LPWAN WG

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97th IETF, Seoul, November 14th, 2016

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- Minutes
  - Etherpad: http://etherpad.tools.ietf.org:9000/p/notes-ietf-97-lpwan?useMonospaceFont=true
  - Minute takers volunteers?

- Remote participation
  - Meetecho: http://www.meetecho.com/ietf97/lpwan
  - Jabber: lpwan@jabber.ietf.org
    - Jabber scribe volunteers?

- Mailing list: lp-wan@ietf.org
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- Meeting materials: https://datatracker.ietf.org/meeting/97/materials.html/#lpwan

Agenda bashing

- Opening, agenda bashing, Charter presentation, WG chairs (10 min)
- LPWAN Overview Introduction, WG Chairs (stepping in for Stephen Farrell)
  - LPWAN Gap analysis, Ana Minaburo (10 min)
  - ~~LoRaWAN overview, Stephen Farrell (15 min + 5 min Q&A)~~
  - Sigfox system description, Juan Carlos Zuniga (15 min + 5 min Q&A)
  - NB-IoT characteristics, Antti Ratilainen (remote) (15 min + 5 min Q&A)
  - WI-SUN overview, Bob Heile (15 min + 5 min Q&A)
- LPWAN Overview Discussion, WG Chairs (5 min) (stepping in for Stephen Farrell)
- *(1h30 mark)*
- LPWAN Static Context Header Compression (SCHC) for IPv6 and UDP, Laurent Toutain (15 min + 5 min Q&A)
  - SCHC for CoAP (10 min)

- RoHC applicability in LPWAN, Ana Minaburo (10 min)
- LPWAN Fragmentation Header, Carles Gomez (10 min)

WG formed October 14th

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  Archive: https://mailarchive.ietf.org/arch/browse/lp-wan/

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Charter Item #1

Produce an Informational document describing and relating some selected LPWA technologies. This work will document the common characteristics and highlight actual needs that the IETF could serve; but it is not intended to provide a competitive analysis. It is expected that the information contained therein originates from and is reviewed by people who work on the respective LPWA technologies.

Charter Item #2

Produce a Standards Track document to enable the compression and fragmentation of a CoAP/UDP/IPv6 packet over LPWA networks. This will be achieved through stateful mechanisms, specifically designed for star topology and severely constrained links. The work will include the definition of generic data models to describe the compression and fragmentation contexts. This work may also include to define technology-specific adaptations of the generic compression/fragmentation mechanism wherever necessary.

Charter - Milestones

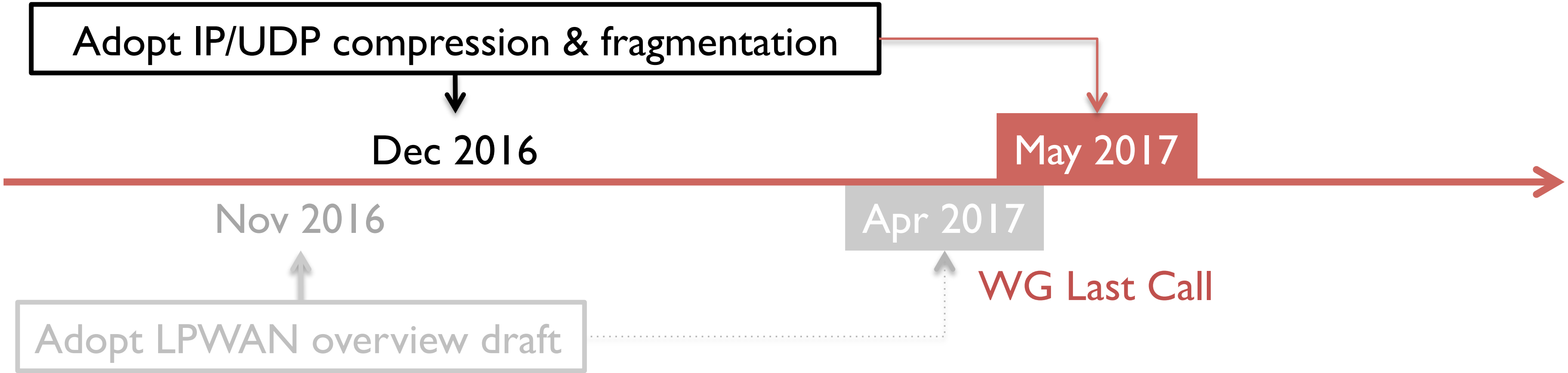
LPWAN

Milestones

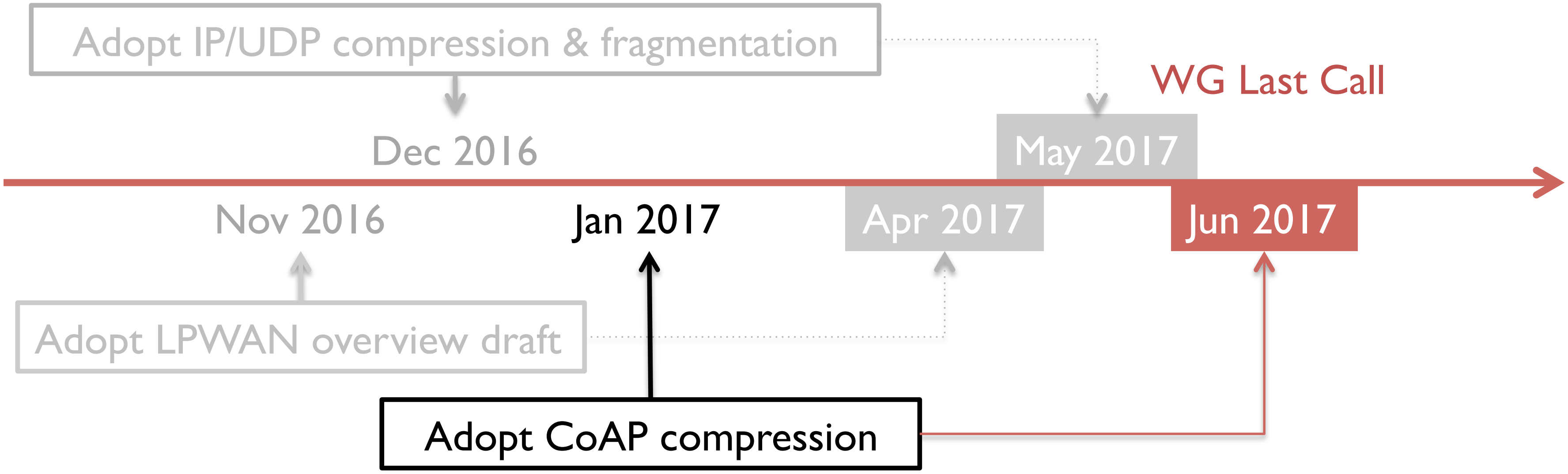
Date	Milestone
Jul 2017	Submit CoAP compression mechanism to the IESG for publication as a Proposed Standard
May 2017	Submit IP/UDP compression and fragmentation mechanism to the IESG for publication as a Proposed Standard
Apr 2017	Submit LPWAN specification to the IESG for publication as an Informational Document
Jan 2017	Adopt CoAP compression mechanism as a WG item
Dec 2016	Adopt IP/UDP compression and fragmentation mechanism as a WG item
Nov 2016	Adopt LPWAN specifications as WG item

Milestones

Milestones


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

Milestones


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

<draft-farrell-lpwan-overview>

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

- Informational work
- Provide enough background information so that the WG can make sufficiently informed decisions while doing standards-track work

draft-minaburo-lpwan-gap-analysis-02

Ana Minaburo, Acklio (ana@ackl.io)
Carles Gomez, UPC/i2Cat (carlesgo@entel.upc.edu)
-Editors-

Status

- Merger of two drafts
  - draft-minaburo-lpwan-gap-analysis-01
    - LPWAN survey and gap analysis covering several WGs
    - Basis of the merged document
  - draft-gomez-lpwan-ipv6-analysis-00
    - IPv6 support analysis and some solutions
    - Only the analysis part included in the merged document

Table of Contents

Basis: draft-minaburo, plus minor improvements, merged text, etc.

New content

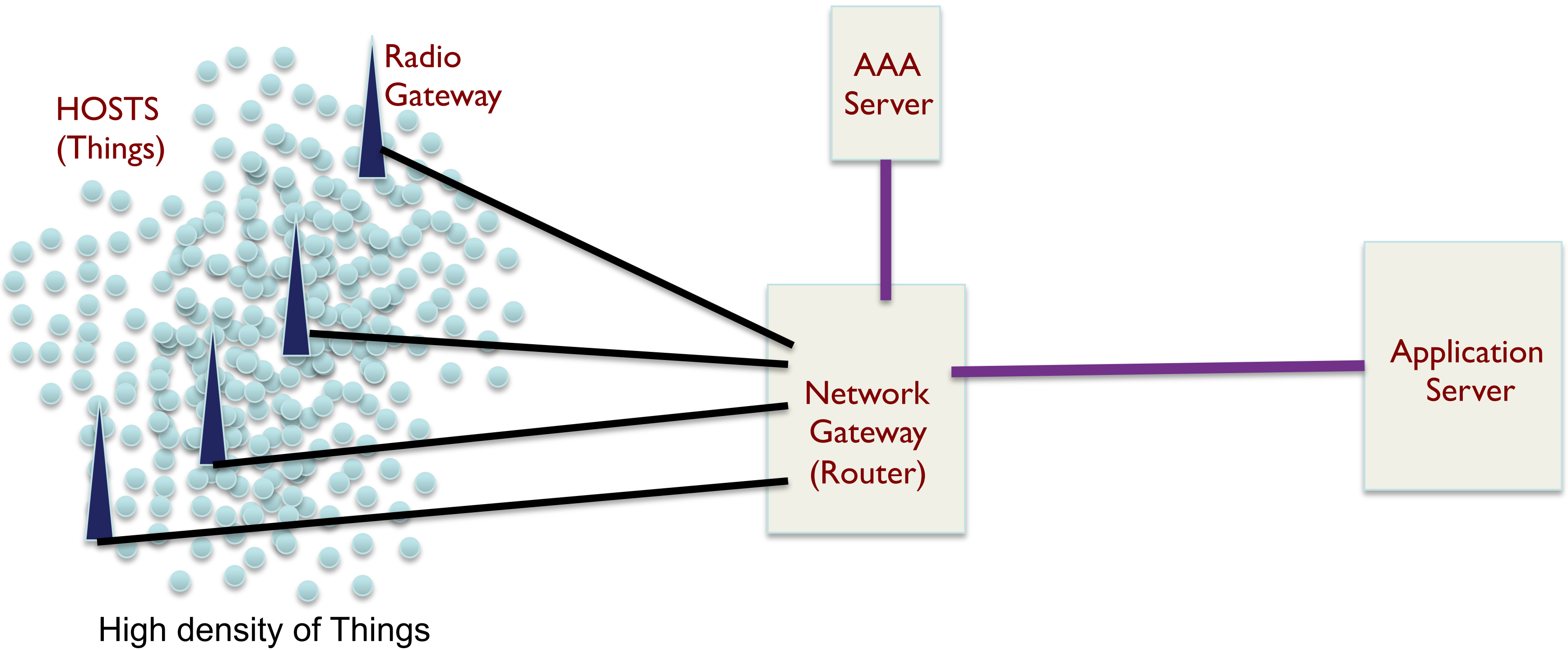
- 2.1. Benchmark change
  - LPWAN measurement scale:
    - Duty cycle regulation brings a reduction of rate to 1 packet per minute or less
      - We need to adapt protocols to LPWAN transmission rate from bit/s to bit/day
      - Adapt timers, delays, buffers, etc.
      - Solutions need to be adapted to this constraint

Benchmark Change

	N = 500			N = 1000			N = 5000			N = 10000		
Payload (Bytes)	10	30	50	10	30	50	10	30	50	10	30	50
Max. throughput per node (Packets/hour)	159	94	68	96	57	41	17	10	7	8.5	5.5	3.5
Max. throughput per node (Bytes/hour)	1590	2820	3400	960	1710	2050	170	300	350	85	165	175
λ of the max. throughput (Packets/hour)	874	500	370	650	390	287	135	74	53	65	37	26.5
Prob. of successful transmission (%)	18.19	18.80	18.38	14.77	14.62	14.29	12.59	13.51	13.21	13.08	14.86	13.21

New content

- 2.2. Architecture



New content

- 3.5. RoHC Header Compression
  - A framework with 2 header format packets versions: RoHCv1 with fixed formats and RoHCv2 using a dynamic generator of header formats (Formal Notation)
  - These protocols are not adapted for different reasons:
    - Header Size (not in average but in reality)
    - Not able for lower energy
    - Not able for the transmission rates
    - Managed by a SN
    - Not CoAP compression
    - End-nodes need to have good memory
  - If used need to be modified, to be redefine from RoHC framework, and adapted for CoAP and LPWAN

Thank you

- Questions?

