LPWAN WG

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98th IETF, Chicago, March 29th, 2017

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Minutes are taken *

This meeting is recorded **

Presence is logged ***

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*** From the Webex login

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- Minutes
  - Etherpad: http://etherpad.tools.ietf.org:9000/p/notes-ietf-98-lpwan?useMonospaceFont=true
  - Minute takers volunteers?

- Remote participation
  - Meetecho: http://www.meetecho.com/ietf98/lpwan
  - Jabber: lpwan@jabber.ietf.org
    - Jabber scribe volunteers?

- Mailing list: lp-wan@ietf.org
  - To subscribe: https://www.ietf.org/mailman/listinfo/lp-wan

- Meeting materials: https://datatracker.ietf.org/meeting/98/materials.html/#lpwan

Agenda bashing

LPWAN

13:00> Opening, agenda bashing (Chairs)
[5min] • Note-Well, Blue Sheets, Scribes, Agenda Bashing
[3min] • Milestones
[2min] 13:05> LPWAN Overview Presentation and Discussion (Stephen Farrel)
[15min] • https://datatracker.ietf.org/doc/draft-ietf-lpwan-overview/
[10min] 13:20> LoRaWAN overview (Alper Yegin)
[20min] • https://datatracker.ietf.org/doc/draft-farrell-lpwan-lora-overview/
[15min] • Q/A
[5min] 13:40> Static Context Header Compression Fragmentation Header (Carles Gomez)
[15min] • https://datatracker.ietf.org/doc/draft-ietf-lpwan-ipv6-static-context-hc/
[15min] 13:55> Static Context Header Compression for IPv6 and UDP (Ana Minaburo)
[15min] • https://datatracker.ietf.org/doc/draft-ietf-lpwan-ipv6-static-context-hc/
[10min] • Q/A
[5min] •

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Agenda bashing

14:10> Static Context Header Compression for CoAP (Laurent Toutain)
[20min] • https://datatracker.ietf.org/doc/draft-ietf-lpwan-ipv6-static-context-hc/
[20min] 14:30> SCHC Implementation (Tomas Lagos)
[5min]] 14:35> Implementation of SCHC over Sigfox (Juan Carlos Zuniga)
[5min] 14:40> > Overview of 802.15.LPWA Interest Group Activities (Charlie Perkins)
[10min] 14:50> Possible future work items (Sri Gundavelli)
[10min] 15:00> Close – 0 flextime

Status

WG formed October 14th

- Charter item #1 (Informational document)
  - Baseline technology description
- Charter item #2 (Standards track document)
  - Enable the compression and fragmentation of a CoAP/UDP/IPv6 packet over LPWA networks

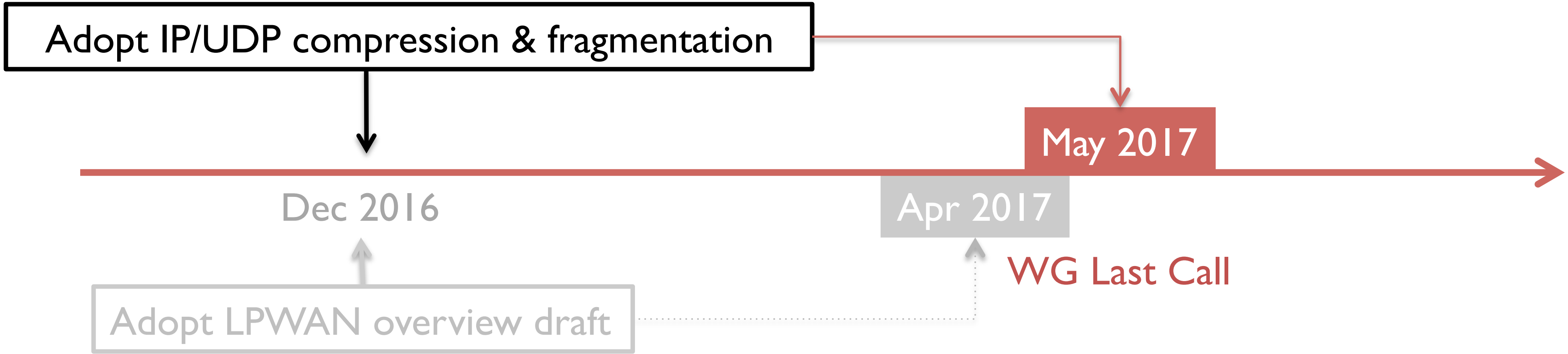
Charter - Milestones

Milestones

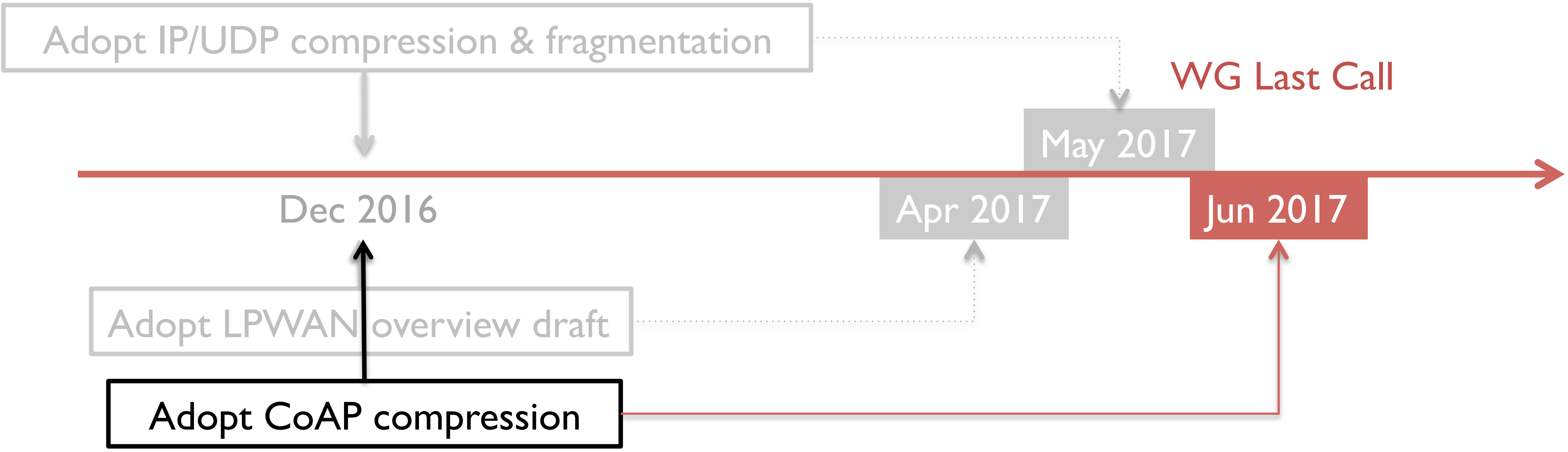
Date	Milestone
Jul 2017	Submit CoAP compression mechanism to the IESG for publication as a Proposed Standard
May 2017	Submit IP/UDP compression and fragmentation mechanism to the IESG for publication as a Proposed Standard
Apr 2017	Submit LPWAN specification to the IESG for publication as an Informational Document
Done	Adopt CoAP compression mechanism as a WG item
Done	Adopt IP/UDP compression and fragmentation mechanism as a WG item
Done	Adopt LPWAN specifications as WG item

Milestones

Milestones

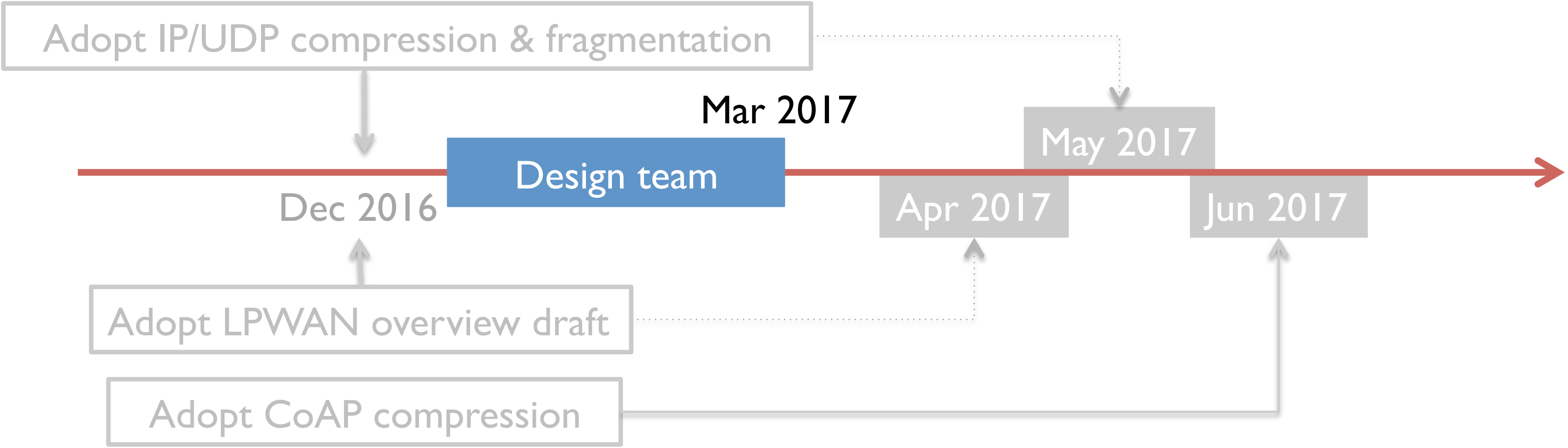

Adopt IP/UDP compression & fragmentation
May 2017
Dec 2016
Apr 2017
WG Last Call
Adopt LPWAN overview draft

Milestones



Adopt IP/UDP compression & fragmentation
WG Last Call
May 2017
Dec 2016
Apr 2017
Jun 2017
Adopt LPWAN overview draft
Adopt CoAP compression

Milestones



Adopt IP/UDP compression & fragmentation
Mar 2017
May 2017
Design team
Dec 2016
Apr 2017
Jun 2017
Adopt LPWAN overview draft
Adopt CoAP compression

<draft-ietf-lpwan-overview>

https://github.com/sftcd/lpwan-ov

Editor: Stephen Farrell
stephen.farrell@cs.tcd.ie
(plus many contributors)

Contributors

The text here is basically all from the set of contributors : Jon Crowcroft, Carles Gomez, Bob Heile, Ana Minaburo, Josep Paradells, Benoit Ponsard, Antti Ratilainen, Chin-Sean SUM, Laurent Toutain, Alper Yegin, Juan Carlos Zuniga, with just a bit of editing from the editor

Content

- Intro, Technology overviews, Generic Terminology, Gap analysis, Security Considerations
- Technologies : LoRaWAN, NB-IoT, SIGFOX, Wi-SUN

Goal of this draft (IIUC)

- Provide enough background information so that the WG can make sufficiently informed decisions while doing standards-track work
- Non-goals :
  - Adding to anyone's set of publications
  - Perfectly polished text usable in 1000 years

Obvious TBDs

- Shorter, crisper text (if possible)
- Check/update technology descriptions
  - Guidance from WG as to what's the minimum needed gratefully accepted
- Continue gap analysis
  - Presumably using some kind of issue tracker ?
- Refine generic terminology
- … all to the point where the WG are happy they are useful enough, and all assuming the WG want to adopt the draft

Issues (one slide for each in a ‘mo)

- Descriptive material in this draft vs. technology specific drafts
- Define common terminology or an LPWAN architecture ?
- How much gap analysis to include here vs. in standards-track work

Issues (one slide for each in a ‘mo)

- Options presented are those that occurred to editor, adding more may well be a fine thing
  - Too much refinement is probably not worthwhile though
- Editor is quite happy with whatever the WG want, suggestions presented are just that, and can of course change over time as WG consensus determines

Issue#1 : Descriptive Material vs. Individual Drafts

1) Work the text to the minimum useful needed, independently of what specific technology proponents want to do with their own I-Ds or other specs. Don’t try too hard to keep it all up-to-the-minute as long as it’s still generally useful.

2) Assume specific technology proponents who want to will pursue their own I-Ds (or other specs) outside the WG (e.g. sending to ISE), eliminate text from this draft where there are overlaps and refer to other drafts/specs as appropriate.

editor suggests: #1

Issue#2 : Generic Terminology or Architecture ?

