IPv6 over the TSCH mode of IEEE 802.15.4e
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Administrivia

• Blue Sheets
• Scribes
• Jabber
Agenda

Intro and Status  (Chairs)  [5min]
   Note-Well, Blue Sheets, Scribes, Agenda Bashing

New Charter and status docs  [20min]
   Status Document
   Status 6lo / ROLL
   New Charter
   Milestones
   Action Plan

PlugTest News ((Miguel Angel Reina Ortega)  [10min]
   Report ETSI 6TiSCH #2 Plugtests (Paris)
   Announcement ETSI 6TiSCH #3 Plugtests (Berlin)

Dynamic Scheduling  [15min]
   <draft-wang-6tisch-6top-protocol-00> (Xavier Vilajosana)
   <draft-dujovne-6tisch-6top-sf0-01> (Diego Dujovne)

Security  [15min]
   status of the work and action plan (Michael Richardson)

Unchartered items, time permitting  [10min]
   <draft-satish-6tisch-aodv-rpl-00> (Satish Anamalamudi)

Any Other Business  [QSP]
IEEE 802.15.4
Information Element allocation
draft-kivinen-802-15-ie-00

Tero Kivinen <kivinen@iki.fi>
Pat Kinney <pat.kinney@kinneyconsultingllc.com>
IEEE 802.15.4 has Information Elements, but there is only 16 of them, and they will allow other standardization organizations to get one, but only one.

- Meaning the whole IETF will get one, and we need to define how that is subtyped so we can show to IEEE 802.15.4 that we do not need another ever. This draft also creates IANA registry for subtypes.

- This draft will provide subtype formatting and make official request from IETF to the IEEE 802.15.4 WG to ask them to allocate one for IETF.

- Users in the IETF: 6tisch, 6lo, core etc.

- Allows putting information in to the 802.15.4 frames without too much extra overhead.

- This draft will most likely need to be AD sponsored, as this is not directly related to only one WG.
New Charter and status docs
Status Documents

• draft 6tisch minimal
  – Completed INT AREA comments handling
  – Expecting feedback from INT DIR reviewers
News from ROLL and 6lo

Separated draft-ietf-6lo-paging-dispatch
From draft-ietf-roll-routing-dispatch
Paging Dispatch remains at 6lo,
Routing Dispatch moved to ROLL,
Both now in last call
News from 6MAN

Use of HbH being challenged (obsolete?)
Use of control bits even more challenged
Current RPL option code point is 63
Done under 6MAN
-> to drop packets escaping the RPL domain
MCR: proposed moving to 43 to allow ignore by non RPL aware end hosts
Rechartered!

From: The IESG <iesg-secretary@ietf.org>
Date: 2016-03-04 13:38 GMT-03:00
Subject: [6tisch] WG Action: Rechartered IPv6 over the TSCH mode of IEEE 802.15.4e (6tisch)
To: IETF-Announce <ietf-announce@ietf.org>
Cc: 6tisch@ietf.org, 6tisch-chairs@ietf.org, The IESG <iesg@ietf.org>

The IPv6 over the TSCH mode of IEEE 802.15.4e (6tisch) WG in the Internet Area of the IETF has been rechartered. For additional information, please contact the Area Directors or the WG Chairs.
Work Items

• Produce a specification of the 6top sublayer that describes the protocol for neighbor nodes to negotiate adding/removing cells. This work will leverage cross participation from IEEE members including the IEEE 6TiSCH Interest Group (IG 6T) to define protocol elements and associated frame formats.
Work Items

• Produce a specification for a default 6top Scheduling Function including the policy to enable distributed dynamic scheduling of timeslots for IP traffic. This may include the capability for nodes to appropriate chunks of the matrix without starving, or interfering with other 6TiSCH nodes <snip>.
Work Items

• Produce a specification for a secure 6TiSCH network bootstrap, adapted to the constraints of 6TiSCH nodes and leveraging existing art when possible.

• Keep updating the "6TiSCH architecture" that describes the design of 6TiSCH networks <snap>
Work Items

• Produce requirements to the DetNet WG, detailing 6TiSCH chunks and tracks, and the data models to manipulate them from an external controller such as a PCE.