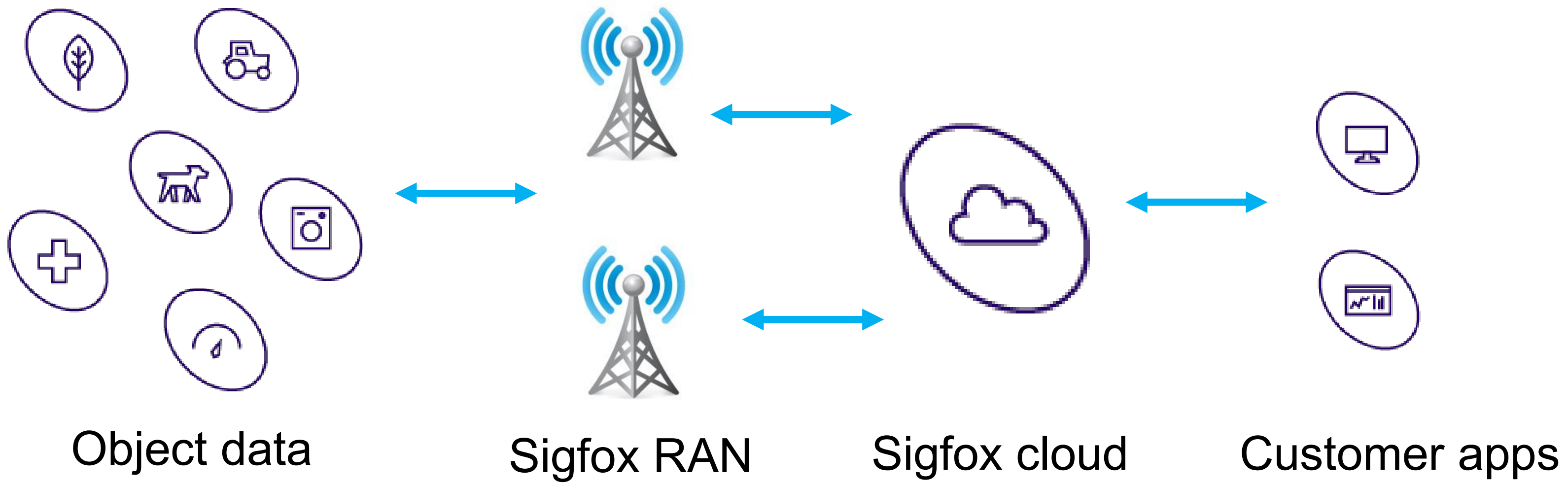
Sigfox System Description

Juan Carlos Zuniga
Benoit Ponsard

draft-zuniga-lpwan-sigfox-system-description-01

Architecture

- Central LPWA Gateway / Cloud-based (Service Center)
- Cooperative Radio Gateways (Base Stations) - MIMO
- Public network (like cellular)
- Central global authentication - no roaming requirements
- End-device application transparent to the network



Relevant L1 UL characteristics

- Channelization mask: 100 Hz ETSI / 600 Hz FCC
- Uplink baud rate: 100 baud ETSI / 600 baud FCC
- Modulation scheme: DBPSK
- Uplink transmission power: compliant with local regulation
- Link budget: 155 dB (or better = good indoor coverage)
- Central frequency accuracy: not relevant, provided there is no significant frequency drift within an uplink packet
- For ETSI-zones, UNB uplink frequency band limited to 868,00 to 868,60 MHz, with maximum output power of 25 mW and a maximum mean transmission time of 1%

Relevant L1 DL characteristics

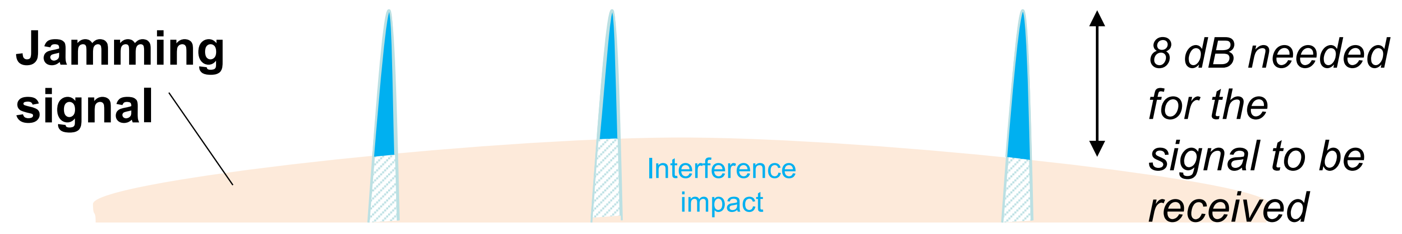
- Channelization mask: 1.5 kHz ETSI/FCC
- Downlink baud rate: 600 baud ETSI/FCC
- Modulation scheme: GFSK
- Downlink transmission power: 500 mW ETSI / 4W FCC
- Link budget: 153 dB (or better)
- Central frequency accuracy: Centre frequency of downlink transmission set by the network according to the corresponding uplink transmission
- For ETSI-zones, UNB downlink frequency band limited to 869,40 to 869,65 MHz, with maximum output power of 500 mW with 10% duty cycle

UNB – Overview

High resilience to interferers

- Robust operation in ISM bands

Anti-jamming capabilities due to UNB intrinsic ruggedness coupled with spatial diversity of the base stations (+20dB)



Relevant L2 characteristics

- Framing

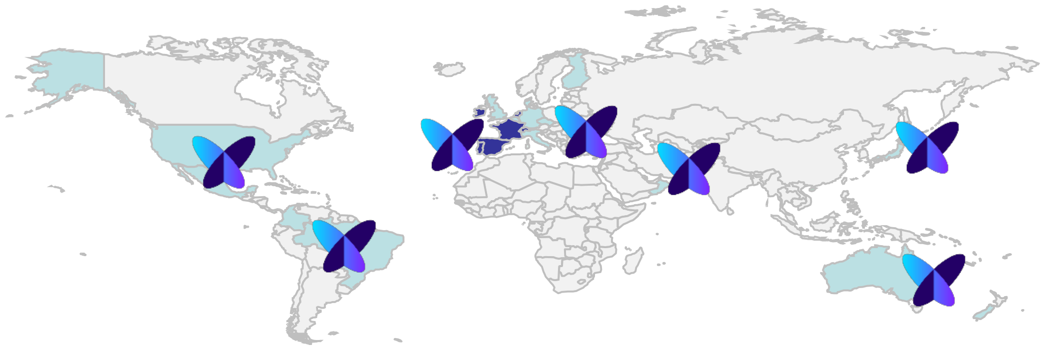
```
+--------+--------+--------+-----------+------------+-----+
|Preamble|Frame   | Dev ID |  Payload  |Msg Auth Code| FCS |
|  (19)  |Sync(29)|  (32)  |  (0-96)   |   (16-40)   | (16)|
+--------+--------+--------+-----------+------------+-----+
                    Uplink Frame Format

+------------+--------+-----+---------+------------+-----+
|  Preamble  |Frame   | ECC | Payload |Msg Auth Code| FCS |
|    (91)    |Sync(13)| (32)| (0-64)  |    (16)    | (8) |
+------------+--------+-----+---------+------------+-----+
                   Downlink Frame Format
```

- Fragmentation and encryption at application layer
- Unicast asynchronous communications
  - 32-bit globally unique device ID
- Unbalanced UL/DL channels
  - Max. limitations: 140 Uplink vs 4 Downlink messages per day
  - Limitations can be slightly relaxed depending on system conditions
- L2 security
  - Message authentication code and unique device ID
  - Key management: pre-provisioned

Network deployment

- Current Network Deployment
  - Sigfox public LPWAN fully deployed in France, Spain, Portugal, Netherlands, Luxembourg, and Ireland
  - Being rolled out in Japan, Germany, UK, Belgium, Denmark, Czech Republic, Italy, Mauritius Island, Australia, New Zealand, Oman, Brazil, Finland, Malta, Mexico, Singapore and the USA
- Coverage
  - 1,3 million square kilometers / Population of 340 million people
  - Max cell size of 50 km



Examples of current applications

Public sector

- Connected waste bins and hydrants
- Air quality and water level monitoring
- Smart parking

Agriculture and environment

- Livestock management
- Smart irrigation
- Precision agriculture

Home and lifestyle

- Home alarm systems
- Smoke detectors
- Water quality and leak sensors
- Connected mailboxes

Utilities

- Water and electricity metering
- Smart building management
- Electricity microgeneration monitoring

Retail

- Smart buttons
- Customer satisfaction assessment

Payload size examples

- ❑ 6 bytes: GPS coordinates
- ❑ 2 bytes: temperature reporting
- ❑ 1 byte: speed reporting
- ❑ 1 byte: object state reporting
- ❑ 0 byte: heartbeat (demonstrate when an object is alive)

Health & assisted living

- Caregivers support and management
- Defibrillators
- Fall detectors

Industry

- Predictive maintenance
- Critical goods management
- Structural health monitoring

Fleet management

- Delivery truck tracking
- Stolen vehicle recovery

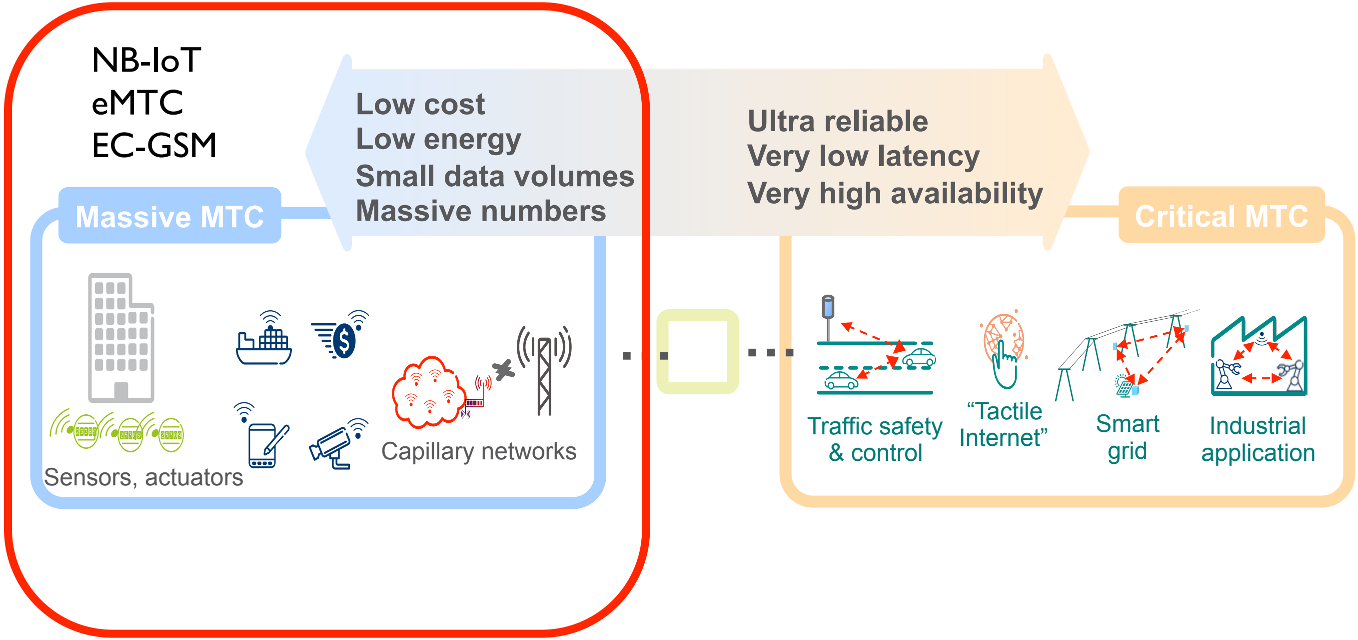
Sigfox Summary

- System tailored for low end, very low cost LPWAN devices
  - Complementing other networks to address the bulk of connected objects
  - Public network, multi-vendor support, university programs
  - Complex SDR BS, MIMO – simpler cert modules at about $2-3
- Radio interface optimized for low power UL communications
  - Asynchronous channel
  - Unlimited sleep time
  - DL communication on demand by device application
- IETF LPWAN WG Interests
  - Definition of common LPWAN management features
  - Definition of common security features
  - Definition of common application profiles

