IETF90 - Toronto

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http://etherpad.tools.ietf.org:9000/p/notes-ietf-90-6tisch

IPv6 over the TSCH mode of IEEE 802.15.4e

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Reminder:

Minutes are taken *
This meeting is recorded **
Presence is logged ***

* Scribe: please contribute online to the minutes at http://etherpad.tools.ietf.org:9000/p/6tisch?useMonospaceFont=true
** Recordings and Minutes are public and may be subject to discovery in the event of litigation.
*** Please make sure you sign the blue sheets

Administrivia

- Blue Sheets
- Scribes (Thanks!)
  - Xavi Vilajosana
  - Pouria Zand
- Jabber (Thanks!)
  - Michael Richardson

Objectives

- Third WG meeting
- Report on progress on WG docs,
- Report on progress around security
- Report on second 6TiSCH plugfest
- Explore unchartered draft and on-going work

Agenda

```
Intro and Status                                          [5min]   (Chairs)

    Note-Well, Blue Sheets, Scribes, Agenda Bashing
    6TiSCH milestones recap

Chartered Drafts                                         [50min]

    * <draft-ietf-6tisch-terminology-02>
      <draft-ietf-6tisch-architecture-03>          (10min)   (Pascal Thubert)
    * <draft-ietf-6tisch-minimal-02>               (10min)   (Xavi Vilajosana)
    * <draft-ietf-6tisch-6top-interface-01>
      <draft-wang-6tisch-6top-sublayer-01>         (10min)   (Qin Wang)
    * <draft-struik-6tisch-security-architecture-elements-00> (Rene Struik,
      <draft-richardson-6tisch--security-6top-01> (20min)    Michael Richardson)

Report on plugfest                                       [10min]

    * overview and goals                            (3min)   (Ines Robles)
    * presentation of outcome                       (7min)   <participants>

Unchartered drafts if time permits                       [20min]

    * <draft-wang-6tisch-6top-coapie-00>           (10min)   (Qin Wang)
    * <draft-dujovne-6tisch-on-the-fly-03>         (10min)   (Nicola Accettura)

Any Other Business                                        [5min]
```

Milestones

12/2013 - WG to adopt 6TiSCH terminology
12/2013 - WG to adopt IEEE802.15.4e TSCH overview
12/2013 - WG to adopt 6TiSCH architecture
12/2013 - WG to adopt 6TiSCH minimal configuration
04/2014 - WG to adopt 6top draft(s)
04/2014 - WG to adopt 6TiSCH data model for CoAP
08/2014 - Submit YANG data model in 6top draft for preliminary OPSDIR review
08/2014 - Submit 6TiSCH architecture for preliminary SECDIR review
11/2014 - Initial submission of 6TiSCH minimal configuration to the IESG
11/2014 - Initial submission of 6top draft(s) to the IESG
11/2014 - Initial submission of 6TiSCH data model for CoAP to the IESG
12/2014 - Initial submission of 6TiSCH terminology to the IESG
12/2014 - Initial submission of 6TiSCH architecture to the IESG
12/2014 - Evaluate WG progress, propose new charter to the IESG
06/2015 - 6TiSCH Minimal and 6top draft(s) in RFC publication queue
12/2015 - 6TiSCH architecture and terminology in RFC publication queue

draft-ietf-6tisch-terminology-02

Maria Rita Palattella (Ed.)
Pascal Thubert
Thomas Watteyne
Qin Wang

Status

- Status:
  - Adopted at 11/2013 after IETF 88
  - Latest version published on July 4th 2014

- Changes since IETF89
  - Published 02
  - Refined / completed text on cell and chunks

Last changes

- Feedbacks from Patrick Wetterwald
- Thomas suggested minor changes (for fixing details)
- Issue 18: Improve definition of shared cell and other details in several terms (missing/fixing references, spelling out acronyms, deleting unclear text)
- Whole diffset at: http://tools.ietf.org/rfcdiff?difftype=--hwdiff&url2=draft-ietf-6tisch-terminology-02.txt

Issue 18

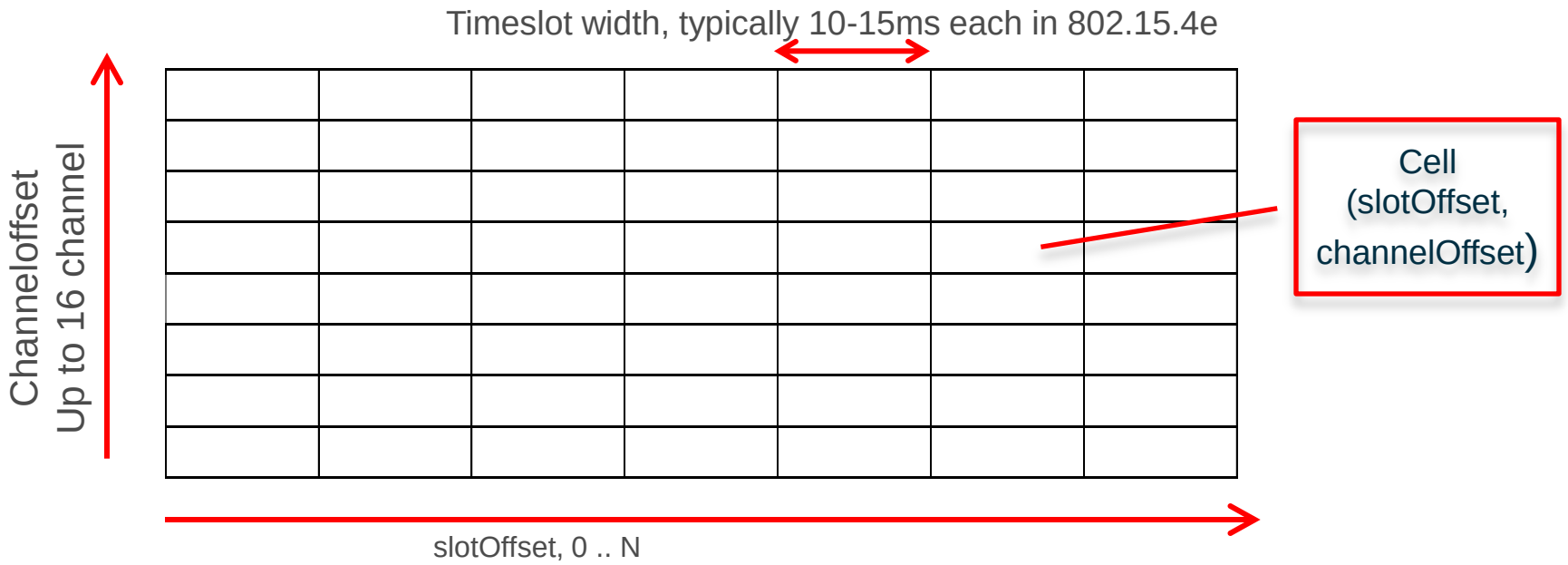
SHARED CELL DEFINITION

OLD:
A cell that is used by more than one transmitter node at the same time and on the same channelOffset. Only cells with TX flag can be marked as "shared". A backoff algorithm is used to resolve contention

NEW:
A cell marked with both the "TX" and “shared” flags. This cell can be used by more than one transmitter node. A backoff algorithm is used to resolve contention. See <xref target="I-D.ietf-6tisch-tsch"/>.

Channel distribution/usage (CDU) matrix

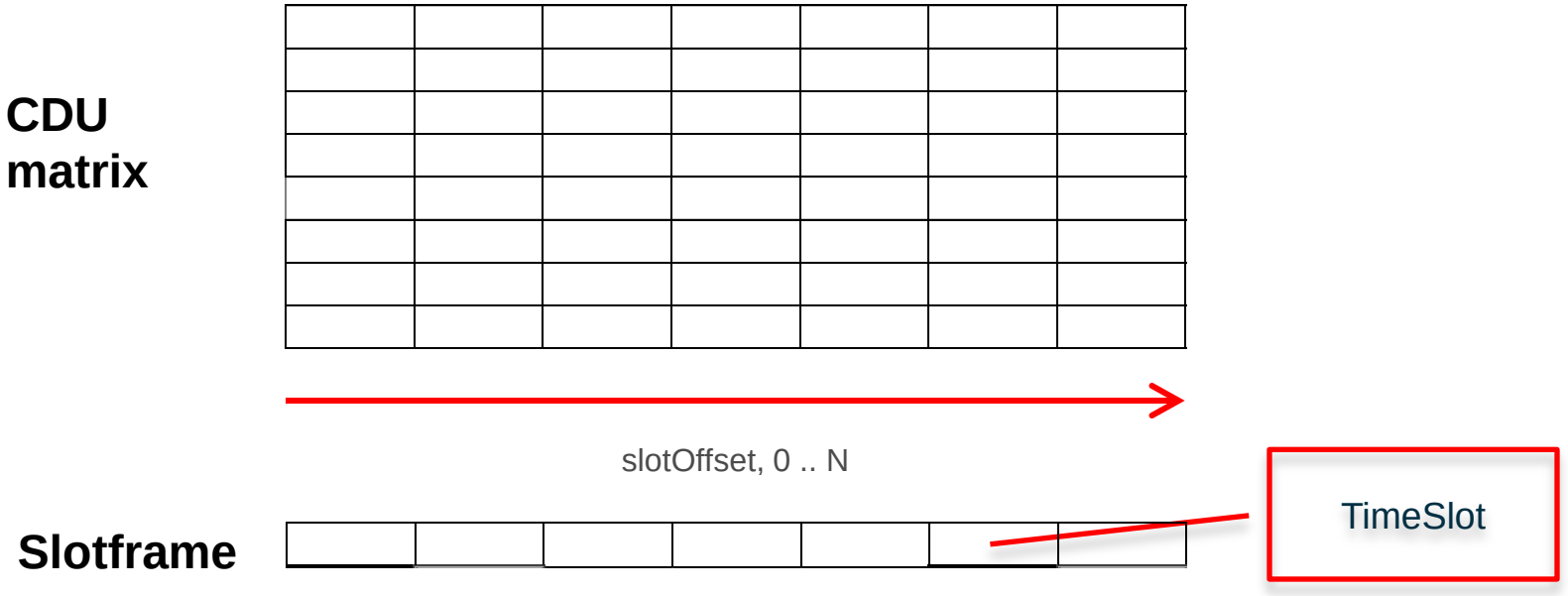
6TiSCH defines a new global concept that is called a **Channel distribution/usage (CDU) matrix**; a **Channel distribution/usage (CDU) matrix** is a matrix of so-called "**cells"** with an height equal to the number of available channels (indexed by ChannelOffsets), and a width in timeslots that is a period of the network scheduling operation (indexed by slotOffsets).



There can be multiple matrix, in which case operations associated to a matrix may overlap with others; A matrix repeats itself over time. CDU-M is defined by 6TiSCH and represents global characteristics of the network, channel (un)used, duration of the timeslot and number of timeslots per iteration of a given matrix.

Slotframe

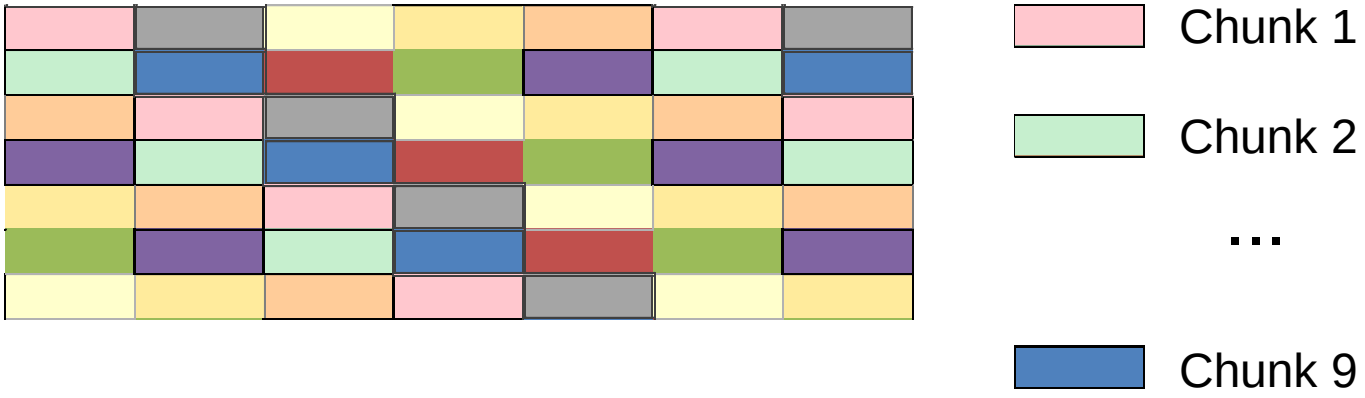
A Slotframe is a MAC-level abstraction that is internal to a node but common to multiple nodes and contains a series of timeslots of equal length and priority. It is characterized by a slotframe_ID, and a slotframe_size. Multiple slotframes can coexist in a node's schedule, i.e., a node can have multiple activities scheduled in different slotframes, based on the priority of its packets/traffic flows. The timeslots in the Slotframe are indexed by the SlotOffset; the first timeslot is at SlotOffset 0.



Multiple slotframes of various sizes => multiple CDU-M, chunks, and overlaps

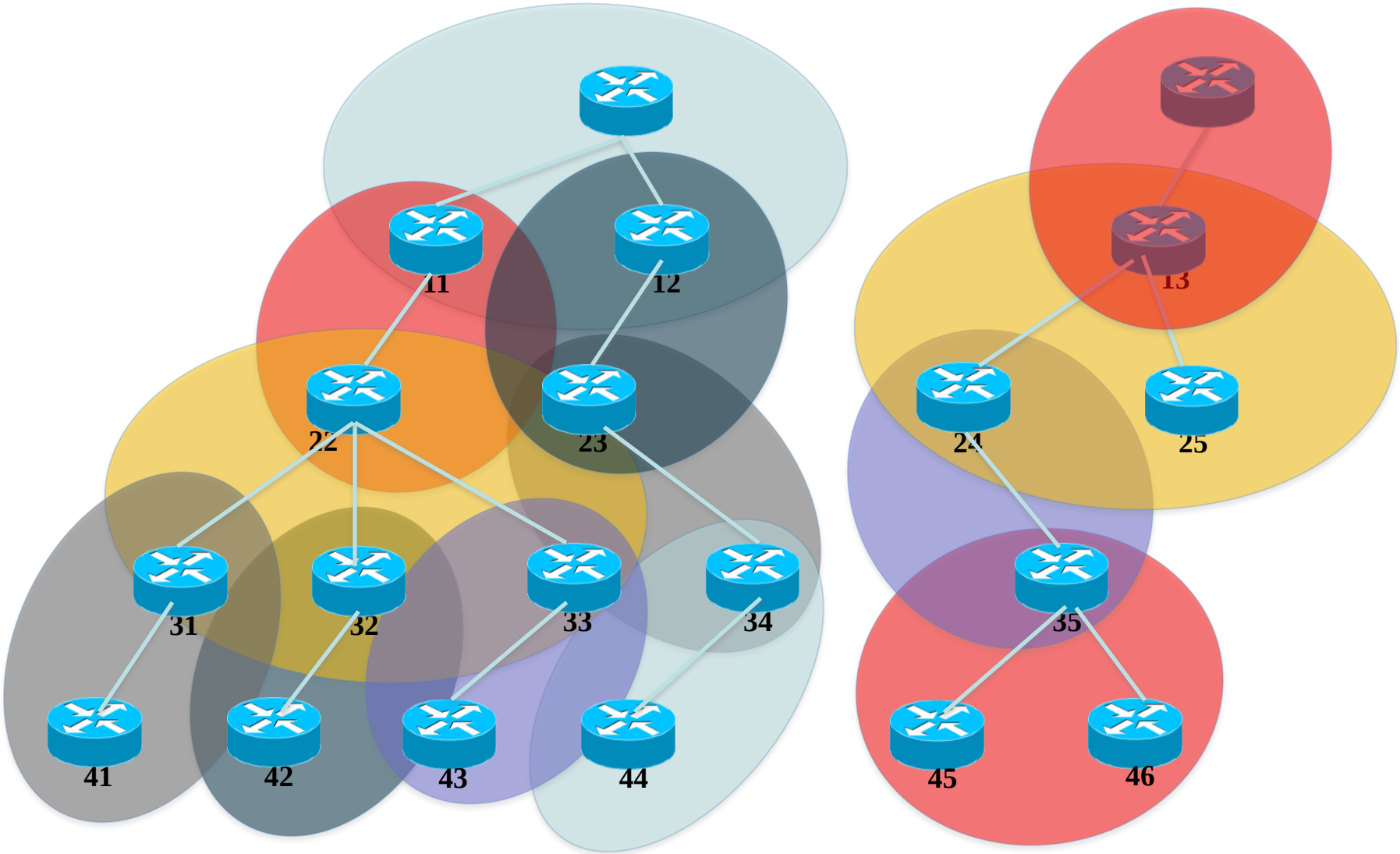
Chunks

A Chunk is a well-known list of cells, well-distributed in time and frequency, within the CDU matrix; a chunk represents a portion of the CDU. The partition of the CDU in chunks is globally known by all the nodes in the network to support the appropriation process, which is a negotiation between nodes within an interference domain. A node that manages to appropriate a chunk gets to decide which transmissions will occur over the cells in the chunk within its interference domain. Ultimately, a chunk represents some amount of bandwidth and can be seen as the generalization of a transmission channel in the time/frequency domain.

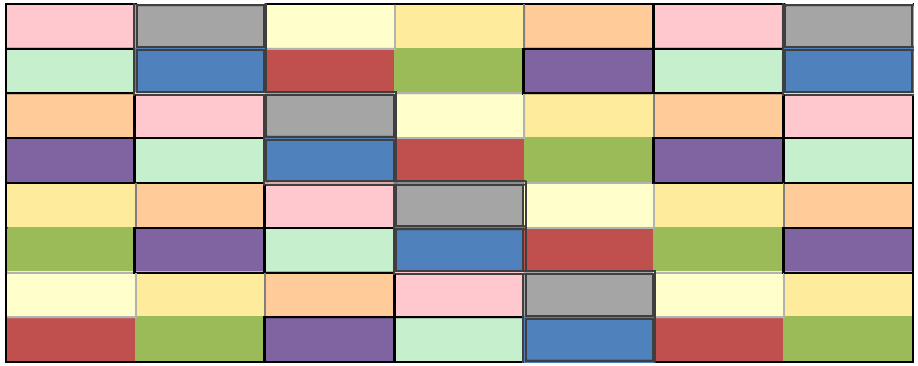


CDU matrix, 7 channels, 7 timeslots, 9 chunks, represented from ASN= 0

Chunk usage



Schedule



The RPL parent allocates timeslots between itself and its children. The parent takes the timeslots off a chunk that it has appropriated.

