IPv6 over the TSCH mode of IEEE 802.15.4

IETF 99 Prague
Monday 17 July 2017

Chairs:
Pascal Thubert
Thomas Watteyne

Etherpad for minutes:
http://etherpad.tools.ietf.org:9000/p/notes-ietf-99-6tisch?useMonospaceFont=true

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Agenda

13:30 Intro and Status (Chairs) [35min]

- Note-Well, Blue Sheets, Scribes, Agenda Bashing [5min]
- Status of the work; progress vs. charter [5min]
- Summary 1st F-Interop 6TiSCH Interoperability Event (Maria Rita Palattella) [10min]
- Summary OpenWSN hackathon (Tengfei Chang) [5min]

13:55 Dynamic Scheduling [25min]

- 6top protocol draft-ietf-6tisch-6top-protocol-07 (Xavi Vilajosana) [15min]
- Service Function 0 draft-ietf-6tisch-6top-sf0-05 (Diego Dujovne) [10min]

14:20 Security [30min]

- draft-ietf-6tisch-minimal-security-03 (Mališa Vučinić) [15min]
- update security DT and other derived work (Michael) [15min]
- draft-ietf-6tisch-dtsecurity-secure-join-01
- draft-richardson-6tisch-join-enhanced-beacon-01
- draft-richardson-6tisch-minimal-rekey-01

Agenda

14:50 Unchartered items, time permitting **[QS]**

- **Innovation Liaison Officer (Xavi Vilajosana)** **[5-10min]**
- **draft-duquennoy-6tisch-asf (Simon Duquennoy)** **[5-10min]**
- **draft-munoz-6tisch-examples-02 (Jonathan Muñoz)** **[5min]**
- **draft-papadopoulos-6tisch-pre-reqs-00 (Georgios Papadopoulos)** **[5min]**
- **draft-lijo-6lo-expiration-time-04 (Lijo Thomas)** **[5min]**

15:25 AOB **[…]**

Volunteers

- notetaker 1: Dominique Barthel
- notetaker 2: Francesca Palombini (?)
- notetaker 3: Tero Kivinen
- notetaker 4: Xavi Vilajosana
- notetaker x: Pascal Thubert
- Jabber scribe: Ines Robles, MCR

RFC 8137

Internet Engineering Task Force (IETF)
Request for Comments: 8137
Category: Informational
ISSN: 2070-1721

T. Kivinen
INSIDE Secure
P. Kinney
Kinney Consulting LLC

May 2017

IEEE 802.15.4 Information Element for the IETF

Abstract

IEEE Std 802.15.4 defines Information Elements (IEs) that can be used to extend 802.15.4 in an interoperable manner. The IEEE 802.15 Assigned Numbers Authority (ANA) manages the registry of the Information Elements. This document formulates a request for ANA to allocate a number from that registry for the IETF and describes how the IE is formatted to provide subtypes.

RFC 8180

Internet Engineering Task Force (IETF) X. Vilajosana, Ed.
Request for Comments: 8180 Universitat Oberta de Catalunya
BCP: 210 K. Pister
Category: Best Current Practice University of California Berkeley
ISSN: 2070-1721 T. Watteyne
Analog Devices
May 2017

Minimal IPv6 over the TSCH Mode of IEEE 802.15.4e (6TiSCH) Configuration

Abstract

This document describes a minimal mode of operation for an IPv6 over the TSCH mode of IEEE 802.15.4e (6TiSCH) network. This minimal mode of operation specifies the baseline set of protocols that need to be supported and the recommended configurations and modes of operation sufficient to enable a 6TiSCH functional network. 6TiSCH provides IPv6 connectivity over a Time-Slotted Channel Hopping (TSCH) mesh composed of IEEE Std 802.15.4 TSCH links. This minimal mode uses a collection of protocols with the respective configurations, including the IPv6 Low-Power Wireless Personal Area Network (6LoWPAN) framework, enabling interoperable IPv6 connectivity over IEEE Std 802.15.4 TSCH. This minimal configuration provides the necessary bandwidth for network and security bootstrapping and defines the proper link between the IETF protocols that interface to IEEE Std 802.15.4 TSCH. This minimal mode of operation should be implemented by all 6TiSCH-compliant devices.

Milestones

New milestones for secure join work?

Done	*Second submission of draft-ietf-6tisch-minimal to the IESG*
Done	*WG call to adopt draft-ietf-6tisch-6top-sf0*
Done	*WG call to adopt draft-ietf-6tisch-6top-sublayer*
Done	*ETSI 6TiSCH #3 plugtests*
Dec 2016	*Initial submission of draft-ietf-6tisch-6top-protocol to the IESG*
Dec 2016	*Initial submission of draft-ietf-6tisch-6top-sf0 to the IESG*
Dec 2016	*Evaluate WG progress, propose new charter to the IESG*
Apr 2017	*Initial submission of 6TiSCH terminology to the IESG*
Apr 2017	*Initial submission of 6TiSCH architecture to the IESG*
Dec 2017	*6TiSCH architecture and terminology in RFC publication queue*

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6TiSCH F-Interop PLUGTESTS REPORT

Maria Rita Palattella
Miguel Angel Reina Ortega

14–15 July 2017
Prague, Czech Republic

Overview of the Event

- Event organized by:
  - ETSI (European Telecommunications Standards Institute)
  - LIST (Luxembourg Institute of Science and Technology)

- Supporting Companies/Projects:
  - OpenMote (hardware, www.openmote.com)
  - OpenWSN (firmware www.openwsn.org)

- Event sponsored and funded by:
  - European Commission

- 16 Participating Companies
  - 7 observer companies

- 6 6TiSCH and 6 OSCoAP independent implementations

Participating companies

#	Company	#	Company
1	Analog Devices	9	INRIA and RISE SICS
2	August Cellars	10	LIST
3	Christian Amsüss	11	Sandelman Software Works
4	CISCO	12	Toshiba Research Europe Ltd
5	Endress+Hauser GmbH & Co. KG	13	Universidad Diego Portales
6	Ericsson	14	Universitat Oberta de Catalunya
7	Gridbee Communications	15	UPMC of Paris
8	INRIA	16	University of Science and Technology Beijing

Participants

Plugtests Agenda

F-Interop 6TiSCH Agenda (14-15 JULY 2017)		
Time	Friday 14	Saturday 15
08:00 11:00		TEST SESSIONS
11:00 13:00	SET-UP / REGISTRATION	
13:00 14:00	LUNCH BREAK	LUNCH BREAK
14:00 19:00	TEST SESSIONS	TEST SESSIONS
19:00 19:30	GOING TO THE RESTAURANT	WRAP UP / TEAR-DOWN
	DINNER	

Summary of Event Planning

- 1 preparation call
  - ETSI/LIST/Experts group led and organized
  - Collaborating Web conf (GotoMeeting) on 3.7.2017
  - Included Vendor Participants
- Test Plan Development
  - 6TiSCH -> Led by Thomas Watteyne, Tengfei Chang, Malisa Vucinic, and Maria Rita Palattella
  - 6TiSCH Online Testing Tools -> Remy Leone
  - OSCoAP -> Led by Malisa Vucinic ??? I don't know


ETSI
Meeting
1st F-Interop 6TiSCH Interoperability Event
6TiSCH
F-INTEROP
AQUILA

Results Reporting

- The results of each interoperability test session have been recorded in a dedicated web application software: the ETSI Test Report Tool (TRT)
  - After each test execution the interoperability result is agreed among all participants and then recorded
  - After each test session the report is submitted to ETSI

Test descriptions

6TiSCH Tests description (publicly available)

Testing: Synch, Minimal, 6top, L2 security, Secure joining

1 TD_6TiSCH_SYN_01
2 TD_6TiSCH_MINIMAL_01
3 TD_6TiSCH_MINIMAL_02
4 TD_6TiSCH_MINIMAL_03
5 TD_6TiSCH_MINIMAL_04
6 TD_6TiSCH_MINIMAL_05
7 TD_6TiSCH_MINIMAL_06
8 TD_6TiSCH_L2SEC_01
9 TD_6TiSCH_SECJOIN_01
10 TD_6TiSCH_SECJOIN_02
11 TD_6TiSCH_SECJOIN_03
12 TD_6TiSCH_SECJOIN_04
13 TD_6TiSCH_6P_01
14 TD_6TiSCH_6P_02
15 TD_6TiSCH_6P_03
16 TD_6TISCH_6P_04

6TiSCH Tests Outcomes 1/2

Total	Passed	Failed	Not Applicable
156	85	14	57
	85,9 %	**14,1 %**	36,5%

- 6TiSCH Synchronization: 100% interoperability
- 6TiSCH MINIMAL: 85% interoperability
  - Aspects to be improved:
    - XXX
    - YYY

6TiSCH Tests Outcomes 2/2

- 6TiSCH L2SEC: 100% interoperability
- 6TiSCH SECJOIN: 0% interoperability
  - 9 tests -> all NA – Q: were the results well reported??
- 6P: 50% interoperability
  - Aspects to be improved:
    - XXX
    - YYY

F-Interop 6TiSCH Online testing tool

DEMO: shall we add some screen shot?
Remy, can you help?