NB-IoT presentation for IETF LPWAN

Antti Ratilainen

NB-IoT targeted use cases



NB-IoT Design targets

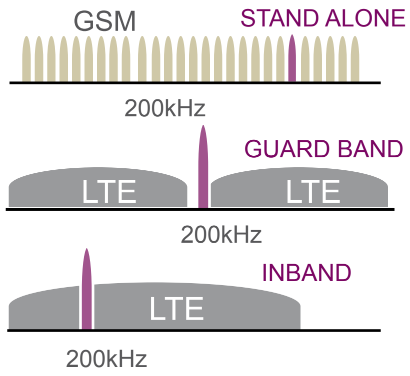
- NB-IoT targets the low-end "Massive MTC" scenario:

Low device cost/complexity: <$5 per module	
Extended coverage:	164 dB MCL, 20 dB better compared to GPRS
Long battery life:	>10 years
Capacity:	40 devices per household, ~55k devices per cell
Uplink report latency :	<10 seconds

Basic Technical Characteristics

NB-IoT

- Targeting implementation in an existing 3GPP network
- Applicable in any 3GPP defined (licensed) frequency band – standardization in release 13
- Three deployment modes
- Processing along with wideband LTE carriers implying OFDM secured orthogonality and common resource utilization
- Maximum user rates 30/60 (DL/UL) kbps



The capacity of NB-IoT carrier is shared by all devices
Capacity is scalable by adding additional NB-IoT carriers

NB-IoT overview

- M2M access technology contained in 200 kHz with 3 deployments modes:
  - **Stand-alone** operation
  - Operation in LTE "**guard band**'
  - Operation within wider LTE carrier (aka **inband**)
- L1:
  - FDD only & half-duplex User Equipment (UE)
  - Narrow band physical downlink channels over 180 kHz (1 PRB)
  - Preamble based Random Access on 3.75 kHz
  - Narrow band physical uplink channel on single-tone (15 kHz or 3.75 kHz) or multi-tone (n*15 kHz, n = [3,6,12])
  - Maximum transport block size (TBS) 680 bits in downlink, 1000 bits in uplink
- L2, L3:
  - Single-process, adaptive and asynchronous HARQ for both UL and DL
  - Data over Non Access Stratum, or data over user plane with RRC Suspend/ Resume
  - MTU size 1500 bytes
  - Extended Idle mode DRX with up to 3 h cycle, Connected mode DRX with up to 9.216 s cycle
  - Multi Physical Resource Block (PRB)/Carrier support

NETWORK DEPLOYMENT

- Maximum coupling loss 164 dB which has been reached with assumptions given in the table below, which shows the link budget for uplink
  - Urban: deep in-building penetration
  - Rural: long range (10-15 km)

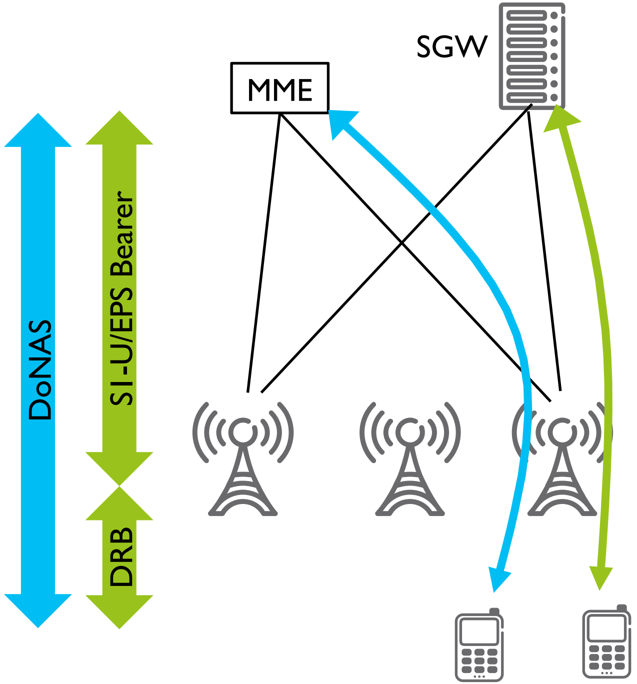
Numerology	15 kHz	3.75 kHz
(1) Transmit power (dBm)	23.0	23.0
(2) Thermal noise density (dBm/Hz)	-174	-174
(3) Receiver noise figure (dB)	3	3
(4) Occupied channel bandwidth (Hz)	15000	3750
(5) Effective noise power = (2) + (3) + 10*log ((4)) (dBm)	-129.2	-135.3
(6) Required SINR (dB)	-11.8	-5.7
(7) Receiver sensitivity = (5) + (6) (dBm)	-141.0	-141.0
(8) Max coupling loss = (1) - (7) (dB)	164.0	164.0

Relevant L1 characteristics

- Highest modulation scheme **QPSK**
- ISM bands vs licensed bands
  - NB-IoT currently specified on licensed bands only
  - Narrowband operation (180 kHz bandwidth)
    - in-band (LTE), guard band (LTE) or standalone operation mode (e.g. refarm the GSM carrier at 850/900 MHz)
  - Half Duplex FDD operation mode with 60 kbps peak rate in uplink and 30 kbps peak rate in downlink
- Maximum transmission block size 680 bits in DL, 1000 bits in UL (In Rel-13)
- Use repetitions for coverage enhancements, up to 2048 reps in DL, 128 reps in UL data channels
- > 10 year battery life time

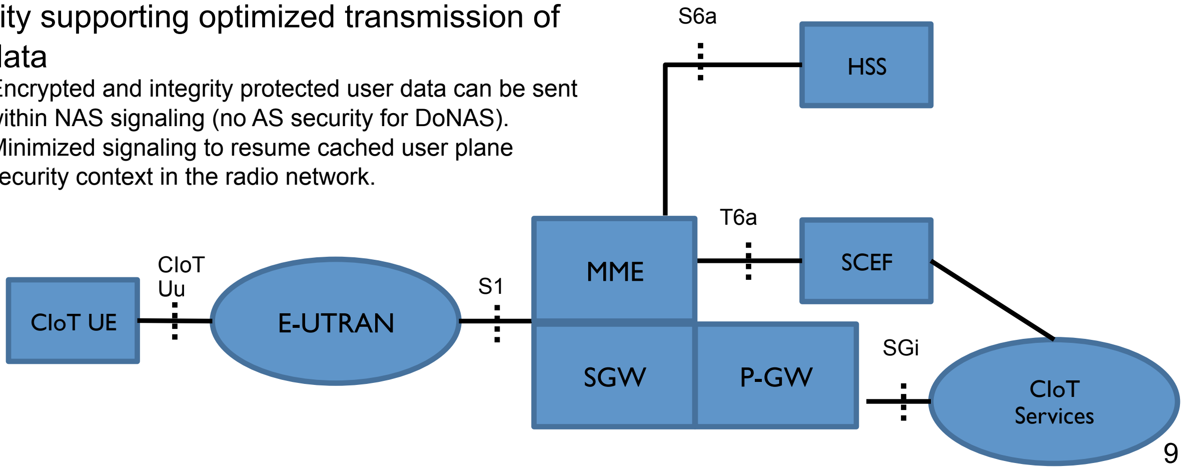
Relevant L2 characteristics

- Supported MTU size is 1500 bytes for both, NAS and AS solutions
- Error correction, concatenation, segmentation and reassembly in RLC Acknowledged Mode
  - Error correction through ARQ
  - Segmentation to segment the SDUs from PDCP into the transmission block sizes for physical layer
- Non-access stratum (NAS) and Access stratum (AS)
  - NAS is a set of protocols used to convey non-radio signaling between the UE and the core network, passing transparently through radio network. The responsibilities of NAS include authentication, security control, mobility management and bearer management
  - AS is the functional layer below NAS, working between the UE and radio network. It is responsible for transporting data over wireless connection and managing radio resources.
  - In NB-IoT, an optimization for data transfer over NAS (DoNAS) signaling is also supported,
  - Also AS optimization called RRC suspend/resume can be used to minimize the signaling needed to suspend/resume user plane connection.
  - Non-IP support, which enables the usage of other delivery protocols than IP as well
- L2 security
  - Authentication between UE and core network.
  - Encryption and integrity protection of both AS and NAS signaling.
  - Encryption of user plane data between the UE and radio network.
  - Key management mechanisms to effectively support mobility and UE connectivity mode changes.



NB-IoT system architecture

- Architecture is based on evolved Packet Core (EPC) used by LTE
- Cellular IoT User Equipment (CIoT UE) is the mobile terminal
- evolved UMTS Terrestrial Radio Access Network (E-UTRAN) handles the radio communications between the UE and the EPC, and consists of the evolved base stations called eNodeB or eNB
- NB-IoT security properties
  - Authentication and core network signaling security as in normal LTE
  - Security supporting optimized transmission of user data
    - Encrypted and integrity protected user data can be sent within NAS signaling (no AS security for DoNAS).
    - Minimized signaling to resume cached user plane security context in the radio network.



Summary for NB-IoT

	NB-IoT
Deployment	In-band & Guard-band LTE, standalone
Coverage (MCL)	164 dB
Downlink	OFDMA, 15 KHz tone spacing, TBCC, 1 Rx
Uplink	Single tone: 15 KHz and 3.75 KHz spacing, SC-FDMA: 15 KHz tone spacing, Turbocode
Bandwidth	180 KHz
Highest modulation	QPSK
Link peak rate (DL/ UL)	DL: ~30 kbps UL: ~60 kbps
Duplexing	HD FDD
MTU size	1500 B
TBS	Max. transmission block size 680 bits in DL, 1000 bits in UL, min. 16 bits
Repetitions	Up to 2048 repetitions in DL and 128 repetitions in UL data channels
Power saving	PSM, extended Idle mode DRX with up to 3 h cycle, Connected mode DRX with up to 10.24 s cycle
UE Power class	23 dBm or 20 dBm

UE categories for massive MTC

	Rel-8 Cat-4	Rel-8 Cat-1	Rel-12 Cat-0	Rel-13 Cat-M1	Rel-13 NB-IOT
Supported duplex modes	FD-FDD / TDD	FD-FDD / TDD	HD-FDD / FD-FDD / TDD	HD-FDD / FD-FDD / TDD	HD-FDD
DL link peak rate [Mbps]	150	10	0.375 / 1	0.3 / 0.8	~0.03*
UL link peak rate [Mbps]	50	5	0.375 / 1	0.375 / 1	~0.06**
Highest DL modulation scheme	64QAM	64QAM	64QAM	16QAM	QPSK
Highest UL modulation scheme	16QAM	16QAM	16QAM	16QAM	QPSK
Max number of DL spatial layers	2	1	1	1	1
Number of receive antennas	2	2	1	1	1
UE bandwidth [MHz]	20	20	20	1.080	0.180
Maximum transmit power [dBm]	23	23	23	20 or 23	20 or 23