Slotframe

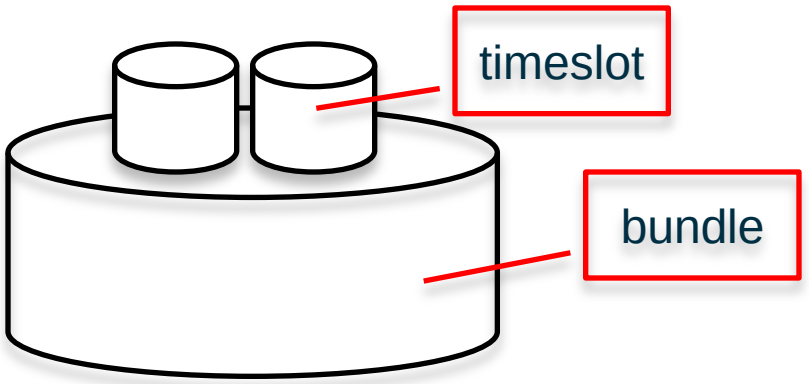
A device maintains a **schedule** that dictates its transmissions and receptions inside the slotframe.

Parent schedule	Xmit mcast	rcv	rcv	xmit		rcv	xmit
Child 1 schedule	rcv			rcv		xmit	
Child 2 schedule	rcv	xmit					rcv
Child 3 schedule	rcv		xmit				

Say a parent appropriates the pink chunk from the CDU matrix above. Now the parent gets to decide when the pink cells are used and by which node.

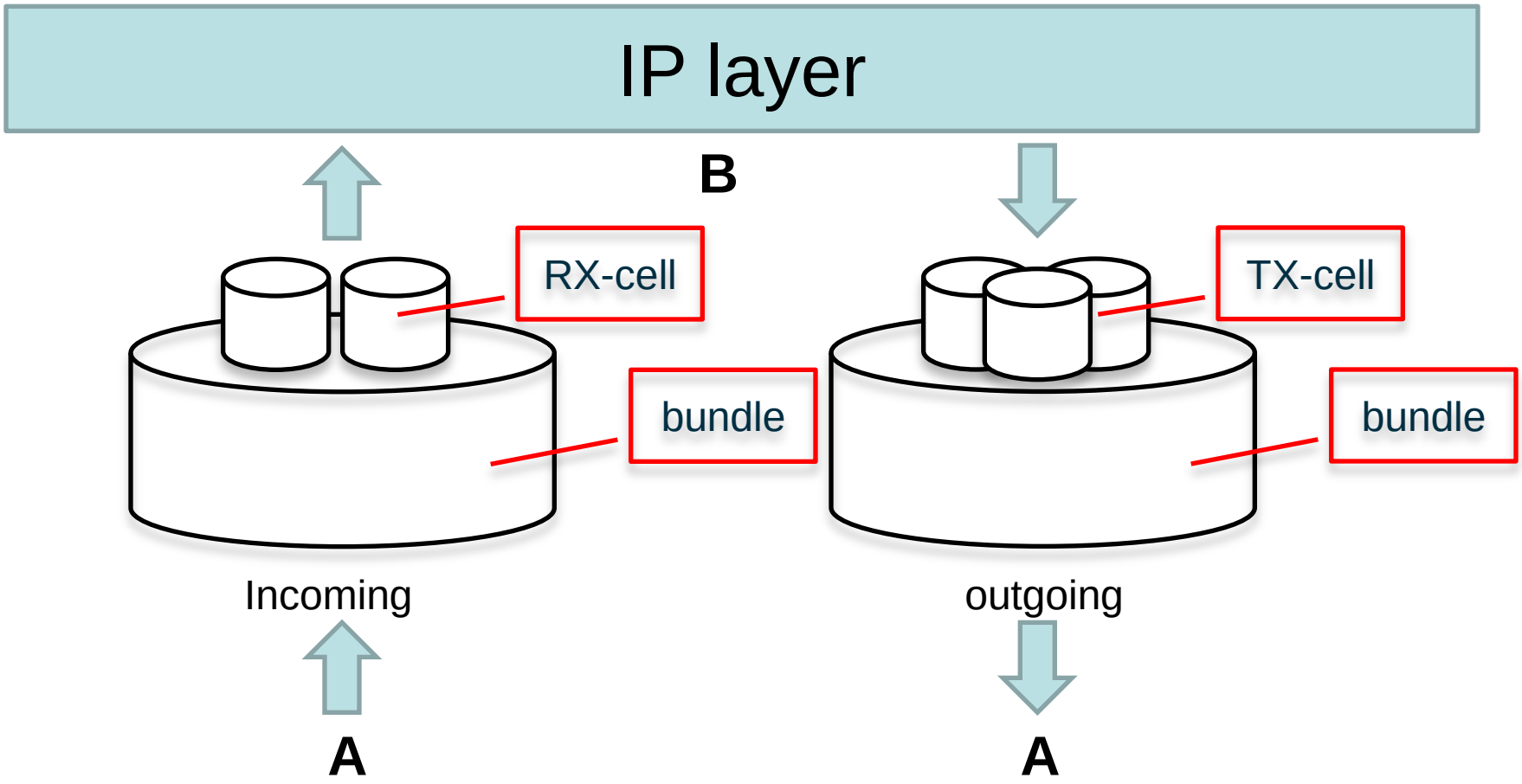
Bundle

6TiSCH finally defines the peer-wise concept of a bundle, that is needed for the communication between adjacent nodes.
A Bundle is a group of equivalent scheduled cells, i.e. cells identified by different [slotOffset, channelOffset], which are scheduled for a same purpose (a Track, a Link), with the same neighbor and overall properties.
The size of the bundle refers to the number of cells it contains. Given the length of the slotframe, the size of the bundle translates directly into bandwidth.
Ultimately a bundle represent a half-duplex link between nodes, one transmitter and one or more receivers, with a bandwidth that amount to the sum of the timeslots in the bundle. Bundles thus come as the pair of an incoming and an outgoing bundle, that is associated to either a (L3) Link or a (L2) Track.
A bundle is globally identified by (source MAC, destination MAC, trackID)



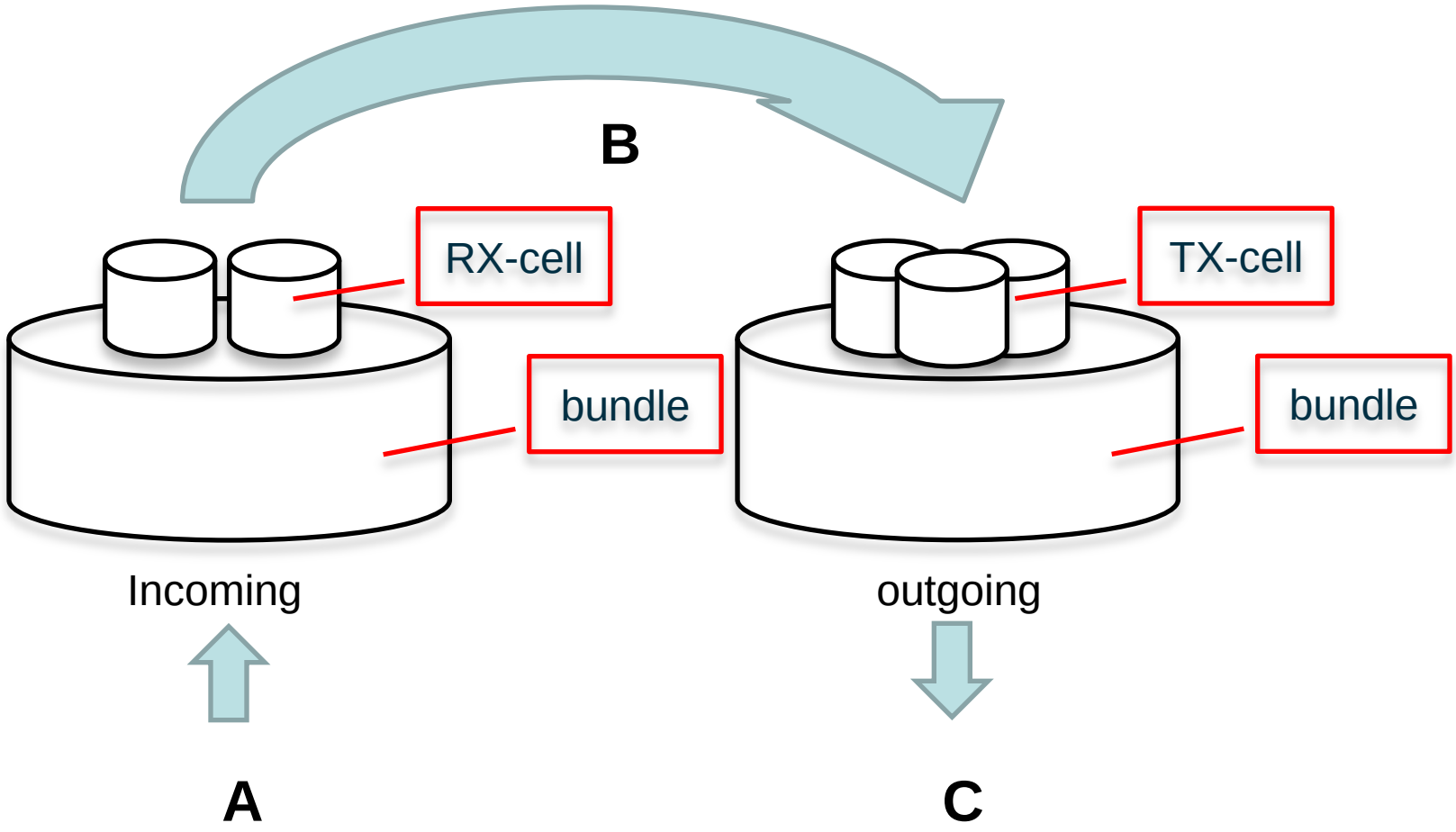
Bundle pair for a (L3) Link

We use a well-known constant as trackId for a L3 link, that I'll refer as NULLT. So an IP link between adjacent nodes A and B comprises 2 bundles, (macA, macB, NULLT) and (macB, macA, NULLT).



Bundle pair for a (L2) Track

Along a track that has a segment …A->B->C… , there are 2 bundles in node B, incoming = (macA, macB, trackId) and outgoing = (macB, macC, trackId).



draft-ietf-6tisch-architecture-03

Pascal Thubert (Ed.)
Thomas Watteyne
Robert Assimiti

Status

- Status:
  - Adopted at 11/2013 after IETF 88
  - Latest version published on July 4th 2014
- Changes since IETF89
  - Published 02 and 03
  - Refined / completed text on forwarding models
  - Improved terminology conformance

Archie's issue list

trac.tools.ietf.org/wg/6tisch/trac/query?component=architecture

6tisch architecture

~~#2~~	limit the number of EBs that need to be collected before joining	draft-ietf-6tisch-architecture@tools.ietf.org	enhancement	closed	major	
~~#3~~	About on the fly	pthubert@cisco.com	defect	closed	major	
#4	add text to desceribe the high level PCE operation for 6Tisch	jvasseur@cisco.com	enhancement	new	major	
~~#7~~	In section 7.2, I might read that broadcast DIO and DAO are not contained in ICMPv6 messages	pthubert@cisco.com	enhancement	closed	major	
~~#8~~	section 7.5 seems jumbled... maybe just not done yet.	pthubert@cisco.com	task	closed	major	milestone1
~~#9~~	Clarify that a TSCH Schedule is a *set* of 2D matrices	pthubert@cisco.com	defect	closed	major	milestone1
#10	6tisch-security: packet size and quantity for join process	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	milestone1
#11	6tisch-security: device IDs	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	milestone1
#12	6tisch-security: join process impact on network	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	milestone1
#13	6tisch-security: join process impact on network, local schedule	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	milestone1
#14	6tisch-security: join process impact on network, join priority flag in 15.4e	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	
#15	6tisch-security: crypto protocol details of join protocol	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	
#16	6tisch-security: authorization/trust management	draft-ietf-6tisch-architecture@tools.ietf.org	task	new	major	
~~#19~~	Improve text of opportunistc cell reuse and packet retracking	pthubert@cisco.com	defect	closed	major	milestone1

Archie 02 changes

- Cover Issue 7, 8 and 9
- Moved packet marking and handling section
- Editorials (Patrick's review)
  - E.g. timeSlot vs. cell
- Whole diffset:

  http://tools.ietf.org/rfcdiff?difftype=--hwdiff&url2=draft-ietf-6tisch-architecture-02.txt

Structural changes in 02

Archie 03 changes

- Cover Issue 19 on retracking
- Add text on PhB and draft @TSVWG
- Improve text of opportunistc cell reuse and packet retracking
- As discussed at last biweekly call
- Whole diffset:

  http://tools.ietf.org/rfcdiff?url2=draft-ietf-6tisch-architecture-03.txt

Issue 19

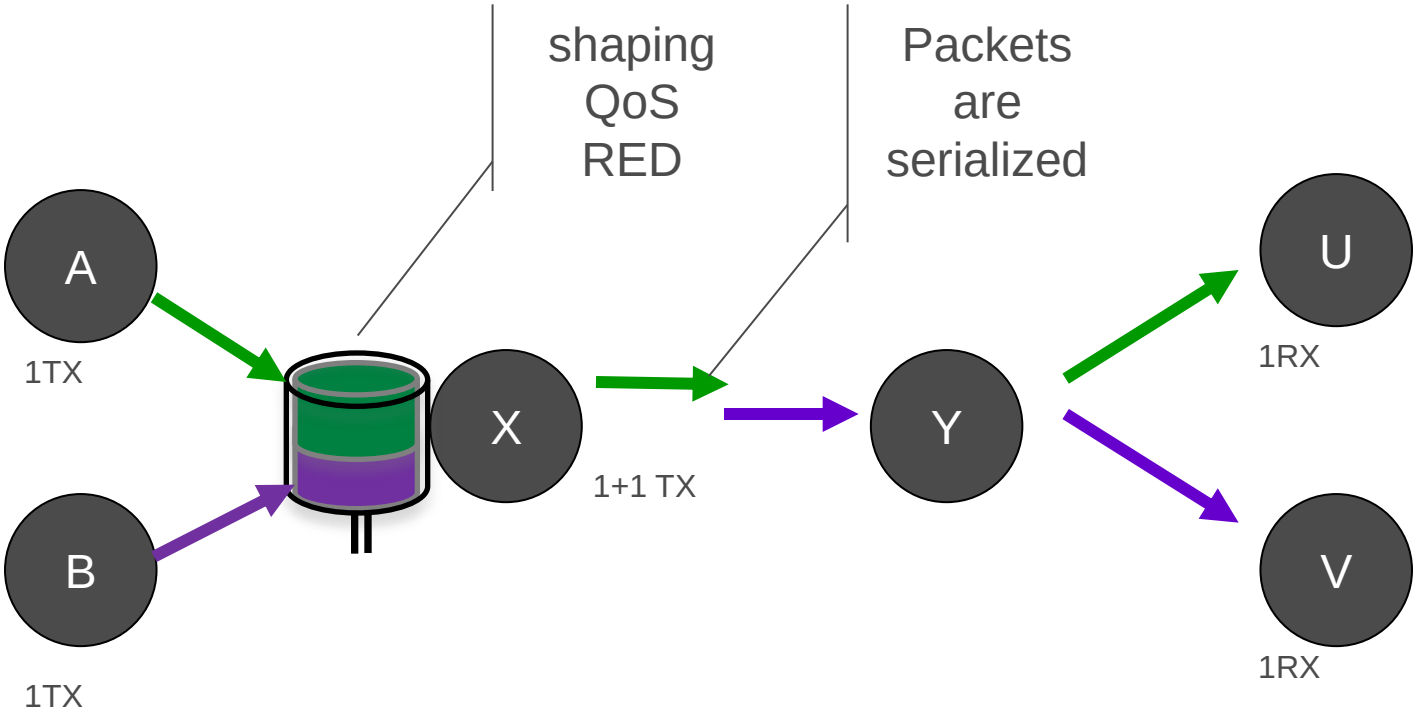
```
1215      MUST be the same for all packets forwarded inside the domain.
1216      </t>
1217 +     <t>
1218 +   For packets that are routed by a PCE along a Track, the tuple formed by the
1219 +   IPv6 source address and a local RPLInstanceID in the packet identify
1220 +   uniquely the Track and associated transmit bundle.
1221 +   Additionally, an IP packet that is sent along a Track uses the
1222 +   Differentiated Services Per-Hop-Behavior Group called
1223 +   Deterministic Forwarding, as described in
1224 +   <xref target="I-D.svshah-tsvwg-deterministic-forwarding"/>.
1225 +   </t>
1226      <t>
```