• Producing YANG Data Models to manage 6tisch is foreseen, but left to a later phase.
## Milestones

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 2016</td>
<td>Second submission of draft-ietf-6tisch-minimal to the IESG</td>
</tr>
<tr>
<td>Apr 2016</td>
<td>WG call to adopt draft-ietf-6tisch-6top-sf0</td>
</tr>
<tr>
<td>Apr 2016</td>
<td>WG call to adopt draft-ietf-6tisch-6top-sublayer</td>
</tr>
<tr>
<td>Jul 2016</td>
<td>ETSI 6TiSCH #3 plugtests</td>
</tr>
<tr>
<td>Jul 2016</td>
<td>Initial submission of draft-ietf-6tisch-6top-sublayer to the IESG</td>
</tr>
<tr>
<td>Oct 2016</td>
<td>Initial submission of draft-ietf-6tisch-6top-sf0 to the IESG</td>
</tr>
<tr>
<td>Dec 2016</td>
<td>Evaluate WG progress, propose new charter to the IESG</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>Initial submission of 6TiSCH terminology to the IESG</td>
</tr>
<tr>
<td>Apr 2017</td>
<td>Initial submission of 6TiSCH architecture to the IESG</td>
</tr>
<tr>
<td>Dec 2017</td>
<td>6TiSCH architecture and terminology in RFC publication queue</td>
</tr>
</tbody>
</table>
Action Plan

- Agile I-Draft->code->test then plugtest
- Kickstart security
Agenda

- Overview of the event
- Participating Companies / Observers
- Plugtests agenda
- Summary of Event Planning
- Results reporting: ETSI Test Session Report tool
- Test Cases list
- High-Level Test Results
- Global Results for Test Cases
- Conclusions
- Roadmap
- Social Event
Overview of the Event

- Event organized by:
  - ETSI (European Telecommunications Standards Institute)

- Supporting Companies:
  - OpenMote, OpenWSN

- 12 Participating Companies
  - 5 different implementations

- 5 Observer companies

- 10 total test pairings, each 2 hour duration
  - Single hop configuration consisting of 8 tests cases
  - Star configuration consisting of 2 test cases
  - Multi hop configuration consisting of 4 optional tests cases
# Plugtests Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Tuesday 02</th>
<th>Wednesday 03</th>
<th>Thursday 04</th>
</tr>
</thead>
<tbody>
<tr>
<td>08:30 - 09:00</td>
<td>Registration &amp; Set up</td>
<td>Room Opening</td>
<td>Room Opening</td>
</tr>
<tr>
<td>09:00 - 12:00</td>
<td>TEST SESSIONS</td>
<td></td>
<td>TEST SESSIONS</td>
</tr>
<tr>
<td>12:00 - 13:00</td>
<td>NETWORKING LUNCH</td>
<td></td>
<td>NETWORKING LUNCH</td>
</tr>
<tr>
<td>13:00 - 14:00</td>
<td>Welcome Presentation</td>
<td>NETWORKING LUNCH</td>
<td>NETWORKING LUNCH</td>
</tr>
<tr>
<td>14:00 - 18:00</td>
<td>TEST SESSIONS</td>
<td>TEST SESSIONS</td>
<td>Tear Down</td>
</tr>
<tr>
<td>18:00 - 18:30</td>
<td>WRAP UP SESSION</td>
<td>WRAP UP SESSION</td>
<td></td>
</tr>
</tbody>
</table>
Summary of Event Planning

Several preparation calls
- ETSI/Experts group led and organized
- Collaborating Web conf (GotoMeeting)
- One preparation call including participants

Test Plan Development
- Led by Thomas Watteyne, Xavier Vilajosana, Maria Rita Palattella and Tengfei Chang
- 14 test cases, including 8 Single Hop + 2 Star + 4 Multi Hop.
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
<table>
<thead>
<tr>
<th>TD_6TiSCH_SYN_01</th>
<th>Check that a 6N can synchronize to the EB sent by the DR and parse all the IEs with their default values.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD_6TiSCH_SYN_02</td>
<td>Check that a 6N can synchronize to the EB sent by the DR and parse all the IEs. (Time slot IE does not contain the default template. To simply the test, only the slot duration is changed to 15ms and keep the other values as used in default template (10ms)).</td>
</tr>
<tr>
<td>TD_6TiSCH_RPL_01</td>
<td>Check the value of EB join priority of child 6N and a parent DR</td>
</tr>
<tr>
<td>TD_6TiSCH_RPL_02</td>
<td>Check the rank of 6Ns is computed correctly, according to OF0 function, as specified in draft-ietf-6tisch-minimal-14</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_02</td>
<td>Check a 6N can COUNT the cells allocated in the schedule to a given neighbour, according to draft-wang-6tisch-6top-sublayer-04.</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_03</td>
<td>Check a 6N can obtain the LIST of cells in the schedule, according to draft-wang-6tisch-6top-sublayer-04.</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_04</td>
<td>Check a 6N can CLEAR the schedule of a node, according to draft-wang-6tisch-6top-sublayer-04.</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_06</td>
<td>Check the timeout after a 6P request, is implemented according to draft-wang-6tisch-6top-sublayer-04.</td>
</tr>
</tbody>
</table>
### Star Test List