* DL system peak rate: 0.23 Mbps **UL system peak rate: 0.25 Mbps

WORK IN PROGRESS, TO BE DONE

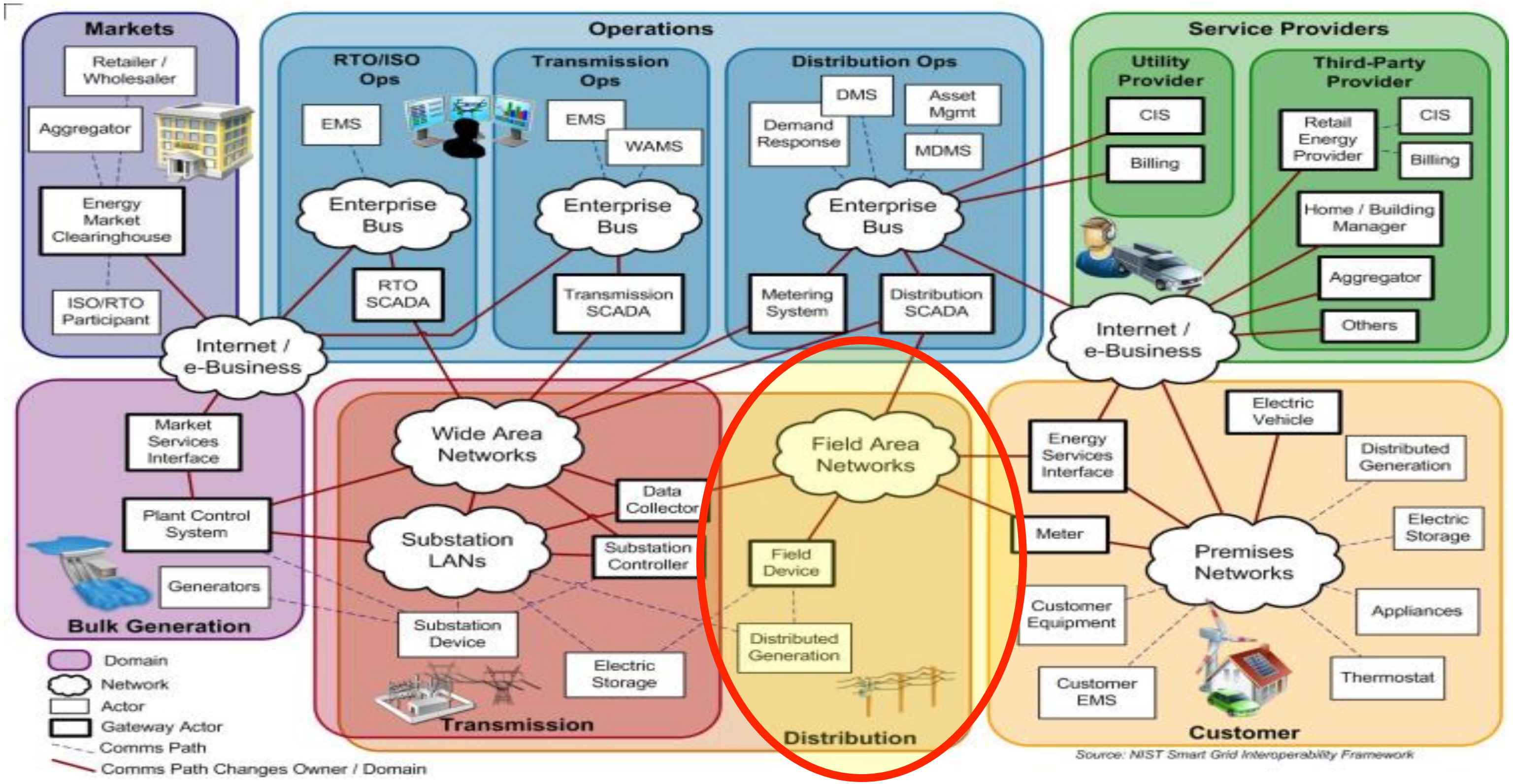
- Further enhancements for NB-IoT (and eMTC) are being worked on for next 3GPP Release.
- These enhancements include the following topics
  - Positioning
  - Multicast
    - Support multi-cast downlink transmission (e.g. firmware or software updates, group message delivery) for NB-IoT
  - Non- Anchor PRB enhancements
  - Mobility and service continuity enhancements
  - New Power Class(es)
    - Evaluate and, if appropriate, specify new UE power class(es) (e.g. 14dBm), and any necessary signaling support, to support lower maximum transmit power suitable for small form-factor batteries, with appropriate MCL relaxations compared to Rel-13