Structural changes

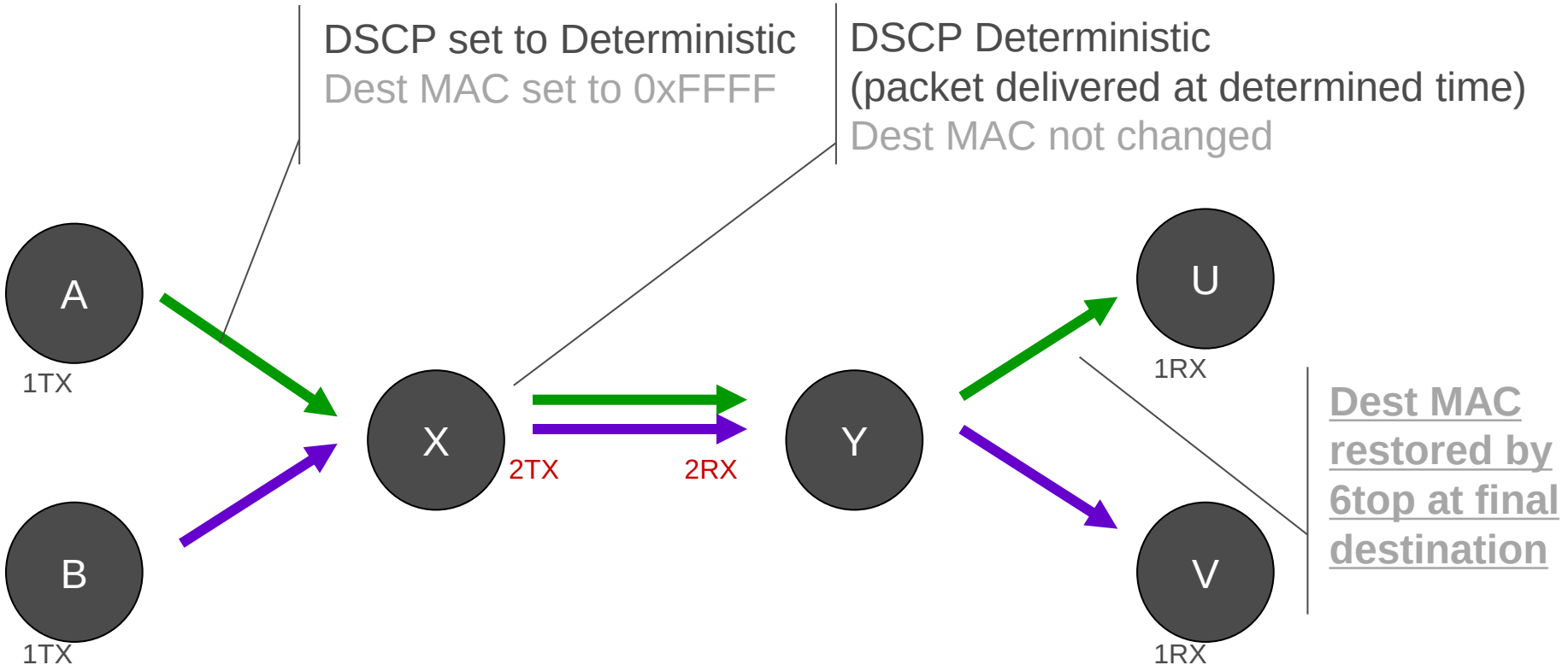
```
79  79    5.  Communication Paradigms and Interaction Models . . . . . 8
80        - 6.  Forwarding Models  . . . . . 8
81        -   6.1.  Track Forwarding . . . . . 8
82        -     6.1.1.  Transport Mode . . . . . 10
83        -     6.1.2.  Tunnel Mode  . . . . . 11
84        -     6.1.3.  Tunnel Metadata  . . . . . 12
85        -   6.2.  Fragment Forwarding  . . . . . 12
86        -   6.3.  IPv6 Forwarding  . . . . . 13
87        - 7.  TSCH and 6top  . . . . . 14
88        -   7.1.  6top . . . . . 14
89        -   7.2.  6top and RPL Objective Function operations . . . . . 14
90        -   7.3.  Network Synchronization  . . . . . 16
91        -   7.4.  SlotFrames and Priorities  . . . . . 17
92        -   7.5.  Distributing the reservation of cells  . . . . . 18
93        - 8.  Schedule Management Mechanisms . . . . . 19
94        -   8.1.  Minimal Static Scheduling  . . . . . 20
95        -   8.2.  Neighbor-to-neighbor Scheduling  . . . . . 20
96        -   8.3.  Remote Monitoring and Schedule Management  . . . . . 21
97        -   8.4.  Hop-by-hop Scheduling  . . . . . 21
      80  + 6.  TSCH and 6top  . . . . . 8
      81  +   6.1.  6top . . . . . 8
      82  +   6.2.  6top and RPL Objective Function operations . . . . . 9
      83  +   6.3.  Network Synchronization  . . . . . 10
      84  +   6.4.  SlotFrames and Priorities  . . . . . 11
      85  +   6.5.  Distributing the reservation of cells  . . . . . 12
      86  + 7.  Schedule Management Mechanisms . . . . . 14
      87  +   7.1.  Minimal Static Scheduling  . . . . . 15
      88  +   7.2.  Neighbor-to-neighbor Scheduling  . . . . . 15
      89  +   7.3.  Remote Monitoring and Schedule Management  . . . . . 16
      90  +   7.4.  Hop-by-hop Scheduling  . . . . . 16
      91  + 8.  Forwarding Models  . . . . . 16
      92  +   8.1.  Track Forwarding . . . . . 17
      93  +     8.1.1.  Transport Mode . . . . . 18
      94  +     8.1.2.  Tunnel Mode  . . . . . 19
      95  +     8.1.3.  Tunnel Metadata  . . . . . 20
      96  +   8.2.  Fragment Forwarding  . . . . . 20
      97  +   8.3.  IPv6 Forwarding  . . . . . 21
98  98    9.  Centralized vs. Distributed Routing  . . . . . 22
```

Track Management

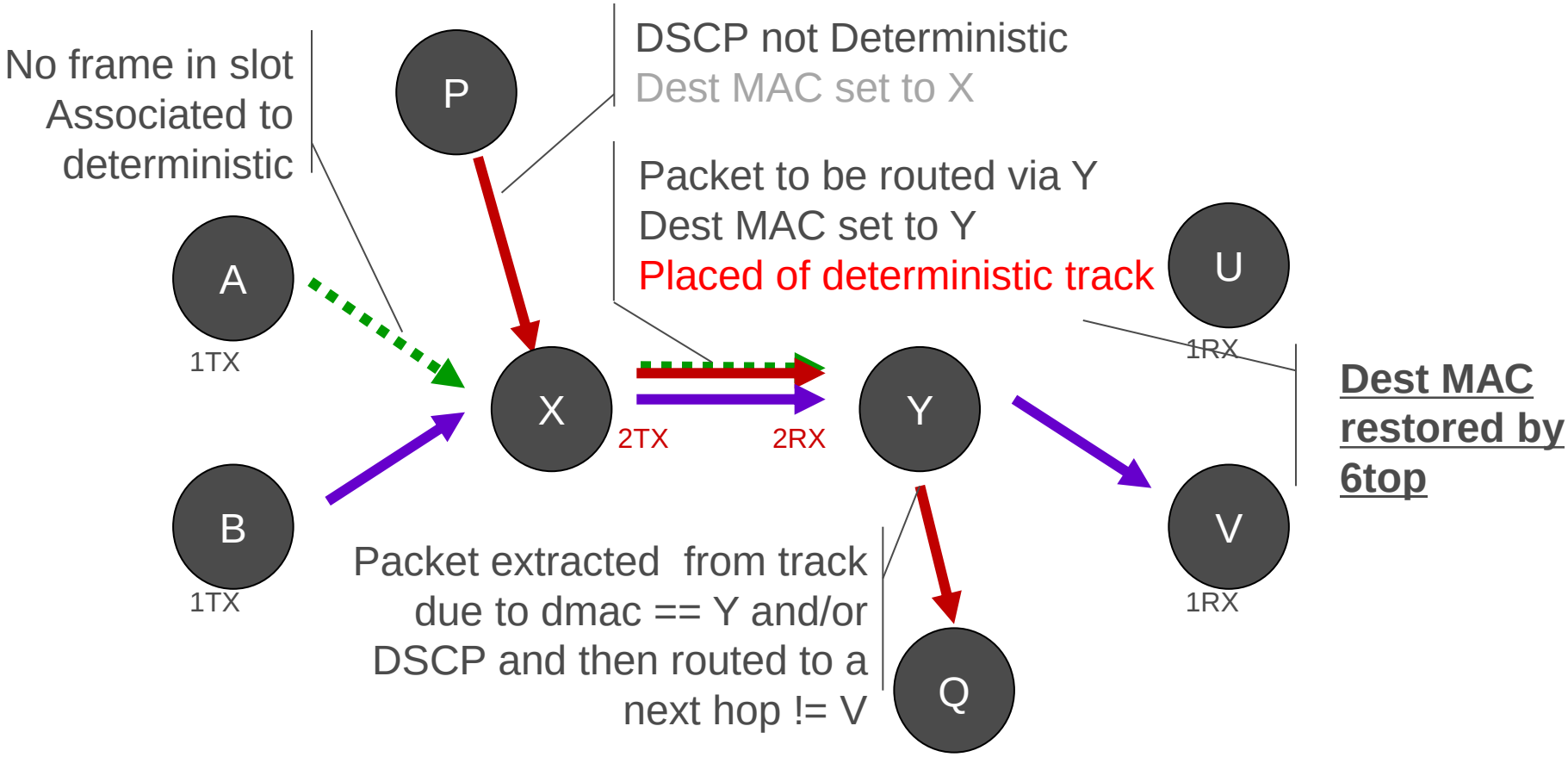
Normal L3 operation



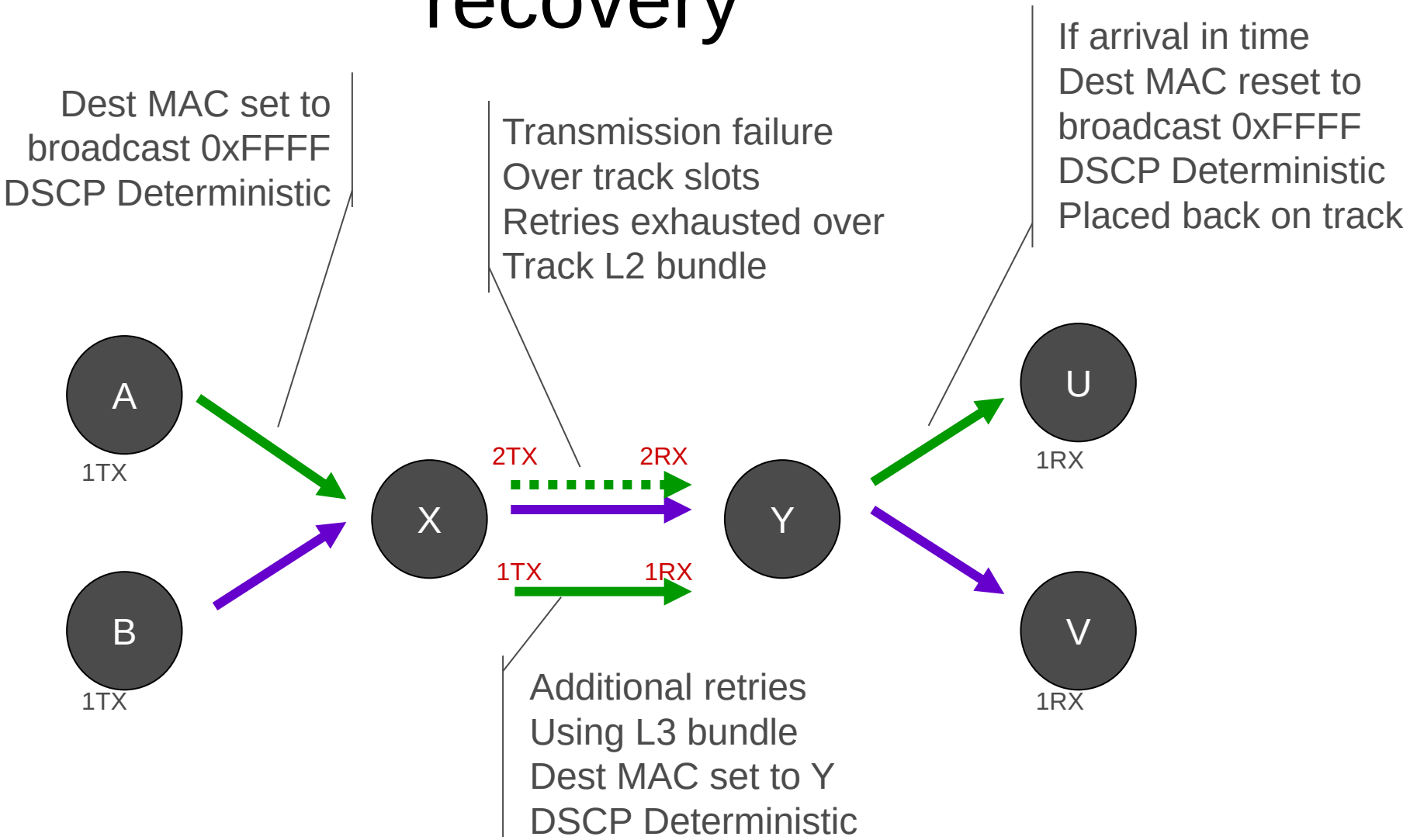
Normal Track operation



(Existing) Opportunistic track slot reuse



(New) Retracking after recovery



draft-ietf-6tisch-minimal-02

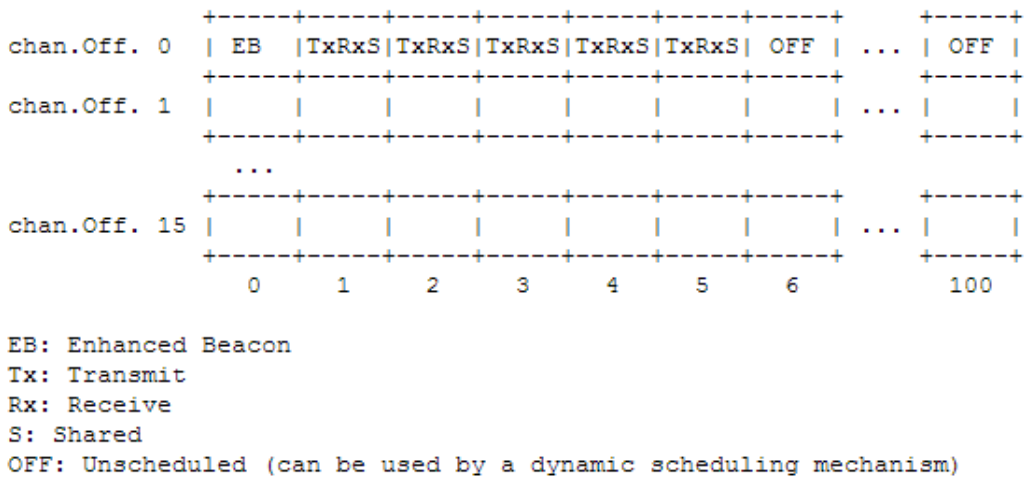
Xavi Vilajosana (Ed.)
Kris Pister

Status

- Status:
  - Adopted at IETF88 Vancouver
  - Latest version (02) published on 4 July 2014 https://datatracker.ietf.org/doc/draft-ietf-6tisch-minimal/
- Changes since IETF89
  - Redefined slotframe length
  - Redefined number of active cells
  - Redefined timeslot length
  - Added Requirement for Timeslot IE and Ch.Hopping IE in EB

Slotframe

- Before
  - 101 time slots slotframe (fixed size)
  - 6 active cells (1EB, 5 Slotted Aloha)
- Problems
  - Not flexible
  - Possibly not enough bandwidth

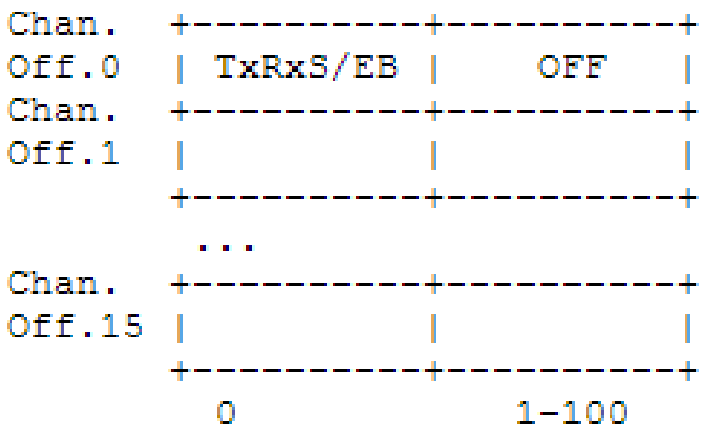


Slotframe

- Now
  - Variable number of time slots in the slotframe
  - 1 active cells (EB and Data in the same cell)
  - Active Cell LinkOption and LinkType
    - DATA (not BEACON), Rx, Tx, Shared
  - TimeKeeping flag never set.
    - Time source neighbor is selected using the DODAG structure of the network
- Pros
  - More flexible
  - Duty cycle can be tuned

Slotframe

Example schedule with 0.99% duty cycle



EB: Enhanced Beacon
Tx: Transmit
Rx: Receive
S: Shared
OFF: Unscheduled (can be used by a dynamic scheduling mechanism)

Timeslot

- Before: 15ms MUST aiming to support old platforms
- Now: 10ms RECOMMENDATION (not a MUST)
  - Using IEEE802.15.4e-2012 default timeslot template (timing)
  - MUST use TimeSlot IE only using 1B payload to send default timeslot template Id.
- Other configurations supported
  - MUST use EB and TimeSlot IE to announce slot timing. 25B payload required at each EB
- Recommendation to use power of 2 multiples of the default timeslot duration (e.g 20ms, 40ms, 80ms) so timeslots can align if coexist with recommended 10ms

EBs

- To be strictly compliant with 15.4e EBs MUST contain:
  - Sync IE (ASN, Join Priority)
  - Timeslot IE (timeslot template, slot length and timing in the slot)
  - Ch.Hopping IE (Ch.Hopping template, using the default)
  - Frame and Link IE (slotframe and link information)
- No dedicated slot for EB. Using single DATA slot from slotframe.
- No pre-configured slotframe at node
  - Learnt from Frame and Link IE from EBs.

draft-ietf-6tisch-6top-interface-01
draft-wang-6tisch-6top-sublayer-01

Qin Wang (Ed.)
Xavier Vilajosana
Thomas Watteyne

Status

- Status:
  - Adopted at IETF89
  - Latest version published on 2014-07-04 http://tools.ietf.org/html/draft-ietf-6tisch-6top-interface
- Changes since IETF89
  - See the following pages.

Change (1)

- #5 **expand PIB acronym**

At the beginning of Section 3, add:

"The data model consists of the MIB (management information base) defined in 6top, and part of the **PIB (personal area network information base)** defined in [IEEE802154e] and [IEEE802154]."

Change (2)

- **#6. merge IEEE802.15.4 PIB and IEEE802.15.4e PIB**

1. Merge

   Section 3.2 YANG model of the IEEE802.15.4 PIB

   Section 3.3 YANG model of the IEEE802.15.4e PIB

   =>

   Section 3.2 YANG model of the IEEE802.15.4 PIB

2. Add content

Add the YANG model of TSCH related attributes into the section.

Change (3)

- #17 **missing attribute description in YANG model**

Improve descriptions in YANG model, especially clarify the following.