Conclusions – 1st 6TiSCH F-Interop Plugtests

- Conclusion
  - Great success! Enabled to detect standard gaps using real implementations, e.g, …
  - Progress through implementation and real testing.

- Recommendations for future:
  - Improve Format of the Plugtests: promote use of online tools.
  - Organize a fully remote F-Interop 6TiSCH Plugtests

ETSI

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THANK YOU!

Maria Rita Palattella
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Summary OpenWSN hackathon

Tengfei Chang

draft-ietf-6tisch-6top-protocol

Qin Wang (Ed.)
Xavier Vilajosana
Thomas Watteyne

Status

- Last Update: 27 June 2017
- Version: 07
- Status: Very stable draft.
- Implementations exist
- Interoperability tests at the ETSI Plugtest
- Next
  - WGLC

Minor Changes

- Reviewed return codes;
  - Inverting NORES and BUSY error codes for concurrent transactions.
  - Changing error code from RESET to CELLLIST_ERR when deleting unscheduled cells.
  - Adding missing implementations.
- Received and addressed WG reviewers comments:
  - Jonathan Munoz
  - Charlie Perkins
- Since last IETF meeting:
  - Reordered sections. Merged protocol behavior and command description
  - Renamed STATUS to COUNT
  - Written-out IANA section

Plugtest Outcomes

- 6P ADD
  - Always returns SUCCESS.
  - Cell List Size tells if success, partial success or failure to add
  - Proposed Change:
    - Use return code SUCCESS when fully or partially allocated
      - List will tell if total or partial
    - Use NO_RES code as a return code if none of the cells could be allocated.

Plugtest Outcomes

- Correcting GEN errors without CLEAR.
  - Problem: CLEAR is costly and GEN error comes from previous transaction.
  - Before CLEAR we can do some things which require some small change:
  - Proposal:
    - In LIST and COUNT operations.
      - Do GEN checking
      - BUT also return the results of the operation.
    - Add text in 4.4.7.3 (see next slide)

Plugtest Outcomes

When a schedule generation inconsistency is detected:

- If the code of the 6P Request is different from CLEAR, the node MUST reply with error code GEN_ERR.
- If the code of the 6P Request is COUNT or LIST, the node MUST execute the operations and return the requested values. This can be used by the SF to correct the inconsistency.
- If the code of the 6P Request is CLEAR, the schedule generation inconsistency MUST be ignored.

Next Steps

- Clarify use of IETF IE together with 6top Information Element
- Resolve Plugtest outcomes.
- WGLC?

draft-ietf-6tisch-6top-sf0-05

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

Status

- Goal: Dynamic and Distributed Scheduling Function Zero for 6tisch
- News: Revision from comments
- Next: ?

Tickets

#Ticket 66, 67, 70, 71, 72, 74, 76, 78, 79, 80, 81, 84, 86, 87, 93, 94, 95: Typos, expressions, deleted text.

#Ticket 67: Transferred to sections from Intro:

- Cell Estimation Algorithm
- Allocation Policy

Tickets

#Ticket 68: Difference between allocated and used cells

- Allocated cell **reserves a resource**
- Used cell is when the **resource is filled with a packet**.

- We count those used **during the last slotframe**.
- SF0 **only allocates TX** cells to the neighbor.
- There are **no shared cells** allocated by SF0.

Tickets

#Ticket 69: Definition of overprovision

Overprovisioning:

- Is the action and effect of **increasing a value representing an amount of resources**.

- In the case of SF0, overprovisioning is done as **a provision to reduce traffic variability effects on packet loss**, to the expense of **artificially allocating a number of cells.**

Tickets

#Ticket 75: Relocation

- It is defined on section **4.3.3 of the 6P draft**
- SF0 **only decides when** the relocation mechanism is activated.
- The replacement cells are **selected randomly** among the available ones.
- There are **no retransmissions** on SF0. If the allocation fails and the bad PDR condition prevails, retriggered on the next slotframe.

Tickets

#Ticket 77: Triggering events

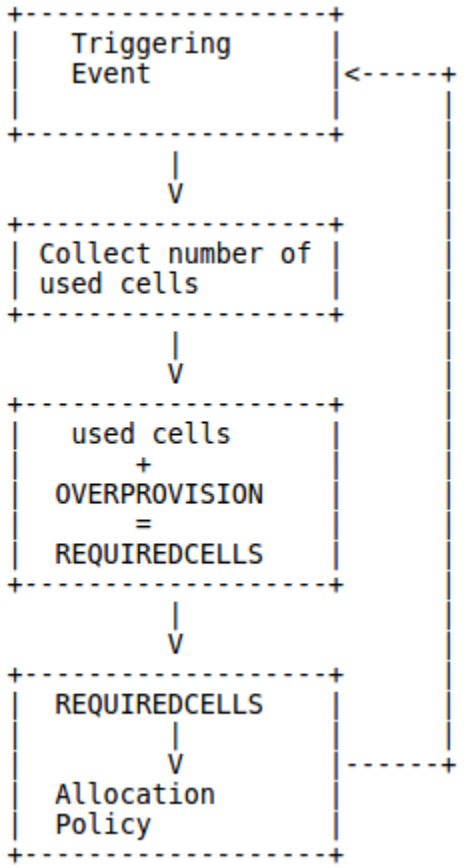
- There is only one triggering event left: When there is a **change in the number of used cells** towards any of the neighbours

#Ticket 82, 83: Cell Estimation Algorithm

- Collect the number of used cells **towards a particular neighbor during the last slotframe**

Tickets

#Ticket 85: Flow diagram for Cell Estimation Algorithm



Tickets

#Ticket 88: OVERPROVISION value

- It is implementation-specific
- A value of 0 (Zero):
  - **Case 1:** The number of scheduled cells is equal to the number of used cells: the algorithm cannot detect an increase in cell usage. Since there is no space for new packets to the neighbour, they are dropped at the queue.
  - **Case 2:** The number of scheduled cells is higher than the number of used cells: the algorithm detects an increase in cell usage. However, the number of used cells will tend to fill the scheduled cells and it will fall into Case 1.
- Conclusion: Zero means that the number of scheduled cells towards a neighbor **will not grow on top of the initial value**.

Tickets

#Ticket 89: OVERPROVISION relationship with SF0THRESH

- There is **no intended relationship**.
- They are independent on purpose to keep modularity.
- The Cell Estimation Algorithm decides **how many** cells to schedule
- The Allocation Policy decides **when** to schedule
- Along the history of SF0, we have changed the Cell Estimation Algorithm without changing the Allocation Policy. This results in complete separation between the two blocks

Tickets

#Ticket 90: CellList error handling

- SF0 **does not handle errors**. If a transaction does not succeed, it will be triggered on the next slotframe if the change in resources is still not satisfied.
- The cells on the CellList will be **randomly chosen**. Although we can add an advantage from the CellList response, we try to keep SF0 simple.

Tickets

#Ticket 91: 6P Timeout value

- SF0 has now a **per-transaction timeout value** which is implementation-specific.

#Ticket 92: PDR Definition

- Packet Delivery Rate (PDR) **is calculated per cell**, as the **percentage** of acknowledged packets, for the **last 10 packet transmission attempts**. There is no retransmission policy on SF0.

Tickets

#Ticket 96: Allocation Policy mechanism

- Initial Value of SCHEDULEDCELLS:

  Node Behavior at Boot

  – "In order to define a known state after the node is restarted, a CLEAR command is issued to each of the neighbor nodes to enable a new allocation process and **at least a SF0THRESH number of cells MUST be allocated to each of the neighbours."**

  – SFOTHRESH value is implementation-specific

- There is **no formula** to determine the number of cells to ADD or DELETE. The number of cells to ADD or DELETE is implementation-specific
- SF0THRESH is supposed to be a **fixed value**. A variable SF0THRESH has not been considered for the draft to keep it simple.