Wi-SUN Alliance
Field Area Network (FAN) Overview

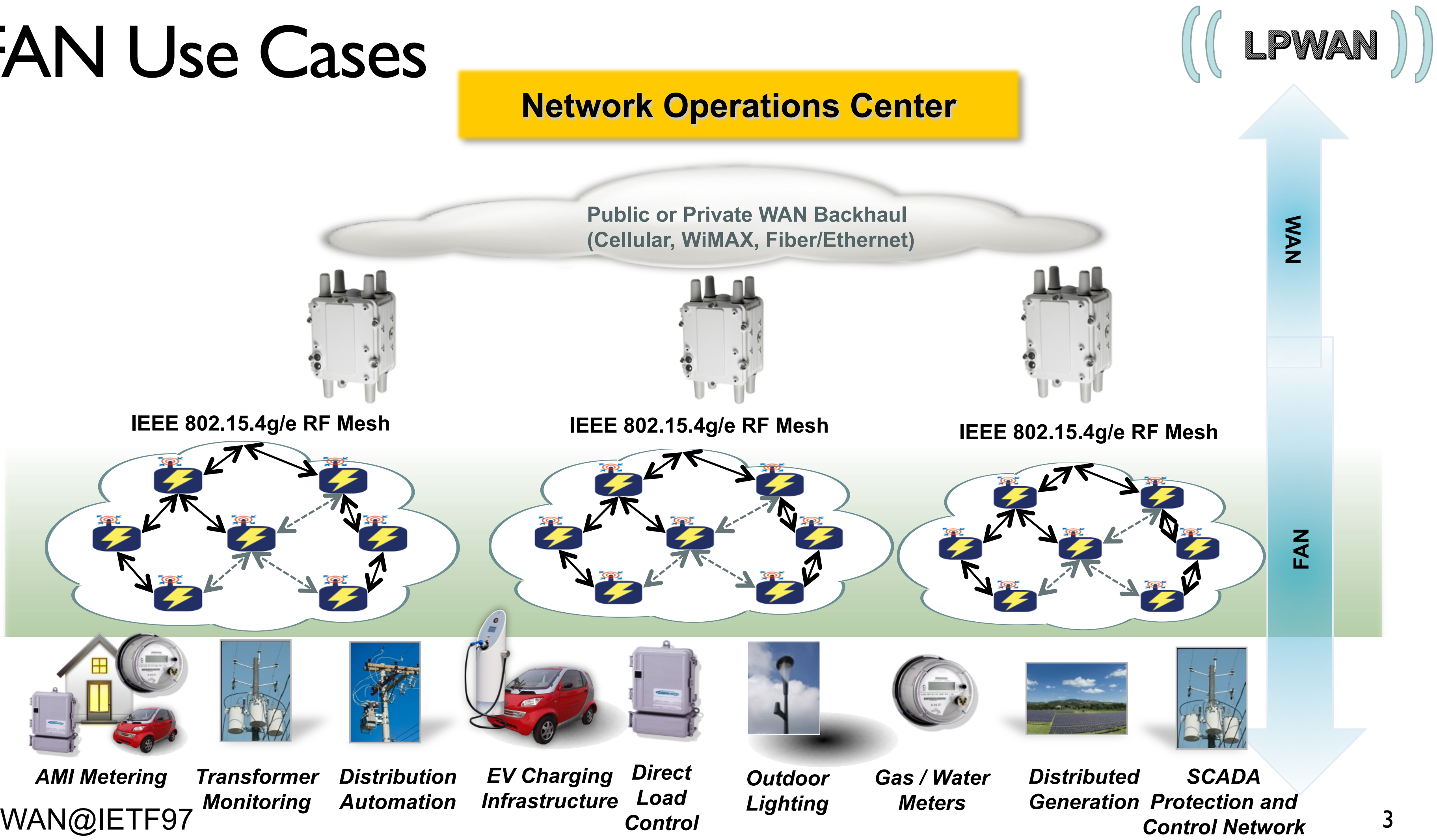
November 2016

Bob Heile, Director of Standards

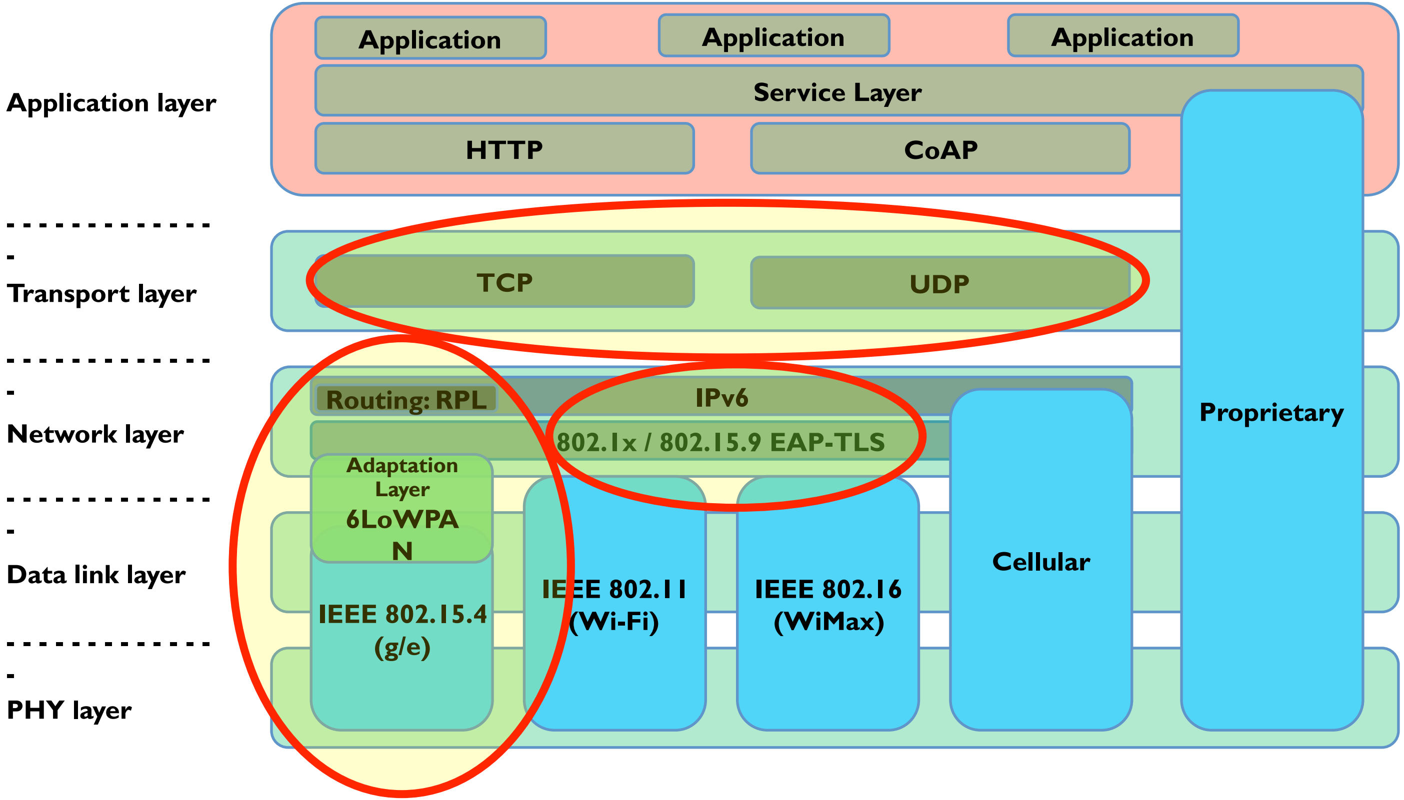
Wi-SUN Alliance FAN



FAN Use Cases



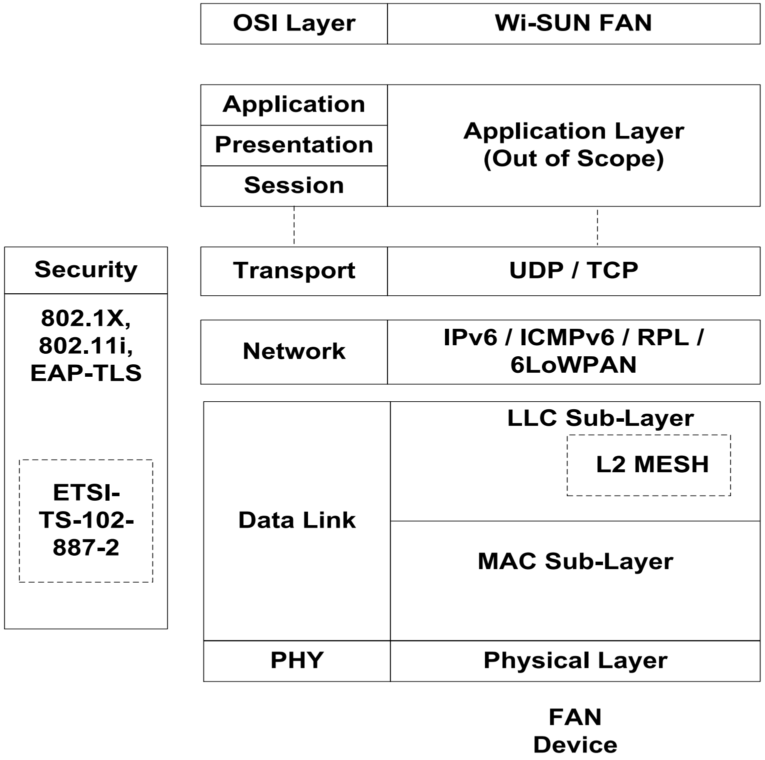
Wi-SUN FAN Communications Overview



Wi-SUN FAN Summary

- Open standards based on IEEE802, IETF, TIA, ETSI
- Architecture is an IPv6 frequency hopping wireless mesh network with enterprise level security
- Simple infrastructure which is low cost, low complexity
- Superior network robustness, reliability, and resilience to interference, due to high redundancy and frequency hopping
- Excellent scalability, long range, and energy friendliness
- Supports multiple Global license-exempt sub GHz bands
- Multi-vendor interoperability
- Very low power modes in development permitting long term battery operation of network nodes.

FAN Stack Overview



IPv6 protocol suite

- TCP/UDP
- 6LoWPAN Adaptation + Header Compression
- DHCPv6 for IP address management.
- Routing using RPL.
- ICMPv6.
- Unicast and Multicast forwarding.

MAC based on IEEE 802.15.4e + IE extensions

- Frequency hopping
- Discovery and Join
- Protocol Dispatch (IEEE 802.15.9)
- Several Frame Exchange patterns
- Optional Mesh Under routing (ANSI 4957.210).

PHY based on 802.15.4g

- Various data rates and regions

Security

- 802.1X/EAP-TLS/PKI Authentication.
- 802.11i Group Key Management
- Optional ETSI-TS-102-887-2 Node 2 Node Key Management

Supports a variety of IP based app protocols :
DLMS/COSEM, ANSI C12.22, DNP3, IEC 60870-5-104, ModBus TCP, CoAP based management protocols.

Protocol layers

- Physical layer
  - FSK modulation
  - Data rates from 50 kbps to 300 kbps
  - Node to node range up to several kilometres where regulations permit
  - Optional forward error correction for better link margin
  - Specified for Australia, Europe, India, Japan, Korea, North/South America, South East Asia

Protocol layers

- Data link layer
  - Frame supports full IP payloads
  - 4 octet FCS for good error detection
  - De-centralised frequency hopping where permitted (ANSI 4957.200)
  - Channel blacklisting for interference mitigation
  - Link layer encryption / integrity checking for privacy & message verification
  - Optional L2 multi-hop layer (ANSI 4957.210)

Protocol layers

- Adaptation Layer : 6LoWPAN
  - IPv6 header compression
  - UDP header compression
  - Fragmentation
  - Neighbour discovery
  - Routing support
- Network layer
  - IPv6
  - DHCPv6 address management

Protocol layers

- Routing
  - ROLL/RPL
- Security
  - L2 Integrity Check and Encryption
  - IEEE 802.1x over IEEE 802.15.4 (IEEE802.15.9)
  - Uses Certificates for Mutual Authentication

FAN Profile - General Comments

- The Alliance feels there is significant value to this LPWAN effort in IETF and strongly supports its objectives.
- The FAN spec was developed to serve the LPWAN space among others.
- Already included are many of the needed networking elements as a result of the longstanding working relationships between IETF and IEEE802.

FAN Profile - General Comments

- Some of the things the Alliance hopes to accomplish through its participation in the LP-WAN WG are:
  - awareness (if changes are needed in the FAN spec),
  - help ensure consistency of approach,
  - share relevant experience, and
  - address co-existence issues & potential interoperability, since these solutions will be used in the same markets in complementary ways.
- Because it is IP based, the Wi-SUN FAN already interconnects to Ethernet and WiFi through routers
- Useful if the same can be accomplished with other approaches

Things We Would Like to See

- Wi-SUN FAN and HAN profiles both use 6lowpan, primarily for header compression.
- Full IP frames supported, but header compression is useful for optimizing bandwidth.
- Very useful to include UDP and CoAP compression methods also
- Not all nodes on a Wi-SUN FAN are necessarily routing, line powered nodes
- Optimized compression for battery powered leaf nodes would help extend battery life.

Thank you for your kind attention

http://www.wi-sun.org

<draft-farrell-lpwan-overview> Continued

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(plus many contributors)

Obvious TBDs

- Shorter, crisper text (if possible)
- Check/update technology descriptions
  - Guidance from WG as to what's the minimum needed gratefully accepted
  - E.g. do we need all the RF stuff ?
- 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)

- Decide target and timing for this
- 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 : Targets and timing

1) Send to IESG as informational RFC before standards track work sent to IESG (the usual legacy approach :-)

2) Work the text 'till the WG are happy, mostly park it while standards-track work done, then update this draft and send both to IESG together. End-game update of this draft should eliminate duplication or conflicts with standards-track text.

3) Work the text 'till the WG are happy enough, and then just let the I-D expire in the fullness of time.

4) Work the text 'till the WG are happy enough, and then make the text into a wiki at some point so folks can independently update it e.g. after the WG has closed.

Editor suggests: #2

Issue#2 : Descriptive Material vs. Individual Drafts

1) Work that 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#3 : 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#4 : 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

Finally : Adopt this as WG item and go from there ?

Yes/no/more-info-needed?

Thanks

Static Context Header Compression (SCHC)

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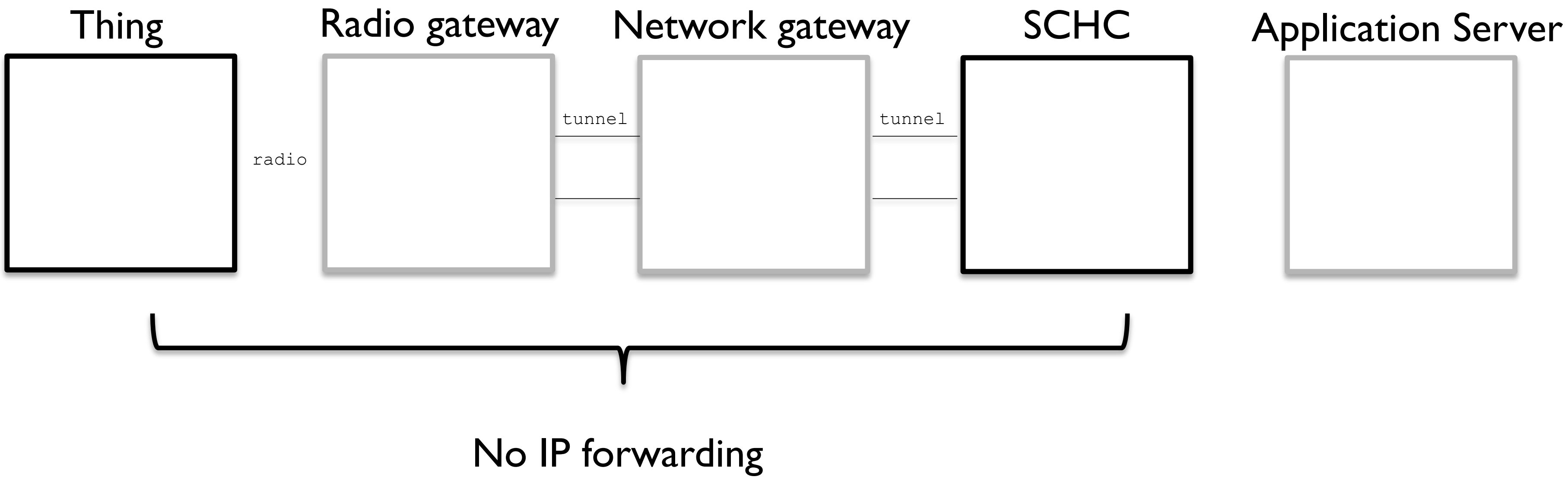
IETF 97 - Seoul

draft-toutain-lpwan-ipv6-static-context-hc-00
draft-toutain-lpwan-yang-static-context-hc-00

Compression for LPWAN

- Optimized for an architecture:
  - Star topology
- Optimized for traffic
  - Nodes have limited capacity
  - Predictable traffic
- Flexible compression

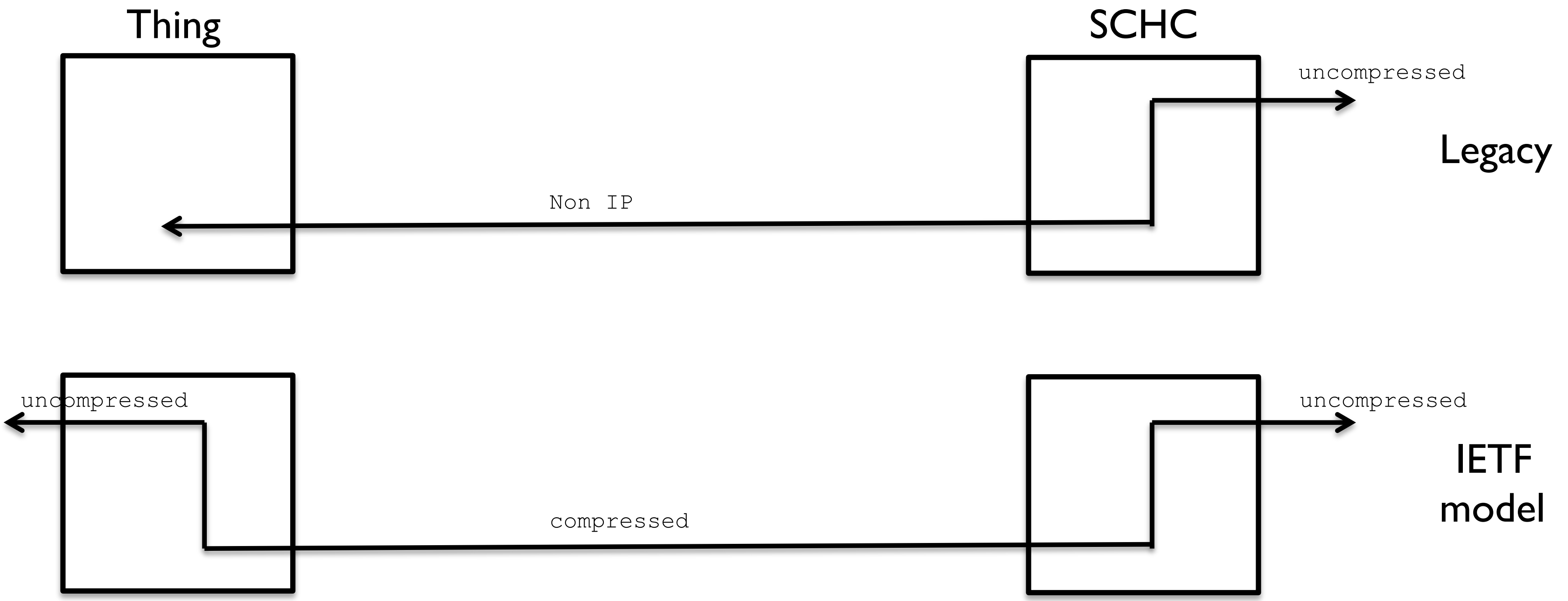
Target Architecture



Objective

- Compress up to 0 bytes well-known headers
- Cover legacy *Thing* with no IP
- … but non-destructive compression
    - *Things* should be able to rebuilt IP stack