<table>
<thead>
<tr>
<th>TD_6TiSCH_6P_01</th>
<th>Check a 6N can ADD a cell in the schedule according to draft-wang-6tisch-6top-sublayer-04</th>
</tr>
</thead>
<tbody>
<tr>
<td>TD_6TiSCH_6P_05</td>
<td>Check a 6N can DELETE a cell in the schedule according to draft-wang-6tisch-6top-sublayer-04</td>
</tr>
<tr>
<td>Test Case ID</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_01</td>
<td>Check that the source routing header is correctly encoded as a 6LoRH Critical RH3, according to draft-ietf-6lo-routing-dispatch-02</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_02</td>
<td>Check that, when the packet’s sent towards the DR, the RPL Information Option is correctly encoded as a 6LoRH RPI, according to draft-ietf-6lo-routing-dispatch-02</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_03</td>
<td>Check that, when the packet’s travel inside the RPL domain, the IP in IP 6LoRH is not be presented in the packet.</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_04</td>
<td>Check that, when the packet travel outside a RPL domain, IP in IP 6LoRH is present in the packet.</td>
</tr>
</tbody>
</table>
On the 80 mandatory test cases planned, 48 have been executed and 32 not executed.

On the 48 Mandatory TC performed, 48 have been OK, which represents a success rate of 100.0%.

Note: This high level of interoperability can be attributed to the fact that participants received a Golden Device prior to the event to perform pretesting.
### Global Results per tests

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Interoperability</th>
<th>Not Executed</th>
<th>Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OK (100.0%)</td>
<td>NO (0.0%)</td>
<td>NA/OT (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_SYN_01</td>
<td>10 (100.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_SYN_02</td>
<td>2 (100.0%)</td>
<td>0 (0.0%)</td>
<td>8 (80.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_RPL_01</td>
<td>10 (100.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_RPL_02</td>
<td>10 (100.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_01</td>
<td>3 (100.0%)</td>
<td>0 (0.0%)</td>
<td>4 (57.1%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_05</td>
<td>2 (100.0%)</td>
<td>0 (0.0%)</td>
<td>4 (66.7%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_02</td>
<td>3 (100.0%)</td>
<td>0 (0.0%)</td>
<td>4 (57.1%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_03</td>
<td>3 (100.0%)</td>
<td>0 (0.0%)</td>
<td>4 (57.1%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_04</td>
<td>3 (100.0%)</td>
<td>0 (0.0%)</td>
<td>4 (57.1%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6P_06</td>
<td>2 (100.0%)</td>
<td>0 (0.0%)</td>
<td>4 (66.7%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_01</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_02</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_04</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>TD_6TiSCH_6LoRH_03</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
</tbody>
</table>
Conclusions

- The event has been successful and gave excellent interoperability results
- Regression testing on IEEE802.15.4e TSCH synchronization and RPL
- Basic 6P functionality tested and working
- The first 6LoRH implementation was presented and triggered interesting discussions about some aspects (feedback to 6lo WG)
- Running code is the only way of working out all details
- Dissector and golden image continue to be essential tools
- The participants were satisfied and gave excellent feedback in the satisfaction survey.
- The number of participants allowed that all the vendors met each other in test sessions during the event
- Participants made the testing go smoothly within a magnificent and friendly ambience

THANKS TO ALL PARTICIPANTS!!
Roadmap for next 6TiSCH Plugtests

2015

- **Q3**: 1st 6TiSCH Plugtests
  - 17-19 July 2015
  - Prague
  - Minimal RPL

2016

- **Q1**: 2nd 6TiSCH Plugtests
  - 2-4 February 2016
  - Paris
  - Minimal 6P Multi Hop

- **Q3**: 3rd 6TiSCH Plugtests
  - 14-16 July 2016
  - Berlin
  - 6P 6LoRH
  - Scheduling function
THANK YOU!

Miguel Angel Reina Ortega
Centre for Testing and Interoperability (CTI)
MiguelAngel.ReinaOrtega@etsi.org
6top Protocol (6P)
draft-wang-6tisch-6top-protocol-00

Qin Wang (Ed.)
Xavier Vilajosana
Status

Latest version published on 2016-03-20
http://www.ietf.org/id/draft-wang-6tisch-6top-protocol-00.txt

This draft is renamed from draft-wang-6tisch-6top-sublayer-04, which was presented at the IETF94.