1) Develop the common terminology text into a fairly complete LPWAN architecture text

2) Aim for a minimal set of common terms that are needed to get started on the standards track work. Definitions of those might move to standards-track document(s) later.

editor suggests: #2

Issue#3 : Handling gap analysis

1) Work that text in this draft exclusively for now, then move whatever's needed into standards-track document(s) as appropriate, keep the remainder here.

2) Remove all that text, and have the WG adopt a separate gap analysis draft

editor suggests: #1

Other issues ?

PRs welcome at:

https://github.com/sftcd/lpwan-ov

LoRaWAN Overview

draft-farrell-lpwan-lora-overview-01

Authors:
Stephen Farrrell (Trinity College Dublin)
Alper Yegin (Actility)

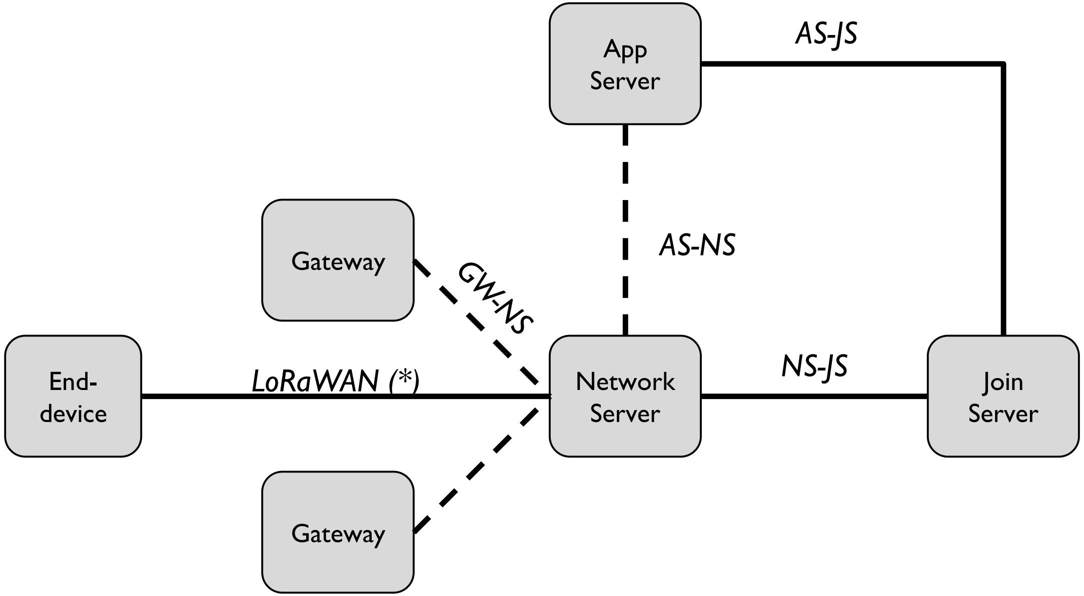
Contributors:
Chun-Yeow Yeoh (VADS Lyfe), Olivier Hersent (Actility),
Dave Kjendal (Senet), Paul Duffy (Cisco),
Joachim Ersnt (Swisscom), Nicolas Sornin (Semtech),
Philippe Christin (Orange)

98th IETF, Chicago, March 29th, 2016

Attributes

- Frequency: Sub-GHz, ISM
- Modulation: LoRa (spread spectrum), FSK
- Channel bandwidth: 125-500Khz
- Data rate: 300bps-50Kbps
- Range: -142dBm GW sensitivity (@300bps), 10+km range, deep indoor
- App payload size: 11-242 bytes
- Battery consumption: 10mA RX, 32mA TX, 5-10 years battery life
- Communication: Bidirectional unicast, downlink multicast
- Mobility and geolocation

Network Reference Model

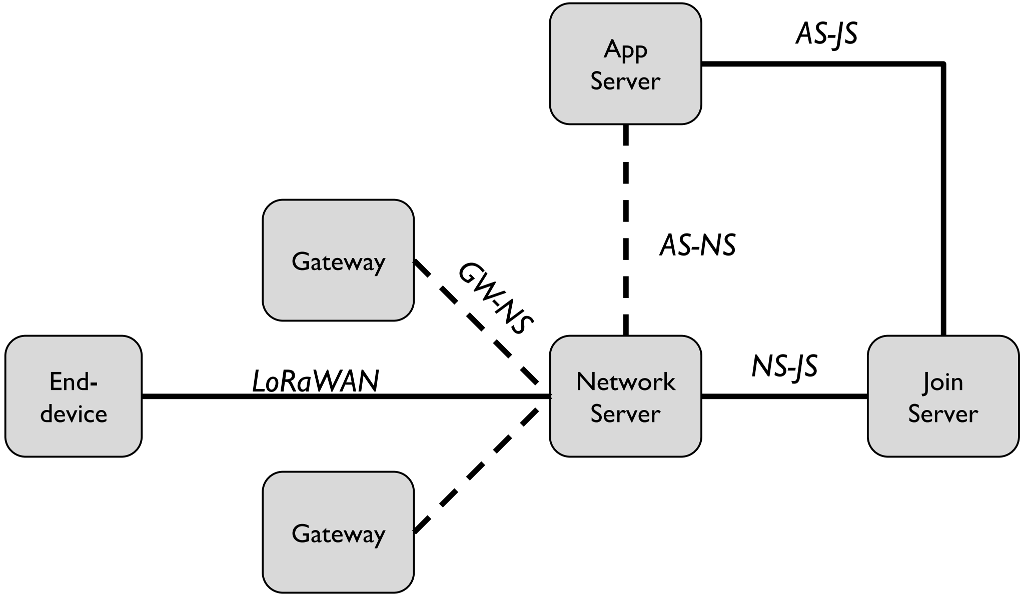


(*) https://www.lora-alliance.org/Contact/Request-Specification-Form

Interface currently out-of LoRa Alliance scope

In-scope interface

Attributes



- Star topology
- Multiple GWs receive uplink transmissions (ULs)
  - GW diversity (coverage, geolocation)
  - Stateless GWs (efficiency, passive roaming)
- Single downlink transmission (DL)
- Adaptive Data Rate (ADR): Device data-rate and transmission power are controlled

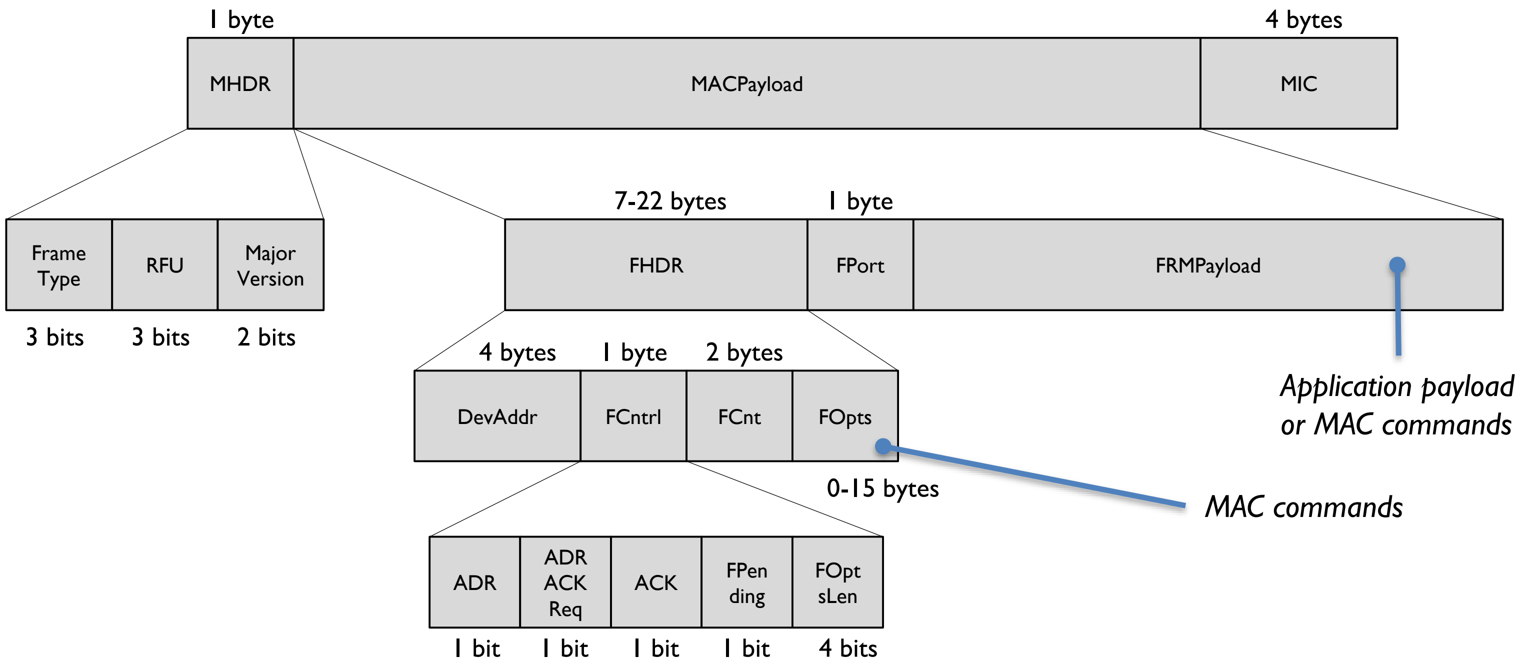
UL/DL Transmission

- Confirmed and Unconfirmed Data
- Multiple transmission of unconfirmed ULs
- Frequency hopping
- ISM duty cycle, dwell time limitations
- Communication modes
  - Class A:
    - UL anytime, DL only at well-defined slots after UL
    - Battery-powered sensors
  - Class B:
    - UL anytime, DL at scheduled slots
    - Battery-powered actuators
  - Class C:
    - UL and DL anytime
    - Mains-powered devices

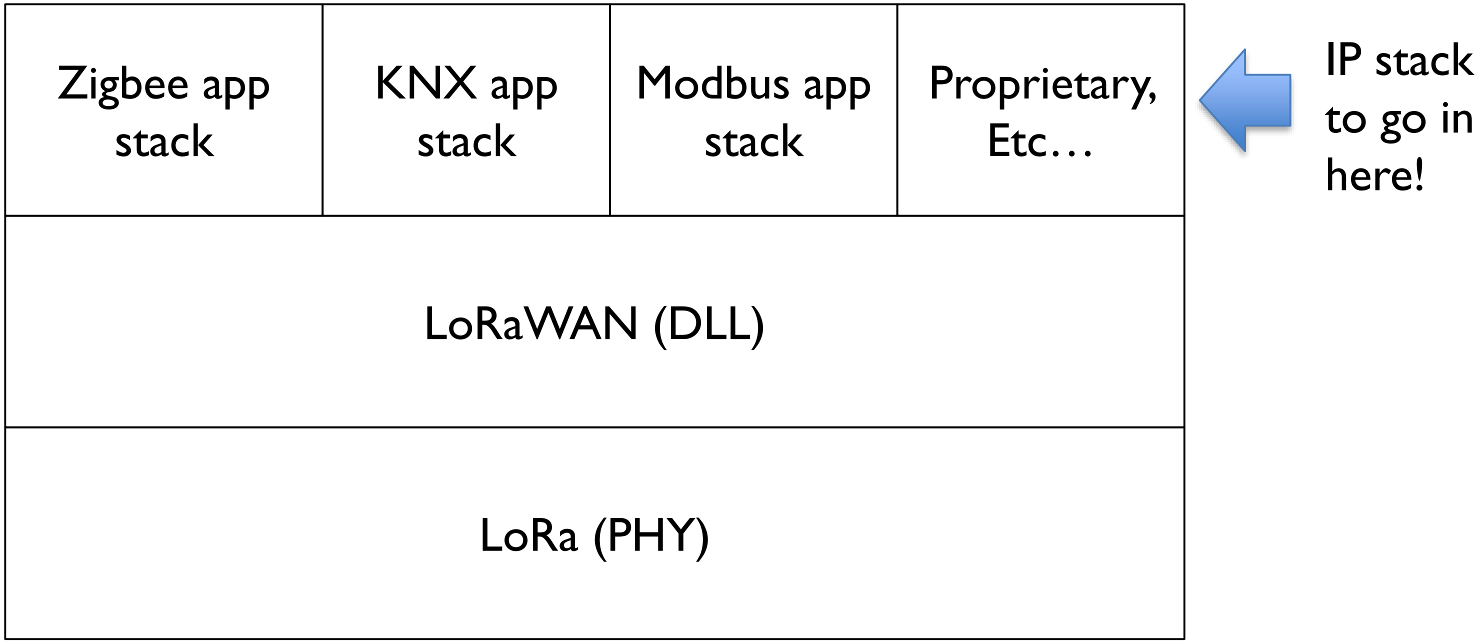
MAC Commands

- Checks
  - Link status
  - Device battery
  - Device margin (signal-to-noise ratio)
- Settings
  - Data rate
  - TX power
  - TX and RX channels
  - RX timing
  - Repetition
  - Duty cycle
  - Dwell time

