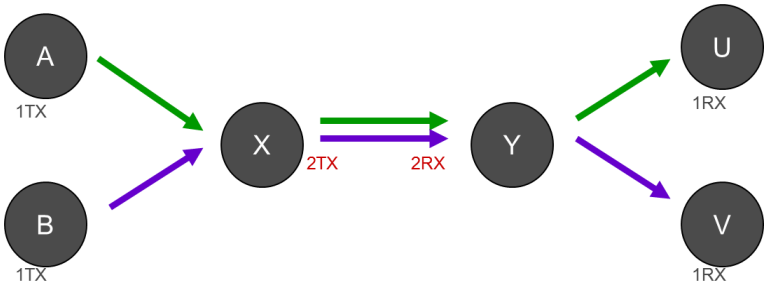


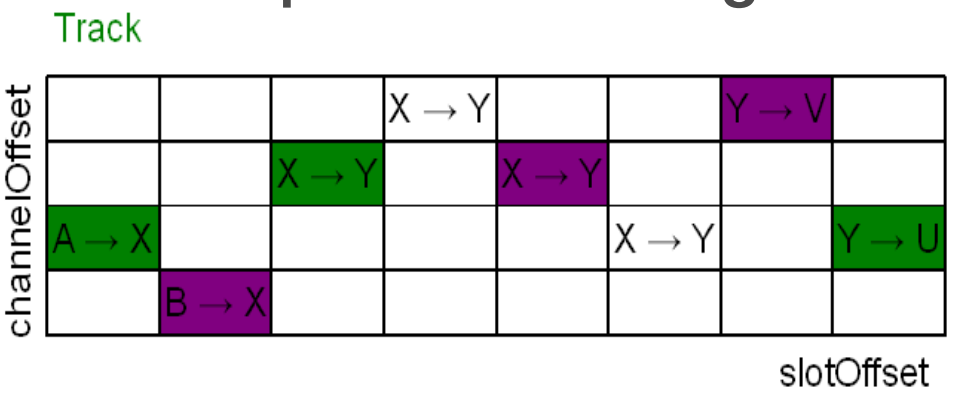




Track Switching in Transport Mode

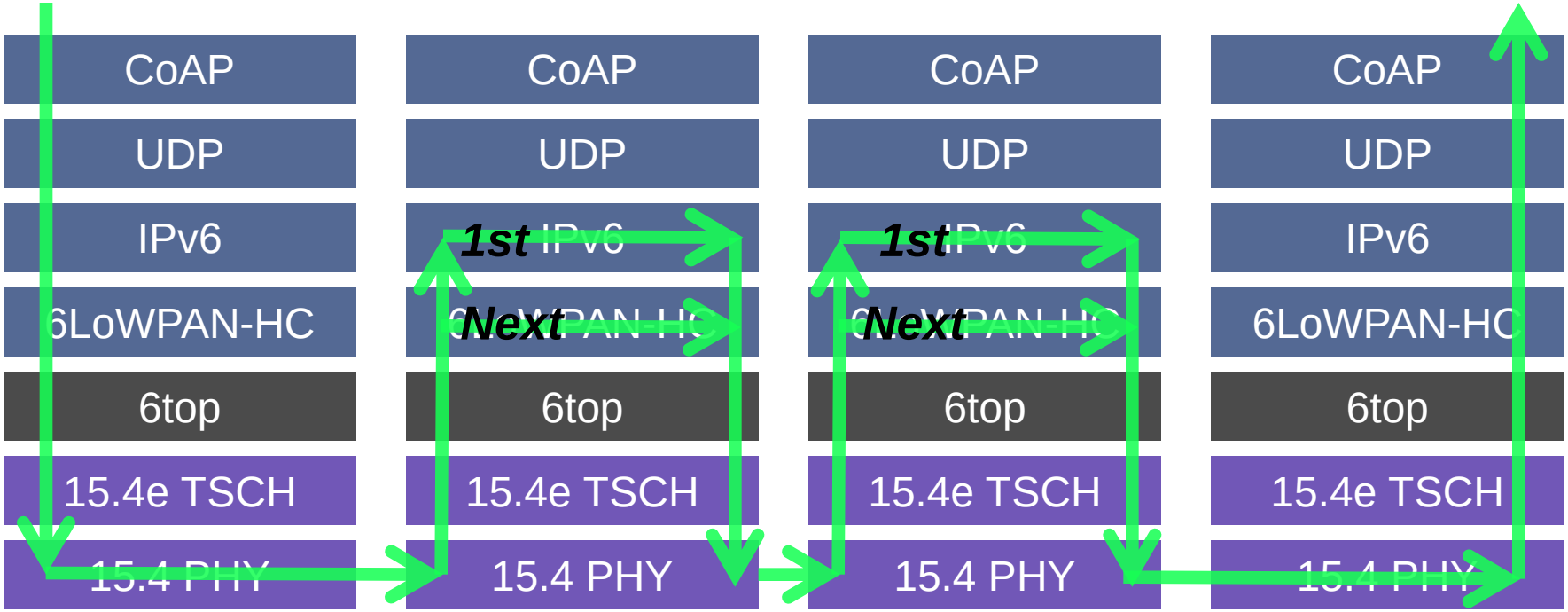


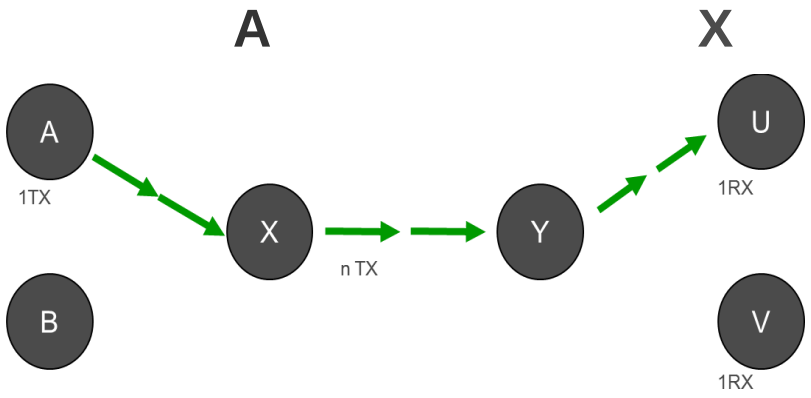


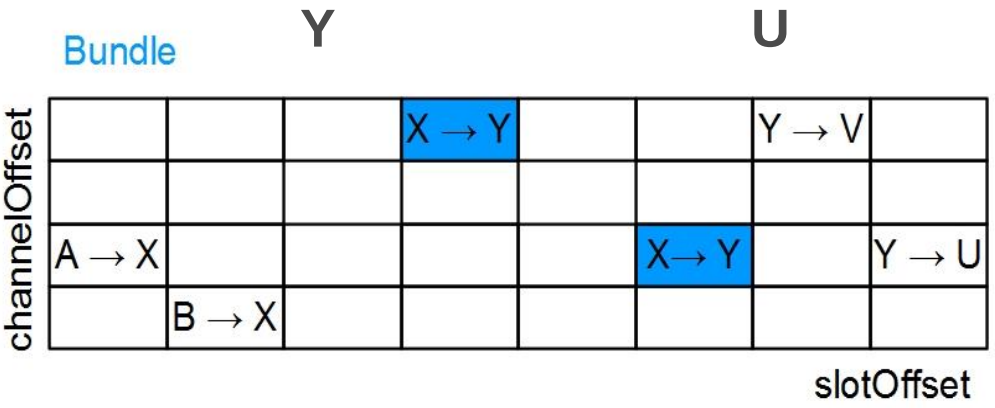


Track Switching in Tunnel Mode

6LoWPAN Fragment forwarding







Clarifying questions?

problem statement
discussion of the charter
• **Introduction**
• description of the WG
• work items
• non-milestone work items
• external work to other WG
presentation of remaining drafts