SF0 / Questions

Questions?

Diego Dujovne
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Faculty of Engineering
School of Informatics and Telecommunications
Santiago, Chile

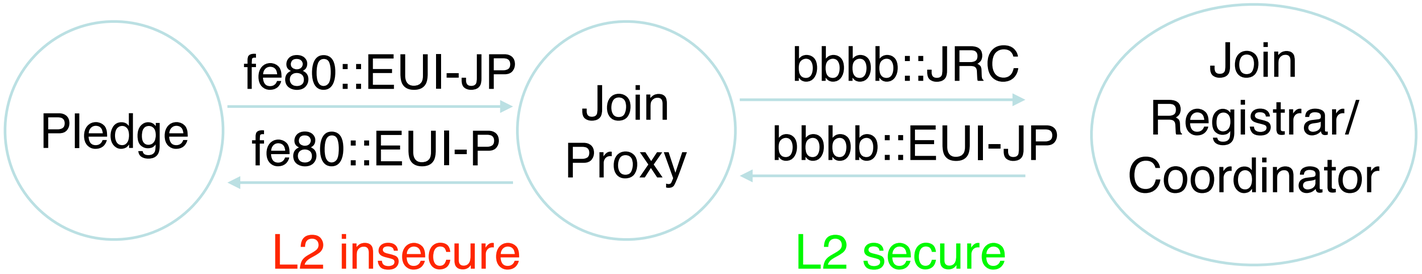
draft-ietf-6tisch-minimal-security

Mališa Vučinić, Inria
Jonathan Simon, Analog Devices
Kris Pister, UC Berkeley
Michael Richardson, Sandelman Software Works

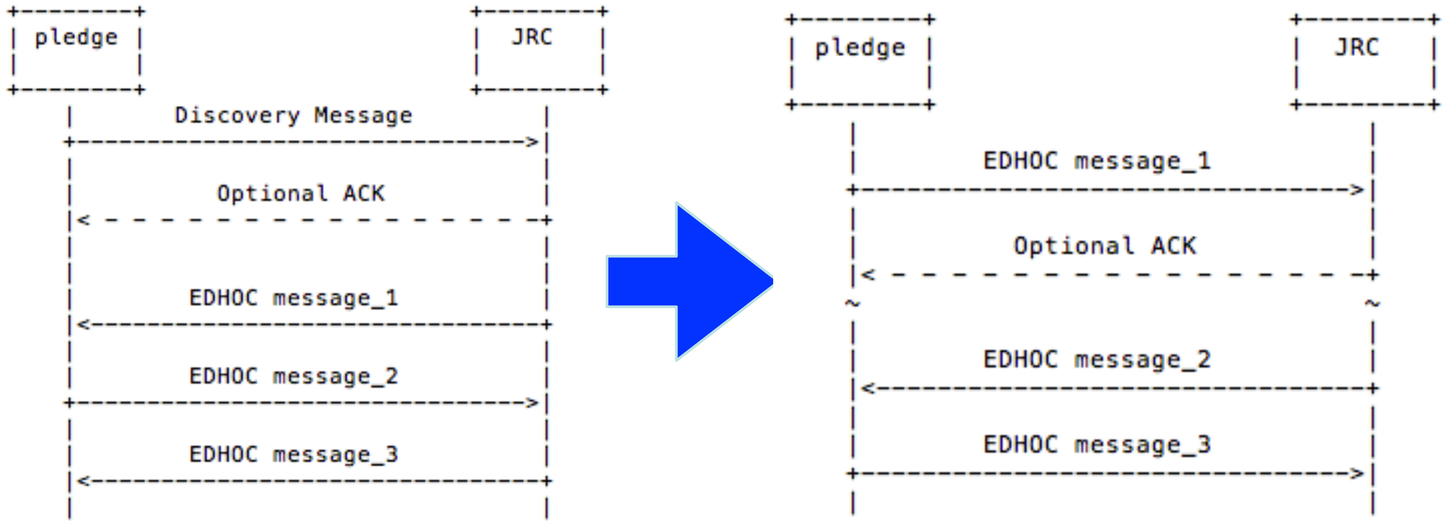
Status

- News
  - draft-ietf-6tisch-minimal-security-03
  - Published on June 15th 2017
- Implementation in OpenWSN completed
  - PSK variant tested during plugtest
- Summary of updates in -03

Communication Overview



Update #1: Security Handshake



- Optional with PSKs
- Mandatory with asymmetric keys

Update #2: How pledge learns JRC address

- Join Proxy (JP) statelessly forwards to JRC
- How JP knows the address of JRC?
  - Learns at join time when it acted as a pledge
  - Join Response now contains the address
  - Omitted if JRC is co-located with DAG root, implied from DODAG ID
  - Assumption: DAG root pre-configured with the address

Update #3: Mandatory to Implement Algorithms

- AEAD algorithm:
  - AES_CCM_16_64_128 from COSE
  - 8 byte authentication tag
  - Corresponds to 802.15.4 CCM* in nonce length
- Hash:
  - SHA-256
- Asymmetric:
  - P-256 Elliptic Curve (secp256r1)
  - ECDSA with SHA-256 signature algorithm