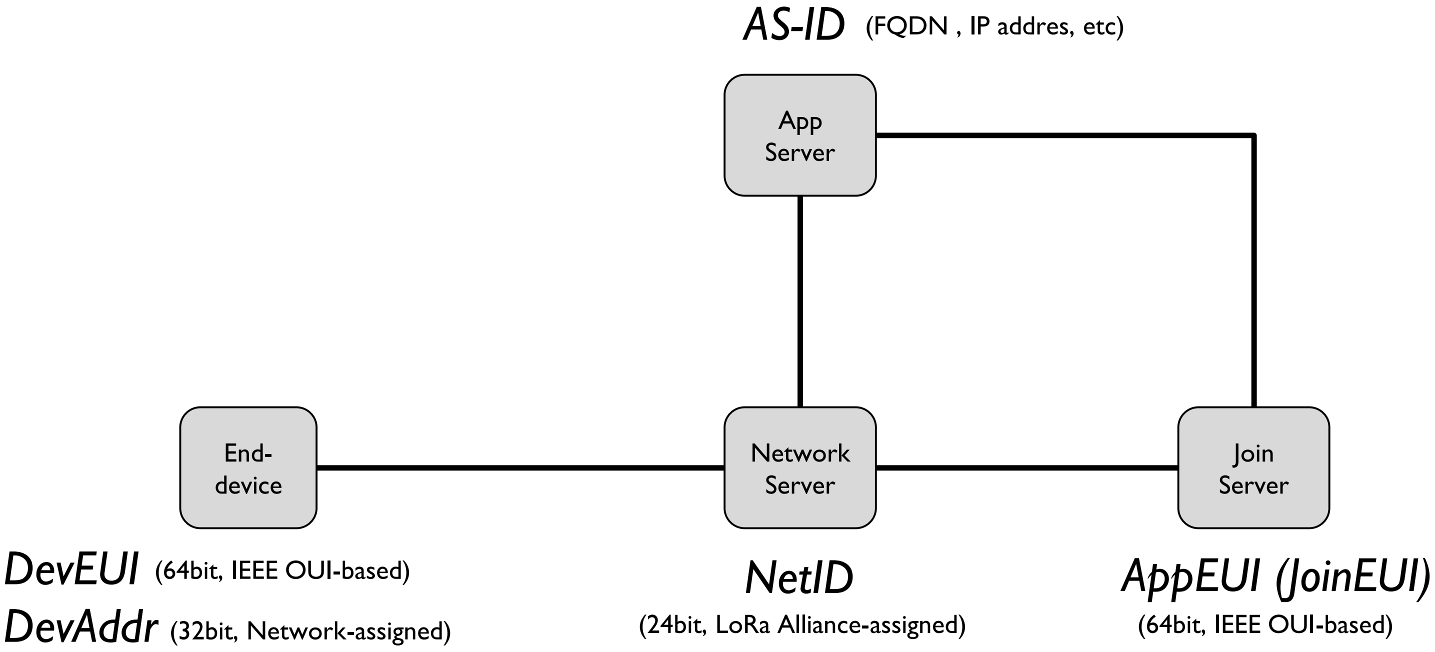
Frame Format



Stack

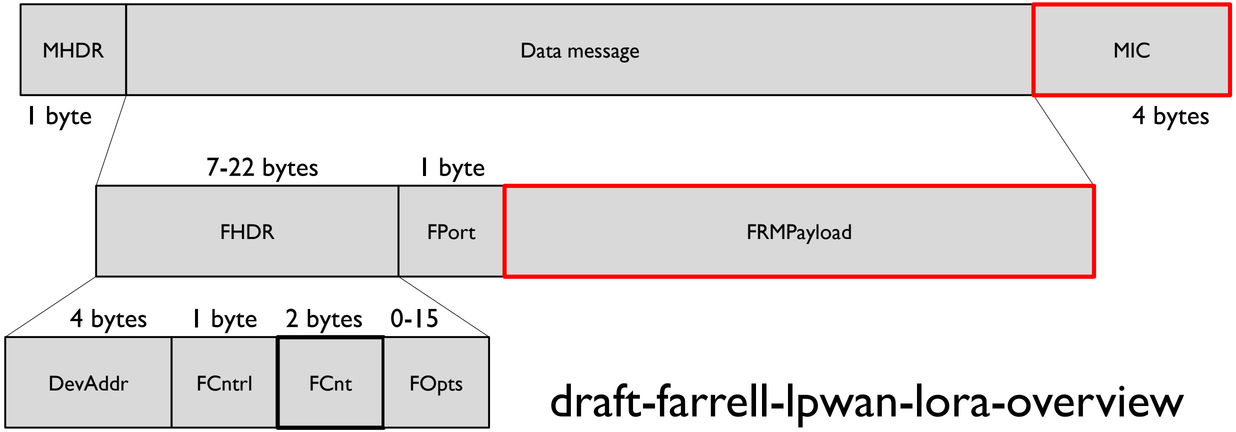

Zigbee app stack
KNX app stack
Modbus app stack
Proprietary, Etc…
LoRaWAN (DLL)
LoRa (PHY)
IP stack to go in here!

Identifiers



Security

- Per-device 128bit root key (AppKey)
- Network and app-layer session keys (NwkSKey, AppSKey) dynamically-generated via Join Procedure, or pre-provisioned
- Over-the-air data origin authentication, integrity protection, replay protection (AES-CMAC)
- Optional encryption of MAC commands
- End-to-end application payload encryption (counter-mode derived from IEEE 802.15.4)



Ongoing Development

- Backend Interfaces Specification
  - Among NS, JS, and AS
  - For Join (Activation) and Roaming Procedures
- LoRaWAN 1.1
  - Additional roaming capabilities
  - Security enhancements

Questions/comments?

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LPWAN SCHC Fragmentation

Authors:
Ana Minaburo <ana@ackl.io>
Laurent Toutain <laurent.toutain@imt-atlantique.fr>
Carles Gomez <carlesgo@entel.upc.edu>

98th IETF, Chicago, March 29th, 2017

Status

- Added to draft-ietf-lpwan-ipv6-static-context-hc-01
- Updated in -02
- Quite different approach compared with previous individual submission drafts on fragmentation

Overview

- LPWAN technologies often with L2 MTU of 10s-100s of bytes
- For such technologies, fragmentation support is mandatory
  - Used if (after header compression) the IPv6 datagram does not fit a single L2 data unit
- Spec offers a gradation of fragment delivery reliability
  - UnReliable (UnR) mode
  - Reliable per-Packet (RpP) mode
  - Reliable per-Window (RpW) mode
- ACK- and NACK-oriented feedback options allowed
- Fragmentation setting choice?
  - Responsibility of the underlying L2 LPWAN technology

Fragmentation header formats

- Not the last fragment:

```
<----------- R ----------->
                <-- N  -->
+----- ... -----+-- ... --+
|    Rule ID    |   CFN   |
+----- ... -----+-- ... --+
```

- Fragment
- UnR/RpP/RpW

- Non-absolute fragment number
- Sequentially, decreasing order
- Starts from 2^N-2
- Wraps from 0 back to 2^N-2
- N=1 (UnR), N≥3 (RpP, RpW)

- Last fragment:

```
<----------- R ----------->
                <-- N --> <---- M ----->
+----- ... -----+-- ... --+---- ... ----+
|    Rule ID    |  11..1  |     MIC     |
+----- ... -----+-- ... --+---- ... ----+
```

- Over the whole IPv6 packet
- Error check after reassembly
- UDP checksum compression
- Algorithm TBD

Last fragment

R, N, M to be decided by underlying L2 technology

ACK format

- General format

```
 <-----  R  ---->
+-+-+-+-+-+-+-+-+------ ... ---+
|     Rule ID     |    bitmap    |
+-+-+-+-+-+-+-+-+------ ... ---+
```

- This is an ACK

- no bitmap: no loss
- bitmap size depends on RpP/RpW
- n-th bit set to 0 means n-th frag lost
- bits of bit order greater than number of frags covered, set to 0
- last bit set to 1, last frag recv'd OK

- Example
  - 11 fragments, 2nd and 9th lost

```
                                        1
<-----  R  ----> 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Rule ID    |1|0|1|1|1|1|1|1|0|1|1|0|0|0|0|1|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Baseline mechanism

- Receiver uses
  - L2 addresses present and Rule ID to identify fragments of a datagram
  - CFN and order of arrival to determine location of a fragment
- RpW mode
  - After fragment with CFN=0, receiver MAY send an ACK
- Receipt of last fragment (CFN=11..1)
  - Receiver uses MIC for integrity check
  - UnR mode: if check fails, datagram discarded
  - RpP, RpW modes: receiver MAY send an ACK
    - Sender retransmits lost fragments
    - Max number of ACK – retry rounds TBD

Examples (I/V)

- UnR mode
  - 11 fragments
  - N=1

```
Sender                   Receiver
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=0---------->|
  |--------CFN=1---------->|MIC checked =>
```

Examples (II/V)

- RpP mode
  - NACK-oriented, N=3
  - 11 fragments

```
 Sender                  Receiver
   |-------CFN=6-------->|
   |-------CFN=5-------->|
   |-------CFN=4-------->|
   |-------CFN=3-------->|
   |-------CFN=2-------->|
   |-------CFN=1-------->|
   |-------CFN=0-------->|
   |-------CFN=6-------->|
   |-------CFN=5-------->|
   |-------CFN=4-------->|
   |-------CFN=7-------->|MIC checked =>
(no NACK)
```

```
 Sender                  Receiver
   |-------CFN=6-------->|
   |-------CFN=5-------->|
   |-------CFN=4---X---->|
   |-------CFN=3-------->|
   |-------CFN=2---X---->|
   |-------CFN=1-------->|
   |-------CFN=0-------->|
   |-------CFN=6-------->|
   |-------CFN=5-------->|
   |-------CFN=4---X---->|
   |-------CFN=7-------->|MIC checked =>
   |<-------NACK---------|Bitmap:1101011110100001
   |-------CFN=4-------->|
   |-------CFN=2-------->|
   |-------CFN=4-------->|MIC checked =>
(no NACK)
```

Examples (III/V)

- RpP mode
  - ACK-oriented, N=3
  - 11 fragments

```
Sender                     Receiver
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4-------->|
  |-------CFN=3-------->|
  |-------CFN=2-------->|
  |-------CFN=1-------->|
  |-------CFN=0-------->|
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4-------->|
  |-------CFN=7-------->|MIC checked =>
  |<-------ACK----------|no bitmap
(End)
```

```
Sender                     Receiver
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4---X---->|
  |-------CFN=3-------->|
  |-------CFN=2---X---->|
  |-------CFN=1-------->|
  |-------CFN=0-------->|
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4---X---->|
  |-------CFN=7-------->|MIC checked =>
  |<-------ACK----------|bitmap:1101011110100001
  |-------CFN=4-------->|
  |-------CFN=2-------->|
  |-------CFN=4-------->|MIC checked =>
  |<-------ACK----------|no bitmap
(End)
```

Examples (IV/V)

- RpW mode
  - NACK-oriented, N=3
  - 11 fragments

