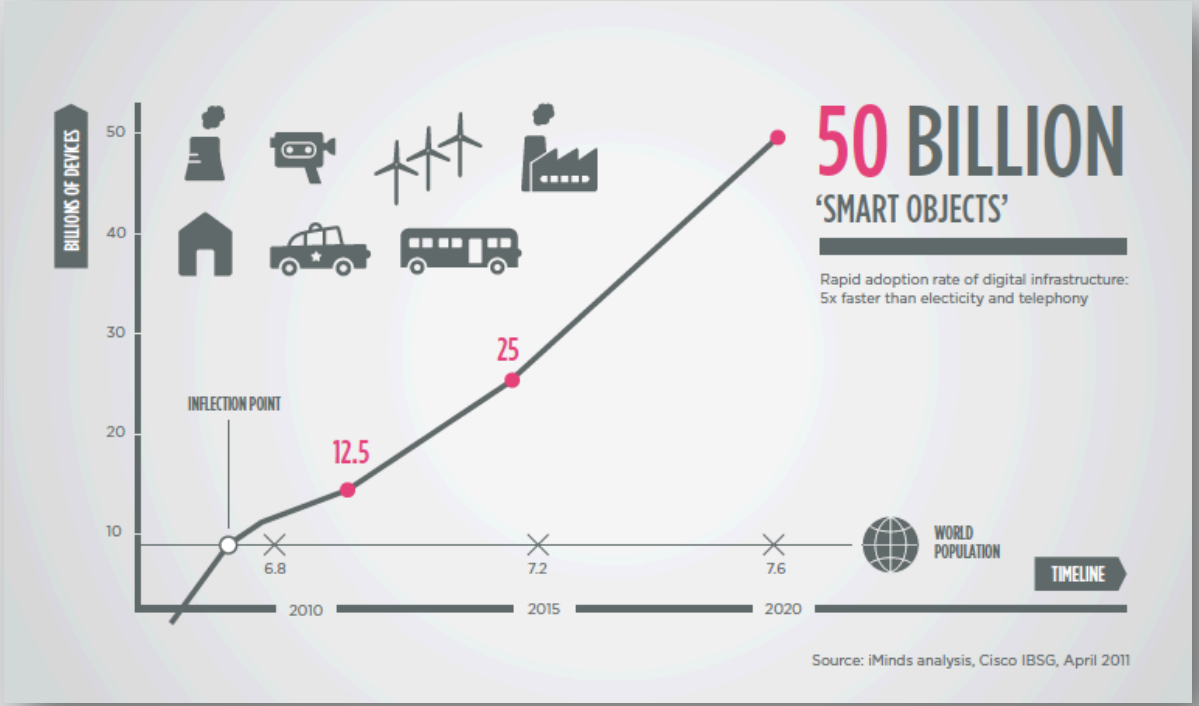
DASH7, PASSIVE RFID AND LPWAN

PROF. MAARTEN WEYN - MICHAEL ANDRE

THE INTERNET OF THINGS



WIRELESSLY CONNECTING A THING…

Thing

What is a light bulb?
What is on/off?
What is dim?

How is network formed?
How do devices join?
How to send packet from A to B?
How to set up connection?
…

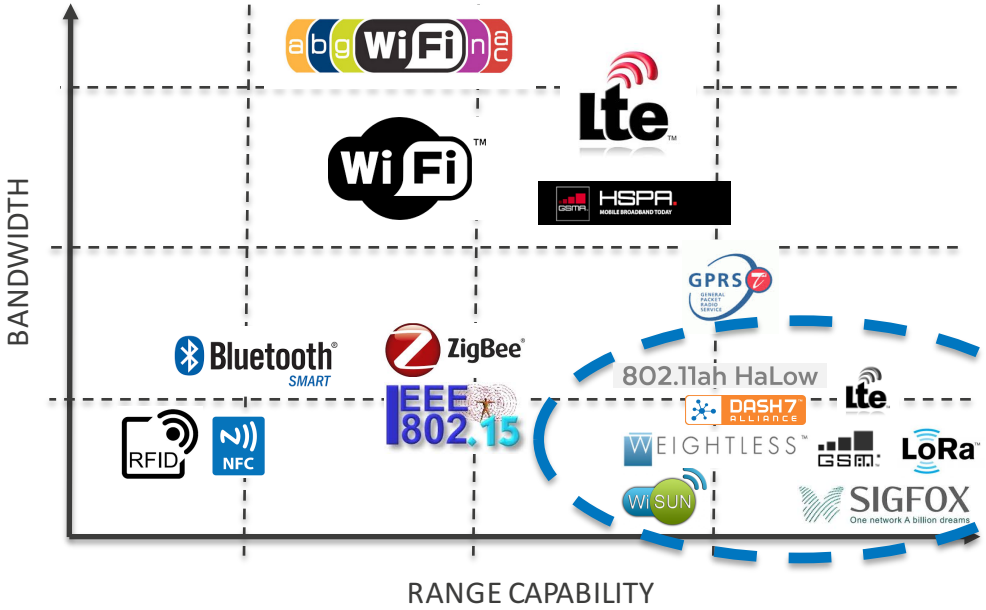
What frequency is used?
How does transmission work?
How is link established?