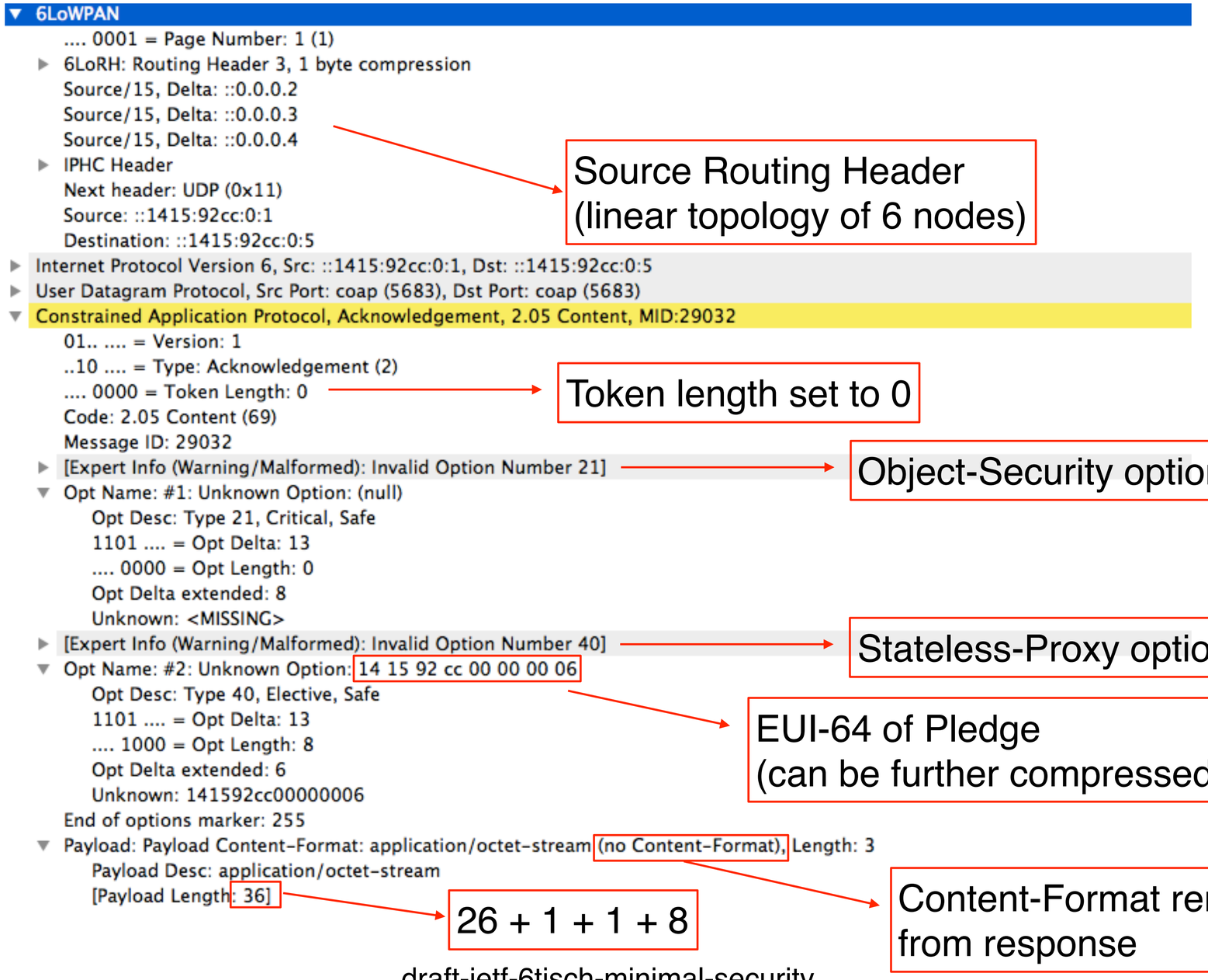
Implementation Status

- In OpenWSN ecosystem with Pre-Shared Keys:
  - draft-ietf-core-object-security-03 in Python
  - draft-ietf-6tisch-minimal-security-03 in Python (JRC)
  - draft-ietf-core-object-security-03 in C
  - draft-ietf-6tisch-minimal-security-03 in C (Pledge and Join Proxy)
- In Contiki:
  - draft-ietf-core-object-security-03
  - draft-ietf-6tisch-minimal-security-03 (ongoing)
  - draft-selander-ace-cose-ecdhe-07 (ongoing)

Implementation Experience

- Issue #1: Problems to fit Join Response in 127 bytes with multiple hops
  - Bottleneck is the link from DAG root to first hop
  - Due to the source routing header, there is a limit on max depth of the network without fragmentation
- Issue #2: Policy by which JP should accept insecure L2 frames from pledges
- Additional clarifications in the document needed on hooks to lower layers

Issue #1: Packet size



draft-ietf-6tisch-minimal-security

Issue #1: Packet size

- Join Response without short and JRC's address

```
81                                      # array(1) # OVERHEAD
   81                                   # array(1) # OVERHEAD
      A3                                # map(3)   # OVERHEAD
         01                             # unsigned(1) # KEY TYPE
         04                             # unsigned(4) # SYMMETRIC
         02                             # unsigned(2) # KEY ID
         41                             # bytes(1)    # OVERHEAD
            01                          # "\x01"      # KEY ID VALUE
         20                             # negative(0) # KEY
         50                             # bytes(16)   # OVERHEAD
            11111111111111111111111111111111 # KEY VALUE
```

- 26 bytes to encode key (16 bytes) and key ID (1 byte)
- Uses CBOR + COSE structures
- Can be optimized with compressed COSE approach like used in OSCOAP

Issue #2: Join Proxy Policy

- Proposal: Provide a mechanism to accept insecure L2 packets at JP only upon a trigger (i.e. DAG root button press)

- Needed signal that join is allowed in EB
  - One option to use draft-richardson-6tisch-join-enhanced-beacon
  - Another option to reserve 0xFF of Join Metric in EBs to signal that node will NOT accept insecure L2 frames
    - Upon a trigger, fill Join Metric with the value according to RFC8180 (calculated from the DAG rank)
    - Expire upon a timeout

Conclusion

- PSK variant stable and implementation ready
- Settled down for EDHOC roles in the asymmetric variant, yet to implement
- Implementations of PSK variant available
- Will publish -04 with implementation experience before WGLC
- Reviews welcome

Update security DT and other derived work

draft-ietf-6tisch-dtsecurity-secure-join-01

draft-richardson-6tisch-join-enhanced-beacon-01

draft-richardson-6tisch-minimal-rekey-01

Michael Richardson

Innovation Liaison Officer

Xavi Vilajosana

draft-duquennoy-6tisch-asf

Simon Duquennoy, Inria
Xavi Vilajosana, UOC
Thomas Watteyne, Inria

draft-duquennoy-6tisch-asf

Simon Duquennoy, Inria
Xavi Vilajosana, UOC
Thomas Watteyne, Inria

Overview

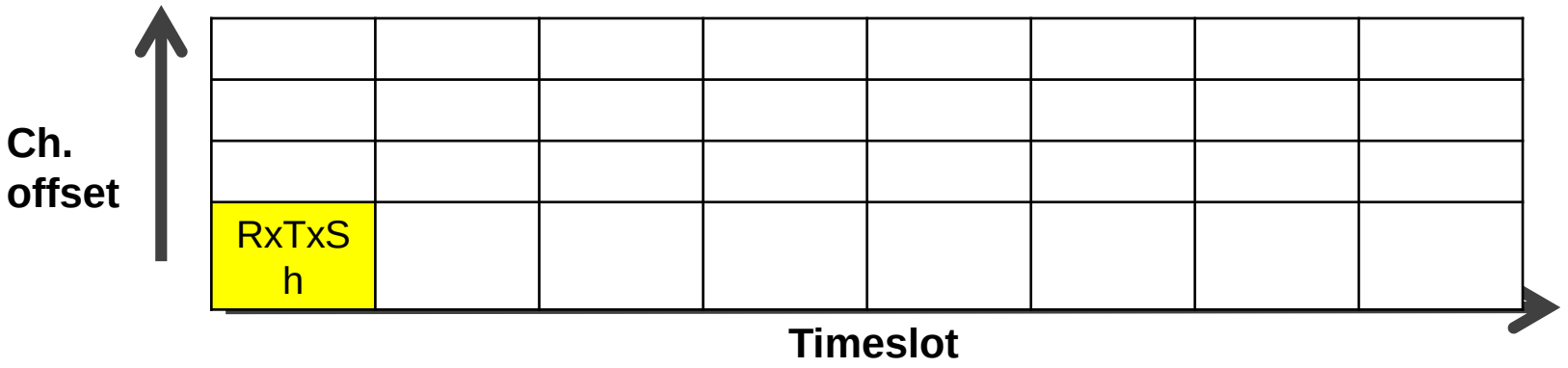
- ASF: Autonomous Scheduling Function
- 1) Autonomous slotframes
  - Slots based on a hash of neighbor's MAC address
  - Slots added/removed locally, no extra signaling
- 2) Slotframe per traffic plane
  - E.g. one for TSCH sync, one for RPL control, one for application
  - The length of each slotframe dictates per-plane capacity

Application and Limitations

- High reliability over distributed routing
  - Schedule adapts instantly to what e.g. RPL decides
  - 5 nines demonstrated in 100+ node testbeds
- No stringent energy/latency requirements
  - Cells are not cascaded along the path
  - Only shared slots
  - Schedule is provisioned for worst case

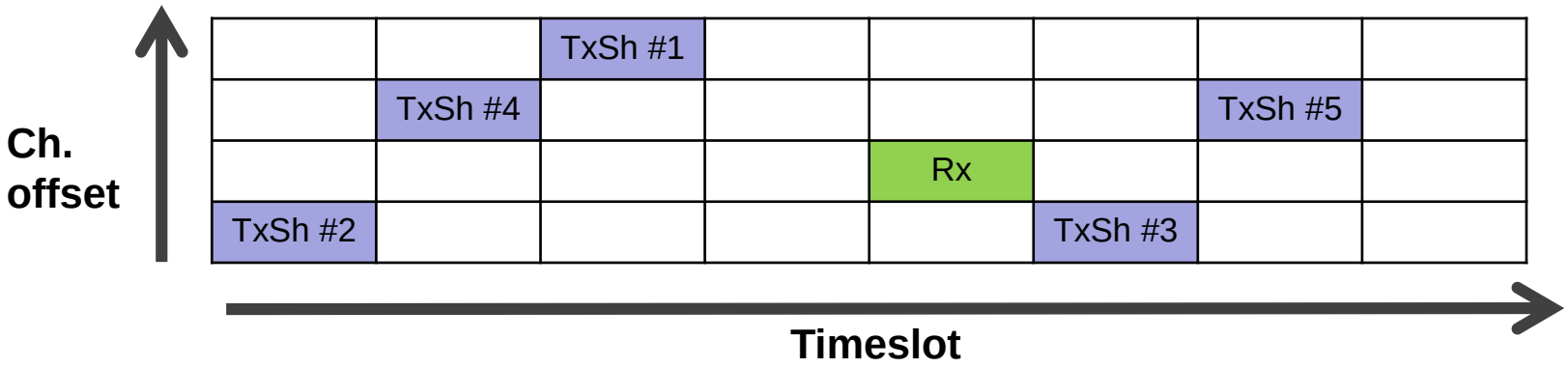
1/3: Rendez-vous slotframe

- Equivalent to 6tisch-minimal RFC 8180
- Used for rendez-vous
- E.g. RPL control, 6LoWPAN-ND, etc.