  - In MonitoringStatList, attributes EnforcePolicy, (QoS, NQoS, Overprovision)
  - In Timesource, attribute Policy
  - In LabelSwitchList, attribute LoadBalancePolicy

Next Step

- Coordinate with draft-wang-6tisch-6top-coapie, and merge softcell negotiation RPC.

Status

- Status:
  - Latest version published on 2014-07-04 http://tools.ietf.org/html/draft-wang-6tisch-6top-sublayer-01.txt
- Changes since IETF89
  - See the following pages.

Change (1)

“the interaction between the upper layer and TSCH is asynchronous. This means that the MAC layer executes a schedule and checks at each timeslot **according to the type of cell**, whether there is something”

“**. . .** the interaction between the upper layer and TSCH is asynchronous. This means that the MAC layer executes a schedule and checks at each timeslot **according to the type of cell (i.e Transmit, Shared or Receive),** whether there is something to send or receive.”

Change (2)

- Clarify the return value of CREATE.softcell

"The command returns the number and the list of created cells defined by (slotframe ID, slotOffset, channelOffset). The number of created cells is **less than the required number of cells** if the required number of cells is higher than the available number of cells in the schedule. The number of created cells **equals to zero** if the negotiation with the target node fails. The number of created cells **equals to zero** if the cellType bitmap indicates that the cell(s) MUST be Hard."

Next Step

- Coordinate with draft-wang-6tisch-6top-coapie to change section 4 “6top communication protocol” and related parts.

- Add example schemes regarding to the policies, e.g.
  - The policy to build a candidate cell set
  - The policy to select cells from the candidate cell set to reserve
  - The behavior of the nodes when the soft cells negotiation fails
  - The policy to select cells corresponding to a delete soft cell command

draft-struik-6tisch-security-architecture-elements-00

Rene Struik

Status

- Status:
  - First version published on July 4, 2014
- Intent:
  - Work-in-progress document capturing security architectural design considerations, including the join process; fit with 802.15.4e/TSCH specification; gap analysis; identification of outstanding issues that need to be addressed; contributions towards addressing these.
  - Current version: concepts only, no specifications (yet)
- 6TiSCH Architecture should include security

Device Roles

Client. May move in and out of networks (that may be alien to it), with little network management functionality on board.

Access Point. May be more tied into a relatively stable infrastructure, with more support for network management functionality or reliable access hereto (e.g., via a back-end system).

Server. Provides stable infrastructure and network management support, either intra-domain or inter domain (thereby, offering homogeneous or even heterogeneous functionality).

CA. Vouches for trust credentials, usually in offline way.

Protocols involving a third party assume these communications to take place via the access point (which is tied into infrastructure).

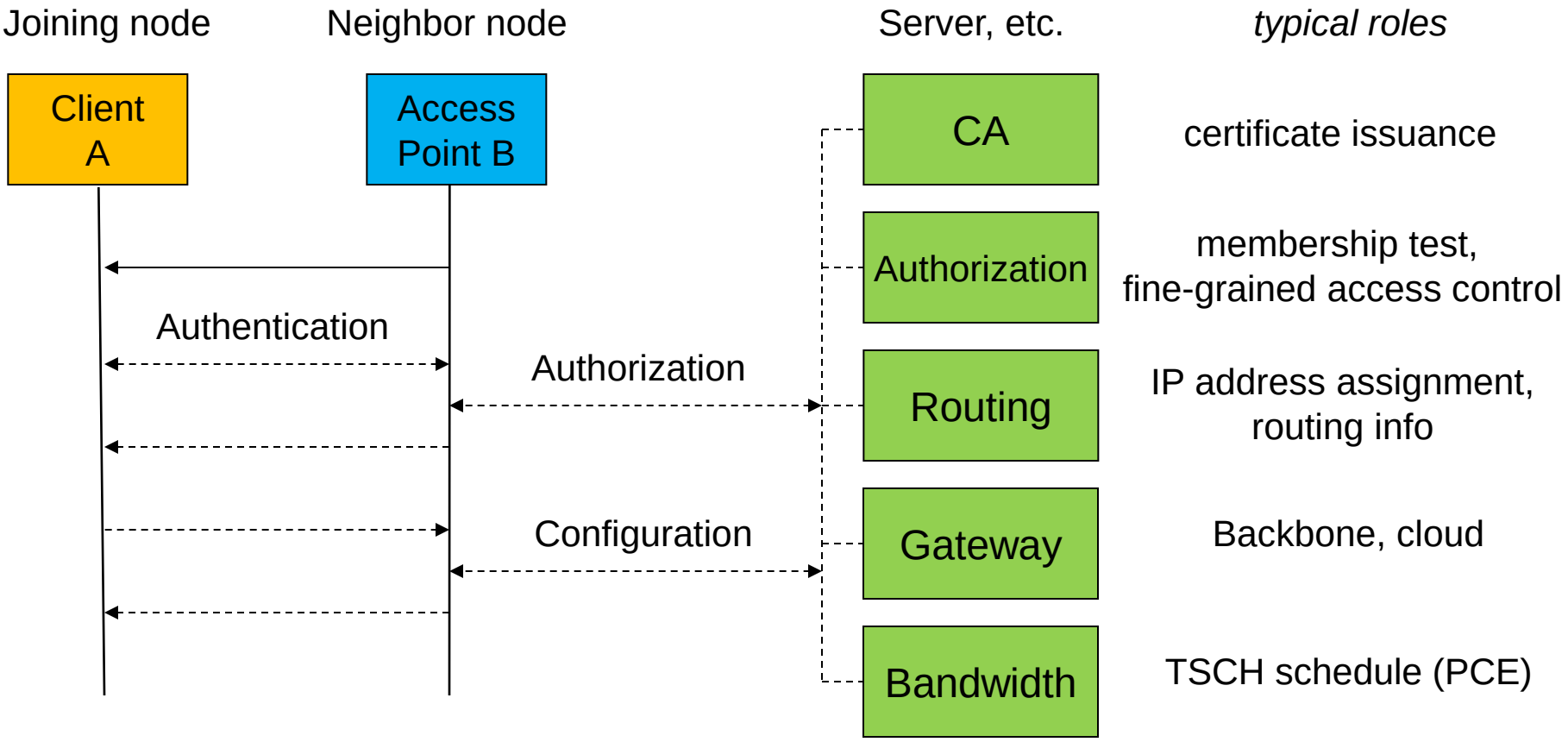
Device Enrolment Steps

Device authentication. Client A and Access Point B authenticate each other and establish a shared key (so as to ensure on-going authenticated communications). *This may involve server KDC as third party.*

Authorization. Access Point B decides on whether/how to authorize device A (if denied, this may result in loss of bandwidth). *Authorization decision may be delegated to server KDC or other 3rd-party device.*

Configuration/Parameterization. Access Point B distributes configuration information to Client A, such as ♦ IP address assignment info; ♦ Bandwidth/usage constraints; ♦ Scheduling info (including on re-authentication policy details). *This may originate from other network devices, for which it acts as proxy.*

Networking Joining



NOTE: in some existing applications, Access point B acts as relay only and third-party provides both authentication and authorization.

Outstanding Issues (1)

- Packet sizes:
  - TODO: get more insight on packet sizes configuration parameters (e.g., as w/HART does).
- Device Ids:

  With industrial control, network manager looks up “tag name” device in pre-configured database.
  - TODO: details on tag name syntax, how assigned, and how bound to, e.g., EUI-64.

Outstanding Issues (2)

- Join process impact on network:
  - Status: Minimize non-local communication flows between joining node and network manager to
    - Pass join information from joining node to network manager and back
    - Pass configuration parameters from network manager to joining node (keys, links, frame links) and neighbor report from joining node to network manager.
  - TODO: analysis impact Access Point B as relay, e.g., in terms of time latency, overheads, and DoS attacks.
  - TODO: negotiation of local schedule with neighbor node for execution of join protocol.
  - TODO: more analysis on time latencies due to TSCH

Outstanding Issues (3)

- Crypto protocol details:
  - Status: Crypto properties well-understood
  - TODO: mitigation DoS attacks, reducing overheads
- Authorization/trust management:
  - TODO: further discussion lifecycle aspects, certificate issuance (ACE could play role here)

Outstanding Issues (4)

- Fit with 802.15.4e/TSCH:
  - TODO: first join message cannot use ASN from Enhanced Beacon, since not trusted (and may differ from ASN of network manager). More analysis needed.
  - TODO: current 802.15.4e does not allow mixing of unsecured and secured traffic.

draft-richardson-6tisch --security-6top-01

Michael Richardson

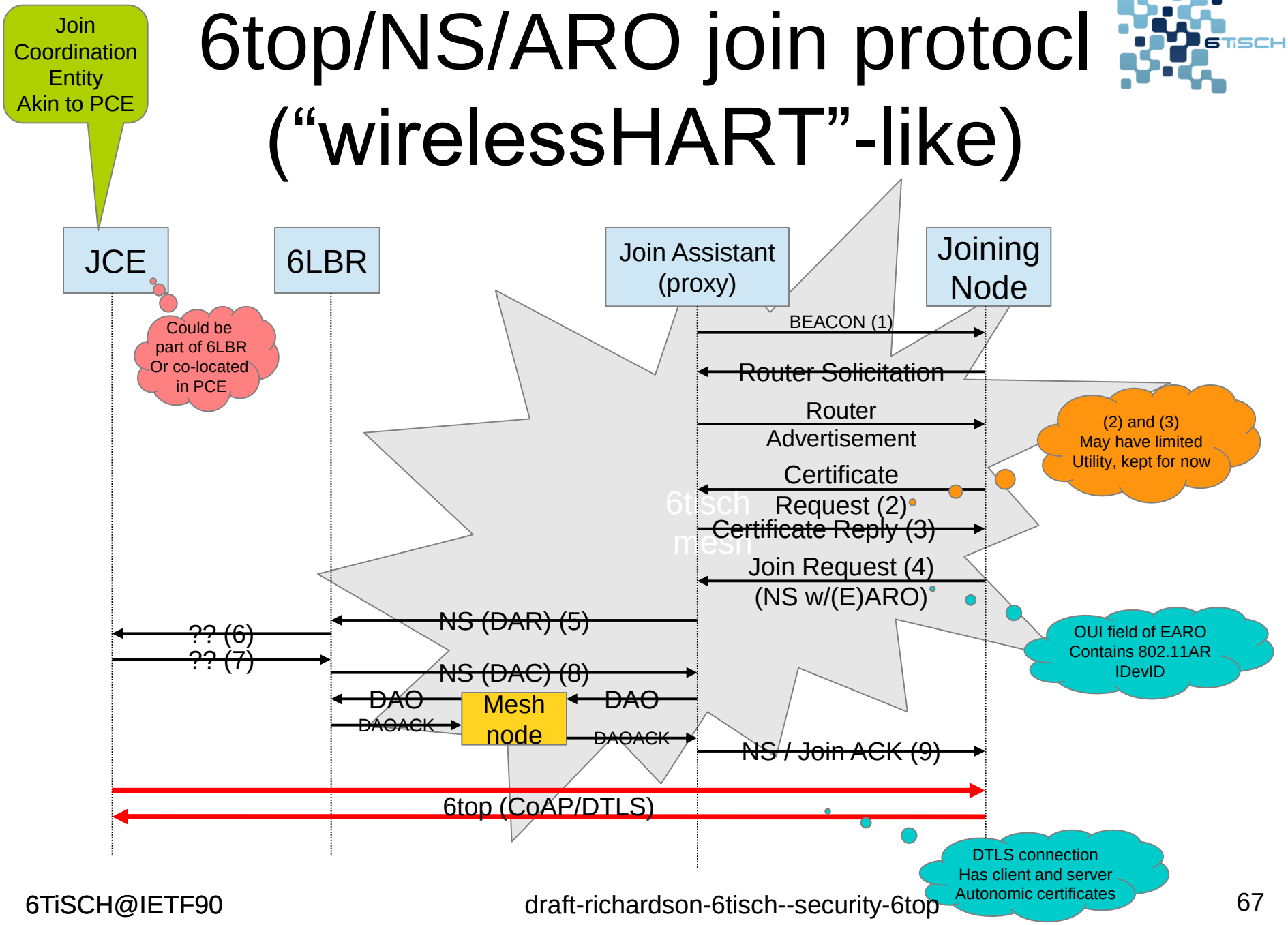
Status

- Weekly calls for 6tisch-security design team
  - Examined packet sizes, number of round trips, size of certificates, contents of certificates, amount of redundant code.
  - draft-richardson-6tisch-security-table-of-contents represents set of questions
    - (not intended for publication)
- Status:
  - Some consideration of the WG before any thoughts of adoption.
  - Looking for proponent for EAP-TLS method.

6tisch design team

- Rene Struik
- Pascal Thubert
- Patrick Wetterwald
- Hank Mauldin
- Jonathan Smith
- Ines Robles
- Michael Behringer
- Nancy Cam Winget
- Paul Duffy
- Maik (Mike) Seewald
- Pat Kinney
- Guiseppe Piro
- Kris Pister
- xɐɯ Pritkin
- Subir Das
- Tom Phinney
- Yoshihiro Obha
- Michael Richardson
- Thomas Watteyne

6top/NS/ARO join protocl ("wirelessHART"-like)



Next steps

- UCAN BOF on Wednesday morning (sadly, concurrent with ROLL)
  - Deals with Autonomic networking, and perhaps, certificate and ownership issues necessary for zero-touch provisioning
- Consensus that this is the right way to go.
- Finish architectural considerations; merge to architecture document
- Get the details of the protocol right.

Questions and concerns

Report LLN PLUGFEST IETF 90

Chairs:

Xavier Vilajosana

<xvilajosana@eecs.berkeley.edu>

Ines Robles<maria.ines.robles@ericsson.com>

PARTICIPANTS*(alphabetically)*

Nicola Accettura
Cedric Adjih
Marcelo Barros
Tengfei Chang
Thomas Eichinger
Vitor Garbellini
Oliver Hahm
Vicent Ladeveze
Jürgen Schönwälder
Pascal Thubert
Nestor Tiglao
Pere Tuset Peiró
Xavier Vilajosana
Qin Wang
Thomas Watteyne

Objectives

The goal of this event is to bring together people interested in hands-on experience around the technology developed by the 6TiSCH, 6lo and ROLL WGs, with a particular focus on the TSCH mode of IEEE802.15.4e, 6lowpan, RPL and new WG specifications.

Generalities

- Status
  - Adopted at 06/03/2014
  - Latest version published on 07/11/2014
- Wiki & Guidelines:
  - https://bitbucket.org/6tisch/meetings/wiki/140720a_ietf90_toronto_plugfest
- Changes since IETF 89
  - Integration of 6lo and ROLL Wgs.; e.g. draft-ietf-6lo-lowpan-mib-01, draft-thubert-6man-flow-label-for-rpl-03 (6man/ROLL)
  - Presentation of tools; e.g. Wireshark dissector, Sewio Open Sniffer
  - Presentation of demos; e.g. Demo BBR; Demo Minimal & 6top
  - It is a pleasure to have again OpenMote, RIOT, OpenWSN, LAB-IoT with new implementations and demostrations :-)
- Remote participation:
  - Meetecho, Webex
- Slides available on:

- Pictures available on:

Participants Summary

Efficient ND based registration to Ethernet Backbone Router End-to-end (SmartMesh) IP

Pascal Thubert

Thomas Watteyne

Joined plugfest
90th IETF Meeting
Toronto

6LoWPAN ND vs. Efficient ND vs. RPL

Work needed for 6TiSCH architecture

Positioning and overlaps

- Need for (6LoWPAN) ND between RPL Nodes?