```
 Sender                     Receiver
     |--------CFN=6--------->|
     |--------CFN=5--------->|
     |--------CFN=4--------->|
     |--------CFN=3--------->|
     |--------CFN=2--------->|
     |--------CFN=1--------->|
     |--------CFN=0--------->|
(no NACK)
     |--------CFN=6--------->|
     |--------CFN=5--------->|
     |--------CFN=4--------->|
     |--------CFN=7--------->|MIC checked =>
(no NACK)
```

```
 Sender                     Receiver
     |--------CFN=6--------->|
     |--------CFN=5--------->|
     |--------CFN=4---X----->|
     |--------CFN=3--------->|
     |--------CFN=2---X----->|
     |--------CFN=1--------->|
     |--------CFN=0--------->|
     |<--------NACK----------|Bitmap:11010111
     |--------CFN=4--------->|
     |--------CFN=2--------->|
(no NACK)
     |--------CFN=6--------->|
     |--------CFN=5--------->|
     |--------CFN=4---X----->|
     |--------CFN=7--------->|MIC checked =>
     |<--------NACK----------|Bitmap:11010001
     |--------CFN=4--------->|MIC checked =>
(no NACK)
```

Examples (V/V)

- RpW mode
  - ACK-oriented, N=3
  - 11 fragments

```
Sender                    Receiver
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4-------->|
  |-------CFN=3-------->|
  |-------CFN=2-------->|
  |-------CFN=1-------->|
  |-------CFN=0-------->|
  |<-------ACK----------|no bitmap
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4-------->|
  |-------CFN=7-------->|MIC checked =>
  |<-------ACK----------|no bitmap
(End)
```

```
Sender                    Receiver
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4---X---->|
  |-------CFN=3-------->|
  |-------CFN=2---X---->|
  |-------CFN=1-------->|
  |-------CFN=0-------->|
  |<-------ACK----------|bitmap:11010111
  |-------CFN=4-------->|
  |-------CFN=2-------->|
  |<-------ACK----------|no bitmap
  |-------CFN=6-------->|
  |-------CFN=5-------->|
  |-------CFN=4---X---->|
  |-------CFN=7-------->|MIC checked =>
  |<-------ACK----------|bitmap:11010001
  |-------CFN=4-------->|MIC checked =>
  |<-------ACK----------|no bitmap
(End)
```

For -03 and/or discussion

- Fragment renumbering for RpP mode
- Window bit for RpW mode
- Timeout for NACK-oriented
  - E.g. miss CFN=0 or CFN=11..1
- L2 MTU variation
- Quick downlink fragment delivery
  - In some technologies, DL transmission only possible after UL transmission
  - Uplink feedback after each fragment as an option?

Thanks!

Comments?

Authors:
Ana Minaburo <ana@ackl.io>
Laurent Toutain <laurent.toutain@imt-atlantique.fr>
Carles Gomez <carlesgo@entel.upc.edu>

Static Context Header Compression (SCHC)

draft-ietf-lpwan-ipv6-static-context-hc-02

Authors:
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C. Gomez <carlesgo@entel.upc.edu>

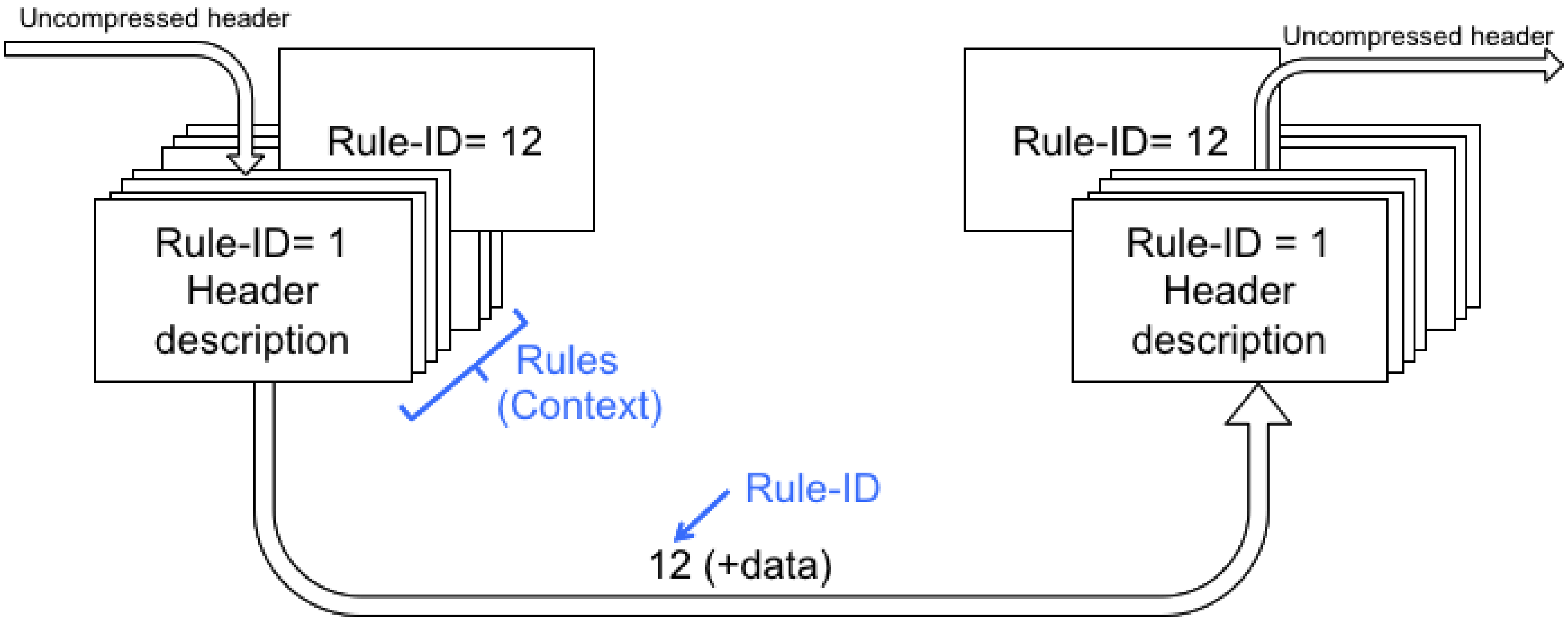
Prresented by:
Ivaylo Petrov <ivaylo@ackl.io>

98th IETF, Chicago, March 29th, 2016

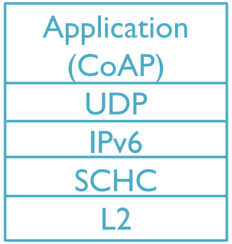
Summary

- SCHC Architecture
- Modifications in this new version

SCHC (Static Context Header Compression)



SCHC Compressor/Decompressor (LC) on architecture




```
          End-System                                       Appl  Servers
   +------------------+                                   +----------------+
   | APP1   APP2 APP3 |                                   |APP1   APP2 APP3|
   |                  |                                   |                |
   |       UDP        |                                   |      UDP       |
   |      IPv6        |                                   |     IPv6       |
   |                  |                                   |                |
   |      LC (contxt)|                                    |                |
   +--------+---------+                                   +-------+--------+
            |    +--+      +--+      +-----------+                .
            +~~ |RG| === |NG| === |LC (contxt)| ... Internet ...
                 +--+      +--+      +-----+-----+

                         Figure 1: Architecture
```

Context

```
  +-----------------------------------------------------------------+
  |                       Rule N                                     |
 +-----------------------------------------------------------------+ |
 |                    Rule i                                        | |
+-----------------------------------------------------------------+ | |
|                Rule 1                                            | | |
|+-------+------------+-------------------+-----------------+| | |
||Field 1 | Target Value | Matching Operator | Comp/Decomp Fct || | |
|+-------+------------+-------------------+-----------------+| | |
||Field 2 | Target Value | Matching Operator | Comp/Decomp Fct || | |
|+-------+------------+-------------------+-----------------+| | |
||...      |    ...       | ...               | ...             || | |
|+-------+------------+-------------------+-----------------+| |-+
||Field N | Target Value | Matching Operator | Comp/Decomp Fct || |
|+-------+------------+-------------------+-----------------+|-+
|                                                                  |
+-----------------------------------------------------------------+
```

What's new

- Minor change in context
  - Add field ID
- Strict rule selection:
  - All fields in packet MUST match all fields in rule
- Add matching lists:
  - Taken from coap draft
  - Basic set of MO and CDF
- Analysis of MO/CDF for IPv6 and UDP Fields

- Add fragmentation

Matching Operators

- Equal:
  - Target Value = Field Value
- Ignore:
  - Field value not tested
- MSB (x):
  - same x most significant bits
- Match-mapping (from CoAP draft) :
  - TV contains a list, FV in that list `TV`
    ```
    {0 :2001:db8:1:1,
     1 : 2001:db8:2:3
     2 : 2001:db8:3:7}
    ```

Compression Decompression Functions

- Add *mapping-sent* (from CoAP draft)
  - Index is sent corresponding to the FV

```
{ 0: 2001:db8:1:1,
  1: 2001:db8:2:3
  2 : 2001:db8:3:7}
```

- Rename *compute-length* and *compute-checksum*
  - More generic (IPv6, UDP, …)

Questions?

- Thank you

SCHC for CoAP

Authors:
Ana Minaburo – Laurent Toutain

98th IETF, Chicago, March 29th, 2016

What’s new

- Move text from CoAP to IPv6 draft
- No new CDF or MO
- But:
  - Extend rule definition with direction
  - Extend MO with position

CDF: Compression Decompression Function – MO: Matching Operator

CoAP specifities

- Value length

Thing

```
CON GET MID=0x1234
Token 0xDEADBEEF
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

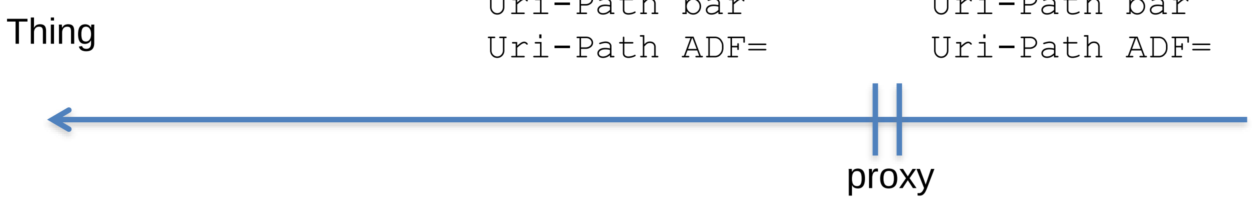
- Regular CoAP client will use « large » ID
  - May be reduced in LPWAN
- Use Proxy (out of the scope)

CoAP specifities

- Value length

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

```
CON GET MID=0x1234
Token 0xDEADBEEF
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```



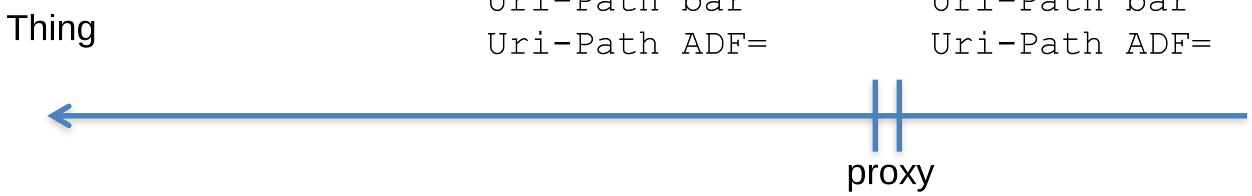
- Regular CoAP client will use « large » ID
  - May be reduced in LPWAN
- Use Proxy (out of the scope)

CoAP specificities

- Value length

CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=

CON GET MID=0x1234
Token 0xDEADBEEF
Uri-Path foo
Uri-Path bar
Uri-Path ADF=

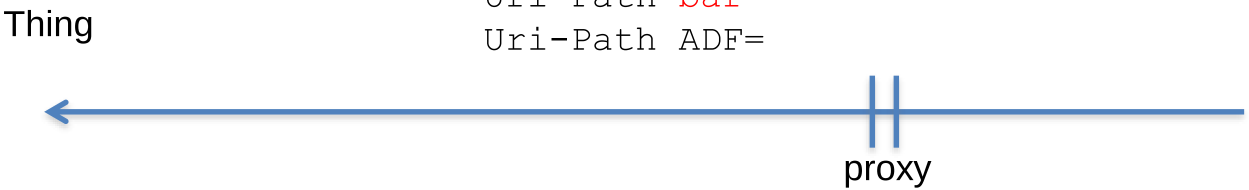


- MID: TV=0x0000 MO=MSB(12) CDF=LSB(4)
- TOK: TV= MO=ignore CDF=value-sent

CoAP specificities

- Position

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

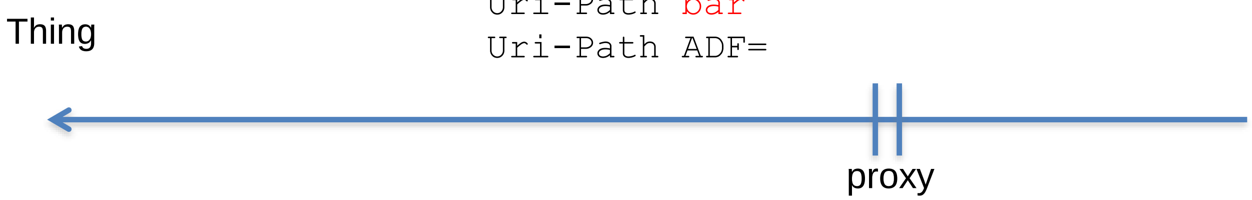


- `/foo/bar` is different from `/bar/foo`
- Add position for MO

CoAP specificities

- Position

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```



- `Uri-Path: TV=foo    MO=equal(1)   CDF=not-sent`
- `Uri-Path: TV=bar    MO=equal(2)   CDF=not-sent`

CoAP specificities

- Variable length

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

- Variable length:
  - Send CoAP option (including length)

- `Uri-Path: TV=   MO=ignore(3)   CDF=value-sent`

CoAP specificities

- Asymmetry

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

Thing