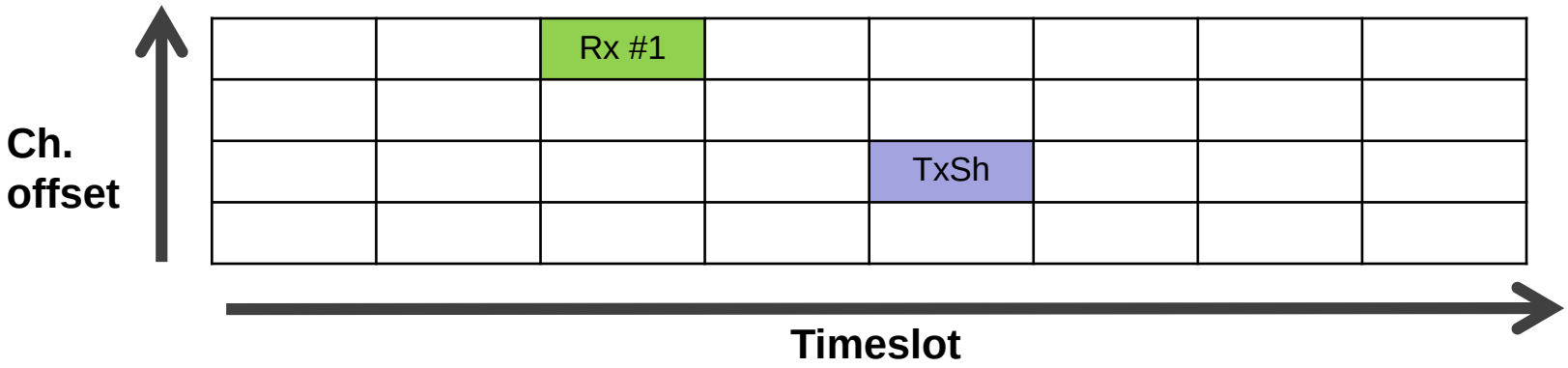
2/3 Receiver-based slotframe

- Nodes have one fixed Rx cell
- Nodes have one Tx (Shared) cell for each neighbor (IPv6 nbr cache)
- E.g. use for unicast to any neighbor



3/3 Sender-based slotframe

- Nodes have one fixed Tx (Shared) cell
- Nodes have one Rx cell for each neighbor (IPv6 nbr cache)
- E.g. use for received from a privileged neighbor, e.g. TSCH time source



Putting it all together

- Each slotframe takes care of a traffic plane (traffic filter)
- Each slotframe uses a different subset of ch. offset
- As slotframes repeat, cells will overlap
  - Apply standard IEEE slot precedence
  - Slotframe len that are co-prime are preferred

Draft Status

- Description of the slotframe types
- Definition of cell coordinates (hash of MAC)
- Example schedule with 4 slotframes
- Definition of configuration parameters
- Open issue: configuration discovery
  - Proposal: new EB IEs
  - Other option: 6P commands (not preferred because adds a transition state between minimal and ASF)

Feedback?

- On the nature of ASF and its slotframes?
- On what the draft should cover and not?
- On configuration parameters?
- On configuration discovery?
- Anything else?

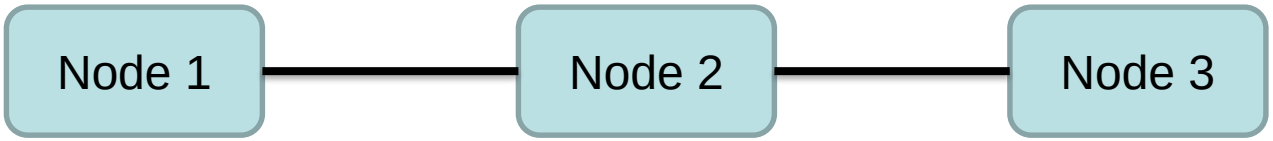
draft-munoz-6tisch-examples-03

Jonathan Munoz
Emmanuel Riou
Dominique Barthel

draft-munoz-6tisch-examples-03

- Goal
  - Informational document
  - Example of every 6TiSCH frame.

- Tools and setup
  - 3 nodes running OpenWSN in simulation mode and Wireshark (after 9th July 17)



draft-munoz-6tisch-examples-03

6TiSCH frame example: [ping 3] ICMPv6 echo request 1->2

```
IEEE 802.15.4 Data, Dst: 14:15:92:cc:00:00:00:02,
                    Src: 14:15:92:cc:00:00:00:01
Frame Control Field: 0xec21, Frame Type: Data
    .... .... .... .001 = Frame Type: Data (0x0001)
    .... .... .... 0... = Security Enabled: False
    .... .... ...0 .... = Frame Pending: False
    .... .... ..1. .... = Acknowledge Request: True
    .... .... .0.. .... = Intra-PAN: False
    .... ...0 .... .... = Sequence Number Suppression: False
    .... ..0. .... .... = Information Elements present: False
    .... 11.. .... .... = Destination Addressing Mode:
                          Long/64-bit (0x03)
    ..10 .... .... .... = Frame Version: 2
    11.. .... .... .... = Source Addressing Mode:
                          Long/64-bit (0x03)

Sequence Number: 34
Destination PAN: 0xcafe
Destination: 14:15:92:cc:00:00:00:02 (14:15:92:cc:00:00:00:02)
Extended Source: 14:15:92:cc:00:00:00:01
(14:15:92:cc:00:00:00:01)
FCS: 0x0366 (Correct)
6LoWPAN
.... 0001 = Page Number: 1
6LoRH: Routing Header 3, 8 byte compression
    100. .... = Routing Header 6lo: Critical Routing Header
(0x04)
    ...0 0000 .... .... = 6loRH Hop Number - 1: 0x0000
    .... .... 0000 0011 = 6loRH Type: Routing Header 3,
                          8 byte compression (0x0003)
Source/8, Delta: ::1415:92cc:0:2
```

```
IPHC Header
    011. .... = Pattern: IP header compression (0x03)
    ...1 1... .... .... = Traffic class and flow label:
Version, traffic class, and flow label compressed (0x0003)
    .... .0.. .... .... = Next header: Inline
    .... ..00 .... .... = Hop limit: Inline (0x0000)
    .... .... 0... .... = Context identifier extension: False
    .... .... .0.. .... = Source address compression:
Stateless
    .... .... ..00 .... = Source address mode: Inline (0x0000)
    .... .... .... 0... = Multicast address compression: False
    .... .... .... .0.. = Dest address compression: Stateless
    .... .... .... ..00 = Dest address mode: Inline (0x00)
Next header: ICMPv6 (0x3a)
Hop limit: 64
Source: bbbb::1
Destination: bbbb::1415:92cc:0:3
Internet Protocol Version 6, Src: bbbb::1, Dst:
bbbb::1415:92cc:0:3
0110 .... = Version: 6
.... 0000 0000 .... .... .... .... .... = Traffic class:
                                  0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 0000 00.. .... .... .... .... .... = Differentiated
                                 Services Codepoint: Default (0)
    .... .... ..00 .... .... .... .... .... = Explicit
Congestion Notification: Not ECN-Capable Transport (0)
.... .... .... 0000 0000 0000 0000 0000 = Flowlabel:
0x00000000
Payload length: 18
Next header: ICMPv6 (58)
Hop limit: 64
Source: bbbb::1
Destination: bbbb::1415:92cc:0:3
Internet Control Message Protocol v6
Type: Echo (ping) request (128)
Code: 0
Checksum: 0x13f9 [correct]
Identifier: 0x3943
Sequence: 1
```