Introduction

Thomas Watteyne

Proposed Charter

- Current version at: https://bitbucket.org/6tsch/charter-ietf-6tsch/src
- First draft announced 7 April 2013
  - Discussed on ML/calls until end of April
  - Minor adjustments in July
- Outline
  - Background/Introduction
  - Description of Working Group
  - Work Items
  - Non-milestone work items

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Description of the WG

Dominique Barthel

A broad community …

- Academia, Equipment manufacturers, Network operators
- Americas, Europe, Asia
- Experts in various technology pieces
  - 802.15.4e
  - ISA100.11a, WiHART
  - PCE, RPL, 6LoWPAN, PANA
- With large WSN deployment experience

… that will deliver

- Multiple implementations
  - Open source
  - Vendor’s implementations
- Multiple OSes and environments

Description of Working Group [1/5]

The Working Group **focuses only on the TSCH mode of the IEEE802.15.4e** standard although the actual PHY layer is not constrained to be IEEE802.15.4 in the 2.4GHz band.

The WG will define an **open standard-based architecture** that covers the formation and the operation of a wireless mesh based on the TSCH technology, and the aggregation of multiple meshes over a high speed backbone as a single subnet, including security, link management for the IPv6 network layer consumption, neighbor discovery and routing.

Description of Working Group [2/5]

The group will document best practices, and standardize the missing components to achieve industrial-grade criteria for jitter, latency, scalability, diversity and low-power operation.

The scope of the work includes the backbone, BackBone Routers (BBRs) that interconnect the LLNs to the backbone, a PCE and other IPv6 entities that are located either on the backbone or farther in the IPv6 network over a backhaul..

Description of Working Group [3/5]

The WG will define a framework for scheduling frames over time slots that supports **three models**:

- **a centralized route computation** that builds and maintains the communication schedule, and distributes it to the nodes. This schedule includes forwarding information associated to time slots; RPL operations only apply to emergency repair actions when the reference topology becomes unusable.
- **a distributed resource reservation** and signaling protocol that establishes tracks between source and destination nodes along multi-hop routes identified by RPL.
- **a best effort resource allocation** that is used to transport data frames on a per hop basis in the absence of a reservation protocol.

Description of Working Group [4/5]

The WG will define how packets that belong to a deterministic IPv6 flow are marked and routed or forwarded over the mesh within jitter and latency budgets.

When possible, **the group will reuse existing protocols** such as IPv6 ND, RPL and 6LoWPAN with the minimum adaptation required to meet criteria for reliability and determinism within the mesh, and scalability over the backbone.

Description of Working Group [5/5]

In particular, the WG will produce **architectural recommendations** defining how those protocols can be used in conjunction within the scope of the WG. The architecture will also address how multiple BBRs are supported for a higher degree of scalability and reliability, and how nodes maintain synchronization within the scope in the presence of multiple BBR.