New in this version:
- Renamed container -> metadata (2B)
- Renamed token -> seqNum (2B)
- 2 and 3 way transaction
- Indication that the SF must specify the statistics to gather
Content

2. Introduction

3. 6TiSCH Operation Sublayer (6top)
   2.1 Hard/Soft Cells
   2.2 Using 6top with the Minimal 6TiSCH Configuration

4. 6top Protocol (6P)
   4.1 6top Transaction
   4.2 Message Format
   4.3 Protocol Behavior
   4.4 Security

5. Guidelines for 6top Scheduling Functions (SF)
   5.1 SF Identifier (SFID)
   5.2 Requirements for a SF
   5.3 Recommended Structure of a SF specification

6. Implementation Status

7. Security Consideration

8. IANA Consideration
Introduction

Figure 1: A simple 6TiSCH network.

Distributed cell scheduling from C to A:
- Add cells
- Delete cells
- Relocate cells
6top stack

Figure 2: The 6top sublayer in the protocol stack.
Using 6top with the Minimal 6TiSCH Configuration

Figure 3: 2-slotframe structure when using 6top alongside the Minimal 6TiSCH Configuration.
6top Protocol (6P) – 2 Steps transaction

Figure 4: A 2-step 6P transaction.
6top Protocol (6P) – 3 Steps transaction

**Figure 5: A 3-step 6P transaction.**
General Message Format

The 6P messages are carried in a payload IE, i.e. IETF Information Element:

- Group ID: IANA_IETF_IE_GROUP_ID
- Length: variable
- Content: defined as follows

```
+-------------+-------------+-------------+-------------+-------------+
| Version     | Code        | SPID        | SeqNum      | Other Fields|
+-------------+-------------+-------------+-------------+-------------+
```

draft-wang-6tisch-6top-protocol
### Code in Request Message:
#### CMD Identifier

<table>
<thead>
<tr>
<th>Value</th>
<th>Command ID</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IANA_6TOP_CMD_ADD</td>
<td>CMD_ADD</td>
<td>add one or more cells</td>
</tr>
<tr>
<td>IANA_6TOP_CMD_DELETE</td>
<td>CMD_DELETE</td>
<td>delete one or more cells</td>
</tr>
<tr>
<td>IANA_6TOP_CMD_COUNT</td>
<td>CMD_COUNT</td>
<td>count scheduled cells</td>
</tr>
<tr>
<td>IANA_6TOP_CMD_LIST</td>
<td>CMD_LIST</td>
<td>list the scheduled cells</td>
</tr>
<tr>
<td>IANA_6TOP_CMD_CLEAR</td>
<td>CMD_CLEAR</td>
<td>clear all cells</td>
</tr>
<tr>
<td>TODO-0xf</td>
<td>reserved</td>
<td></td>
</tr>
</tbody>
</table>