6TiSCH frame example: [ping 3] ICMPv6 echo request 2->3

```
IEEE 802.15.4 Data, Dst: 14:15:92:cc:00:00:00:03,
                    Src: 14:15:92:cc:00:00:00:02
Frame Control Field: 0xec21, Frame Type: Data
    .... .... .... .001 = Frame Type: Data (0x0001)
    .... .... .... 0... = Security Enabled: False
    .... .... ...0 .... = Frame Pending: False
    .... .... ..1. .... = Acknowledge Request: True
    .... .... .0.. .... = Intra-PAN: False
    .... ...0 .... .... = Sequence Number Suppression: False
    .... ..0. .... .... = Information Elements present: False
    .... 11.. .... .... = Destination Addressing Mode:
                          Long/64-bit (0x03)
    ..10 .... .... .... = Frame Version: 2
    11.. .... .... .... = Source Addressing Mode:
                          Long/64-bit (0x03)
Sequence Number: 35
Destination PAN: 0xcafe
Destination: 14:15:92:cc:00:00:00:03 (14:15:92:cc:00:00:00:03)
Extended Source: 14:15:92:cc:00:00:00:02
(14:15:92:cc:00:00:00:02)
FCS: 0x793f (Correct)
6LoWPAN
IPHC Header
    011. .... = Pattern: IP header compression (0x03)
    ...1 1... .... .... = Traffic class and flow label:
Version, traffic class, and flow label compressed (0x0003)
    .... .0.. .... .... = Next header: Inline
    .... ..00 .... .... = Hop limit: Inline (0x0000)
    .... .... 0... .... = Context identifier extension: False
    .... .... .0.. .... = Source address compression:
Stateless
 .... .... ..00 .... = Source address mode: Inline (0x0000)
    .... .... .... 0... = Multicast address compression: False
    .... .... .... .0.. = Dest address compression: Stateless
    .... .... .... ..00 = Dest address mode: Inline (0x0000)
Next header: ICMPv6 (0x3a)
Hop limit: 64
Source: bbbb::1
Destination: bbbb::1415:92cc:0:3
Internet Protocol Version 6, Src: bbbb::1, Dst:
bbbb::1415:92cc:0:3
0110 .... = Version: 6
.... 0000 0000 .... .... .... .... .... = Traffic class:
                                0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 0000 00.. .... .... .... .... .... = Differentiated
                                Services Codepoint: Default (0)
    .... .... ..00 .... .... .... .... .... = Explicit
Congestion Notification: Not ECN-Capable Transport (0)
.... .... .... 0000 0000 0000 0000 0000 = Flowlabel:
0x00000000
Payload length: 18
Next header: ICMPv6 (58)
Hop limit: 64
Source: bbbb::1
Destination: bbbb::1415:92cc:0:3
Internet Control Message Protocol v6
Type: Echo (ping) request (128)
Code: 0
Checksum: 0x13f9 [correct]
Identifier: 0x3943
Sequence: 1
```

6TiSCH frame example: [ping 3] ICMPv6 echo reply 3->2 [1/2]

```
IEEE 802.15.4 Data, Dst: 14:15:92:cc:00:00:00:02,
                    Src: 14:15:92:cc:00:00:00:03
Frame Control Field: 0xec21, Frame Type: Data
    .... .... .... .001 = Frame Type: Data (0x0001)
    .... .... .... 0... = Security Enabled: False
    .... .... ...0 .... = Frame Pending: False
    .... .... ..1. .... = Acknowledge Request: True
    .... .... .0.. .... = Intra-PAN: False
    .... ...0 .... .... = Sequence Number Suppression: False
    .... ..0. .... .... = Information Elements present: False
    .... 11.. .... .... = Destination Addressing Mode:
                          Long/64-bit (0x03)
    ..10 .... .... .... = Frame Version: 2
    11.. .... .... .... = Source Addressing Mode:
                          Long/64-bit (0x03)
Sequence Number: 23
Destination PAN: 0xcafe
Destination: 14:15:92:cc:00:00:00:02 (14:15:92:cc:00:00:00:02)
Extended Source: 14:15:92:cc:00:00:00:03
(14:15:92:cc:00:00:00:03)
FCS: 0x84f7 (Correct)
6LoWPAN
.... 0001 = Page Number: 1
6LoRH: Routing Protocol Information
    100. .... = Routing Header 6lo: Critical Routing Header
(0x04)
    ...0 .... .... .... = Packet direction:
                          UP false, DOWN true: False
    .... 0... .... .... = Error detected: False
    .... .0.. .... .... = No link to destination: False
    .... ..1. .... .... = Context identifier extension: True
    .... ...1 .... .... = Context identifier extension: True
    .... .... 0000 0101 = 6loRH Type: Routing Protocol
Information
 RPL Instance: 0x00
    Sender Rank: 0x07
IPHC Header
    011. .... = Pattern: IP header compression (0x03)
    ...1 1... .... .... = Traffic class and flow label:
Version, traffic class, and flow label compressed (0x03)
    .... .0.. .... .... = Next header: Inline
    .... ..10 .... .... = Hop limit: 64 (0x0002)
    .... .... 0... .... = Context identifier extension: False
    .... .... .0.. .... = Source address compression:
Stateless
    .... .... ..01 .... = Source address mode: 64-bits inline
(0x01)
    .... .... .... 0... = Multicast address compression: False
    .... .... .... .0.. = Dest address compression: Stateless
    .... .... .... ..01 = Dest address mode: 64-bits inline
(0x01)
    [Source context: fe80::]
    [Destination context: fe80::]
Next header: ICMPv6 (0x3a)
Source: fe80::1415:92cc:0:3
Destination: fe80::1
Internet Protocol Version 6, Src: fe80::1415:92cc:0:3, Dst:
fe80::1
0110 .... = Version: 6
.... 0000 0000 .... .... .... .... .... = Traffic class:
                                  0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 0000 00.. .... .... .... .... .... = Differentiated
                                 Services Codepoint: Default (0)
    .... .... ..00 .... .... .... .... .... = Explicit
Congestion Notification: Not ECN-Capable Transport (0)
.... .... .... 0000 0000 0000 0000 0000 = Flowlabel:
0x00000000
```

6TiSCH frame example: [ping 3] ICMPv6 echo reply 3->2 [2/2]

```
Payload length: 18
Next header: ICMPv6 (58)
Hop limit: 64
Source: fe80::1415:92cc:0:3
Destination: fe80::1
Internet Control Message Protocol v6
Type: Echo (ping) reply (129)
Code: 0
Checksum: 0x12f9 [incorrect, should be 0x8d6e]
    [Expert Info (Warn/Checksum): ICMPv6 Checksum Incorrect
Identifier: 0x3943
Sequence: 1
Data (10 bytes)
0000  00 01 02 03 04 05 06 07 08 09
        Data: 00010203040506070809
        [Length: 10]
```

6TiSCH frame example: [ping 3] ICMPv6 echo reply 2->1 [1/2]

```
IEEE 802.15.4 Data, Dst: 14:15:92:cc:00:00:00:01,
                    Src: 14:15:92:cc:00:00:00:02
Frame Control Field: 0xec21, Frame Type: Data
    .... .... .... .001 = Frame Type: Data (0x0001)
    .... .... .... 0... = Security Enabled: False
    .... .... ...0 .... = Frame Pending: False
    .... .... ..1. .... = Acknowledge Request: True
    .... .... .0.. .... = Intra-PAN: False
    .... ...0 .... .... = Sequence Number Suppression: False
    .... ..0. .... .... = Information Elements present: False
    .... 11.. .... .... = Destination Addressing Mode:
                          Long/64-bit (0x03)
    ..10 .... .... .... = Frame Version: 2
    11.. .... .... .... = Source Addressing Mode:
                          Long/64-bit (0x03)
Sequence Number: 36
Destination PAN: 0xcafe
Destination: 14:15:92:cc:00:00:00:01 (14:15:92:cc:00:00:00:01)
Extended Source: 14:15:92:cc:00:00:00:02
(14:15:92:cc:00:00:00:02)
FCS: 0x7dbc (Correct)
6LoWPAN
.... 0001 = Page Number: 1
6LoRH: Routing Protocol Information
    100. .... = Routing Header 6lo: Critical Routing Header
(0x04)
    ...0 .... .... .... = Packet direction:
                          UP false, DOWN true: False
    .... 0... .... .... = Error detected: False
    .... .0.. .... .... = No link to destination: False
    .... ..1. .... .... = Context identifier extension: True
    .... ...1 .... .... = Context identifier extension: True
    .... .... 0000 0101 = 6loRH Type: Routing Protocol
Information
  RPL Instance: 0x00
    Sender Rank: 0x03
IPHC Header
    011. .... = Pattern: IP header compression (0x03)
    ...1 1... .... .... = Traffic class and flow label:
Version, traffic class, and flow label compressed (0x0003)
    .... .0.. .... .... = Next header: Inline
    .... ..10 .... .... = Hop limit: 64 (0x0002)
    .... .... 0... .... = Context identifier extension: False
    .... .... .0.. .... = Source address compression:
Stateless
    .... .... ..01 .... = Source address mode: 64-bits inline
(0x01)
    .... .... .... 0... = Multicast address compression: False
    .... .... .... .0.. = Dest address compression: Stateless
    .... .... .... ..01 = Dest address mode: 64-bits inline
(0x01)
    [Source context: fe80::]
    [Destination context: fe80::]
Next header: ICMPv6 (0x3a)
Source: fe80::1415:92cc:0:3
Destination: fe80::1
Internet Protocol Version 6, Src: fe80::1415:92cc:0:3, Dst:
fe80::1
0110 .... = Version: 6
.... 0000 0000 .... .... .... .... .... = Traffic class:
                                  0x00 (DSCP: CS0, ECN: Not-ECT)
    .... 0000 00.. .... .... .... .... .... = Differentiated
                                 Services Codepoint: Default (0)
    .... .... ..00 .... .... .... .... .... = Explicit
Congestion Notification: Not ECN-Capable Transport (0)
```