```
ACK 2.05 MID=0x000A
Token 0x1A
Content 0x51

value
```

Direction in the entry rule

- A new entry in the rule
  - Upstream
  - Downstream
  - Bidirectionnal (by default)
- MO applies only for the appropriate direction
- Depending of the scenario
  - Thing is server: request is downstrean
  - Thing is client: request is upstream

Example

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

←

→

```
ACK 2.05 MID=0x000A
Token 0x1A
Content 0x51
```

value

FID	TV	MO	CDF	Dir
version	1	Equal	Not-sent	bi
Type	CON	Equal	Not-sent	down
Type	{ACK:0, RST:1}	Match-mapping	Mapping-sent	up
TKL	1	Equal	Not-sent	bi
Code	GET	Equal	Not-sent	down
Code	{2.05:0, 4.04:1}	Match-mapping	Mapping-sent	up
MID	0x0000	MSB(12)	LSB(4)	bi
Token		Ignore	Value-sent	bi
Uri-Path	Foo	Equal 1	Not-sent	down
Uri-Path	Bar	Equal 2	Not-sent	down
Uri-Path		Ignore 3	Value-sent	down
Content	0x51	Equal	Not-sent	up

draft-ietf-lpwan-coap-static-context-hc-01

Example

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

4+8+24= 36 bits

```
ACK 2.05 MID=0x000A
Token 0x1A
Content 0x51
```

value

FID	TV	MO	CDF	Dir
version	1	Equal	Not-sent	bi
Type	CON	Equal	Not-sent	down
Type	{ACK:0, RST:1}	Match-mapping	Mapping-sent	up
TKL	1	Equal	Not-sent	bi
Code	GET	Equal	Not-sent	down
Code	{2.05:0, 4.04:1}	Match-mapping	Mapping-sent	up
MID	0x0000	MSB(12)	**LSB(4)**	bi
Token		Ignore	**Value-sent**	bi
Uri-Path	Foo	Equal 1	Not-sent	down
Uri-Path	Bar	Equal 2	Not-sent	down
Uri-Path		Ignore 3	**Value-sent**	down
Content	0x51	Equal	Not-sent	up

Example

```
CON GET MID=0x000A
Token 0x1A
Uri-Path foo
Uri-Path bar
Uri-Path ADF=
```

4+8+16= 28 bits

1+1+4+8 = 14 bits