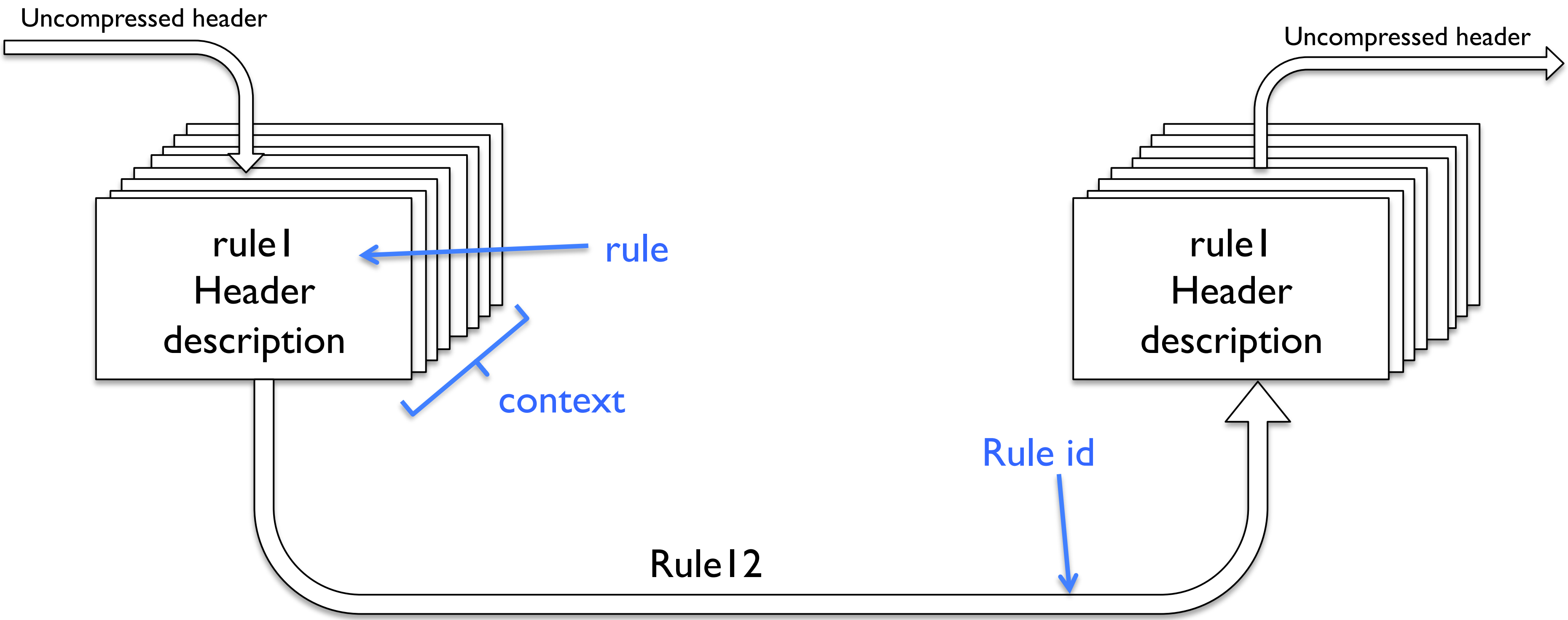
Target Architecture



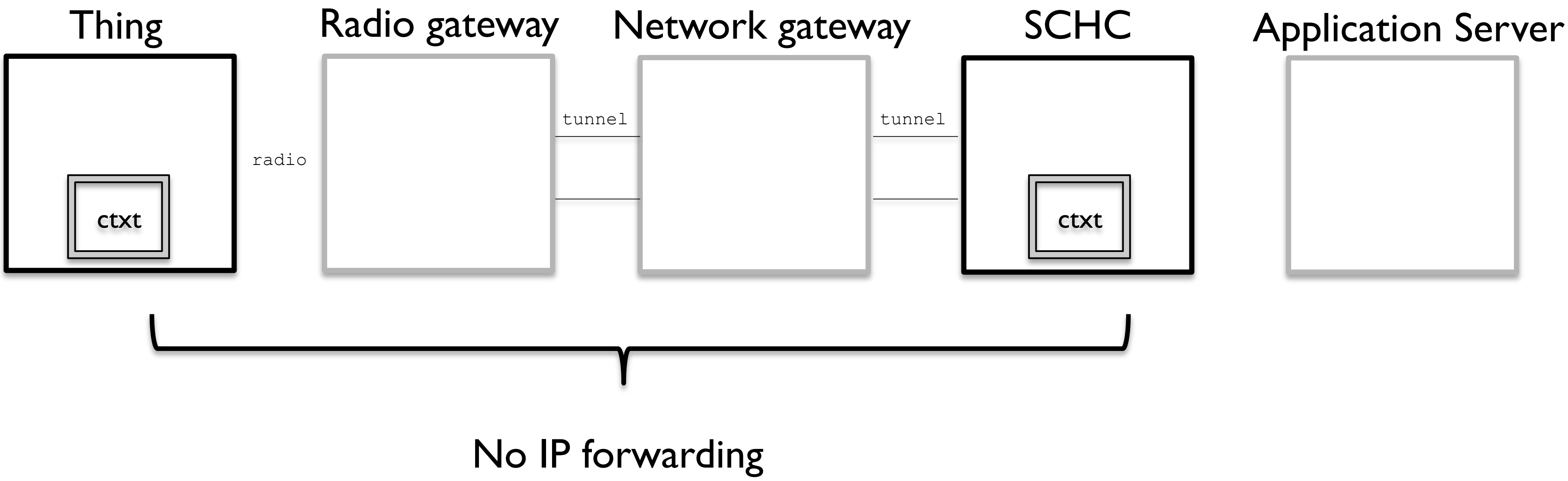
Predictable traffic

- Applications on a *Thing* are controlled
  - Traffic is known
- Fields are classified:
  - Static: well-known
  - Dynamic: send on the link
  - Computed: rebuilt from other information

Static Context Header Compression



Target Architecture



Vocabulary

```
    +-----------------------------------------------------------------+
    |                      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 | | |
  |         +--------------+-------------------+-----------------+ |-+
  |                                                                 |
  +-----------------------------------------------------------------+
```

- Context is the same at both ends
- Provisioned with the node

Matching Operators (MO)

- Compare the Target Value to the field value.
- A rule is selected if all the MO match
  - If no rules, packet is dropped
- Draft defines 3 MO:
  - Ignore: always true
  - Equal: compare TV to FV
  - MSB(L): compare the `L` Most Significant Bit

Compression Decompression Functions (CDF)

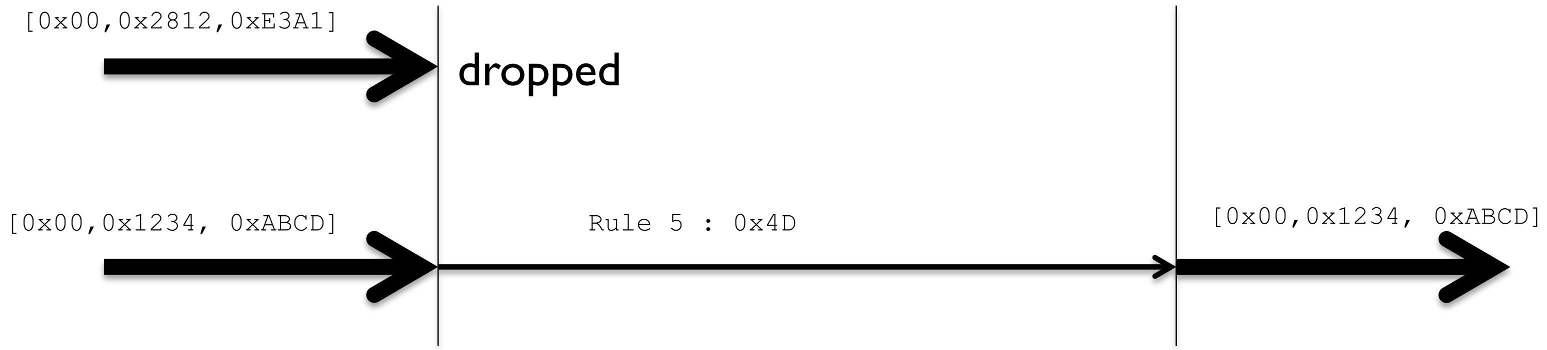
- How to compress/decompress a field if the rule is selected.
- Draft IPv6/UDP defines 6 CDF:

Function	Compression	Decompression
not-sent	elided	use value stored in ctxt
value-sent	send	build from received value
LSB(length)	send LSB	ctxt value OR rcvd value
compute-IPv6-length	elided	compute IPv6 length
compute-UDP-length	elided	compute UDP length
compute-UDP-checksum	elided	compute UDP checksum
ESiid-DID	elided	build IID from L2 ES addr
LAiid-DID	elided	build IID from L2 LA addr

Example

Rule 5

	Target Value	Matching Operator	Comp/Decomp Fct
F1	0x00	Ignore	not-sent
F2	0x1230	MSB(12)	LSB(4)
F3	0xABC0	MSB(12)	LSB(4)



IPv6/UDP

Field	Comp Decomp Fct	Behavior
IPv6 version IPv6 DiffServ IPv6 NH	not-sent	The value is not sent, but each end agrees on a value.
	value-sent	Depending on the matching operator, the entire field value is sent or an adjustment to the context value
IPv6 Length	compute-IPv6-length	Dedicated fct to reconstruct value
IPv6 Hop Limit	not-sent+MO=ignore	The receiver takes the value stored in the context. It may be different from one originally sent, but in a star topology, there is no risk of loops
	not-sent+matching	Receiver and sender agree on a specific value.
	value-sent	Explicitly sent

IPv6/UDP

```
|IPv6 ESPrefix |not-sent            |The 64 bit prefix is stored on     |
|IPv6 LAPrefix |                    |the context                        |
|              |value-sent          |Explicitly send 64 bits on the link|
+--------------+--------------------+-----------------------------------+
|IPv6 ESiid    |not-sent            |IID is not sent, but stored in the |
|IPv6 LAiid    |                    |context                            |
|              |ESiid-DID|LAiid-DID|IID is built from the ES/LA Dev. ID|
|              |value-sent          |IID is explicitly sent on the link.|
|              |                    |Size depends of the L2 technology  |
+--------------+--------------------+-----------------------------------+
|UDP ESport    |not-sent            |In the context                     |
|UDP LAport    |value-sent          |Send the 2 bytes of the port number|
|              |LSB(length)         |or least significant bits if MSB   |
|              |                    |matching is specified in the       |
|              |                    |matching operator.                 |
+--------------+--------------------+-----------------------------------+
|UDP length    |compute-UDP-length |Dedicated fct to reconstruct value |
+--------------+--------------------+-----------------------------------+
|UDP Checksum  |compute-UDP-checksum|Dedicated fct to reconstruct value|
|              |value-sent          |                                   |
+--------------+--------------------+-----------------------------------+
```

YANG

- SCHC is designed to be managed with YANG
- For instance:
  - Assign a prefix to a *Thing*
  - A *Thing* sets the Destination Address