6TiSCH frame example: [ping 3] ICMPv6 echo reply 2->1 [2/2]

```
.... .... .... 0000 0000 0000 0000 0000 = Flowlabel:
0x00000000
Payload length: 18
Next header: ICMPv6 (58)
Hop limit: 64
Source: fe80::1415:92cc:0:3
Destination: fe80::1
Internet Control Message Protocol v6
Type: Echo (ping) reply (129)
Code: 0
Checksum: 0x12f9 [incorrect, should be 0x8d6e]
    [Expert Info (Warn/Checksum): ICMPv6 Checksum Incorrect]
Identifier: 0x3943
Sequence: 1
Data (10 bytes)

0000  00 01 02 03 04 05 06 07 08 09
    Data: 00010203040506070809
    [Length: 10]
```

Questions?

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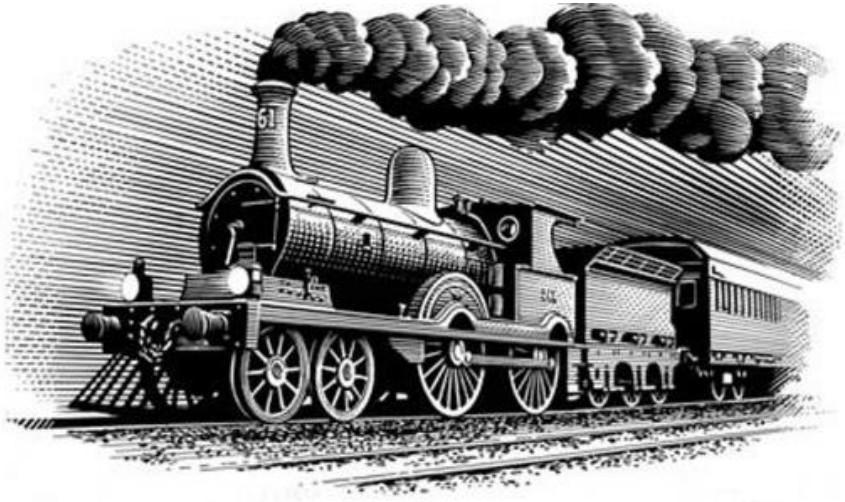
Exploiting Packet Replication and Elimination in Complex Tracks in 6TiSCH LLNs

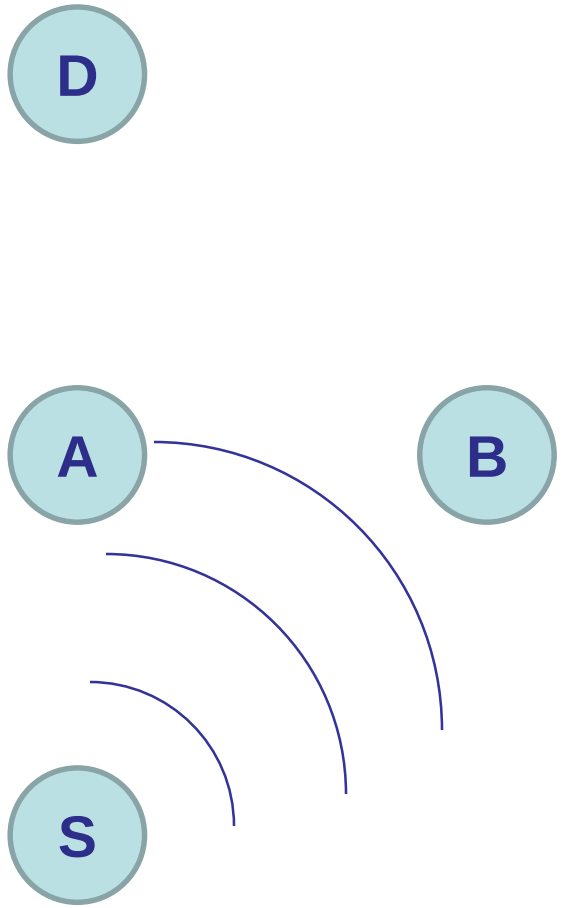
Georgios Z. Papadopoulos
Nicolas Montavont
Pascal Thubert

Toward Determinism

- In addition to reliable communication;
- The information need to be carried out in a pre-defined and constant delay;
- Should exhibit ultra-low jitter performance;

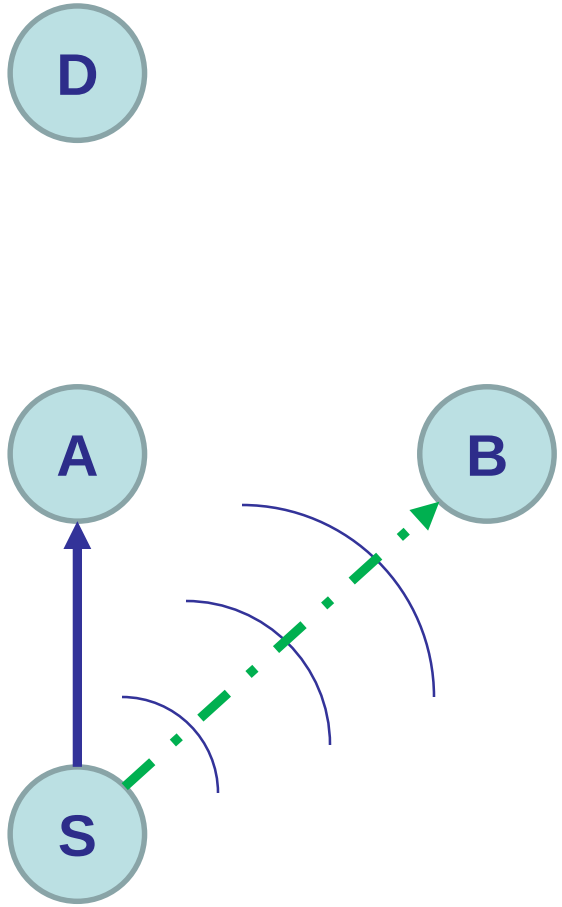


Wireless Topology



Promiscuous Overhearing

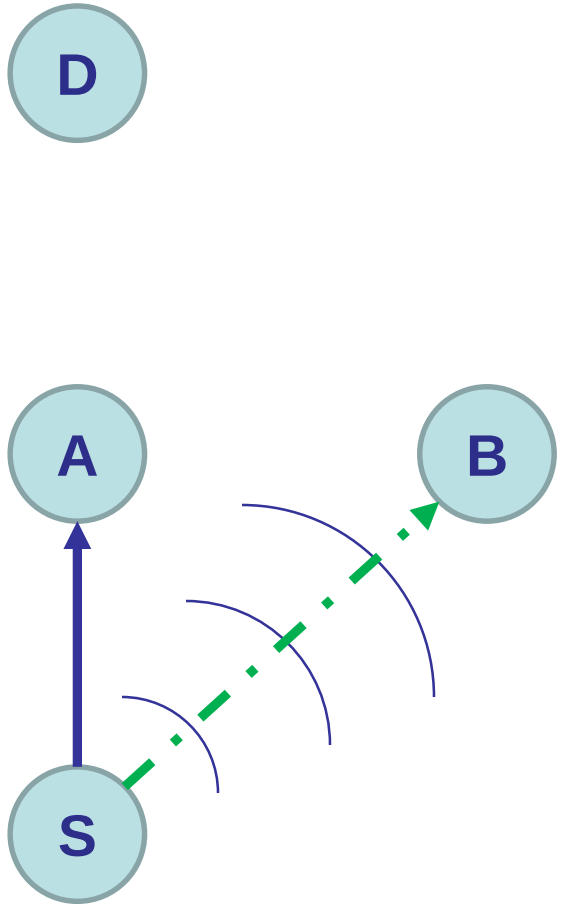
- Overhearing
  - Wireless medium is broadcast
  - any neighbor of a transmitter may overhear a transmission