```
ACK 2.05 MID=0x000A
Token 0x1A
Content 0x51
```

value

FID	TV	MO	CDF	Dir
version	1	Equal	Not-sent	bi
Type	CON	Equal	Not-sent	down
Type	{ACK:0, RST:1}	Match-mapping	**Mapping-sent**	up
TKL	1	Equal	Not-sent	bi
Code	GET	Equal	Not-sent	down
Code	{2.05:0, 4.04:1}	Match-mapping	**Mapping-sent**	up
MID	0x0000	MSB(12)	**LSB(4)**	bi
Token		Ignore	**Value-sent**	bi
Uri-Path	Foo	Equal 1	Not-sent	down
Uri-Path	Bar	Equal 2	Not-sent	down
Uri-Path		Ignore 3	Value-sent	down
Content	0x51	Equal	Not-sent	up

Open issues

- Options in other RFCs/draft
  - Observe:
    - Send delta-TLV
    - Use of proxy to reduce Observe value
  - Block:
    - Send delta-TLV
      - Block minimum size (16 B) can be bigger than LPWAN payload
    - SCHC fragmentation instead ?

Open issues

- Path structure:
  - Number of element in a path
    - /foo/bar?value=xxx
    - /foo?value=xxx&value2=yyyy
  - 2 rules?
  - create a null element?

- Feedback from platforms
  - CoMI, LWM2M, IoTivity,…

Security

- Do not modify end-to-end security:
  - OSCoAP

Timer and values

- Are value and timer defined in RFC compatible with LPWAN traffic ?
  - Max-age in seconds ?
  - Issue new recommanded values for LPWAN ?

name	default value
MAX_TRANSMIT_SPAN	45 s
MAX_TRANSMIT_WAIT	93 s
MAX_LATENCY	100 s
PROCESSING_DELAY	2 s
MAX_RTT	202 s
EXCHANGE_LIFETIME	247 s
NON_LIFETIME	145 s

– Impact on Mid and Token size

SCHC implementation for LoRaWAN

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Diego Dujovne <diego.dujovne@mail.udp.cl >

98th IETF, Chicago, March 29th, 2017

Undergraduate thesis

Objective

- IPv6 on LoRa Networks
- Reduce the IPv6 header
- Implement the neighbor discovery protocol

6LoWPAN

- 2 Bytes corresponding to:

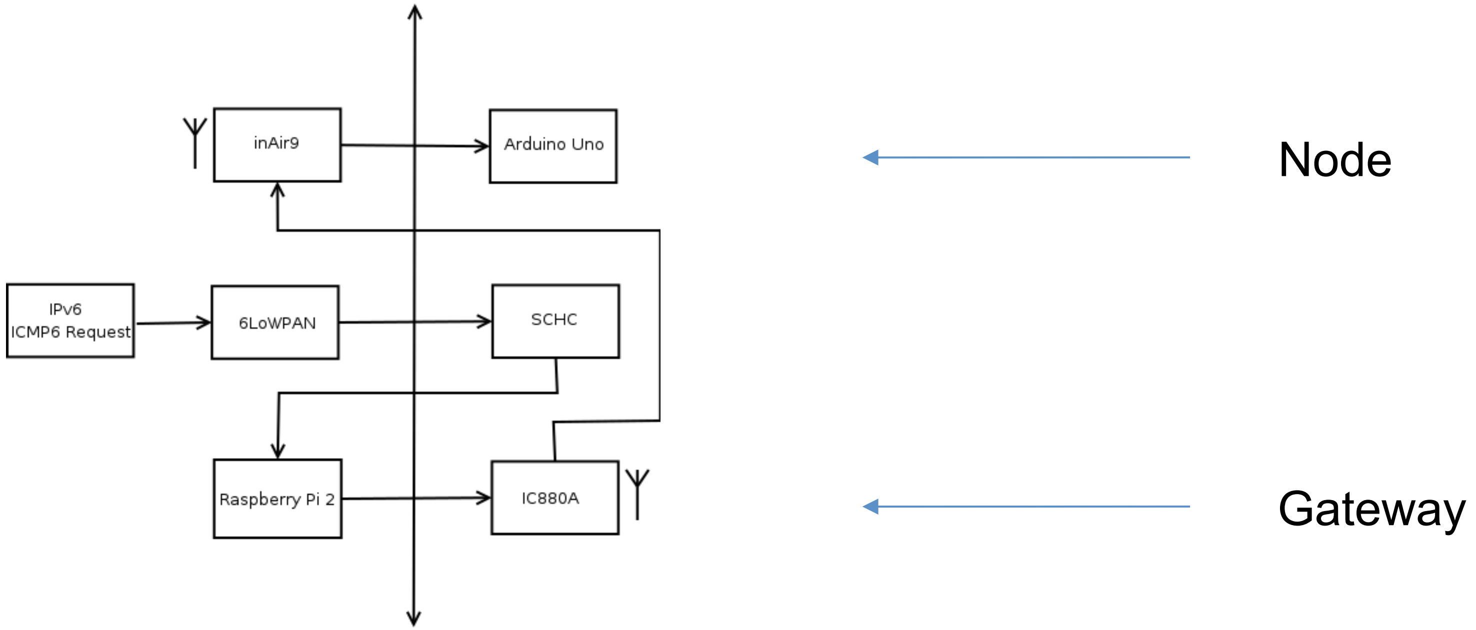
0	1	1	TF	NH	HLIM	CID	SAC	SAM	M	DAC	DAM

- Best case :
  - Hop limit is a standard value, Traf. Class and Flow label are set to 0 and Link Local addresses are used over a single hop network, 4 Bytes Header

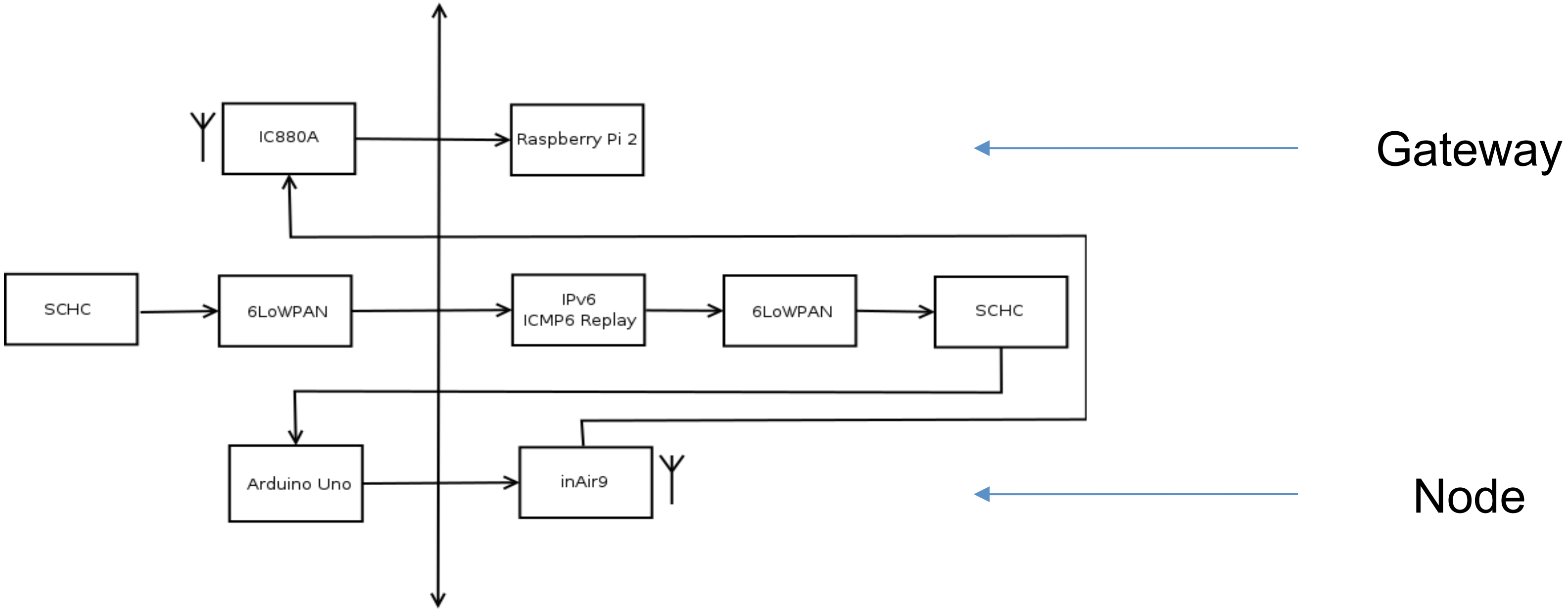
SCHC compression for 6LoWPAN header

- Encode 6LoWPAN header with SCHC rule.
- Decode SCHC rule to 6LoWPAN header.

Project diagram
Gateway - Node



Project diagram
Node - Gateway



Accomplishment

- Use of Link-local address on Nodes and Gateway
- ICMPv6(request – reply)
- SCHC over 6LoWPAN

Thank you

Authors:
Tomás Lagos <tomas.lagos@mail.udp.cl>
Diego Dujovne <diego.dujovne@mail.udp.cl >

https://github.com/tlagos1/LoRA_IPv6_implementation

SCHiCago Demonstration

SCHC over Sigfox

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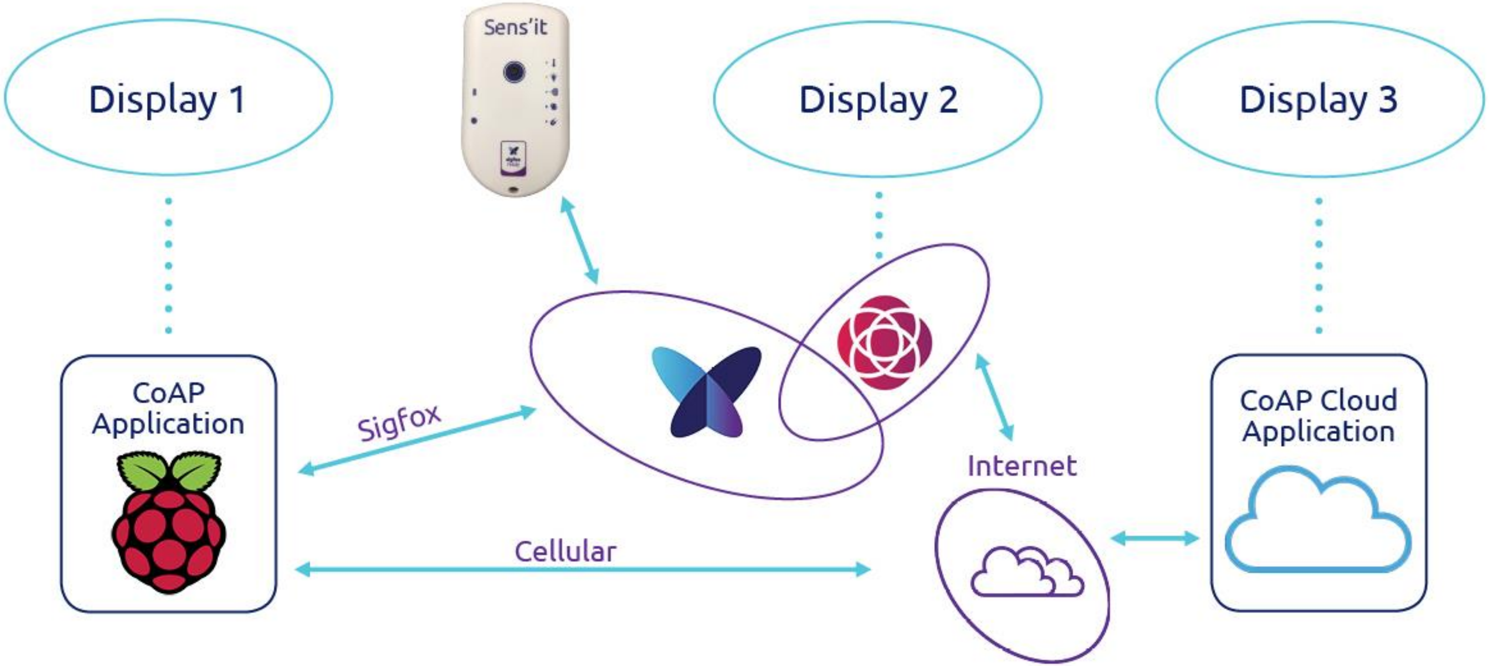
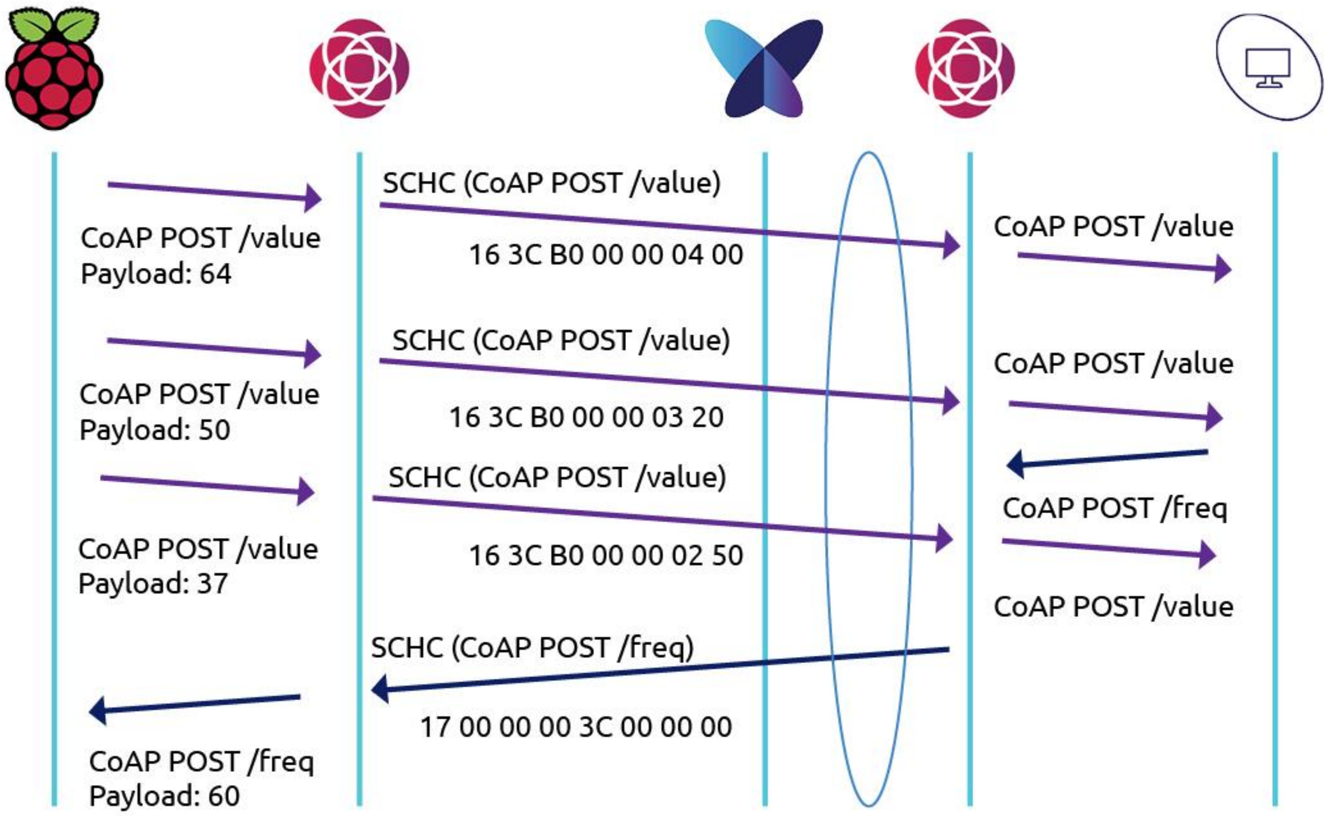
Arunprabhu Kandasamy <arun@ackl.io>

98th IETF, Chicago, March 29th, 2016

SCHiCago Demonstration

- Static Context Header Compression (SCHC) method proposed in LPWAN WG
  - draft-ietf-lpwan-ipv6-static-context-hc
  - draft-ietf-lpwan-coap-static-context-hc
- Two scenarios to be demonstrated at Bits-n-Bites event (Thursday)
- Scenario 1
  - Interoperability of CoAP/UDP/IPv6 application over SCHC/Sigfox and over Cellular
  - Multi-mode Sigfox/Cellular device capable of performing SCHC and CoAP functions
- Scenario 2
  - CoAP/UDP/IPv6/SCHC to legacy constrained device
  - Single mode device with simple microcontroller, responding directly to compressed packets


Display 1
Sens'it
Display 2
Display 3
CoAP Application
Sigfox
Internet
CoAP Cloud Application
Cellular



SCHC (CoAP POST /value)
CoAP POST /value
Payload: 64
16 3C B0 00 00 04 00
CoAP POST /value
SCHC (CoAP POST /value)
CoAP POST /value
CoAP POST /value
Payload: 50
16 3C B0 00 00 03 20
SCHC (CoAP POST /value)
CoAP POST /freq
CoAP POST /value
Payload: 37
16 3C B0 00 00 02 50
CoAP POST /value
SCHC (CoAP POST /freq)
17 00 00 00 3C 00 00 00
CoAP POST /freq
Payload: 60

IEEE 802.15 LPWAN

LPWAN Interest Group
LPWAN Standard – IEEE 802.15.4K
LPWAN Standard – IEEE 802.15.4G

LPWAN Interest Group

Background

A variety of proprietary system or quasi standards have been developed. Examples for such systems are LoRa [LORA] or SIGFOX [SIGFOX]. Furthermore, also 3GPP is working on NB-IoT (Narrow Band-Internet of Things), an extension of the 3GPP specification to cover similar application as the LPWA networks [NB-IOT]. Nevertheless, also existing IEEE specifications (e.g. 802.15.4k and 802.15.4g) may be able to cover many of the LPWA applications. However, the performance of the existing IEEE solutions and other existing standards is not fully clear.

Purpose

- This Interest Group will therefore evaluate the performance of different candidate technologies in selected use-cases for their use in LPWA networks.
- Final aim of this Interest Group is a white paper that shows the potential pros and cons of different technology candidates as well as of existing standards.

LPWAN Interest Group

Accomplishments

- LPWA Use Cases: 15-16-0770-05
- Candidate Technology Qualitative Evaluation: 15-17-0228-00
- Liaison letter to ETSI LTN: 15-17-0241-00
- Proposal for Suitability Analysis of IG LPWA Report: 15-17-0155-01
- FHSS Link Performance Evaluation for LPWAN Systems: 15-17-0209-00

LPWAN Interest Group

Project Plan

- March 2017 Plenary (Vancouver)
  - Discussion of evaluation criteria
  - Presentation of contributions with focus technology options for LPWA
- Proposed Conference Call:
  - 11 April 16:00 (CEST), 07:00AM (PDT)
  - Details will be circulated on IG LPWA reflector and on mentor
- ~~May 2017 Daejeon~~
- July 2017 Plenary (Berlin)
  - Final discussion on IG report

LPWAN Standard: IEEE 802.15.4K

Initial Purpose

- Facilitate point to multi-thousands of points communications for critical infrastructure monitoring devices
- Addresses the application's user needs of minimal network infrastructure
- Enables the collection of scheduled and event data from a large number of non-mains powered end points that are widely dispersed, or are in challenging propagation environments
- Facilitate low energy operation necessary for multi-year battery life,
- Minimizes network maintenance traffic and device wake durations
- Addresses the changing propagation and interference environments.

Overview

- Star or extended star topology
- Asymmetric links, controller has more power and computation ability
- Frequency Bands: 169, 433, 470, 780, 863, 915, 917, 920, 921, 922, 2450 MHz
- Direct Sequence - Code Division Multiple Access (CDMA), chip rates 100 – 2000 c/s
- FSK – Data rates: 12.5 to 37.5 kb/s for FSK, spreading factors of 1 - 16
- Maximum frame size: 16 – 32 octets for DSSS, up to 2047 octets for FSK

LPWAN Standard IEEE 802.15.4K

Features

- PHY fragmentation (FRAK) – Frame is sent in multiple (< 64) packets
  - Allows for full featured MAC header
- Transparent repeaters (TRLE) for range extension
  - Does not require special configuration of end devices
- Forward Error Correction (FEC): both FSK and DSSS
  - Increased reliability and range

LPWAN Standard
IEEE 802.15.4G

Purpose

To provide a global standard that facilitates very large scale process control applications such as the utility smart-grid network. This standard supports large, geographically diverse networks with minimal infrastructure. Smart Metering Utility Networks can potentially contain millions of fixed endpoints.

Overview