`draft-toutain-lpwan-yang-static-context-hc-00`

YANG model for SCHC

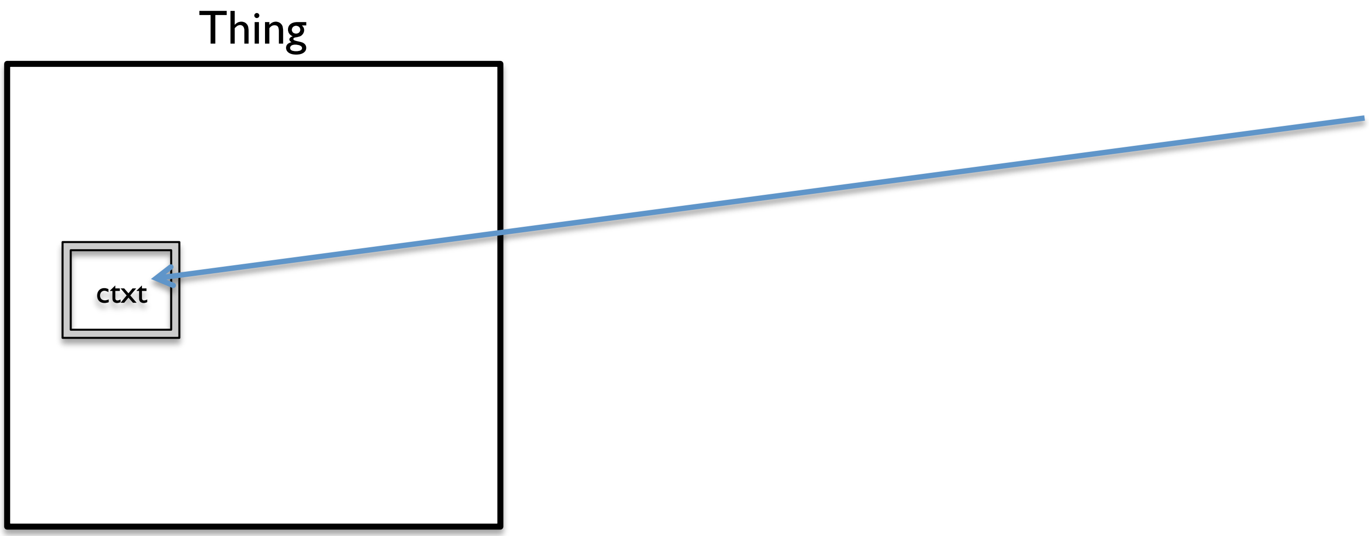
```
module: ietf-lpwan-compression
+--rw compression-context
   +--rw context-rules* [rule-id]
      +--rw rule-id        uint8
      +--rw rule-fields* [position]
         +--rw name?                                   string
         +--rw position                                uint8
         +--rw target-value?                           lpwan-types
         +--rw matching-operator?                      matching-operator-type
         +--rw matching-operator-value                 lpwan-types
         +--rw compression-decompression-function?
                                         compression-decompression-function-type
         +--rw compression-decompression-function-value?   lpwan-types
```

CoMI

```
   SID        Assigned to
---------  --------------------------------------------------
1000       Module ietf-lpwan-compression
1001       identity /compression-decompression-function
1002       identity /compression-decompression-function/cdf-compute-ipv6-length
1003       identity /compression-decompression-function/cdf-compute-udp-checksum
1004       identity /compression-decompression-function/cdf-compute-udp-length
1005       identity /compression-decompression-function/cdf-esiid-did
1006       identity /compression-decompression-function/cdf-laiid-did
1007       identity /compression-decompression-function/cdf-lsb
1008       identity /compression-decompression-function/cdf-not-sent
1009       identity /compression-decompression-function/cdf-value-sent
1010       identity /matching-operator
1011       identity /matching-operator/mo-equal
1012       identity /matching-operator/mo-ignore
1013       identity /matching-operator/mo-msb
1014       node /compression-context
1015       node /compression-context/context-rules
1016       node /compression-context/context-rules/rule-fields
1017       node /compression-context/context-rules/rule-fields/compression-decompression-function
1018       node /compression-context/context-rules/rule-fields/compression-decompression-function-value
1019       node /compression-context/context-rules/rule-fields/matching-operator
1020       node /compression-context/context-rules/rule-fields/matching-operator-value
1021       node /compression-context/context-rules/rule-fields/name
1022       node /compression-context/context-rules/rule-fields/position
1023       node /compression-context/context-rules/rule-fields/target-value
1024       node /compression-context/context-rules/rule-id

File ietf-lpwan-compression@2016-11-01.sid created
Number of SIDs available : 200
Number of SIDs assigned : 25
```

Target Architecture




```
iPATCH /c Content-Format(application/cool-value-pairs+cbor)
  [
    [field-SID, rule-id, field-pos], value
  ]
```

Next step

- Adopt

`draft-toutain-lpwan-ipv6-static-context-hc-00`

as a working group item ?

SCHC for CoAP

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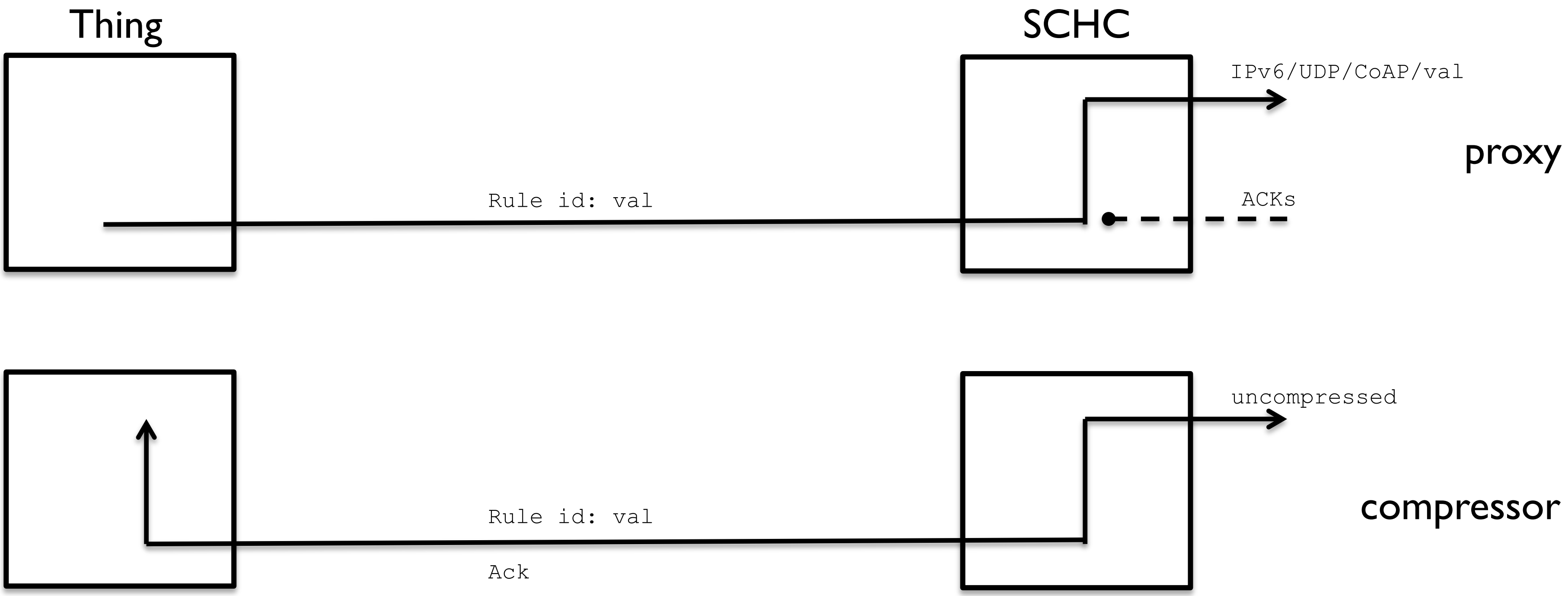
IETF 97 - Seoul

draft-toutain-lpwan-coap-static-context-hc-00

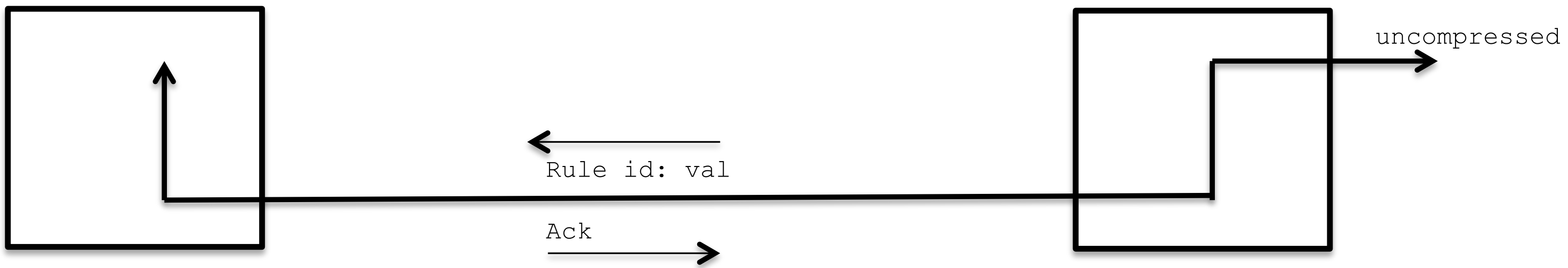
CoAP is different from IPv6/UDP

- Flexible list of fields
  - Options, Token
- Request and response do not contain the same fields
- *Thing* can be a client or a server
  - If server do not control the field size sent by the client
    - E.g. 8 byte token
- Different level of acknowledgements
  - CON/ACK and REST code

CoAP as a client



CoAP as a server



Compression Decompression Fcts (CDF)

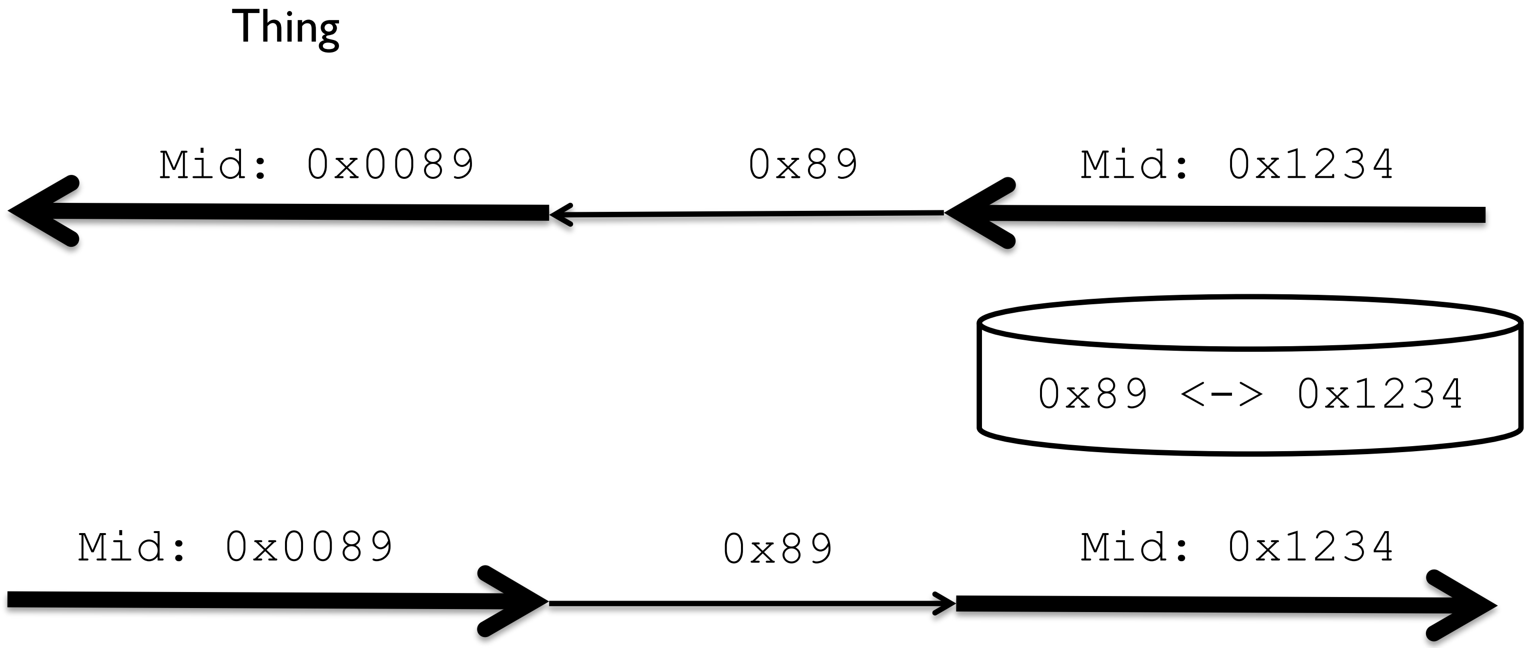
- Static-mapping (client/server)
  - Bi-directionnal mapping between two values
  - For code, path,…
- Remapping (server)
  - Allocate a smaller value
  - For MSG id, Token
  - non conservative
- Entropy-reduction (server)
  - Limit value increase to 1
  - For Observe
  - Non conservative
- Compute-token-length (client/server)