- **A scheduler for multiple receivers;**
- **ACK collisions?**

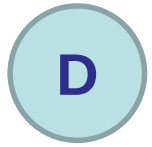
Packet Replication

- Replication
  - Data packet is transmitted to both Default & “Alternate” Parent

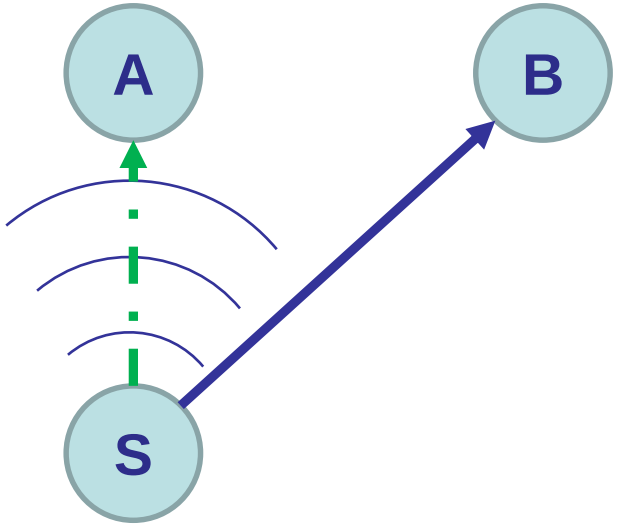


Packet Replication

- Replication
  - Data packet is transmitted to both Default & “Alternate” Parent

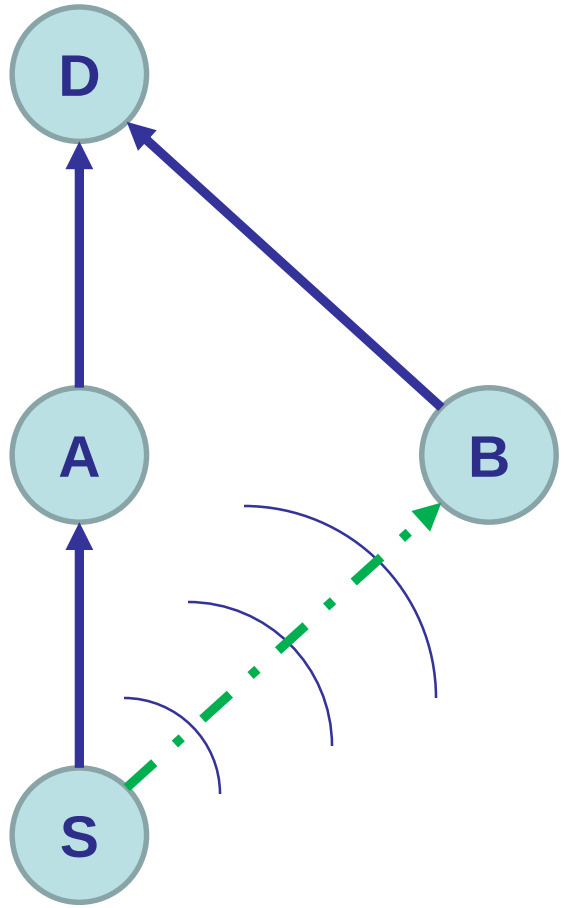


➢ **RPL DODAG Information Object (DIO) should be extended**



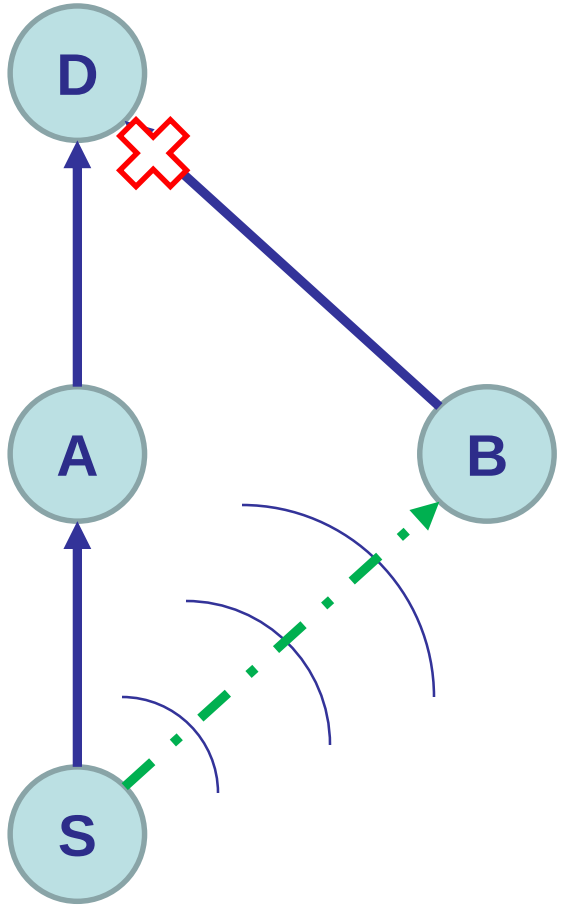
Packet Elimination

- Elimination
  - Discard the duplicated packet “previously received packet”



Packet Elimination

- Elimination
  - Discard the duplicated packet “previously received packet”

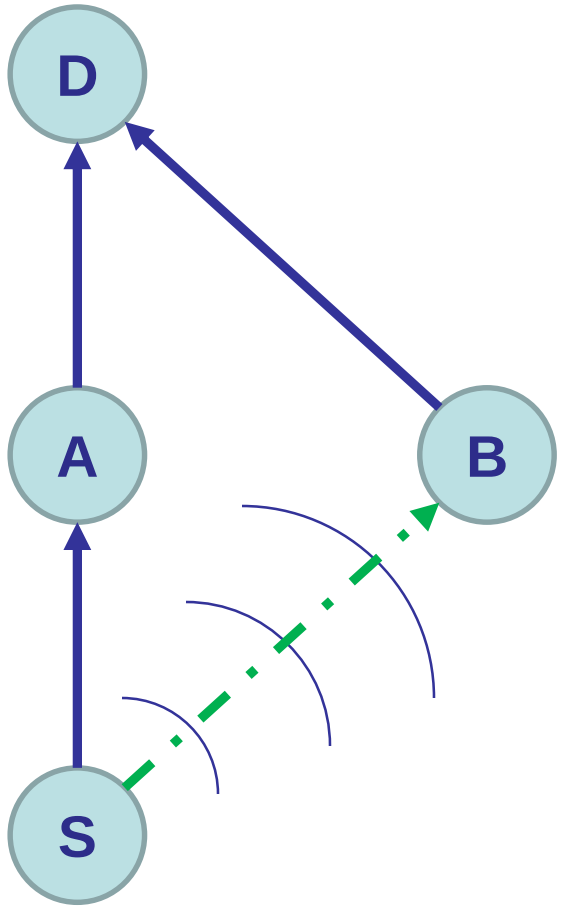


➢ **Tagging Packets for Flow Identification.**

TSCH Schedule: example

Channel offset	0	1	2	3
3		S → A S → B		
2				B → D
1				
0	EB		A → D	

Slotframe



- **A scheduler for multiple receivers;**
- **6P ADD Request Format.**

Requirements

- Alternative Parent Selection;
  - RPL DODAG Information Object (DIO) message format SHOULD be extended
  - routing protocol should be extended to allow for 6TiSCH nodes to select AP(s)
- Promiscuous Overhearing;
  - 6top Protocol should be extended to allow a cell reservation with two receivers
  - 6P ADD Request Format should be transmitted either twice or once in multicast
- Cells without ACKs;
  - only one parent MUST acknowledge the data packet
  - Or an efficient way for double ACKS
- Packet Elimination.
  - Tagging Packets for Flow Identification

Feedback

- Volunteers to REVIEW the draft;
- Feedback for missed Requirements;
- Is PRE relevant in 6TiSCH WG?

Questions?

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