Wireless communication

MEANS SELECTING AN APPROPRIATE TECHNOLOGY

and understanding limitations and trade-offs

WIRELESS LANDSCAPE



LPWAN features

- Long range
- Low data rate
- Low power
- License free / licensed
- Different system models

WIRELESS TECHNOLOGY

WIRELESS TRADE-OFFS

Licensed/Unlicensed Spectrum
License Cost / ISM regulations / Collisions

Range: higher frequencies result in shorter range, more complex coding reduces range

Data rate: more BW or advanced coding within given BW results in higher achievable data rates of system

Energy consumption
Tx duration – Rx scheduling and duration

Topology
Star – Mesh – Point to Point

THE CONTENDERS

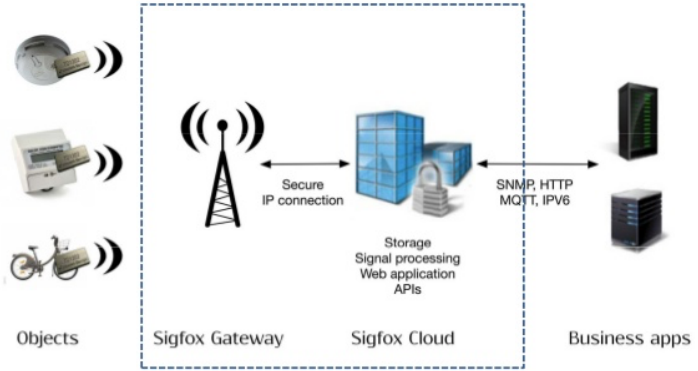

sigfox

sigfox

Radio implementing patented technology (< 5EUR)

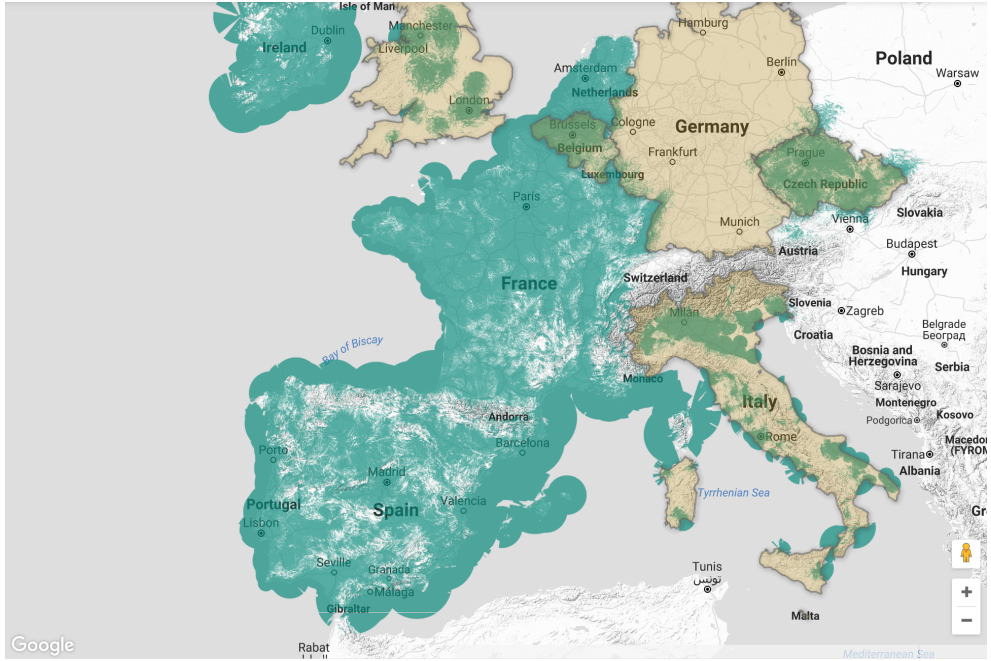
E.g. TI, Silicon Labs, Atmel

SigFox Ready™ device with subscription



Class 0, 1, 2 or 3 (0 = best RF performance)