- Operation in regionally available frequency bands, ranging from 169 to 2450 MHz
- Three physical layer types: MR-FSK, OFDM, O-QPSK
- Data rate of at least 4.8 to 400 kb/s
- Achieve the optimal energy efficient link margin given the environmental conditions encountered in Smart Metering deployments.
- Principally outdoor communications
- PHY frame sizes up to a minimum of 2047 octets
- Simultaneous operation for at least 3 co-located orthogonal networks
- Connectivity to at least one thousand direct neighbors characteristic of dense urban deployment
- Provides mechanisms that enable coexistence with other systems in the same band(s) including IEEE 802.11

LPWAN Standard
IEEE 802.15.4G

Features

- Mesh topologies
  - Increased reliability and range
- Channel hopping
  - Coexistence and interference rejection
- Forward Error Correction
  - 1/2-rate systematic or nonsystematic convolution coding with constraint length K = 4
- Common signalling mode
  - to facilitate the multi-PHY management (MPM)

An Introduction to IEEE 802 IG LPWA (Low Power Wide Area)

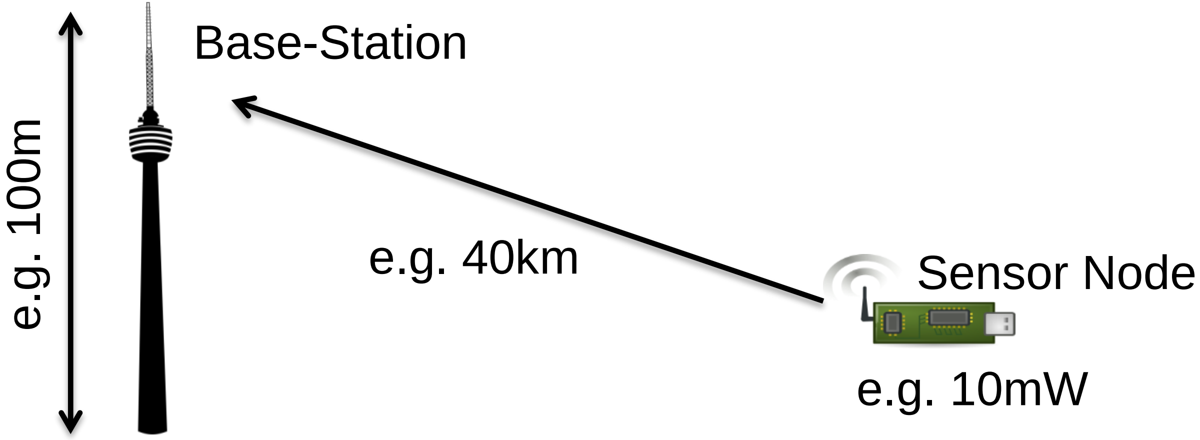
Charlie Perkins <charles.perkins@earthlink.net>
Joerg Robert <joerg.robert@fau.de>

98th IETF, Chicago, March 29th, 2016

Contents

- What are LP-WANs?
- Typical Applications and Characteristics
- Reason for the Low LP-WAN Bit-Rates
- Downlink Issues
- Costs of using IP Directly
- Channel Access
- Current Work in IEEE 802.15

What are LP-WANs?



- Small and cost-efficient sensor nodes transmit data over long distances with ultra-low power (1/10 of typical Wi-Fi transmit power)
- The sensor nodes are powered by tiny batteries (e.g. coin type)
- One base-station may serve millions of sensor nodes
- Multi-hop transmission is typically not used

Typical Applications

Application	Description
Alarms and Security	Monitoring of doors, windows, etc.
Smoke Detectors	Real time alerts, monitoring battery life, etc.
Cattle Monitoring	Location and health monitoring of cattle
Logistics	Location and monitoring of goods
Smart Parking	Available parking space indication in real-time
Smart Metering	Automatic reading of gas/water meters
Structural Health Monitoring	Monitor structural health of bridges, etc.

- LP-WANs mostly address sensor applications
- Further use-cases are listed in [1]

Typical LP-WAN Characteristics

	LP-WAN	Wi-Fi
Bit-Rate	< 1 kBps	>> 1 Mbps
Latency	Up to minutes	<< 1 s
Payload length	~ 16 byte	> 1 kbyte
Max. number of uplink packets / day	~ 200	Millions
Max. number of downlink packets / day	< 20	Millions
Max. distance w/o directive antennas	Up to 40 km	< 100 m
Typical power supply	Coin type / AA	Electrical Outlet / Li-Ion
Battery lifetime	Several years	Hours (laptop/mobile)
Typical frequency bands	< 1 GHz	2.4 GHz, 5.4 GHz

Reason for Low LP-WAN Bit-Rates

- Minimum energy to transmit one bit
- Received power P_{Rx} is the transmitted power P_{Tx} minus the path loss from interference (noise)
- For a few details, see next three slides

Reason for Low LP-WAN Bit-Rates (I/III)

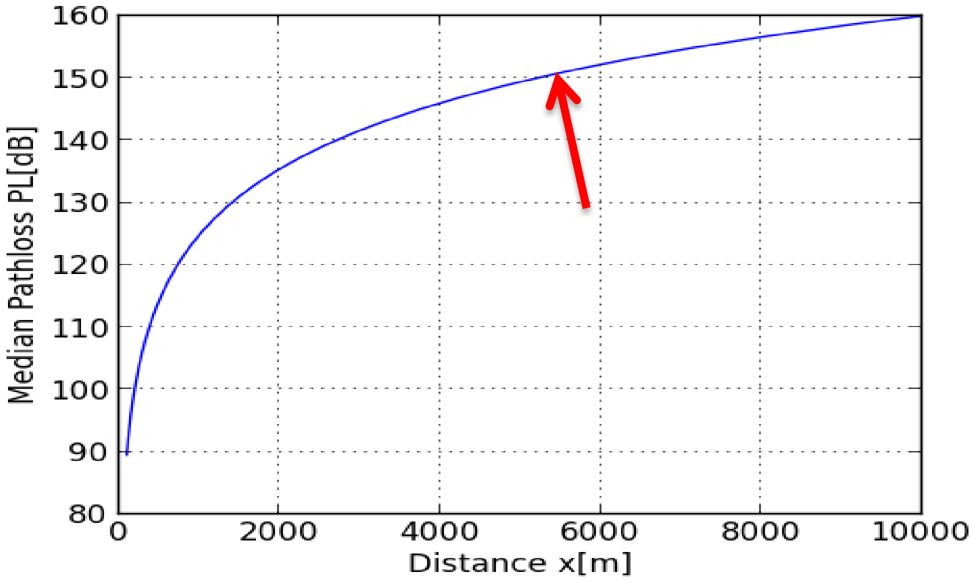
- According to information theory the successful transmission of an information bit requires a certain energy
- The energy per bit is given by the reception power P_{Rx} divided by the bit-rate R
- The theoretical maximum payload bit-rate is then given by [2]:

$$R_{\max}[\text{bit/s}] = 10^{\frac{P_{Rx}[\text{dBm}]+174\text{dBm/Hz}+1.59\text{dB}}{10}}$$

- Assumptions:
  - Eb/N0=-1.59dB (information theoretic value for error-free decoding)
  - Noise figure 0dB
  - Noise power spectral density -174dBm/Hz

Reason for Low LP-WAN Bit-Rates (II/III)

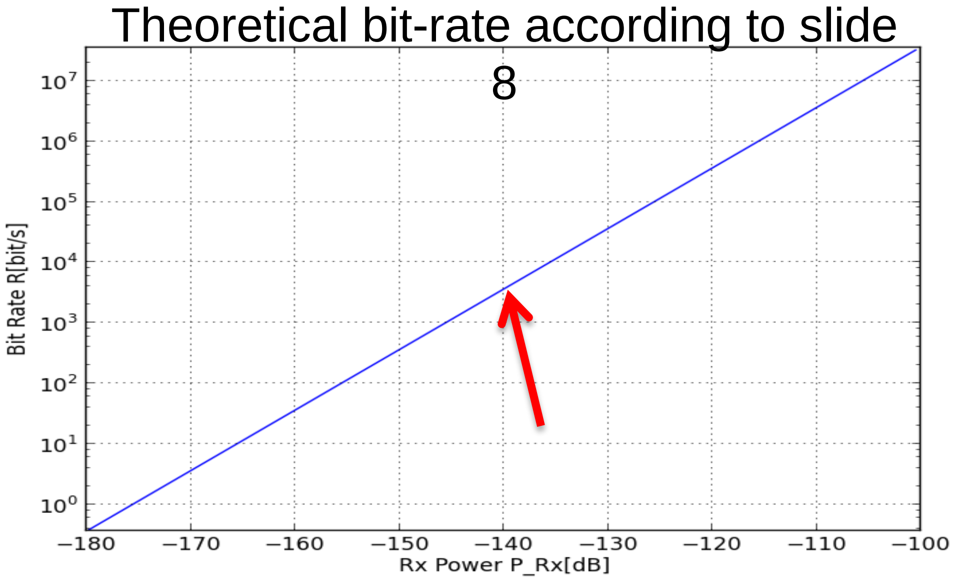
Path loss according to channel model



Base-station antenna height: 30m
Sensor node antenna height: 2m

- The received power P_{Rx}[dBm] is given by the transmitted power P_{Tx}[dBm] minus the path loss PL[dB] {plus antenna gain, not considered here}
- The path loss PL[dB] for the outdoor-rural channel model [3] corresponds to PL=150dB for a distance of x=5000m
- So, at x=5000m, P_{Rx} equals 10dBm - 150dB = -**140dBm**

Reason for Low LP-WAN Bit-Rates (III/III)



- P_{Rx}[dBm] = -140dBm results in a maximum bit-rate of $R = 3 \cdot \frac{10^3 \text{Bit}}{\text{s}} = 3\text{kBit/s}$

➢ Transmitting each bit is expensive!

➢ Packet overhead has significant impact

Downlink-Issues

- The uplink and downlink have the same regulatory restrictions, but the base-station is more sensitive [4]
  - ➢ Downlink is more critical than uplink
- The base-station may be able to receive from thousands of sensor nodes simultaneously, but it can only transmit to a single downlink node at a time [4]
  - ➢ Only a few packets can be transmitted in the downlink

➢ Acknowledging uplink packets is impractical

➢ Due to downlink, LP-WANs are highly asymmetric

Costs of using IP (and TCP) directly

- The typical payload length is only a few bytes. Even a few bytes overhead can significantly impact efficiency.
  - Reduced battery life, increased channel load and latencies

- IP headers (for IPv4 / IPv6) are much longer than a typical LP-WAN payload.

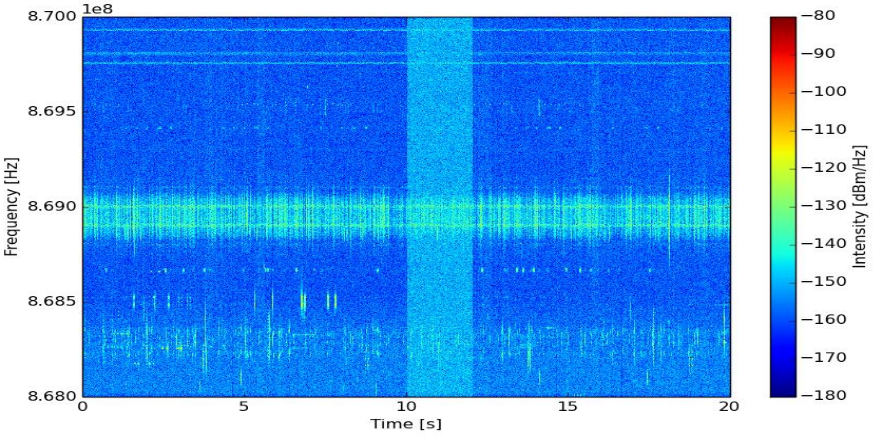
- Connection oriented protocols (e.g. TCP) require significant downlink traffic, and further increase overhead.

➢ **Gateways** are very beneficial (as discussed within IETF [5])

Channel Access

- Base-stations are often mounted on exposed sites, while sensor nodes are near the ground
- ➢ Very high uplink traffic [6]
- ➢ Algorithms such as CSMA have “hidden node” problems
- ➢ Significant levels of interference from other systems can be expected [7]

Measured interference (Erlangen/Germany)



➢ Current research for LP-WANs focuses on improved channel access algorithms based on ALOHA, and methods to improve robustness (with respect to interference)

Current Work in IEEE 802.15

- Interest Group (IG) LPWA is developing a report on use-cases and potential technologies for LP-WAN [1]
  - Final IG report is expected end of July 2017

- IG LPWA has already defined and analyzed:
  - Use-cases
  - Regulatory aspects
  - Channel / interference models

- Current focus of IG LPWA is on analyzing:
  - Suitability of existing IEEE standards of LP-WAN
  - Candidate technologies and their suitability for LP-WAN (e.g. modulation, forward error correction, channel access, encryption, privacy, ...) [8]

Procedure for Evaluating a Candidate Technology

Suitability

- Analyze the general suitability of a candidate technology

Qualitative Evaluation

- Analyze pros and cons, and dependency on other technologies

Quantitative Evaluation

- Exact performance (for selected technologies)

Use-Case Parameters for Evaluations

- Channel Model
- Interference Model
- Active Interfering Users
- Communication Mode
- Data Period
- Data Length
- Availability
- Frequency Regulation
- Cell Radius
- Data Security
- Node Velocity
- Latency
- Typical Power Supply
- LP-WAN Localization

Example of Current Work – Suitability Evaluation

Use-case parameters are matched against the evaluation results. A use-case is not supported if any parameter is not supported (see next slide) [9]

Example:

- Modulation DSSS (Direct Sequence Spread Spectrum)
  - Spreading offers additional robustness, but fails in case of strong interference from other frequency users