Redistributing ND in RPL at the RPL edge

- Non-RPL leaf using 6LoWPAN ND to attach
- Requires TID in ARO as added in Efficient ND
- **draft-thubert-6lo-rfc6775-update-reqs-01**

Redistributing routing protocol into ND

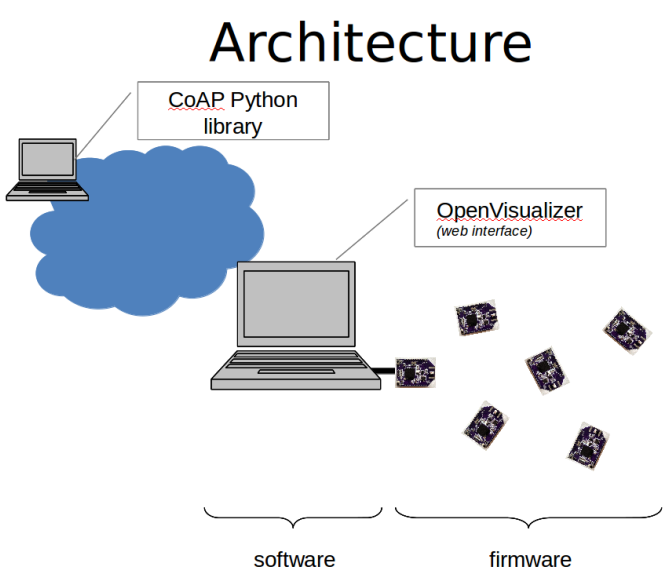
- e.g. RPL root advertising DAO state as ARO
- Demonstrated here with Smartmesh IP

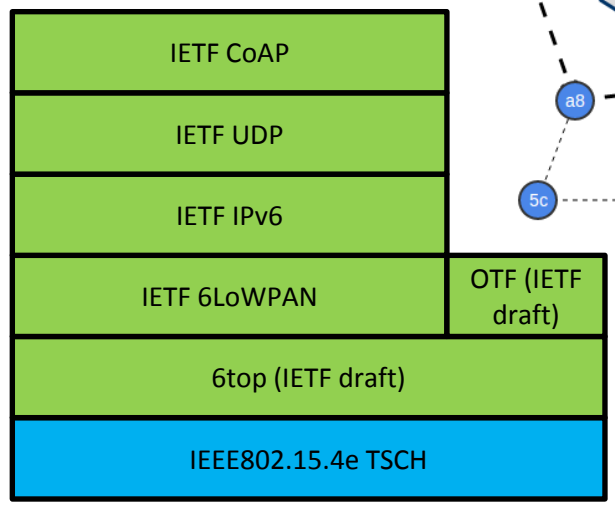
Marcelo Barros, Nicola Accettura, Pere Tuset, Qin Wang, Tengfei Chang, Thomas Watteyne, Vitor Garbellini, Xavi Vilajosana

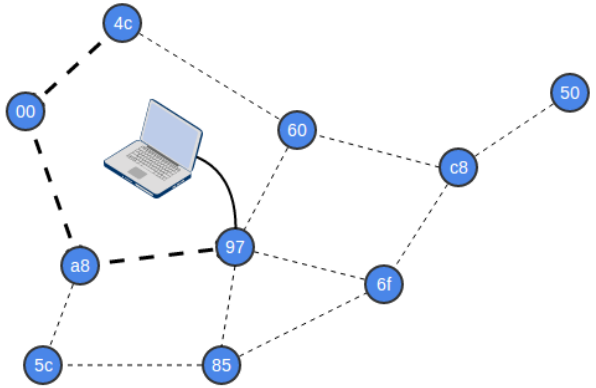
http://www.openwsn.org/

Overview

- http://www.openwsn.org/
- Goal: **open-source** implementations of a protocol stack based on **Internet of Things** standards, using a **variety** of hardware and software platforms
- Supported standards: **IEEE802.15.4e TSCH**, 6TiSCH, 6LoWPAN, RPL, CoAP







OpenWSN Web Interface

Vitor Garbellini - Brazil
<garbellinivitor@gmail.com>

Marcelo Barros - Federal University of Uberlândia / Brazil
<marcelobarrosalmeida@gmail.com>

Goals

- Dynamic layout adjusted automatically for any screen size (divisions, tables, maps, menus)
- Better look and feel
- Mobile devices support
- Routing visualization
- Minimal modifications on current source code
- Based on Bootstrap, for a rich component library (http://getbootstrap.com/)

“6TiSCH Operation Sublayer (6top)” draft-wang-6tisch-6top-sublayer-01

Qin Wang, Tengfei Chang
University of Science & Technology Beijing
wangqin@ies.ustb.edu.cn
tengfei.chang@gmail.com

What will be shown

- Implementation of 6top sublayer
- Reserve and remove one cell at one time
- Reserve and remove cell along the routing path by calling 6top cell reservation command (OTF implemented by Thomas)
- On openmotestm platform

Demonstrating "On-The-Fly Scheduling" draft-dujovne-6tisch-on-the-fly-03

Thomas Watteyne


Topology
Motes
Event Bus
Topology
Routing
Documentation
DAGroot
Map
Satellite
University of California
Marvell Nanofabrication Laboratory
Hearst
Kresge Engineering
Gayley Rd
2600
1
2
3
4
5
Map data ©2014 Google
Terms of Use
Report a map error
Goal: when mote 5 adds a cell to mote 4 through 6top negociation, all nodes in the 4-3-2-1 multi-hop route do the same
• Requirements
• IEEE802.15.4e TSCH network
• 6top sublayer
• CoAP
• Implementation done in OpenWSN

"Analysis of TSCH networks using open source tools: OpenMote + Wireshark"

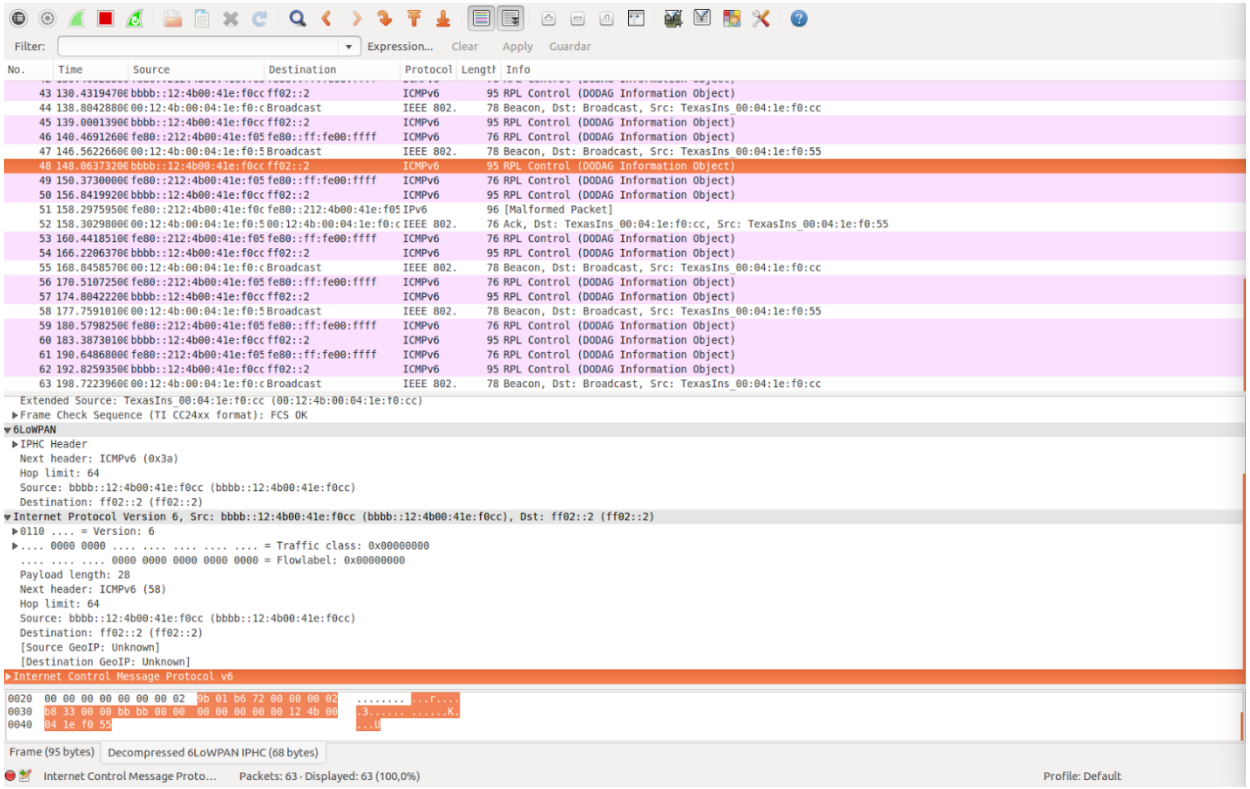
Pere Tuset-Peiró
OpenMote Technologies
peretuset@openmote.com

July 20, 2014
Toronto, Canada

What will be shown

- An IEEE 802.15.4e sniffer build using the OpenMote platform and Wireshark
  - Currently only supports one channel but support for a specific product

for IEEE 802.15.4e multi-channel sniffing is planned



FIT IoT-lab

www.iot-lab.info

A very large scale open testbed for the Internet of things

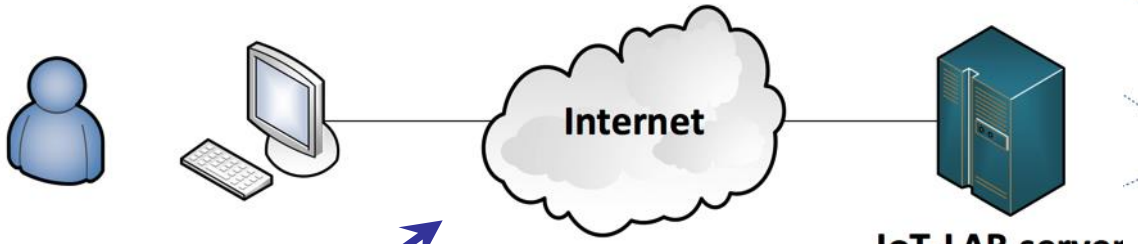
Presented by: Cédric Adjih (Inria)

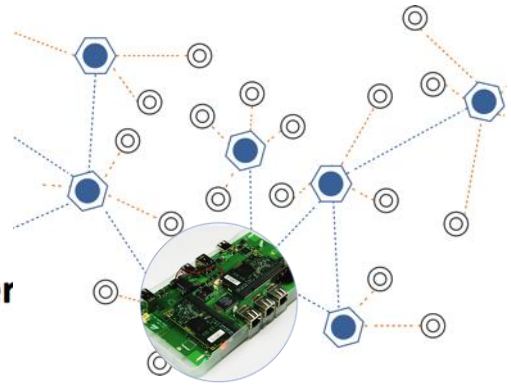
IETF

INVESTISSEMENTS D'AVENIR

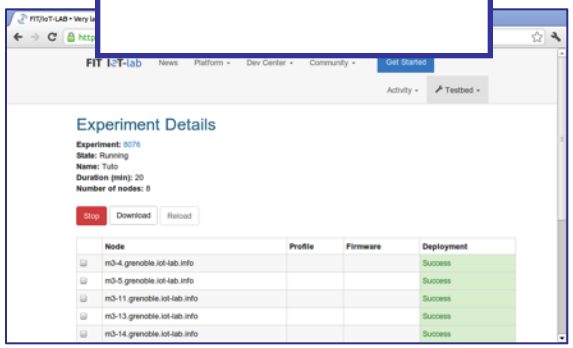
FIT IoT-LAB

- **Demo**

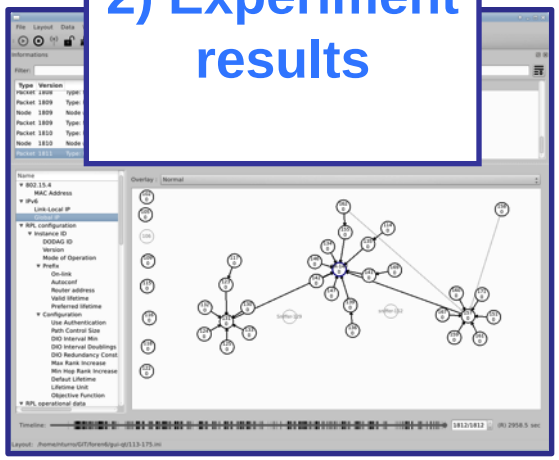




1) Experiment configuration



2) Experiment results



Open systems
with IETF protocols
(RPL/COAP/6TiSCH/…)

Counters for Troubleshooting and Monitoring the 6LoWPAN Layer

Anuj Sehgal, Jürgen Schönwälder
Jacobs University Bremen,
Germany draJ-ieL-6lo-lowpan-mib-01

SNMP Access to the Counters

bash ⌘1

```
$ snmpwalk -v 1 -c public -Os -O
p -v Mesh
lowpanReasmTimeout.0 = 3 seconds
lowpanInReceives.0 = 877
lowpanInHdrErrors.0 = 0
lowpanInReasmReqds.0 = 406
lowpanInReasmFails.0 = 4
lowpanInReasmOKs.0 = 30
lowpanInCompReqds.0 = 505
lowpanInCompFails.0 = 0
lowpanInCompOKs.0 = 507
lowpanInDiscards.0 = 88
lowpanInDelivers.0 = 508
lowpanOutRequests.0 = 508
lowpanOutCompReqds.0 = 509
lowpanOutCompFails.0 = 0
lowpanOutCompOKs.0 = 511
lowpanOutFragReqds.0 = 31
lowpanOutFragFails.0 = 0
lowpanOutFragOKs.0 = 31
lowpanOutFragCreates.0 = 291
lowpanOutDiscards.0 = 0
lowpanOutTransmits.0 = 782
End of MIB
$
```

3. scli

scli ⌘1

```
$ ~/src/scli/scli/scli
100 scli version 0.4.0 (c) 2001-2010 Juergen Schoenwaelder
scli > set scli protocol SNMPv1
scli > open snmp://[aaaa::11:22ff:fe33:4455]:1610//
(aaaa::11:22ff:fe33:4455) scli > show system info
Name:              AVR Raven
Agent:             snmp://public@[aaaa::11:22ff:fe33:4455]:1610//
Description:       6LoWPAN MIB Test Node
Contact:           Anuj Sehgal <s.anuj@jacobs-university.de>
Location:          Jacobs University Bremen
Vendor:            Jacobs University <http://www.jacobs-university.de/>
Services:          datalink network transport application
Agent-Boot-Time:   2014-07-18 11:26:47 +02:00
(aaaa::11:22ff:fe33:4455) scli >
```

1. scli

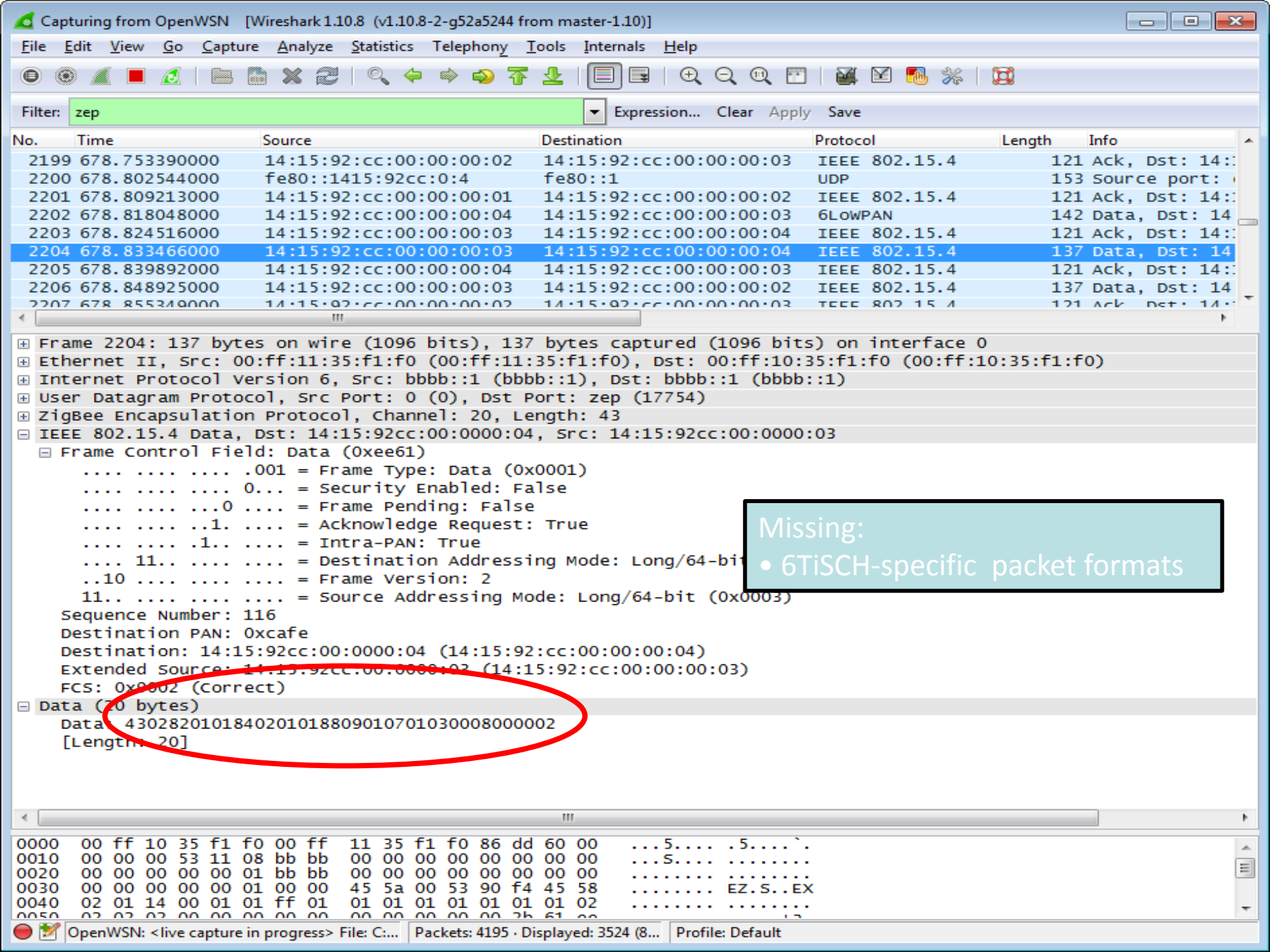
scli ⌘1

```
Agent:    snmp://public@[aaaa::11:22ff:fe33:4455]:1610// up 0 days 00:04:25    09:38:33
Descr:    6LoWPAN MIB Test Node
Command:  monitor 6lowpan stats

inDelivers          3 (887)      outRequests         3 (855)
inDiscards          0 (79)          v
  ^                                outCompReqds        3 (855)
inCompOKs           3 (889)      outCompFails        0 (0)
inCompFails         0 (0)        outCompOKs          3 (855)
inCompReqds         3 (889)         v
  ^                              outFragReqds        2 (340)
inReasmOKs          2 (357)      outFragFails        0 (0)
inReasmFails        0 (6)        outFragOKs          2 (339)
inReasmReqds        6 (1346)     outFragCreates      6 (1178)
  ^                                v
inHdrErrors         0 (0)        outDiscards         0 (0)
inReceives          7 (1884)     outTransmits        7 (1692)
```