### Code in Response Message:
#### Return codes.

<table>
<thead>
<tr>
<th>Value</th>
<th>Return Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IANA_6TOP_RC_SUCCESS</td>
<td>RC_SUCCESS</td>
<td>operation succeeded</td>
</tr>
<tr>
<td>IANA_6TOP_RC_VER_ERR</td>
<td>RC_VER_ERR</td>
<td>unsupported 6P version</td>
</tr>
<tr>
<td>IANA_6TOP_RC_SFID_ERR</td>
<td>RC_SFID_ERR</td>
<td>unsupported SFID</td>
</tr>
<tr>
<td>IANA_6TOP_RC_BUSY</td>
<td>RC_BUSY</td>
<td>handling previous request</td>
</tr>
<tr>
<td>IANA_6TOP_RC_RESET</td>
<td>RC_RESET</td>
<td>abort 6P transaction</td>
</tr>
<tr>
<td>IANA_6TOP_RC_ERR</td>
<td>RC_ERR</td>
<td>operation failed</td>
</tr>
<tr>
<td>TODO-0xf</td>
<td>reserved</td>
<td></td>
</tr>
</tbody>
</table>
6P cell format

```
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| slotOffset | channel0Offset |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```
6P Request Message Format

ADD /DELETE

COUNT /LIST /CLEAR

<table>
<thead>
<tr>
<th>Version</th>
<th>Code</th>
<th>SFID</th>
<th>SeqNum</th>
<th>NumCells</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metadata</td>
<td>CellList ...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>---------------</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Version</th>
<th>Code</th>
<th>SFID</th>
<th>SeqNum</th>
<th>Metadata</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metadata</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>---------</td>
<td>------</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

6TiSCH@IETF95
draft-wang-6tisch-6top-protocol
6P Response Message Format

Response to an ADD, DELETE or LIST command: A list of 0, 1 or multiple 6P Cells. The format of a 6P Cell is defined in Section 4.2.5.

Response to COUNT command: The number of cells scheduled from the requesting node to the receiver node by the 6P protocol, encoded as a 2-octet unsigned integer.

Response to CLEAR command: No other fields are present in the response.
6P Confirmation Message Format

<table>
<thead>
<tr>
<th>Version</th>
<th>Code</th>
<th>SFID</th>
<th>SegNum</th>
<th>Other Fields...</th>
</tr>
</thead>
</table>

Code: same as the return code in Response message
Other field: same as that in Response message
6P behavior

- Version checking
- SFID checking
- Concurrent 6P Transaction
- Timeout
- SeqNum match
- Adding cells
- Aborting a 6P Transaction
- Deleting cells
- Handling error response
6P behavior (Example1)

Assume: Node C decides to add cells to node A in a 2-steps transaction

Node C

SF: make NumCells, Candidate Cell List

6P: coding and sending ADD Request Message

6P: receiving and decoding ADD Request Message

SF: Act according to Return code

Node A

6P: receiving and decoding Response Message

SF: verify Candidate cell list, make scheduled cell list and return code

6P: coding and sending back Response Message
6P behavior (Example2)

Assume: Node C decides to add cells to node A in 3-steps transaction

Node C

SF: make NumCells

6P: coding and sending ADD Request Message

6P: receiving and decoding Response Message

SF: verify Candidate cell list, make scheduled cell list and return code

6P: coding and sending Confirmation Message

Node A

6P: receiving and decoding ADD Request Message

SF: make candidate cell list and return code

6P: coding and sending Response Message

6P: receiving and decoding confirmation Message

SF: Act according to Return code
Guideline for SF

SF Identifier

<table>
<thead>
<tr>
<th>Range</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x00-0xef</td>
<td>managed</td>
</tr>
<tr>
<td>0xf0-0xfe</td>
<td>unmanaged</td>
</tr>
<tr>
<td>0xff</td>
<td>reserved</td>
</tr>
</tbody>
</table>

Figure 8: SFID range.

Recommended structure

- Introduction
- Scheduling Function Identifier
- Rules for Adding/Deleting Cells
- Rules for CellList
- 6P Timeout Value
- Meaning of the Metadata Field
- Node Behavior at Boot
- 6P Error Handling
- Examples
- Implementation Status
- Security Considerations
- IANA Considerations
Guideline for SF (cont)

The specification for an SF

- MUST specify an identifier for that SF.
- MUST specify the rule for a node to decide when to add/delete one or more cells to a neighbor.
- MUST specify the rule for a Transaction source to select cells to add to the CellList field in the 6P ADD Request.
- MUST specify the rule for a Transaction destination to select cells from CellList to add to its schedule.
- MUST specify a value for the 6P Timeout, or a rule/equation to calculate it.
- MUST specify a meaning for the "Metadata" field in the 6P ADD Request.
- MUST specify the behavior of a node when it boots.
- MUST specify what to do after an error has occurred (either the node sent a 6P Response with an error code, or received one).
- MUST specify the list of statistics to gather. An example statistic if the number of transmitted frames to each neighbor. In case the SF requires no statistics to be gathered, the specific of the SF MUST explicitly state so.
Next Step

• IEEE Liaison Considerations

If the specification described in this document is supported by the 6TiSCH WG, the authors of this document ask the 6TiSCH WG chairs to liaise with the IEEE to request a Payload Information Element Group ID to be assigned to the IETF (Group ID IANA_IETF_IE_GROUP_ID described in Appendix A).
Thanks!

- Q&A
draft-dujovne-6tisch-6top-sf0-01

Diego Dujovne
Luigi Alfredo Grieco
Maria Rita Palattella
Nicola Accetura
Status

• Define the default **Scheduling Function** for the 6top layer

• News:
  – New *Bandwidth Estimation Algorithm*
  – Added *Differentiation between bandwidth and Cells*
  – Added *Whitelist/Blacklist*

• TODO list at the end.
Bandwidth Estimation Algorithm (BEA)

• The original BAE was based on the availability of **neighbour bandwidth** requests and **local bandwidth** requests.

• This assumed the Application had a way to **establish requests**. This assumption **does not apply** anymore.