  - Spreading increases the required channel bandwidth and / or the length of the packets, making the data more vulnerable
  - ➢ DSSS is not suitable if large “Cell Radius” is required

Results of the DSSS Suitability Evaluation on the Use-Cases

Access Control	Public Lighting
Alarms and Security	Smart Grid - Fault Monitoring
Asset Tracking	Smart Grid - Load Control
Assisted Living	Smart Metering
Cattle Monitoring	Smart Parking
Field Monitoring	Smoke Detectors
Global Tracking	Structural Health Monitoring
Industrial Plant Condition Monitoring	Vending Machines - general
Industrial Production Monitoring	Vending Machines - privacy
Light Switch	Waste Management
Pet Tracking	Water Pipe Leakage Monitoring
Pipeline Monitoring - Terrestrial	

Conclusion

- LPWANs are mainly suitable for monitoring applications
- Long range communications results in very low payload bit-rates
- IP overhead is too large for many applications
- Channel access and interference are critical design considerations

- IG LPWA (within IEEE 802.15) is currently investigating LPWAN technologies and technical prospects of a new standard.
- The IG (Interest Group) report is expected in July 2017. A Study Group or Task Group might be formed as a result.

Thank You for Your Interest!

Literature

[1] IEEE 802.15, IG LPWA, LPWA Use-Cases, https://mentor.ieee.org/802.15/dcn/16/15-16-0770-05-lpwa-lpwa-use-cases.xlsx

[2] Proakis, J. G., Salehi, M.; Digital Communications, McGRAW-Hill, 2008

[3] IEEE 802.15, IG LPWA, Proposal for LPWAN Channel Models, https://mentor.ieee.org/802.15/dcn/17/15-17-0036-01-lpwa-proposal-for-lpwan-channel-models.pptx

[4] IEEE 802.15, IG LPWA, LP-WAN Downlink Issues, https://mentor.ieee.org/802.15/dcn/17/15-17-0164-00-lpwa-lp-wan-downlink-issues.pptx

[5] IETF, LPWAN Overview, https://datatracker.ietf.org/doc/draft-ietf-lpwan-overview/

[6] IEEE 802.15, IG LPWA, Number of Active Interfering Users, https://mentor.ieee.org/802.15/dcn/17/15-17-0035-00-lpwa-number-of-active-interfering-users.pptx

Literature (cont.)

[7] IEEE 802.15, IG LPWA, Proposal for sub-GHz Interference Model, https://mentor.ieee.org/802.15/dcn/17/15-17-0037-01-lpwa-proposal-for-sub-ghz-interference-model.pptx

[8] IEEE 802.15, IG LPWA, Candidate IEEE Standards and Technologies for IG Report, https://mentor.ieee.org/802.15/dcn/17/15-17-0211-01-lpwa-candidate-ieee-standards-and-technologies-for-ig-report.pptx

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LPWAN Extensions

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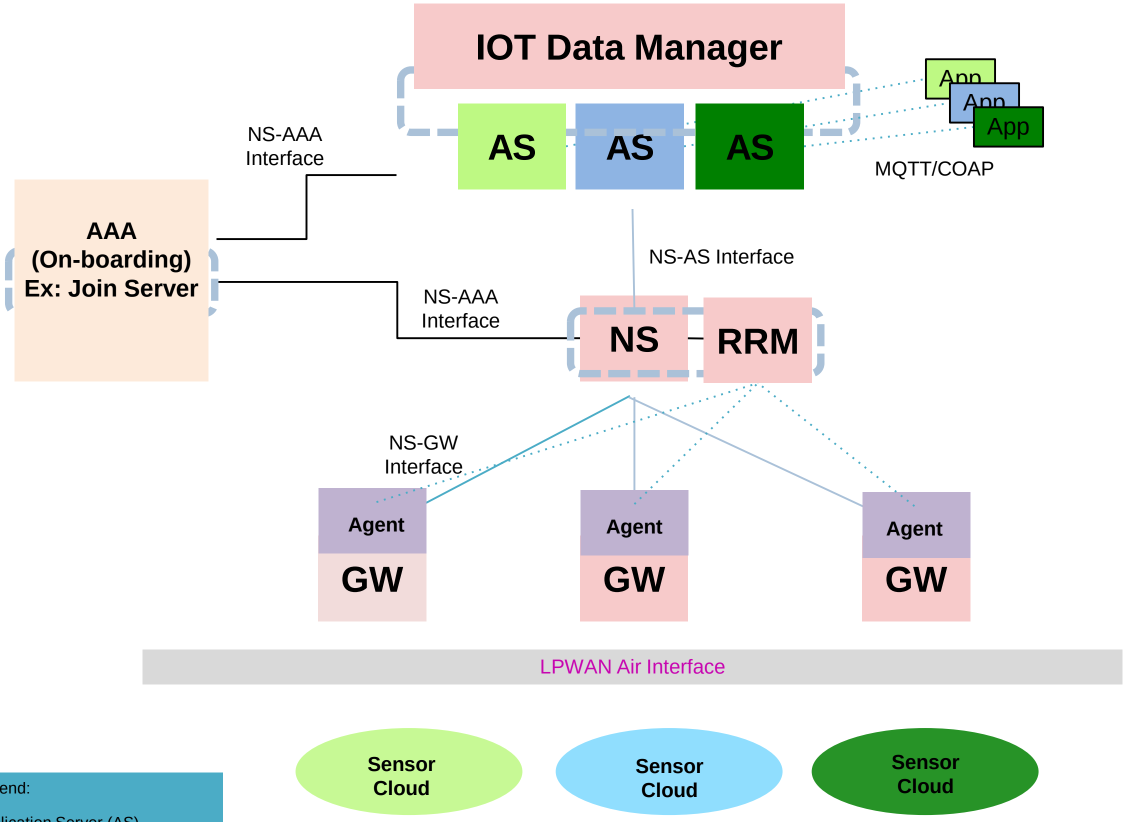
LPWAN Functional Architecture



Legend:

Application Server (AS)
Network Server (NS)
Radio Resource Manager (RRM)

New Extensions

Standardization of the interface between:

1.) network server and the gateway
2.) network server and application server
3.) radio resource management on gateways

There is a need for network server from vendor to interwork with gateways with other vendors over standardized interfaces. These are the key gaps that is disallowing vendor interoperability in LPWAN deployments today.

LPWAN - Radio Resource Management

LPWAN

- The following are the key radio and service related aspects that will be managed on the gateway.

Category	Description
Radio Configuration	Radio configuration settings on the LoRA Gateway
Per-Channel Statistics	Channel specific performance characteristics
Gateway Configuration	Configuration of the protocol handlers and packet forwarder functions.
Device Bindings	Details related to every single device that has currently some session state on the NS and on the Gateway.
Device Statistics & Counters	General statistics and counters related to sensor attachments, failures, protocol and security violations

Radio Configuration

Object	Description
Country Setting Mode	Operating mode/region
Number of Channels configured	Number of Channels enabled on the Lora Gateway
Guard Band	Guard-band between channels; Default 150Mhz between channels
Spreading Factor	Spreading factor used in each supported channel; SF6 – SF12
Power Transmission	Downlink Power Transmission towards Lora end device; dBm or mW
ISM Band	Supported ISM Bands; Enum; 169MHz, 434MHz, 470MHz, 868MHz, 915MHz
Channel Table {Central Frequency, Bandwidth, Spreading Factor}	List of channels with channel specific details
Antenna Type/Height/Gain	Type of antenna improvement of Rx and Diversity; Height; Gain

Per-Channel Statistics

Object	Description
Noise	Noise levels in the channel;
Duty Cycle	Duty Cycle of the LoRA gateway per Sub-band
Packet Error Rate	Receiver sensitivity per channel
CRC Error Rate	Percentage of packets received with CRC errors per-channel
CRC Error Packet Forwarded Count	Number of packets with CRC errors forwarded to Network Server
CRC No-Error Packet Forwarded Count	Number of packets with no-CRC errors forwarded to the network server
Tx Packet Rate	Percentage of total transmitted packets towards network server over each channel

LoRA Packet Forwarded Configuration

Object	Description
CRC Packet Handling	Behavior of the gateway w.r.t handling CEC error packets
Packet Scheduling Behavior	If the gateway should forward packets based on the NS scheduled times, or it should ensure the DL slots match the device negotiated slot
Device Black List Table	List of devices not authorized to use this gateway
Device White List Table	List of devices allowed to use this gateway
NS based on Application Type	List of application types with the corresponding Network Server address

Per-Device Bindings

Object	Description
Protocol Version	LoRa Protocol version that the device supports
Sensor Identifier	DevEUID / DevId
RSSI	Received Signal Strength Indication
SNR	SNR ratio on the received LoRA fram
CRC Coding Rate	CRC error coding to perform forward error detection and correction
Data Rate	Bit-rate of the received LoRA frame
Packet Error Rate	Gateway receiver sensitivity
CRC Error Rate	Percentage of total received packets with CRC errors
Number of packets with CRC errors forwarded to the NS	Number of packets with CRC errors that are forwarded to the NS
Number of packets with CRC errors forwarded to the NS	Number of packets with non CRC errors that are forwarded to the NS
Retransmitted Packet Count	Total number of re-transmits based on FrameCounter

Per-Device Bindings

LPWAN

4b

Object	Description
Tx Packet Rate	percentage of total transmitted packets towards NS received over each uplink channel for each end device
Packets with incorrect MIC	Total number of packets failing MIC
Packets with repeated DeviceNonce	Number of Join requests with re-used DevNonce
RX1 Delay	the delay between uplink and first down slot(RX2_DELAY must be RX1_DELAY + 1s)
Channel list	List of channel frequencies end device is using
Duty Cycle	limitation of the maximum aggregated transmit duty cycle of an end-device
Rx1 data rate offset	Rx1 data rate offset from Tx data rate.
Rx2 data rate	RX2 Data Rate
RX2 Channel	
Battery Level	Battery level obtained using DevStatusReq
Fcnt UP / FCNT DN	Frame Counters UP and DOWN / Difference

Device Statistics & Counters

Object	Description
Total Unique Devices Seen	Total unique device count
List of Devices with protocol violations	Table of device entries that are non-conforming to the LoRA protocols

Questions?