SIGFOX – COVERAGE TODAY



Live coverage Country under roll-out

Source: www.sigfox.com/coverage

SIGFOX – TECHNICAL INFORMATION

- Based on ETSI Low Throughput Network (LTN) + patented features
- Ultra Narrow Band (UNB)

UPLINK (DEVICE → BS)

- 868 MHz (EU)
- Max radiated power: 14dBm
- Max Duty Cycle allowed: 1%
- Modulation: DBPSK @ 100bps using 100Hz channel in 200kHz band
- Max. 140 msg/day of 12 bytes payload (→ 2s TX time!) to meet duty cycle
- TX: msg is sent 3 times at diff. pseudo-random freq. to ensure delivery (no collision avoidance or recovery)
- RX: every BS listens to 200kHz band
- Private key per device + hash for auth.

DOWNLINK (BS → DEVICE)

- 869 MHz band (EU)
- Max radiated power: 27dBM
- Max duty cycle: 10%
- Modulation: GFSK @ 600bps using 600Hz channel
- Max. 4 msg/day/device of 8 bytes
- High sensitivity of BS (-142dBm)
- TX
  - Timing initiated by device
  - Base station adapts to frequency (+offset) of node

SIGFOX – UPLINK SCALABILITY

DEVICE → BS (no collisions, i.e. theory)

MESSAGE TRANSMISSION / DEVICE

- Total msg size (12B payload) = 26B
- TX time for 1 msg @ 100bps = 2.08s
- TX time for 3 transmissions (with 45ms TX offset) = 6.33s
- **10msg/day = 63.33s air time/device/day**