Bandwidth Estimation Algorithm (BEA) / Current

Current Scheduled Bandwidth

Remaining Available Bandwidth

New Outgoing Bandwidth (NOB)

Minimum Remaining Bandwidth (MRB)

Overprovisioning

Current Outgoing Bandwidth Usage (COBU)

New Outgoing Bandwidth (NOB)

New Incoming Bandwidth Requirements (NIBR)

Bandwidth Estimation Algorithm

draft-dujovne-6tisch-6top-sf0
Bandwidth Estimation Algorithm (BEA) / Current

• The new BAE considers the **Current Outgoing Bandwidth Usage** as an **indirect estimator** of local bandwidth requirements.

• There is an **Overprovisioning** stage to compensate **underestimated** local bandwidth requirements.
Bandwidth Estimation Algorithm (BEA) / Alternative

Current Outgoing Bandwidth Usage (COBU)

New Outgoing Bandwidth (NOB)

New Incoming Bandwidth Requirements (NIBR)

Bandwidth Estimation Algorithm

Establish an high SF0THRESH to replace MRB and obtain Overprovisioning
Bandwidth Estimation Algorithm (BEA)

• A relocation request from the neighbour is considered as an **Incoming Bandwidth Requirement**;
  – It is expected to **Increase** Packet Delivery Rate on the relocated cells
  – Thus **Increasing** the Required Bandwidth
Bandwidth and Cells

• The **Bandwidth** is related to the **Number of Cells** by each cell`s **Packet Delivery Rate**.

• The BEA estimates the Bandwidth and the **Allocation Policy translates** this request into cells.
CellList / WhiteList

- **Transaction Source Node**
  - Select slotOffset Randomly
  - Verify slotOffset Free
  - Choose channelOffset Randomly
  
  For each Cell, repeat until **NumCell**

- **Transaction Destination Node**
  - CellList, NumCell
  - Verify if slotOffset is free
  - Yes: Allocate Cell
  - No: Check next Cell from CellList

  For each Cell, repeat until ((**NumCell**) or (**CellList empty**))
CellList / BlackList

- **Transaction Source Node**

  List of currently Scheduled Cells

- **Transaction Destination Node**

  For each Cell, repeat until \(( \text{NumCell} ) \) or \(( \text{CellList empty} )\))

  Random Cell

  Verify if slotOffset is NOT in BlackList

  - Yes
    - Allocate Cell
  - No
    - To avoid an eternal loop, the random cells are chosen from the remaining cells on the schedule.
TODO: Timeout

• The current timeout:

The 6P Timeout Value provided by SF0 allows the maximum number of TSCH link-layer retries. Given the TSCH parameters for the backoff mechanism, macMinBE and macMaxBE, and the length in seconds of the minimal Slotframe, SM, the timeout value is computed as: timeout = (2^(macMaxBE+1)-2^macMinBE) * SM

• Considers the **worst-case** for Minimal in the starting phase, with a high number of retransmissions.

• **Proposal:**
  – Move this to the “Behaviour at Boot” section
  – Define the Timeout in steady state condition as the time until the next scheduled cell
TODO: Metadata

• The current Metadata usage:

  The Metadata 16-bit field is used as follows:

  BITS 0-7 [SLOTFRAME] are used to identify the slotframe number
  BITS 8-14 are RESERVED
  BIT 15 [WBLIST] is used to indicate that the CellList provided is
  a Whitelist (value=0) or a Blacklist (value=1).

• Defines only the **Slotframe number** and the **WhiteSpace/BlackList** indicator.

• What to do with the reserved bits?
TODO: Node behavior at boot

- The current Node behaviour:

  In order to define a known state after the node is restarted, a CLEAR command is issued to each of the neighbour nodes to enable a new allocation process.

- **Proposal 1:** Should add the Max timeout to use when only Minimal cells are available
- **Proposal 2:** Distribute a number of temporary cells from a limited pool of cells to accelerate the join (and SF0 allocation) process
TODO: Cell Relocation

- The current Cell Relocation Policy:

  SF0 uses Packet Delivery Rate (PDR) statistics to monitor the currently allocated cells for cell re-allocation (by changing their slotOffset and/or channelOffset) when it finds out that the PDR of one or more softcells below 20% of the average PDR.

- **Proposal:** 20% is an arbitrary value. Do you have another value for this relocation threshold?
TODO: Forced deletion

• In a distributed allocation process the only entity allowed to define cell allocation is the SF.

• As a consequence, we need to add a function to the SF to free cells in specific cases, for example if a node dissapears from the Neighbour list.
TODO

• Define a **formula to calculate the statistics**, and which fields from the 6top MIB required for SF0.
  – We are only using now the Packet Delivery Rate as the percentage of packets successfully transmitted to/from the neighbor
  – We do not specify the timeframe for this calculation. The average over a minute? A second? An hour?

• Define a **policy for cell depletion** (no more available cells):
  – All cells are temporary and must be renewed periodically (à la DHCP)
  – Periodically monitor cell usage and delete unused cells
  – Any other options?
Questions?
Security

Michael Richardson
Simplying assumption 1: 6tisch like has a PCE/JCE
draft-pritikin-bootstrapping-keyinfrastructures-00
→ draft-ietf-anima-bootstrapping-keyinfra-02

Term mapping
JCE → ANIMA Registrar
Joint Assistant → ANIMA “Proxy”

Simplying assumption 2: leverage 802.1AR work
Fundamental to anima-bootstrapping
Challenge 1: how does the network authenticate?
ANIMA bootstrap defines “ownership voucher”
Contrast ANIMA and 6tisch

- Goal of ANIMA bootstrap is to create Enrollment over Secure Transport (RFC7030)
- ANIMA accommodates HTTPS or DTLS/CoAP + Blockwise. Hard sell to make DTLS Mandatory to Implement.
- Network is not constrained
  - After bootstrap, may be multi-gigabit
- While device is not constrained in aggregate, ANIMA ACP code may run on control plane/line-card CPU: some hardware offload available, but not universal.

ANIMA

VS

- Goal of 6tisch bootstrap is to create secured CoAP/6top transport from JCE/PCE to new node to transport YANG.