IEEE802.15.4e Wireshark dissector

Vincent Ladeveze

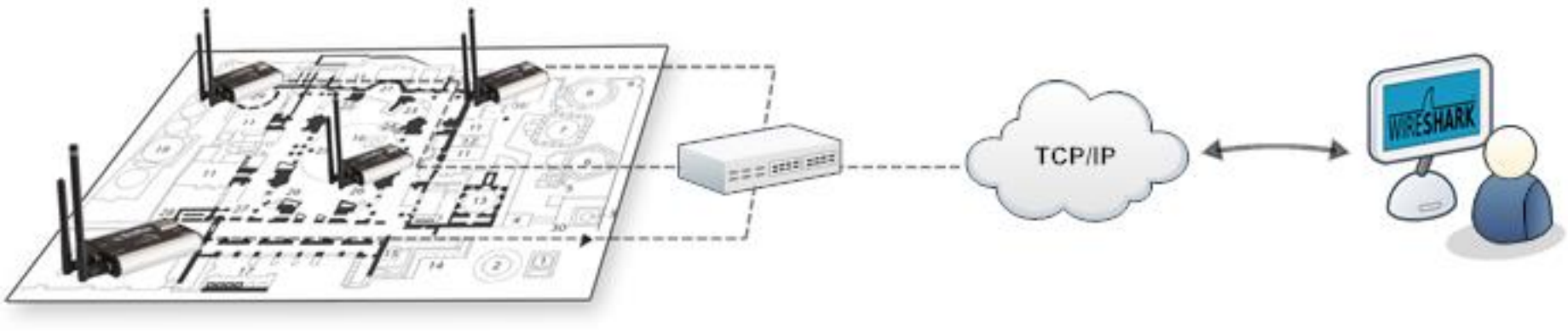

Capturing from OpenWSN [Wireshark 1.10.8 (v1.10.8-2-g52a5244 from master-1.10)]
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter: zep
Expression... Clear Apply Save
No. Time Source Destination Protocol Length Info
2199 678.753390000 14:15:92:cc:00:00:00:02 14:15:92:cc:00:00:00:03 IEEE 802.15.4 121 Ack, Dst: 14:
2200 678.802544000 fe80::1415:92cc:0:4 fe80::1 UDP 153 Source port:
2201 678.809213000 14:15:92:cc:00:00:00:01 14:15:92:cc:00:00:00:02 IEEE 802.15.4 121 Ack, Dst: 14:
2202 678.818048000 14:15:92:cc:00:00:00:04 14:15:92:cc:00:00:00:03 6LoWPAN 142 Data, Dst: 14
2203 678.824516000 14:15:92:cc:00:00:00:03 14:15:92:cc:00:00:00:04 IEEE 802.15.4 121 Ack, Dst: 14:
2204 678.833466000 14:15:92:cc:00:00:00:03 14:15:92:cc:00:00:00:04 IEEE 802.15.4 137 Data, Dst: 14
2205 678.839892000 14:15:92:cc:00:00:00:04 14:15:92:cc:00:00:00:03 IEEE 802.15.4 121 Ack, Dst: 14:
2206 678.848925000 14:15:92:cc:00:00:00:03 14:15:92:cc:00:00:00:02 IEEE 802.15.4 137 Data, Dst: 14
Frame 2204: 137 bytes on wire (1096 bits), 137 bytes captured (1096 bits) on interface 0
Ethernet II, Src: 00:ff:11:35:f1:f0 (00:ff:11:35:f1:f0), Dst: 00:ff:10:35:f1:f0 (00:ff:10:35:f1:f0)
Internet Protocol Version 6, Src: bbbb::1 (bbbb::1), Dst: bbbb::1 (bbbb::1)
User Datagram Protocol, Src Port: 0 (0), Dst Port: zep (17754)
ZigBee Encapsulation Protocol, Channel: 20, Length: 43
IEEE 802.15.4 Data, Dst: 14:15:92cc:00:0000:04, Src: 14:15:92cc:00:0000:03
Frame Control Field: Data (0xee61)
.... .001 = Frame Type: Data (0x0001)
.... 0... = Security Enabled: False
....0 .... = Frame Pending: False
....1. .... = Acknowledge Request: True
.... .1.. .... = Intra-PAN: True
.... 11.. .... = Destination Addressing Mode: Long/64-bit
..10 .... = Frame Version: 2
11.. .... = Source Addressing Mode: Long/64-bit (0x0003)
Sequence Number: 116
Destination PAN: 0xcafe
Destination: 14:15:92cc:00:0000:04 (14:15:92:cc:00:00:00:04)
Extended Source: 14:15:92cc:00:0000:03 (14:15:92:cc:00:00:00:03)
FCS: 0x8002 (Correct)
Data (20 bytes)
Data: 43028201018402010188090107010300080000002
[Length: 20]
Missing:
• 6TiSCH-specific packet formats
0000 00 ff 10 35 f1 f0 00 ff 11 35 f1 f0 86 dd 60 00 ...5.... .5....`.
0010 00 00 00 53 11 08 bb bb 00 00 00 00 00 00 00 00 ...S.... ....
0020 00 00 00 00 00 00 01 bb bb 00 00 00 00 00 00 00 ....
0030 00 00 00 00 00 01 00 00 45 5a 00 53 90 f4 45 58 .... EZ.S..EX
0040 02 01 14 00 01 01 ff 01 01 01 01 01 01 01 01 02 ....
OpenWSN: <live capture in progress> File: C:...
Packets: 4195 · Displayed: 3524 (8...
Profile: Default

Live demonstration of Sewio's open sniffer solution

Nestor Tiglao
nmctiglao@yahoo.com

Sewio Open Sniffer

- Fully open, Low-cost
- 802.15.4, Zigbee, 6LowPAN
- Multiplatform, multiband, time-precise (usec)
- Sniffing, Scanning, and Continuous Transmission capability
- http://www.sewio.net/



The friendly Operating System for the Internet of Things

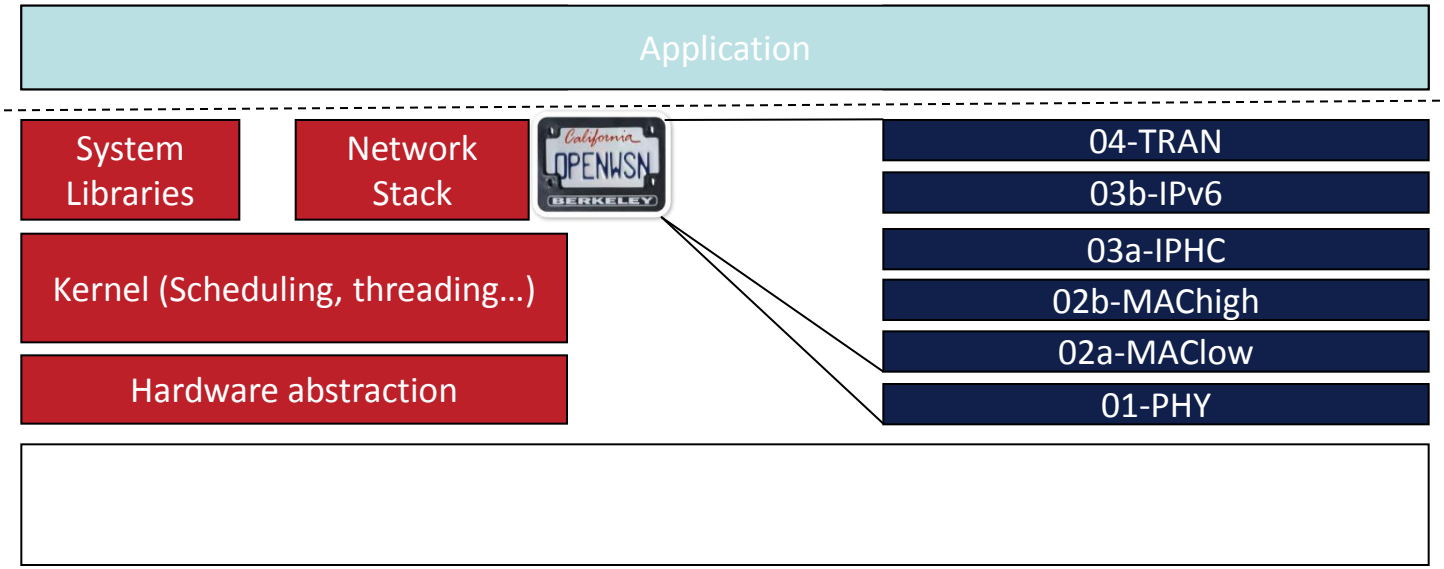
Approach: OpenWSN stack integration in RIOT

Leveraging the reasons for the success of the Internet:

- Interconnectivity through open standards (6LoWPAN, RPL, CoAP…)
- Open Source implementation
- Simple, but powerful API (like POSIX)

One crucial thing to make the IoT happen:

- reliable and robust networking over (multi-hop) wireless links
- 6TiSCH is a promising approach
- Work towards 6TiSCH support in RIOT's network stack



Demonstrating "The IP Flow Label within a RPL Domain" draft-thubert-6man-flow-label-for-rpl

Xavier Vilajosana
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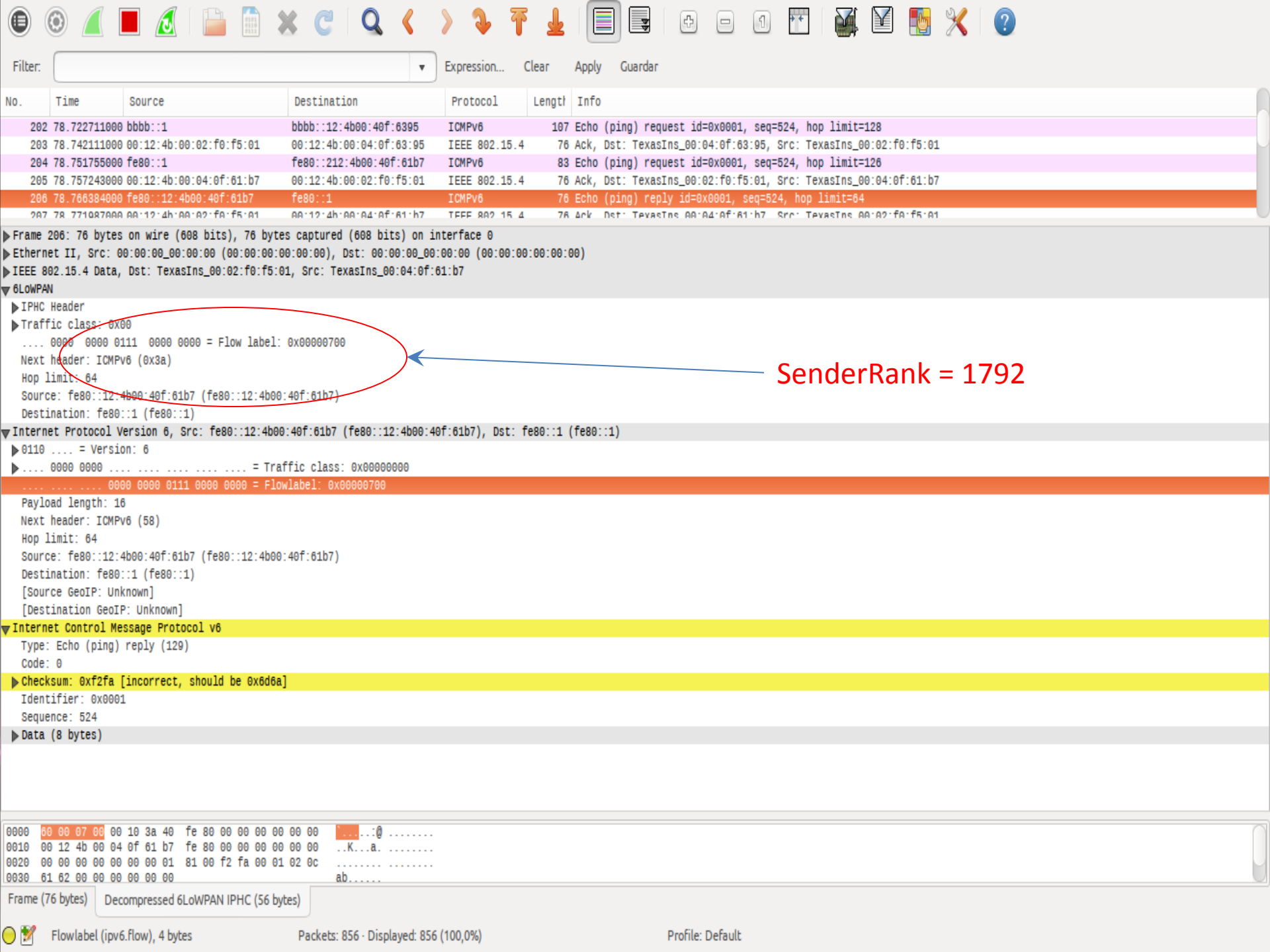
xvilajosana@eecs.berkeley.edu


Filter:
Expression...
Clear
Apply
Guardar
No. Time Source Destination Protocol Lengtl Info
202 78.722711000 bbbb::1 bbbb::12:4b00:40f:6395 ICMPv6 107 Echo (ping) request id=0x0001, seq=524, hop limit=128
203 78.742111000 00:12:4b:00:02:f0:f5:01 00:12:4b:00:04:0f:63:95 IEEE 802.15.4 76 Ack, Dst: TexasIns_00:04:0f:63:95, Src: TexasIns_00:02:f0:f5:01
204 78.751755000 fe80::1 fe80::212:4b00:40f:61b7 ICMPv6 83 Echo (ping) request id=0x0001, seq=524, hop limit=126
205 78.757243000 00:12:4b:00:04:0f:61:b7 00:12:4b:00:02:f0:f5:01 IEEE 802.15.4 76 Ack, Dst: TexasIns_00:02:f0:f5:01, Src: TexasIns_00:04:0f:61:b7
206 78.766384000 fe80::12:4b00:40f:61b7 fe80::1 ICMPv6 76 Echo (ping) reply id=0x0001, seq=524, hop limit=64
Frame 206: 76 bytes on wire (608 bits), 76 bytes captured (608 bits) on interface 0
Ethernet II, Src: 00:00:00_00:00:00 (00:00:00:00:00:00), Dst: 00:00:00_00:00:00 (00:00:00:00:00:00)
IEEE 802.15.4 Data, Dst: TexasIns_00:02:f0:f5:01, Src: TexasIns_00:04:0f:61:b7
6LOWPAN
IPHC Header
Traffic class: 0x00
.... 0000 0000 0111 0000 0000 = Flow label: 0x00000700
Next header: ICMPv6 (0x3a)
Hop limit: 64
Source: fe80::12:4b00:40f:61b7 (fe80::12:4b00:40f:61b7)
Destination: fe80::1 (fe80::1)
Internet Protocol Version 6, Src: fe80::12:4b00:40f:61b7 (fe80::12:4b00:40f:61b7), Dst: fe80::1 (fe80::1)
0110 .... = Version: 6
.... 0000 0000 .... = Traffic class: 0x00000000
.... 0000 0000 0111 0000 0000 = Flowlabel: 0x00000700
Payload length: 16
Next header: ICMPv6 (58)
Hop limit: 64
Source: fe80::12:4b00:40f:61b7 (fe80::12:4b00:40f:61b7)
Destination: fe80::1 (fe80::1)
[Source GeoIP: Unknown]
[Destination GeoIP: Unknown]
Internet Control Message Protocol v6
Type: Echo (ping) reply (129)
Code: 0
Checksum: 0xf2fa [incorrect, should be 0x6d6a]
Identifier: 0x0001
Sequence: 524
Data (8 bytes)
SenderRank = 1792
0000 60 00 07 00 00 10 3a 40 fe 80 00 00 00 00 00 00 `.....:@ ....
0010 00 12 4b 00 04 0f 61 b7 fe 80 00 00 00 00 00 00 ..K...a. ....
0020 00 00 00 00 00 00 00 01 81 00 f2 fa 00 01 02 0c ....
0030 61 62 00 00 00 00 00 00 ab......
Frame (76 bytes)
Decompressed 6LoWPAN IPHC (56 bytes)
Flowlabel (ipv6.flow), 4 bytes
Packets: 856 · Displayed: 856 (100,0%)
Profile: Default

draft-wang-6tisch-6top-coapie-00

Qin Wang (Ed.)
Xavi Vilajosana
Thomas Watteyne
Raghuram Sudhaakar
Pouria Zand

Status

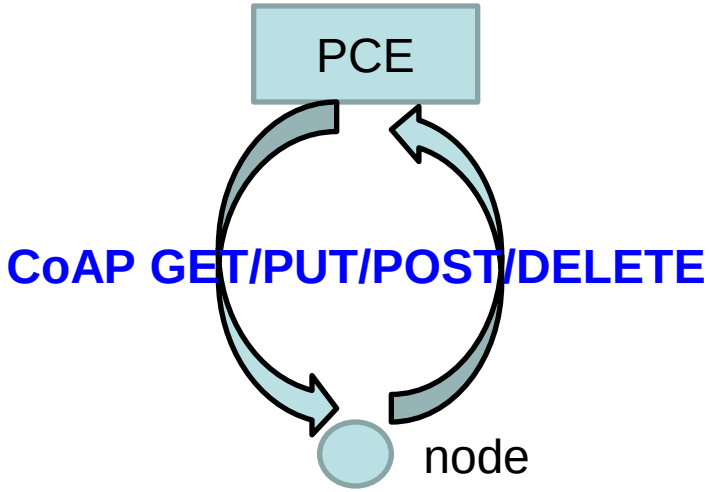
- Status:
- Latest version published on 2014-07-04
  http://tools.ietf.org/html/draft-wang-6tisch-6top-coapie-00.txt
- Changes since IETF89
  - New draft

Table of Contents

Introduction

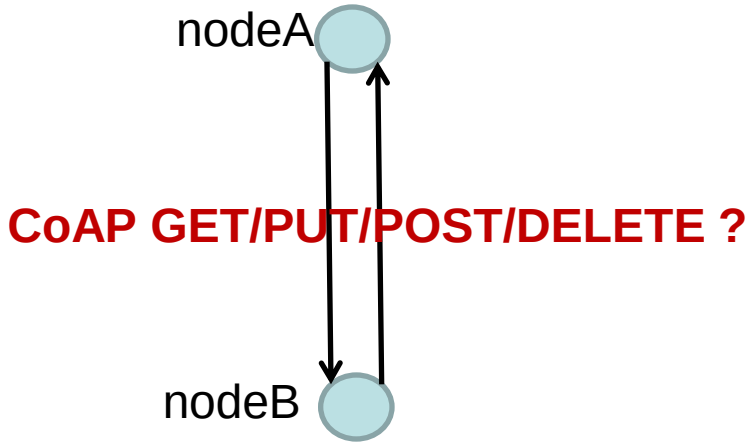
6top Schedule Management Mechanisms (draft-ietf-6tisch-architecture)

- Remote Schedule Management



1. draft-ietf-6tisch-interface: define the data model
2. draft-ietf-6tisch-coap: define how to access the data in 6top sublayer
3. RFC7252: CoAP specification

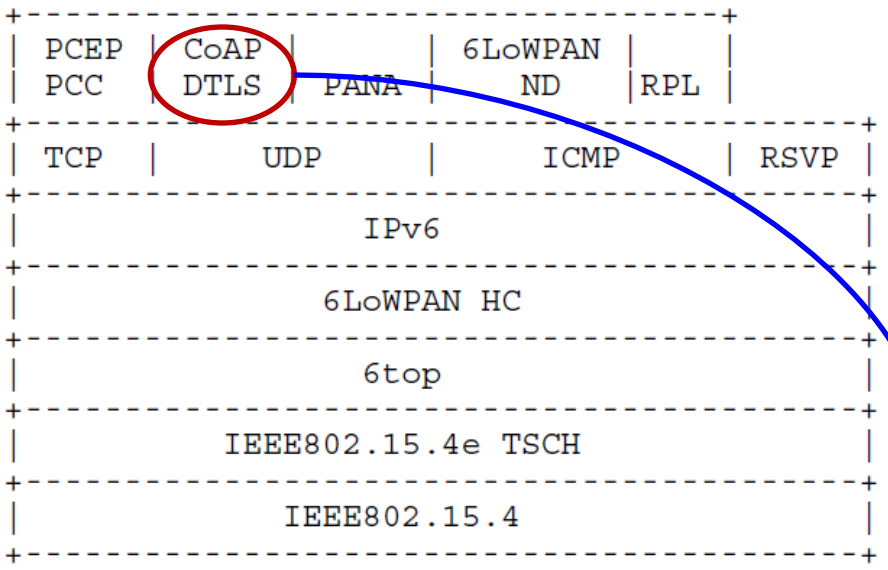
- Neighbor-to-Neighbor Scheduling



Problem:

How to reuse transfer protocol CoAP just above MAC layer?