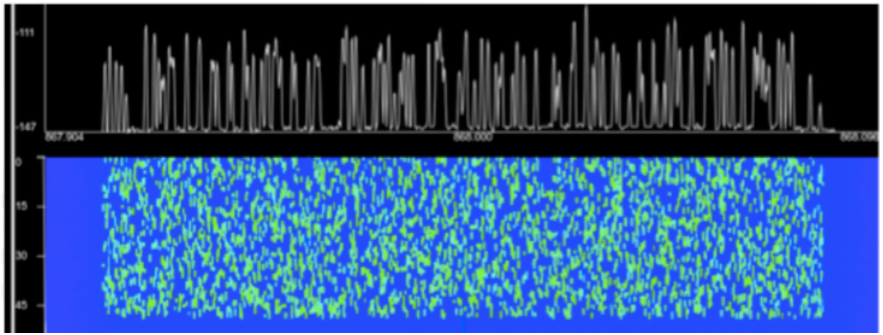
TOTAL AVAILABLE AIR TIME / DAY / BS

- 200 channels of 100Hz (within 200kHz) → 17.280.000s air time

MAX. DEVICES / BS = 272.856

 # Unique msgs / 60s = +/- 1895

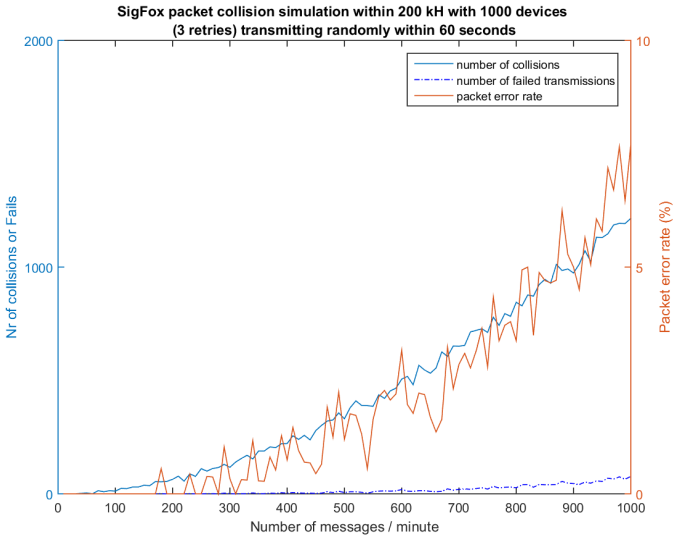
assuming perfect collision-free system

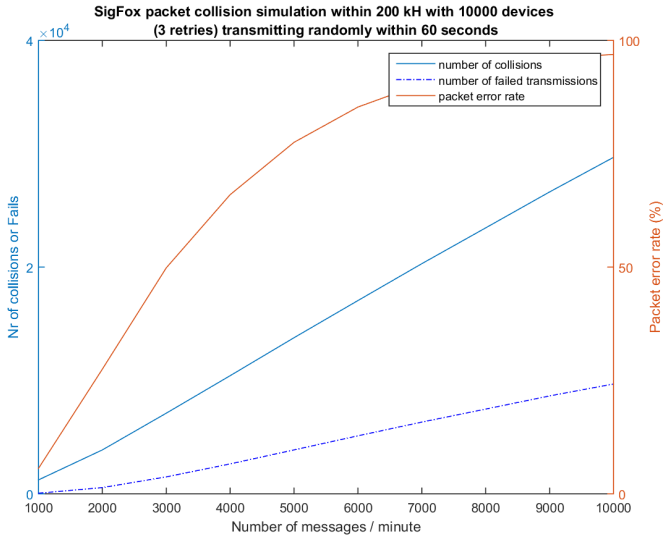


Source: SigFox

SIGFOX – UPLINK SCALABILITY

DEVICE → BS (collisions) - Simulation





Source: Maarten Weyr


LoRa®

1. LoRa = PHY
    1. Novel radio modulation patented by Semtech, based on Chirp Spread Spectrum (CSS), with very high sensitivity

Technology	Rx sensitivity	Data rates
Wi Fi	-84 dBm	< 54 Mbps
Bluetooth SMART	-90 dBm	< 1Mbps
GPRS	-109 dBm	< 80 Kbps
LoRa	-138 dBm	300 bps – 10 Kbps

Source: i2CAT

2. LoRaWAN = communication protocol (MAC) and system architecture for the network
    1. Open, defined by LoRa Alliance

LORA - SPECTRUM USAGE AND DATA RATES

SUB-GHZ BAND: ETSI ERC 70-03 (EU)

Sub-band	Freq. Range (MHz)	Conditions (Pwr/DC)
g	863 - 868	14 dBm @ 1% or LBT+AFA
g1	868 – 868.6	14 dBm @ 1% or LBT+AFA
g2	868.7 – 869.2	14 dBm @ 0.1% or LBT+AFA
g3	869.4 – 869.65	27 dBm @ 10% or LBT+AFA
g4	869.7 - 870	14 dBm @ 1% or LBT+AFA

LBT+AFA = Listen Before Talk with Adaptive Frequency Agility

LoRaWAN default channels

Freq. (MHz) / BW	Conditions (Pwr/DC)	Orthogonal Spreading factors
868.10 (g1) / 125kHz	14 dBm @ 1%	7-12
868.30 (g1) / 125kHz		7-12
868.50 (g1) / 125kHz		7-12

Spreading Factor (SF)	Bit Rate
SF=12	250 bps
SF=11	440 bps
SF=10	980 bps
SF=9	1.7 Kbps
SF=8	3.1 Kbps
SF=7	5.4 Kbps