- DTLS/CoAP only + 6top, blockwise may be controversial?
- Network is constrained (not challenged)
- Devices are very code and ram constrained.
- Battery power is common (but not universal)

6TiSCH
Contrast ANIMA and NETCONF

- Goal of ANIMA bootstrap is to create Enrollment over Secure Transport (RFC7030)
- ANIMA accommodates HTTPS or DTLS/CoAP + Blockwise. Hard sell to make DTLS Mandatory to Implement.
- ANIMA replaces IDevID with LDevID ASAP.
- ANIMA assumes link-local connectivity, device owner is link network operator
- ANIMA tends to be for “infrastructure”

VS

- Goal of NETCONF is to provide signed bootstrap data (YANG) to device.
- Variety of sources: HTTP, HTTPS, DNS, mDNS, DHCP, removable storage...
- NETCONF uses IDevID directly
- NETCONF assumes device owner likely is not link operator, or operator is unsophisticated (home user)
- NETCONF more appliance, and high-volume access device focused, rather than core infrastructure.
Contrast 6tisch and NETCONF!

- Goal of 6tisch bootstrap is to create secured CoAP/6top transport from JCE/PCE to new node to transport YANG.
- Devices and networks constrained.
- 6tisch will replace IDevID with LDevID for use with 802.15.9 or other per-link KMP
- No cheap broadcast/multicast, or service discovery
- Device owner is network owner.

vs

- Goal of NETCONF is to provide signed bootstrap data (YANG) to device.
- Variety of sources: HTTP, HTTPS, DNS, mDNS, DHCP, removable storage...
- NETCONF uses IDevID directly
- NETCONF assumes device owner likely is not link operator, or operator is unsophisticated (home user)
- NETCONF more appliance, and high-volume access device focused
Join Problem

How to let random uninitialized, “drop shipped”, potentially malicious nodes into your network without destroying the network.

- 802.1x/EAP/PANA has this “solved” for initialized nodes which know which network they want to join; need to be pre-provisioned with certificates.
  - needs EAP-TLS to make this work, which then includes new layers of fragmentation. This code is used once.
  - PANA/1x authenticator function scales with number of nodes attempting to join, is subject to DoS attack, defending against may be too expensive for constrained nodes
  - 1x function for ANIMA ACP bootstrap may interfere with 1x function being provided by routers/switches for end-hosts!

- The goal is to provision new nodes with certificates, at which point “traditional” methods may be used to join network.
Both 6tisch/LLN, ANIMA and NETCONF share Manufacturer Installed Certificates (“MIC”) [IDevID], and have a supply chain relationship with network operator via which Ownership Vouchers can be communicated.
New Node /Registrar communications

- New Node ↔ Proxy use Link Local addresses.

- Communication is CoAP/DTLS over UDP
  - (or HTTPS/TCP)

- Proxy ↔ Registrar communication is forwarded (D)TLS traffic; proxy is uninvolved in security.
  - Proxy is neither trusted, nor needs to be truthworthy

- Green Encapsulation arrow can be implemented in different ways
Proxy/Join Assistant proxy methods

**HTTPS**

1. Via circuit proxy (process per connection), or HTTP proxy.

2. Via NAT66 of link-layer enrollment addresses to ACP ULA address

3. Stateless IPIP encapsulation of link-local traffic to registrar

**CoAP/DTLS**

1. UDP circuit proxy

2. NAT66 of link-layer to ACP ULA address

3. Stateless IPIP encapsulation of link-local traffic to registrar

   a) Essentially this is routing-dispatch IPIP encapsulation

Brian Carpenter was visibly ill

See draft-richardson-anima-state-for-joinrouter-00: Considerations for stateful vs stateless join router in ANIMA bootstrap, for longer discussion

Least amount of new Code for constrained Devices, highest Resistance to DoS Costs some bandwidth
Asymmetrical AODV-P2P-RPL in 6tisch Networks

draft-satish-6tisch-aodv-rpl-00
Satish Anamalamudi
Mingui Zhang
Charlie Perkins
Dongxin Liu
S.V.R Anand
satish.anamalamudi@huawei.com
Overview

• AODV route discovery mode
  – Instance-1 Route Discovery.
  – Instance-2 Route Discovery.

• AODV-RPL Resource Reservation at 6TOP.
  – Asymmetrical links
  – Symmetrical links
Overview of AODV-RPL

• Works on the top of RPL [RFC6550]
  – Hop-by-hop based P2P traffic flows.
  – Bi-directional asymmetric links with PairedDODAG’s. (Motivated from the discussions in mailing list).

• Route Control messages
  – Instance-1 from Source to Destination.
  – Instance-2 from Destination to Source.

• Data transmission
  – Instance-1 from Destination to Source.
  – Instance-2 from Source to Destination.

---

S : Source
R : Intermediate nodes
D : Destination

---
Instance-1 Route Discovery

- **Link Nature**
  - "A" bit is added in DIO message.
  - Describe the link nature (Asymmetric or Symmetric).
  - Source reset “A” bit to “0” during Instance-1 route discovery.
  - Intermediate node set ’A’ bit to 1 if link is asymmetric.
  - ‘A’ bit is set to mean that the route is asymmetric.
  - Link nature at destination for Instance-2 is decided by “A” bit.
Instance-2 Route Discovery

- **Symmetric Links**
  - **Destination:**
    - If “A” bit is “0” then Instance-2 control message is unicast.
    - Same links for Instance-1 and Instance-2.

- **Asymmetric Links**
  - **Destination:**
    - If “A” bit is “1” then Instance-2 control message is multicast.
    - Different links for Instance-1 and Instance-2.
    - Intermediate routers set “A” bit based on available radio resources (cells).
AODV-RPL Resource reservation at
6TOP

• Source run Bandwidth Estimation Algorithm (BEA).
• Check required cells for application data.
• NumCells in 6P ADDRequest is set to “Required cells”.
• Append 6PADD Request to DIO-RREQ-Instance-1.
• CellList(slotoffset, channeloffset) is set to zero.
• Intermediate nodes will re-multicast if it has radio resources.
• “A” bit changes based on available radio resources(cells).