Introduction (cont.)



IDEA: wrap CoAP message in a MAC payload IE. Then,

- The IE definition
- How to express the neig-to-neig (6top-to-6top) scheduling process in CoAP
- How to fit CoAP messages into MAC layer frame with length constraint.
- ……

Octets: 1/2	0/1	0/2	0/1/2/8	0/2	0/1/2/8	0/1/5/6/10/14	variable	variable	2
Frame Control	Sequence Number	Destination PAN Identifier	Destination Address	Source PAN Identifier	Source Address	Auxiliary Security Header	Information Elements	Frame Payload	FCS
		Addressing fields					Header IEs / Payload IEs		
MHR							MAC Payload		MFR

CoAP IE

Format of a CoAP IE.

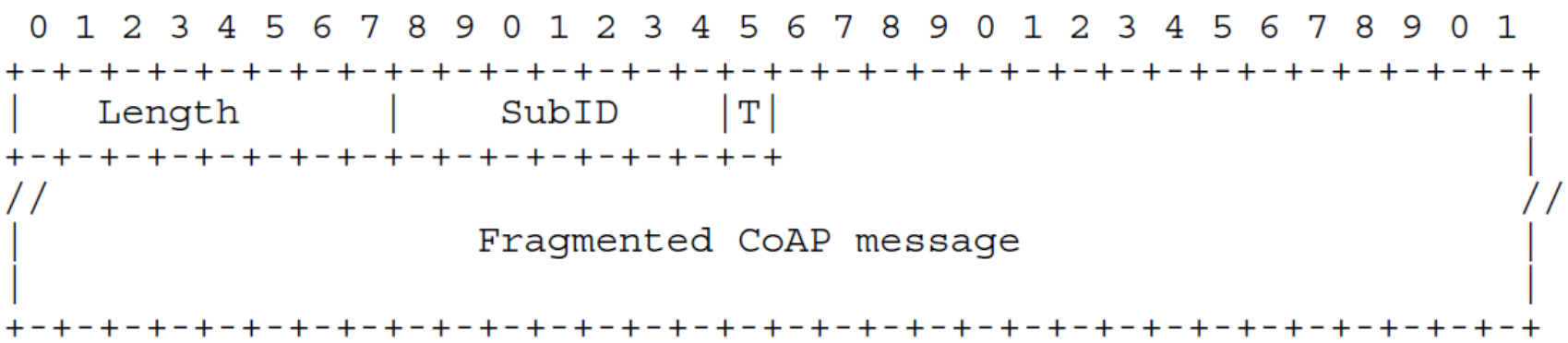


Figure 1

The fields in CoAP IE header are defined as follows.

- Length = 1
- SubID = 0x44
- T = 0 (short type)

Temporary id

CoAP IE with CoAP message

Format of CoAP IE with CoAP message.

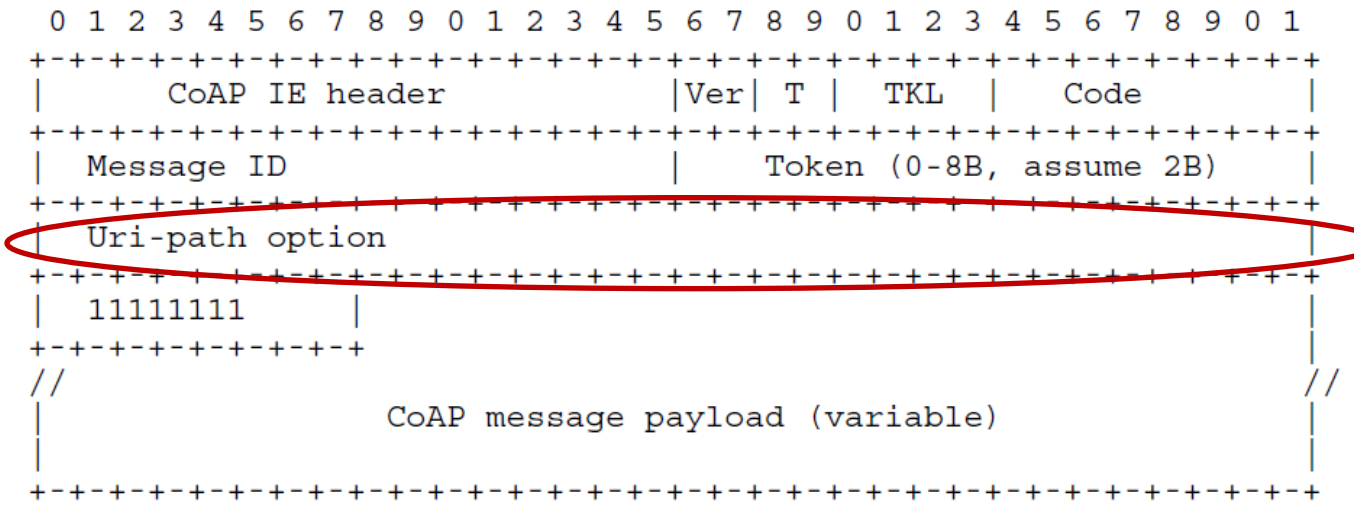


Figure 2

The Token Length (TKL)is set to 2;

Per [RFC7252], the Uri-path field consists of the following sub-fields:

- Option Delta: 4bits, set to 11
- Option Length: 4bits, set to 3
- Option value: 3 bytes

RPC definition

```
rpc softcell-negotiation {
   input {
         leaf Opcode {
            type enumeration {
               enum RESERVATION;
               enum REMOVE;
            }
         }
         leaf RequiredBW {
            type uint8;
         }
         leaf SlotframeID {
            type uint8;
        }
        leaf TrackID {
            type uint16;
            description
            "TrackID points to a tuple(TrackOwnerAddr,InstanceID)";
        }
        leaf NumofCandidate {
            type uint8;
        }
        List CandidateList {
            key "SlotOffset ChannelOffset";
            leaf SlotOffset{
               type uint16;
            }
            leaf ChannelOffset{
               type uint16;
            }
        }
    }
```

RPC definition(cont.)

```
    output {
       leaf NumOfCells {
          type uint8;
       }
       List ResultedCells {
          key "SlotOffset ChannelOffset";
          leaf SlotOffset{
             type uint16;
          }
          leaf ChannelOffset{
             type uint16;
          }
       }
    }
}
```

CoAP supports – Uri option

Uri-Host option = target node address;

Taken from the dest address field in MAC header

Uri-Path option =

6t/6/[6top resource name]

6t/4/[15.4 resource name]

6t/e/[extension resource name]

CoAP supports - fragmentation

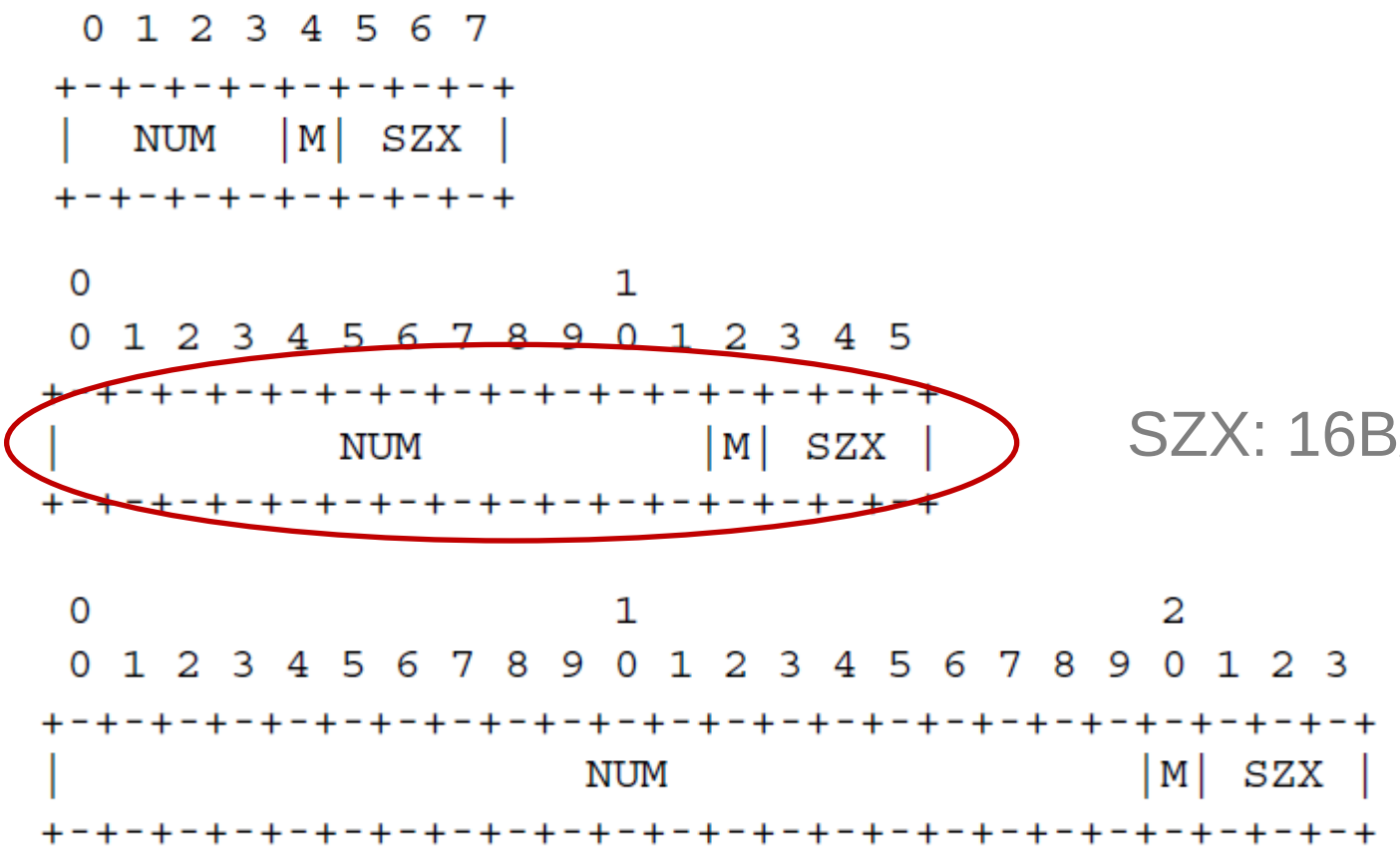


Figure 1: Block option value

SZX: 16B/32B/64B

CoAP supports- fragmentation

Format of CoAP IE content with fragmented message.

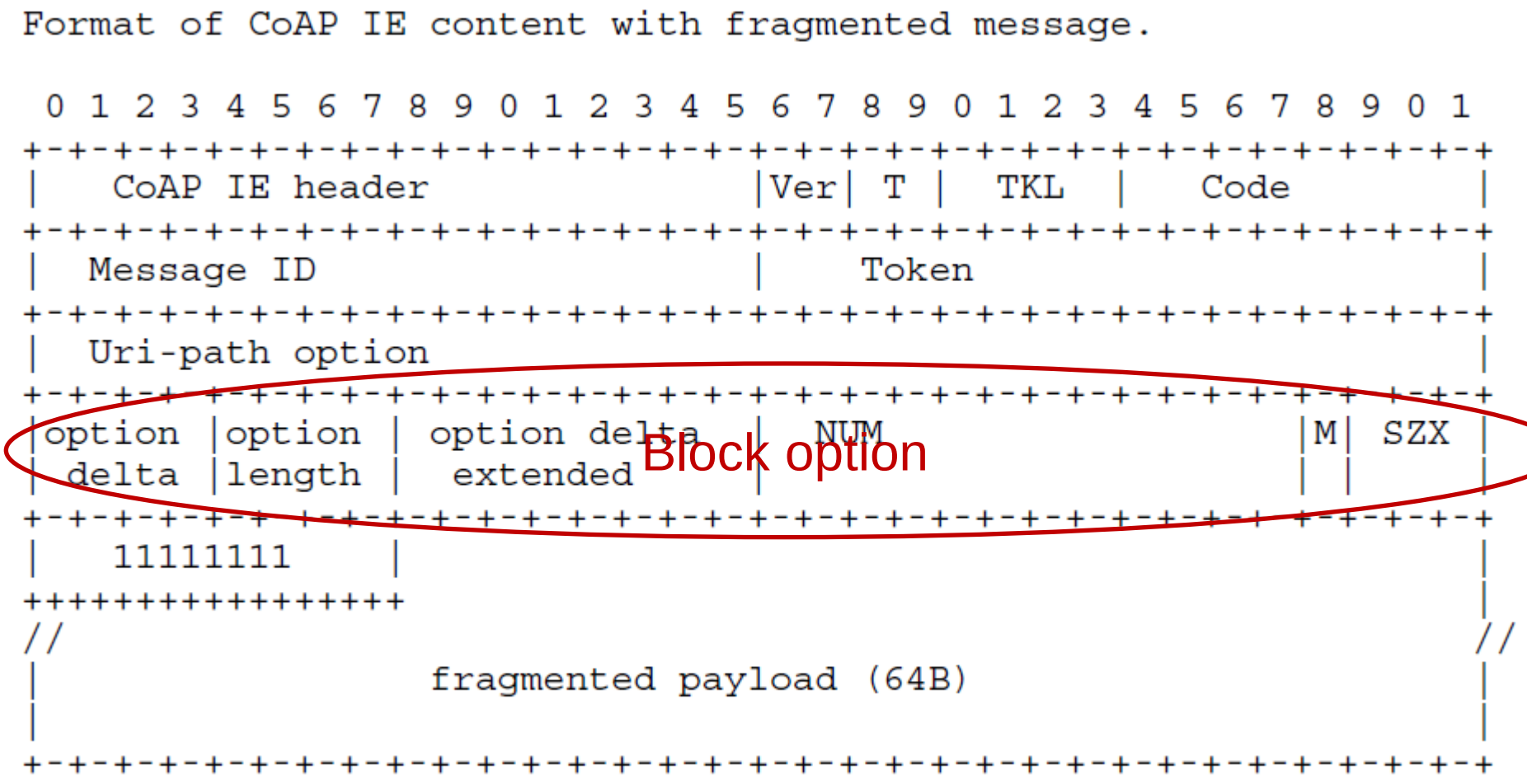
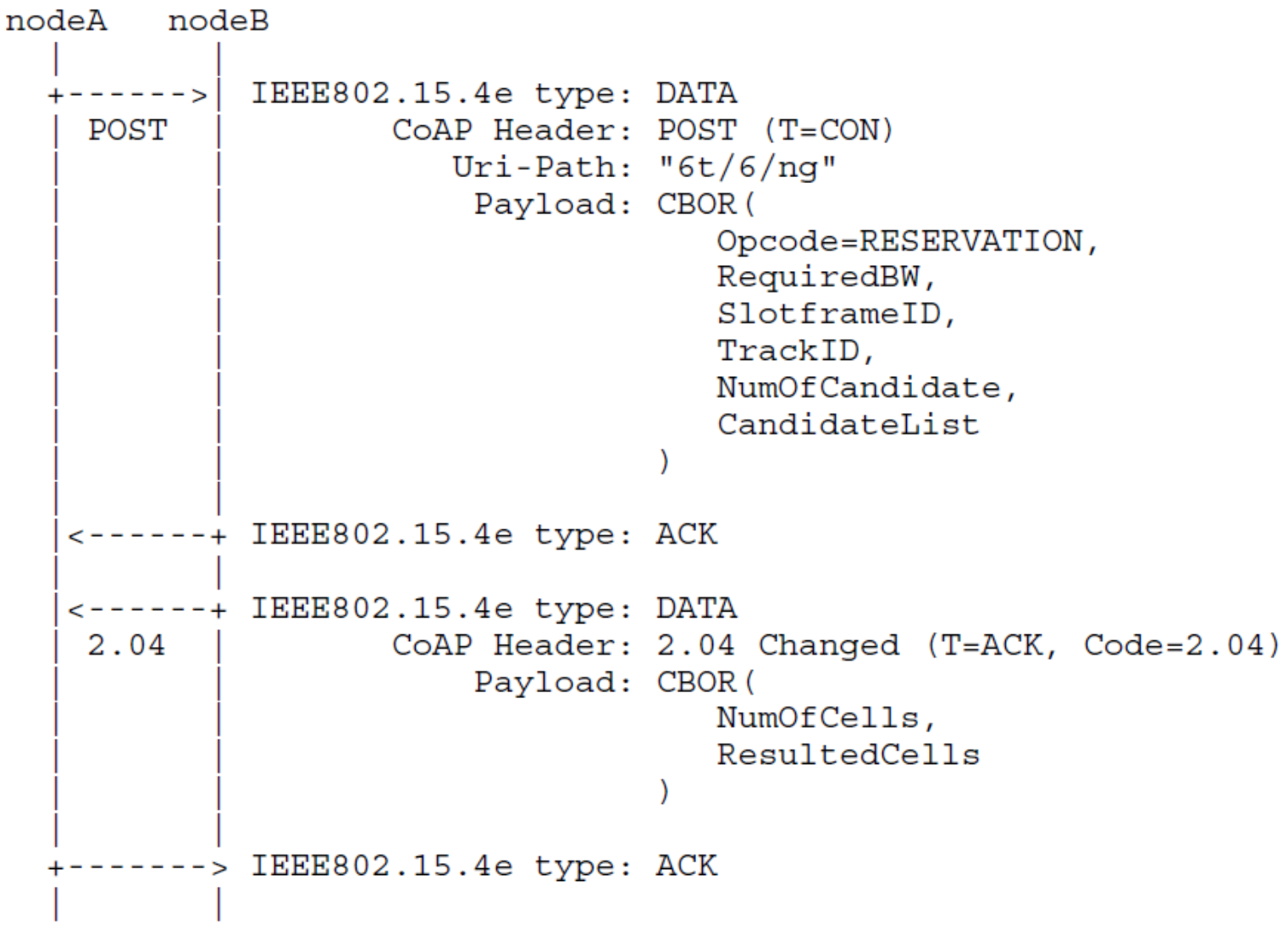