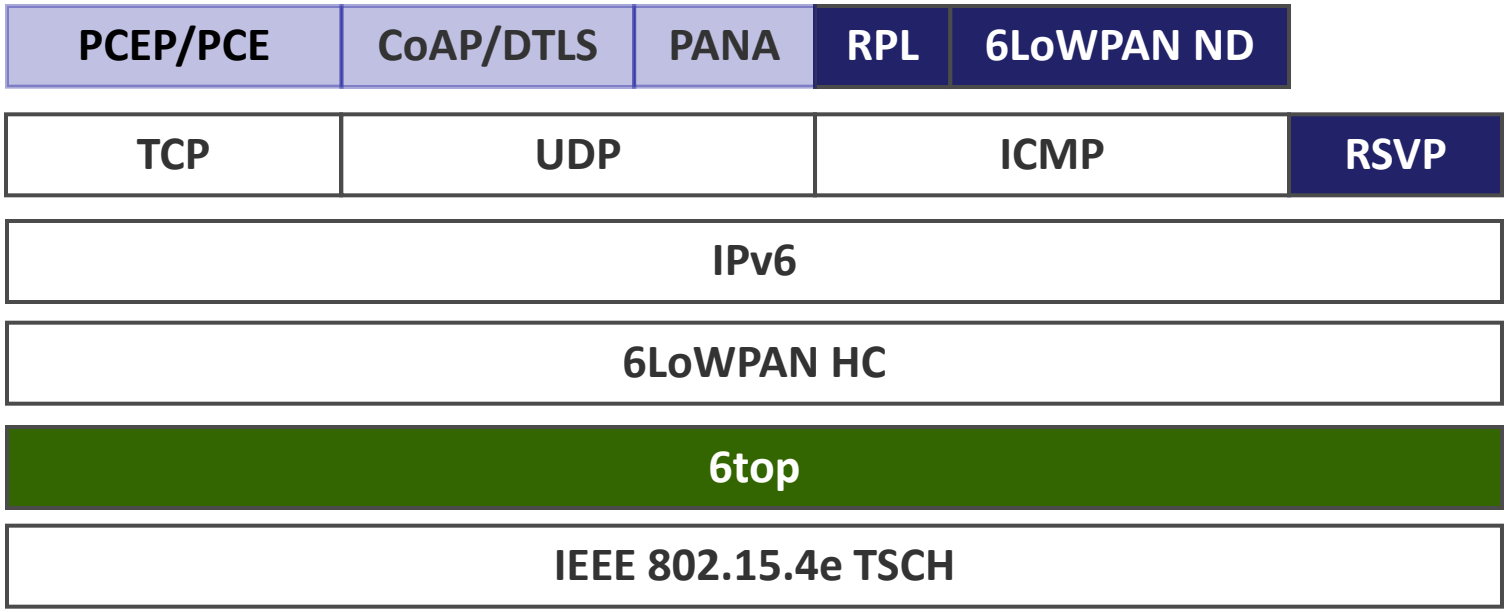
To achieve those goals, the WG will **informally coordinate** on requirements with organizations including IPSO Alliance, IoT6, ISA, IEEE and other SDOs and organizations. The WG will interface with other IETF WGs, potentially including 6MAN, ROLL, 6Lo, CoRE, PCE, COMAN, LWIG, TSVWG and other appropriate groups in the IETF Internet, Routing and Security areas, to distribute the required work appropriately.

problem statement
discussion of the charter
• Introduction
• description of the WG
• **work items**
• non-milestone work items
• external work to other WG
presentation of remaining drafts

Work items

Raghuram Sudhaakar

Overview of Work Items



1. 6top specification
2. 6TSCH centralized routes and tracks management
3. 6TSCH distributed routes and tracks management
4. Minimal 6TSCH Configuration
5. 6TSCH architecture
6. TSCH overview
7. 6TSCH security architecture and requirements

proposed standard

Informational

BoF question

Are the goals of this WG clear, well-scoped, solvable, and useful?

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External work to other WG

Pascal Thubert

Main items

- 6MAN
  - WiND (aka efficient ND)
  - flow label for RPL domain
- ROLL/6lo
  - Backbone Router
  - Fragment Forwarding and Recovery
  - Node relocation
  - ? OF impacts
- TSVWG
  - Deterministic PHB
- PCE WG *(requirement stage)*
  - PCEP over UDP / CoAP
  - metrics and topology advertisement
  - PCE / proxy / relay location
  - track installation

Conclusion

- Identified work that belongs to other WGs
  - Some at requirement stage (PCE)
  - Some well advanced (ROLL, 6MAN)

  => To ensure consistency and coordination

- Identified external entities
  - Cross monitoring
  - Like we did in the past
  - e.g. ISA100.11a / 6LoWPAN

BoF question

Who is willing to edit documents, comment documents, implement?

Open Discussion

BoF questions

1. Is this a topic that the IETF should address?
2. Are the goals of this WG clear, well-scoped, solvable, and useful?
3. Who is willing to edit documents, comment documents, implement?
4. Should a 6TSCH WG be formed?