```
DIO-RREQ-Instance-1
A=0       6P-ADDR request
     (NumCells)

S<------------------------->R
```

6TiSCH@IETF95  IETF 95 – 6tisch WG
April 4, 2016
Resource reservation for Symmetrical links

- Path from Source to Destination have transmit and receive cells for both directions.
- ’A’ bit is remain to set to ’0’.
- Destination unicast Instance-2 in same path.
- Symmetric links
  - transmit-receive cells for Instance-1 and transmit-receive cells for Instance-2 in same path.
Resource reservation for Asymmetrical links

<table>
<thead>
<tr>
<th>DIO-RREQ-Instance-1</th>
<th>DIO-RREQ-Instance-1</th>
</tr>
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<tbody>
<tr>
<td>A=0</td>
<td>A=1</td>
</tr>
<tr>
<td>6P-ADDRequest</td>
<td>6P-ADDRequest</td>
</tr>
<tr>
<td>(NumCells)</td>
<td>(NumCells)</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>S&lt;----------------------------------</td>
<td>R&lt;----------------------------------</td>
</tr>
<tr>
<td></td>
<td>D&lt;----------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>DIO-RREQ-Instance-2</td>
<td>DIO-RREQ-Instance-2</td>
</tr>
<tr>
<td>6P-ADDRequest</td>
<td>6P-ADDRequest</td>
</tr>
<tr>
<td>(NumCells)</td>
<td>(NumCells)</td>
</tr>
</tbody>
</table>

- Intermediate node may have cells available only for one direction.
- ’A’ bit is set to ’1’ during route discovery in Instance-1.
- For “A=1”, Destination multicast the Instance-2 message.
- Available Cells and “A” bit decide the link nature.
Cell Scheduling for Data transmission

- Source know the path to Destination in Instance-2.
- Destination know the path to Source in Instance-1.
- Actual 6P negotiation (6P ADD Request, 6P ADDResponse).
- Request and allocates the CellList (slotoffset, channeloffset).
- Data transmission in scheduled cells.

Advantages of AODV-RPL
- Address vector is completely removed.
- Address size overhead is minimized.
Next Steps

• Comments and Questions
• Ask for WG adoption.

Thanks!
AOB ?