Range

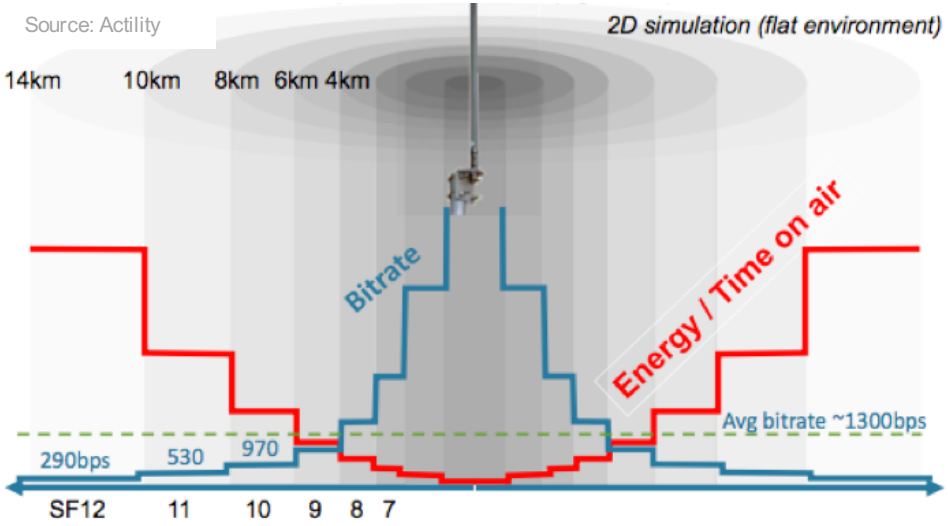
LORA - SPECTRUM USAGE AND DATA RATES

EU VS NORTH AMERICA

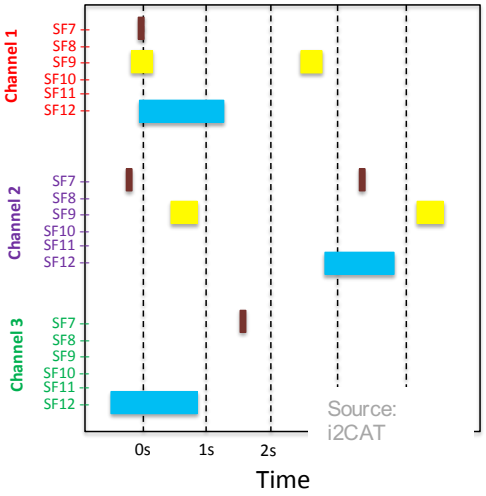
	Europe	North America
Frequency band	867-869MHz	902-928MHz
Channels	8+1+1	64+8+8
Channel BW Up	125/250kHz	125/500kHz
Channel BW Down	125kHz	500kHz
TX Power Up	+14dBm	+20dBm typ. (+30dBm allowed)
Tx Power Down	+14dBm	+27dBm
SF Up	7-12	7-10
Data rate	250bps – 50kbps	980bps-21.9kbps
Link budget up	155 dB	154dB
Link budget down	155 dB	157dB

LORA - DATA RATE VERSUS RANGE

RANGE VERSUS SPREADING FACTOR



Air time



LORAWAN – THEORETICAL THROUGHPUT NODE

Back of envelope calculations for max data throughput per hour:

SF	Data rate [b/s]	Max. #b/h	Max. data length [B]	Max. Pt Size [B]	Min. Over-head	Max #Pt/h	Max data/h [B/h]	Max TX energy [J]
12	250	9000	51	80	36.2%	**14**	714	3.5
11	440	15840	51	80	23.8%	**24**	1224	3.4
10	980	35280	51	80	23.8%	**55**	2805	3.5
9	1760	63360	115	144	20%	**55**	6325	3.5
8	3125	112500	222	251	12%	**56**	12432	3.5
7	5470	196920	222	251	12%	**98**	21756	3.5

868MHz:
1% RDC

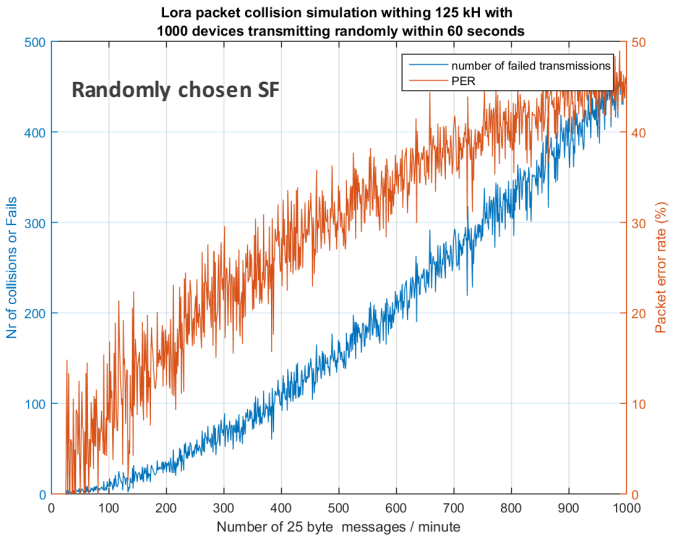
20B PHY header
9B MAC header

14dBm TX power
29.6 mA supply current

LORAWAN – SCALABILITY

COLLISIONS - SIMULATION

No collision avoidance mechanism



Source: Maarten Weyn (mweyn.wesdec.be)