Figure 3

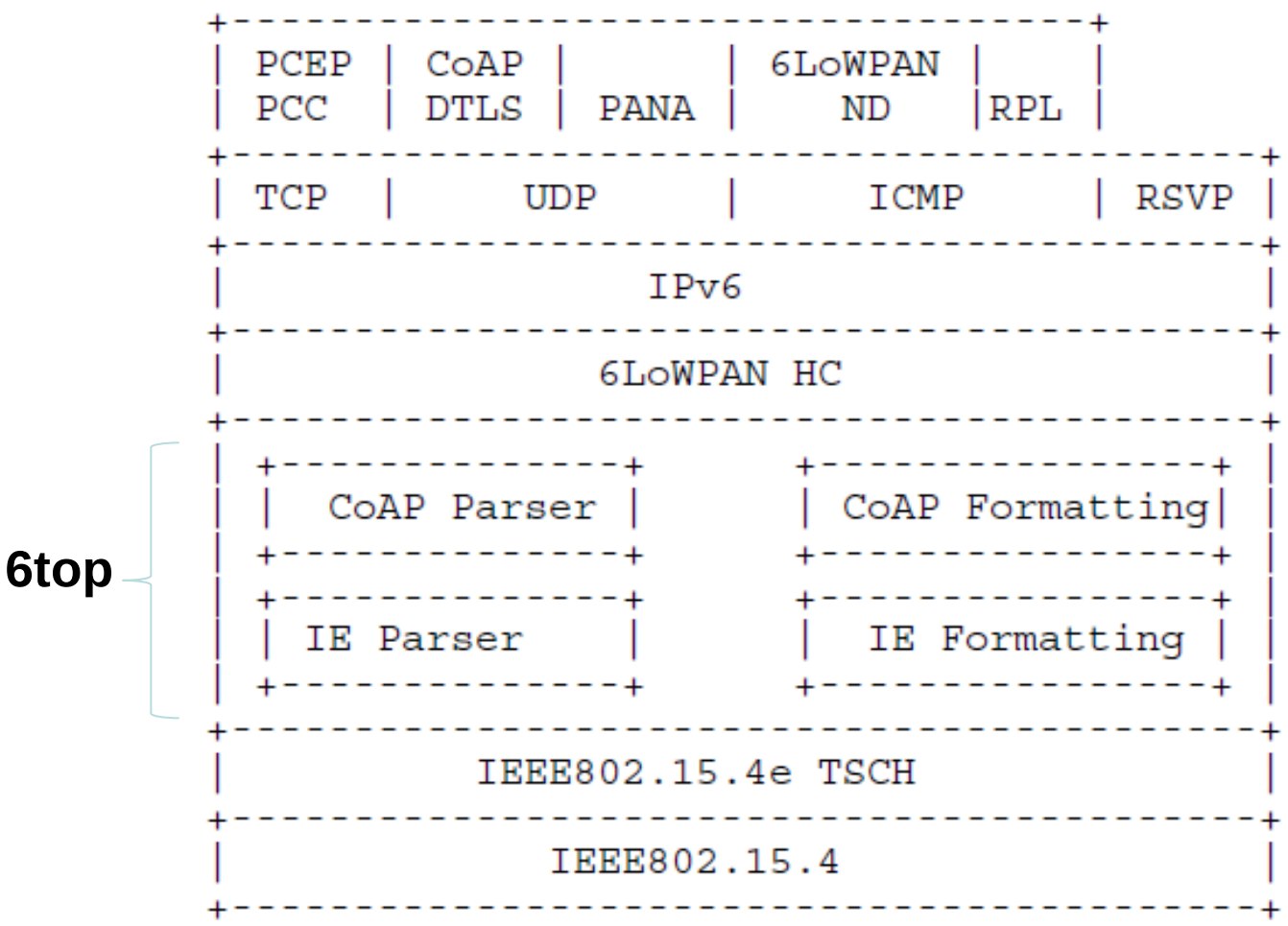
CoAP supports – softcell negotiation



CoAP supports-

- Acknowledgement
  - CoAP ACK : For both non-fragmented CoAP message and fragmented CoAP message, an Acknowledgement message of CoAP is used.
  - MAC ACK: Enhanced ACK frame can carry CoAP ACK message, but cannot replace CoAP ACK.
- Observe
  - Option for 6top-to-6top communication

Implementation Consideration



Next Step

- Request discussion and suggestion
- Merge into the three existing drafts
  - Section 2. CoAP IE => draft-wang-6tisch-6top-sublayer
  - Section 3. RPC definition => draft-ietf-6tisch-6top-interface
  - Section 4. CoAP supports => draft-ietf-6tisch-coap
  - Section 5. Implementation consideration => draft-wang-6tisch-6top-sublayer

draft-dujovne-6tisch-on-the-fly-03

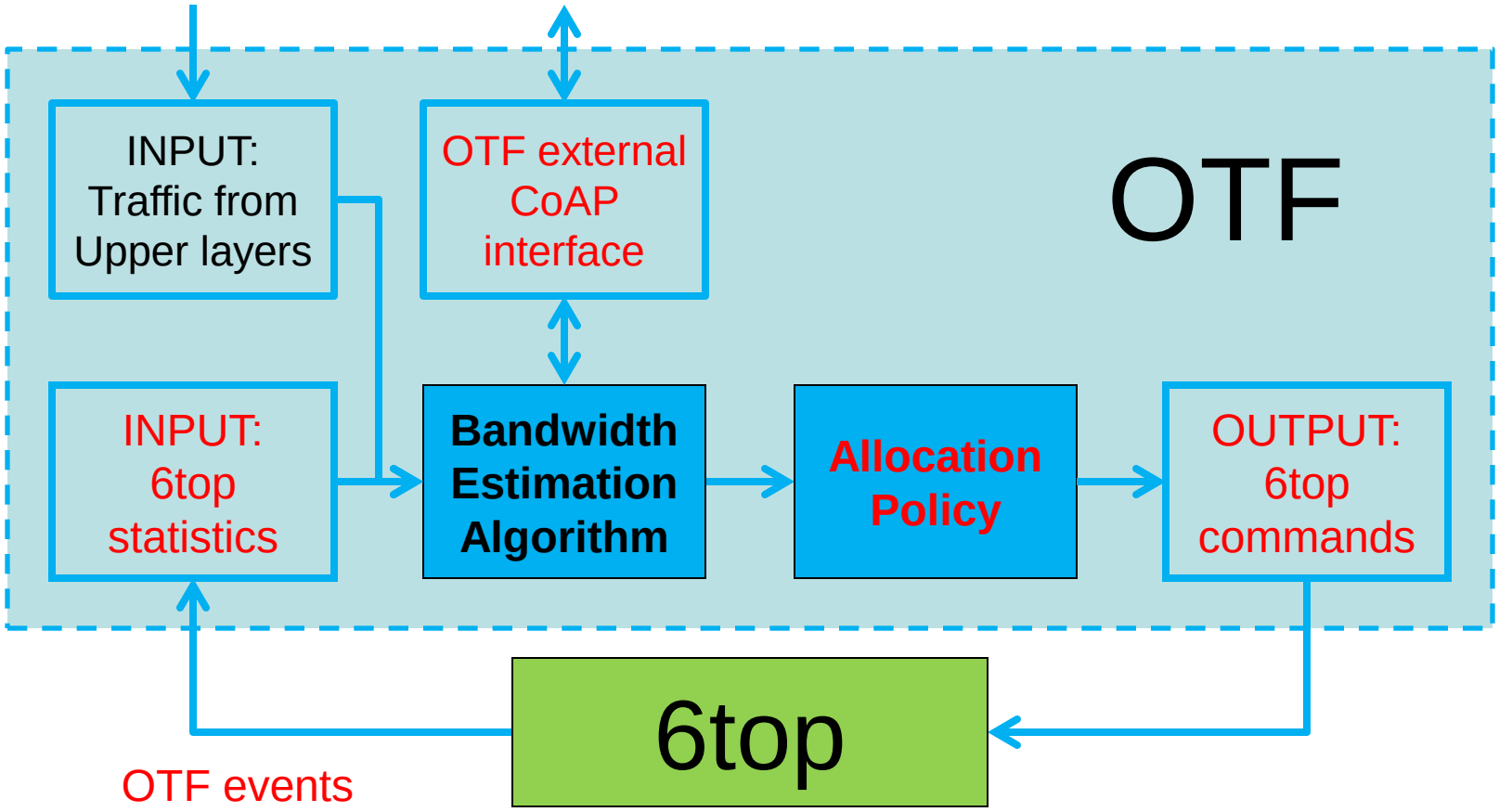
Diego Dujovne (Ed.)
Luigi Alfredo Grieco
Maria Rita Palattella
Nicola Accettura

Status

- Status:
  - Individual submission
  - Latest version published on 2014/7/4

    http://tools.ietf.org/html/draft-dujovne-6tisch-on-the-fly-03.txt
- Changes since IETF89
  - Introduction of a threshold for distinguishing among allocation policies: reactive, proactive
  - Identification of 6top commands to be used for creating and deleting soft cells
  - Identification of statistics provided by 6top
  - Identification of possible events triggering OTF operations
  - Definition of the OTF external CoAP interface

OTF and 6top


INPUT:
Traffic from
Upper layers
OTF external
CoAP
interface
OTF
INPUT:
6top
statistics
Bandwidth
Estimation
Algorithm
Allocation
Policy
OUTPUT:
6top
commands
6top
OTF events

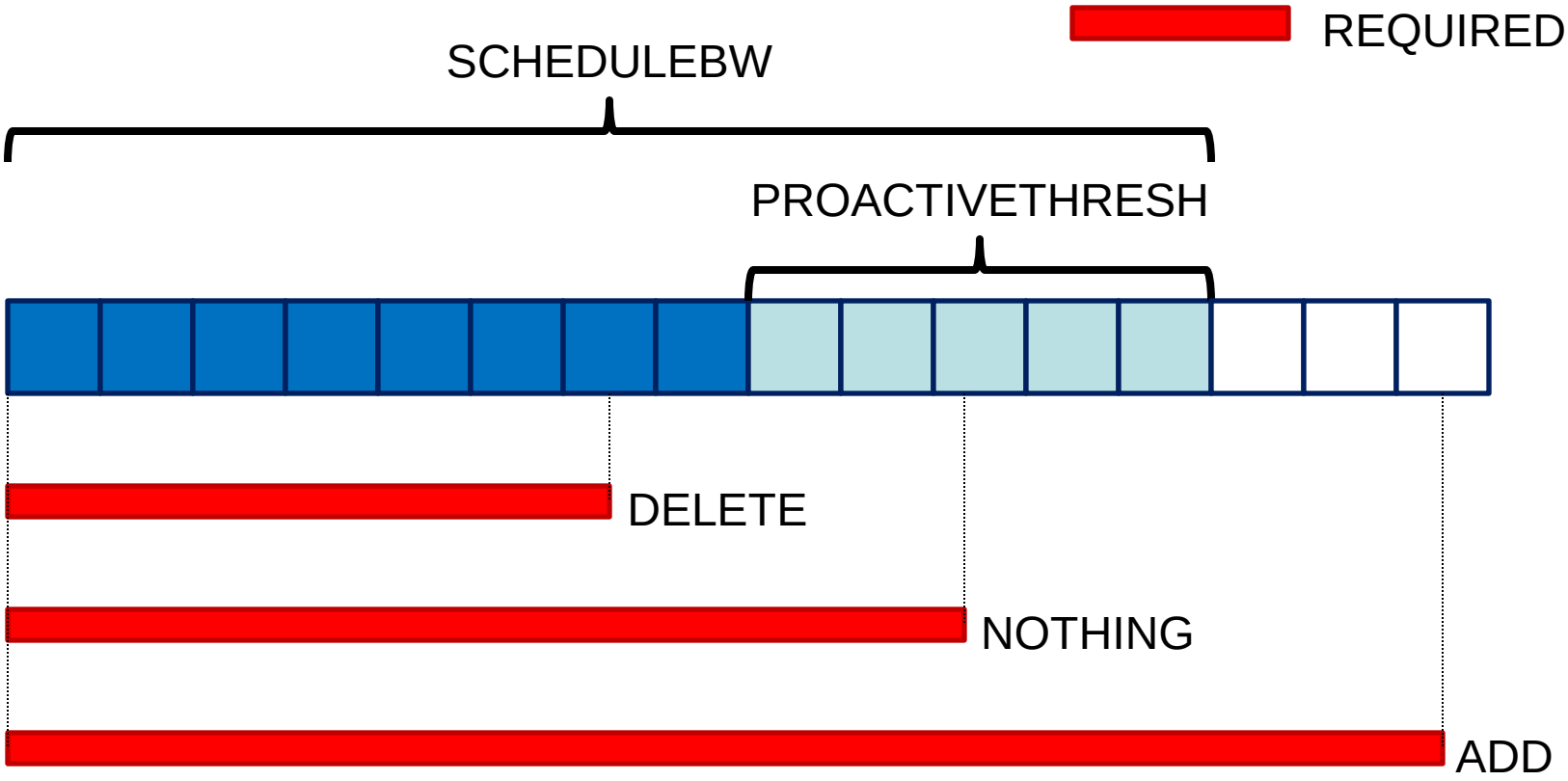
OTF events

- Creation of a new bundle (under discussion)
- No cells available for a given transmission
- A bundle is used less than a pre-established threshold
- A bundle is used over a pre-established threshold
- The bundle is deleted

INPUT from 6top

- CellList:
  - Per-cell statistics (also per-bundle statistics)
  - Accessed through the CoAP-YANG Model
  - However, softcells can be re-allocated in time by 6top itself
- MonitoringStatusList:
  - Per-neighbor and slotframe statistics
  - # hard and soft cells to a given node with a specific neighbor
  - QoS (expressible as PDR, ETX, RSSI, LQI) on the actual bandwidth, and the over-provisioned bandwidth
- NeighborList provides:
  - Per-neighbor statistics
  - E.g., if the LQI is under threshold, OTF may ask 6top to delete some cells, in order to reserve them for better-connected links
- QueueList:
  - Per-Queue statistics
  - Traffic load
  - OTF, based on queue statistics may trigger 6top creating or deleting soft cells

Allocation policies



- REQUIREDBW and PROACTIVETHRESH are implementation-dependant
- REQUIREDBW is related to the BW between two nodes, on any track or group of tracks, depending on the metric that is used.

OUTPUT to 6top

- CREATE.softcell
- DELETE.softcell
- OTF specifies the track the soft cell belongs to (i.e., best effort track, TrackID=00), but not its slotOffset and channelOffset
- If at least one cell on the best effort track already exists, the commands translate into INCREASE and DECREASE the bundle size, respectively

OTF external CoAP interface

- Enables algorithm selection
- Passes configuration parameters to the current algorithm

```
        +-----------------------------------------+
Header  | POST                                    |
        +-----------------------------------------+
Uri-Path| /6t/e/otf/alg                           |
        +-----------------------------------------+
Options | CBOR( {AlgNo: 123} )                    |
        +-----------------------------------------+
```

POST message to select algorithm

```
        +-----------------------------------------+
Header  | GET                                     |
        +-----------------------------------------+
Uri-Path| /6t/e/otf/alg                           |
        +-----------------------------------------+
Options | CBOR( {AlgNo: 123} )                    |
Options | Accept: application/cbor                |
        | Uri-Query: ABNF(AlgNo==123)             |
        +-----------------------------------------+
```

GET message to obtain algorithm number

```
        +-----------------------------------------+
Header  | POST                                    |
        +-----------------------------------------+
Uri-Path| /6t/e/otf/alg/par                       |
        +-----------------------------------------+
Options | CBOR( {Par: 0x1234} )                   |
        +-----------------------------------------+
```

POST message to send paramters to the algorithm

Any Other Business?

IEEE 802.15.4 Revision (complete in 2015)

Revision to 802.15.4-2011 with roll-ups of:

- 802.15.4e-2012 MAC TSCH, IE, LE, et al
- 802.15.4f-2012 PHY RFID
- 802.15.4g-2012 PHY SUN
- 802.15.4j-2013 PHY MBAN
- 802.15.4k-2013 PHY LECIM
- 802.15.4m-2014 PHY TVWS
- 802.15.4p-2014 PHY RCC

Also corrigenda as per 15-12-0367, changes requested by ETSI, and clarifications to such entities as timing for Acknowledgment frames, et al.

IEEE 802.15.4-Revision Comment Categorization

Clause 4 General Description:	46 comments
Clause 5 MAC Functional Description:	135 comments
Clause 6 MAC Frame Formats:	229 comments
Clause 7 MAC Services:	50 comments
Clause 8 Security:	67 comments
Clause 9 General PHY Requirements:	43 comments
Clause 10 PHY Services:	17 comments
Clause 11 O-QPSK PHY:	2 comments
Clause 12 BPSK PHY:	15 comments
Clause 13 ASK PHY	7 comments
Clause 14 CSS PHY	5 comments
Clause 15 HRP UWB PHY	32 comments
Clause 16 GFSK PHY	5 comments
Clause 17 MSK PHY	10 comments
Clause 19 SUN MR-FSK PHY	17 comments
Clause 20 SUN OFDM PHY	13 comments
TSCH (throughout draft)	28 comments

802.15.4 Revision Schedule

- Comment collection
  - Start — 23 May
  - End — 6 June
- Letter Ballot
  - Start — 14 June
  - End — 13 July (San Diego)
- Recirculations (2 or 3 15-day)
  - Start — ~~27 July~~ — 31 Aug
  - End — ~~14 Oct~~ — 24 Nov
- Sponsor Ballot (30-day)
  - Start — ~~17 Nov~~ — 1 Dec
  - Ends — ~~17 Dec~~ — 30 Dec
- Recirculations (2 10-day)
  - Start — ~~5 Jan 2015~~ — 5 Feb 2015
  - End — ~~2 Mar 2015~~ — 3 Apr 2015
- EC submittal — 13 March 2015 (Berlin)
- RevCom — 5 June 2015

Thank you!