Static-mapping

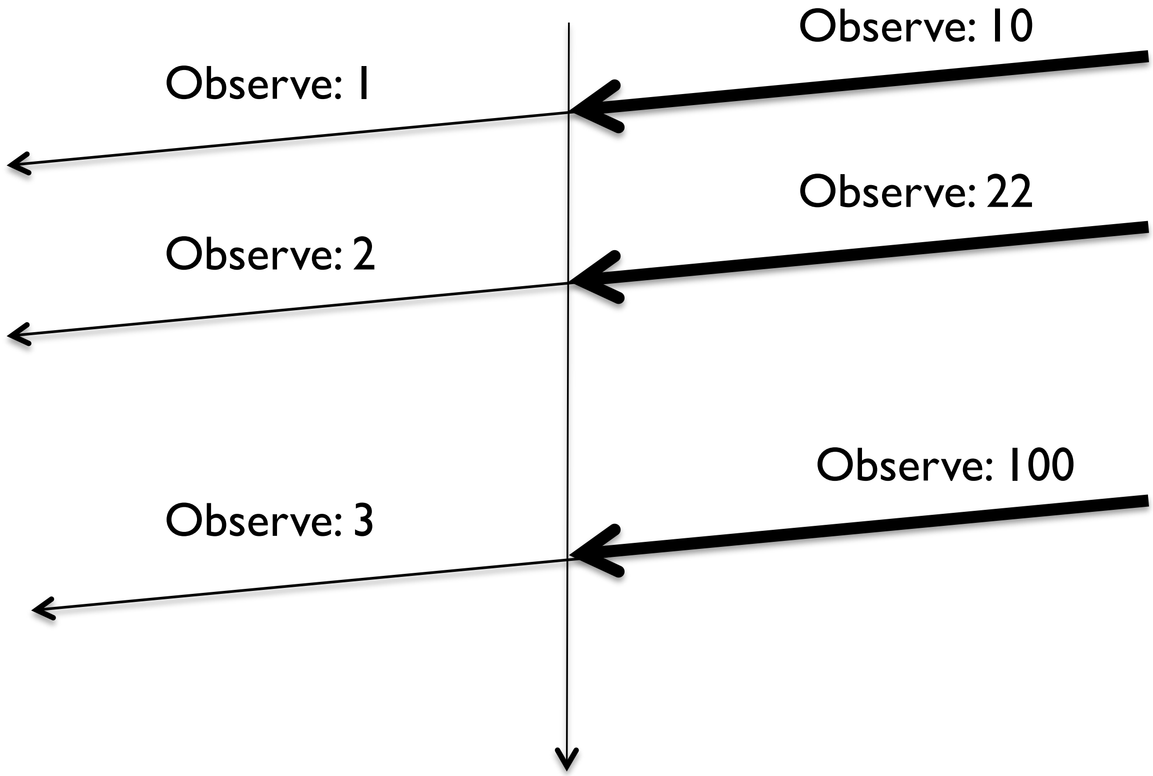
Code	Description	Mapping
0.00		0x00
0.01	GET	0x01
0.02	POST	0x02
0.03	PUT	0x03
0.04	DELETE	0x04
0.05	FETCH	0x05
0.06	PATCH	0x06
0.07	iPATCH	0x07
2.01	Created	0x08
2.02	Deleted	0x09
2.03	Valid	0x0A
2.04	Changed	0x0B
2.05	Content	0x0C

…

remapping


Thing
Mid: 0x0089
0x89
Mid: 0x1234
0x89 <-> 0x1234
Mid: 0x0089
0x89
Mid: 0x1234

Entropy-reduction



Example

```
 rule id 1
+-------------+-------+-----+---------------+----------------+
| Field       |TV     |MO   |CDF            | Sent           |
+=============+=======+=====+===============+================+
|CoAP version | 01    |=    |not-sent       |                |
|CoAP Type    |       |     |value-sent     |TT              |
|CoAP TKL     | 0000  |=    |not-sent       |                |
|CoAP Code    |       |     |static-map     |  CC CCC        |
|CoAP MID     |       |     |dynamic-map    |         M-ID   |
|CoAP Path    |/path  |     |not-sent       |                |
+-------------+-------+-----+---------------+----------------+
```

```
                     End System                      LPWA LC
                        |                            |
                        |        rule id=1           |<----------------------
                        |<---------------------------|    +-+-+--+----+--------+
  <-------------------- |  TTCC CCCM MMMM MMMM       |    |1|0| 4|0.01| 0x1234 |
 +-+-+--+----+--------+ |  0000 0010 0000 0001       |    |  0xb4   p    a   t |
 |1|0| 1|0.01| 0x0001 | |                            |    |  h    |
 |  0xb4   p    a   t | |                            |    +-------+
 |  h    |              |                            |     dynamic mapping
 +-------+              |                            |     +--------+--------+
                        |                            |     |0x1234  |  0x01  |
                        |                            |     +--------+--------+
------------------------>|       rule id=1           |
+-+-+--+----+--------+  |--------------------------->|
|1|2| 0|2.05| 0x0001 |  |    TTCC CCCM MMMM MMMM     |------------------------>
+-+-+--+----+--------+  |    1000 0000 0000 0001     | +-+-+--+----+--------+
                        |                            | |1|2| 0|2.05| 0x1234 |
                        v                            v +-+-+--+----+--------+
```

draft-minaburo-lpwan-RoHCapplicability-00

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RoHC documents

- RFC 3095 ROHC: Framework and four profiles: RTP, UDP, ESP, and uncompressed
- RFC 3096 Requirements for robust IP/UDP/RTP header compression
- RFC 3828 The Lightweight User Datagram Protocol (UDP-Lite)
- RFC 3843 ROHC: A Compression Profile for IP
- RFC 4019 ROHC: Profiles for User Datagram Protocol (UDP) Lite
- RFC 4997 Formal Notation for RObust Header Compression (ROHC-FN)
- RFC 6846 ROHC: A Profile for TCP/IP (ROHC-TCP)
- RFC 5225 Robust Header Compression Version 2 (ROHCv2): Profiles RTP, UDP, IP, ESP and UDP-Lite

RoHC

- Define originally for IP/UDP/RTP streams
  - LPWAN traffic in not a stream => long convergence time
  - Bandwidth is extremely short to support IR packets (larger than a full header)
- Nodes with no resources problem
- Allows unidirectional and bidirectional links
- Low Bandwidth transmission (but not constrained)
- Learned Context Information: Send full header, followed by field deltas
  - Impossible to send full headers in LPWAN

RoHC versions

- RoHCv1: profiles: IP, IP/UDP, IP/UDP/RTP, IP/ESP
- RoHCv2: RoHC framework and Formal Notation enable the definition of new profiles

RoHC Formal Notation

- Formal Notation designed to define the RoHC compression profiles

```
+----+----+---+---+---+---+---+---+
|version|type | sequence_no|
+----+----+---+---+---+---+---+---+
```

- The same description in FN is:

```
Header {
    Uncompressed{
        Version [2];
        Type [2]
        Sequence_no [4];
        }
    Compressed header {
        Version =:= uncompressed_value (3,1);
        Type =:= irregular(2);
        Sequence_no =:= Wlsb(0, -3);
        }
        }
```

Only description

RoHCv2

RoHCv1 Framework

- C/D state machines
- Mode of Operation
- Encoding Methods

Formal Notation

- Packet Description to produce new profiles
- Fields Compression

RoHCv2

RoHC Applicability

- RoHC Framework (RFC 5795)
  - Use a Master SN to manage context synchronization, control compression and reduce the header size
    - Encoded with W-LSB
  - Complex (168p (RFC 3095) + 36p (RFC 5795) + 60p (RFC4997) + 122p (RFC5225)) vs to CoAP = 40p and IPv6 = 39p
  - Does not compress CoAP header, which is asymmetric
  - For multimedia flows
  - Not routable packets
  - Control information is sent in the format packet
  - ACL for small flows = 6 bytes
  - ACL for larger flows = 3 bytes

This is an average, in reality the header size goes from 52 bytes to 4 bytes (with UDP checksum) or 2 bytes (no UDP checksum)

Next Steps

- RoHC for LPWAN
  - Modify and adapt the RoHC framework (complex)
  - Work on CoAP profile (using FN = not for asymmetric flows)
  - Adapt Framework to LPWAN networks
    - Asymmetric CoAP behavior – response can be a data packet
  - Patents?
- 6LoWPAN for LPWAN
  - Adapt and Modify the 6LoWPAN compression which reduces the IPv6 addresses
  - Adapt for asymmetric links,
- Or Concentrate efforts on a specific solution for LPWANs

draft-gomez-lpwan-fragmentation-header-03

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Universitat Politècnica de Catalunya / Fundació i2cat

Jon Crowcroft
University of Cambridge

Updated content (I/III)

- Fragmentation header
  - From 3-byte to 2-byte format
- First fragment

```
                      1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 0|    datagram_size     | tag |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- Subsequent fragments

```
                      1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|1 1|    datagram_offset   | tag |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Updated content (II/III)

- Format now not bound to 6LoWPAN dispatch
  - To be aligned with LPWAN work on header compression
- Name
  - Old: Optimized 6LoWPAN Fragmentation Header for LPWAN (6LoFHL)
  - New: LPWAN Fragmentation Header (LFH)

Updated content (III/III)

- Adaptation layer fragmentation header overhead (bytes)

	IPv6 datagram size (bytes)							
	11		40		100		1280	
L2 payload (bytes)	4944	LFH	4944	LFH	4944	LFH	4944	LFH
10	----	4	----	10	----	26	----	320
15	0	0	24	8	64	16	799	198
20	0	0	19	6	59	12	794	144
25	0	0	14	4	34	10	399	112
30	0	0	9	4	24	8	269	92

Discussion: 1-byte format ?

Option A

- Possible format
  - 1 bit: fragmentation header or not
  - 7 bits: fragment number
  - No tag, no ‘more fragments’ bit
- Is this feasible at all ?
  - LoRaWAN: yes (enough to number all fragments for a 1280-byte packet)
  - Sigfox: yes (uplink), no (downlink)

Option A: issues

- Incomplete packets
  – E.g. received sequence of fragments 1, 2, 1, 2, 3, 4
    - If two packets carried by 4 fragments each had been sent, the first one is incomplete
- Additional delay
  – Receiver does not know when all fragments of a packet have been received
    - Must wait for a time that, given message rate constraints, may be significant
- Apparently correct reassembly
  – E.g. received sequence of fragments1, 2, 3, being in reality 1-A, 2-B, 3-B

Option B

- Possible format
  - 1 bit: fragmentation header (or not)
  - 1 bit: more fragments (or not)
  - 6 bits: fragment number
  - No tag
- Is this feasible at all ?
  - LoRaWAN: yes (enough to number all fragments for a 1280-byte packet)
  - Sigfox: no

Option B: issues

- No incomplete packets issue
  - The ‘more fragments’ bit allows to identify incomplete packets
- No additional delay
  - Receiver knows whether all fragments of a packet have been received
- Apparently correct reassembly
  - E.g. received sequence of fragments 1, 2, 3, being in reality 1-A, 2-B, 3-B

Summary

- LoRaWAN
  - Can use option B
  - 1-byte, but 'apparently correct reassembly' issue
- Sigfox
  - Can use option A for the uplink (only)
  - 1-byte, but 'incomplete packets', 'apparently correct reassembly', and 'additional delay' issues