ALOHA

ALOHA CHANNEL ACCESS ASSUMPTION

- If you have data, send it
- If another station transmits, then collision

THEORETICAL PERFORMANCE OF ALOHA SYSTEM

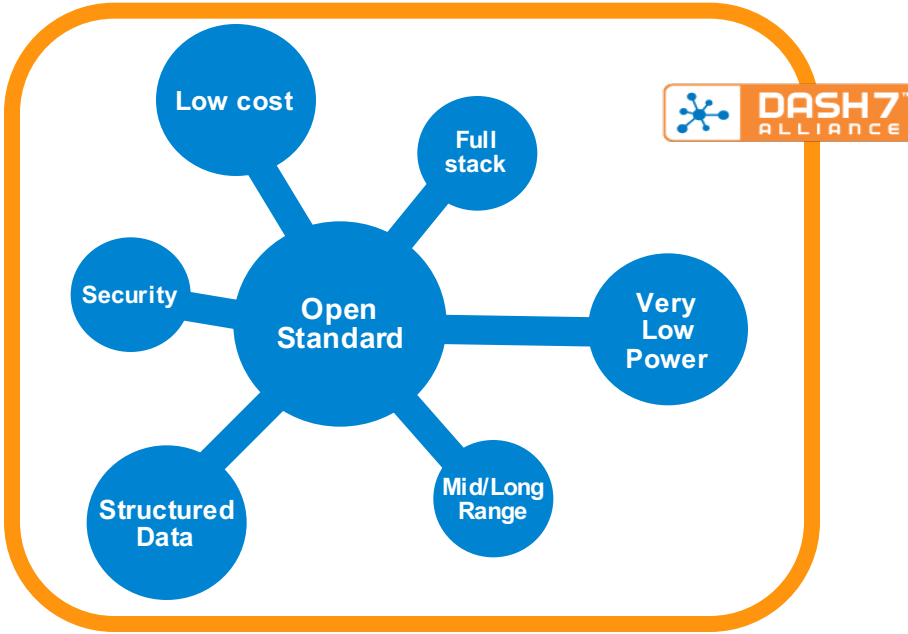
With air utilisation lower than 18%, 97% of transmissions are likely to succeed!

Air utilization can be reduced by using lower SF, i.e. most nodes in vicinity of BS or more BSs!


DASH7™
ALLIANCE

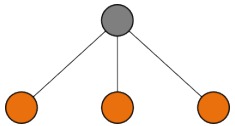
OPEN STANDARD OF ULTRA LOW POWER MID-RANGE SENSOR AND ACTUATOR COMMUNICATION

- Wireless Sensor and Actuator Network Protocol (WSAN)
- Originates from ISO 18000-7 (“dash7”)
  - describes the parameters for active air interface communications at 433 MHz (2008 - 2009)
- Extended to support IoT functionalities
- Now support all sub-GHz ISM/SRD bands
- Star or tree network topology (no mesh)
- v1.1 of the spec published in Q1 2017.
- Active members of the Protocol Action Group: Wizzilab, University of Antwerp, Wroclaw Technical University and CORTUS



NETWORK TOPOLOGY

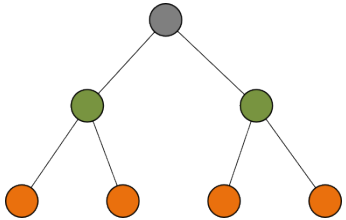
Star



Passive RFID
Tags can only be read in the intermediate proximity of a reader

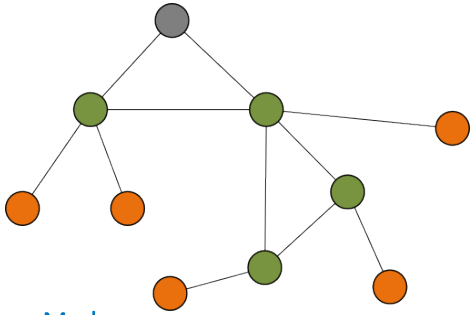
Active RFID
Longer range interrogators – Master/Slave

Tree



DASH7
Simple routing (2 hops)
subcontrollers are power but only few are needed
Tag-to-Tag & Tag-Talk-First

Mesh

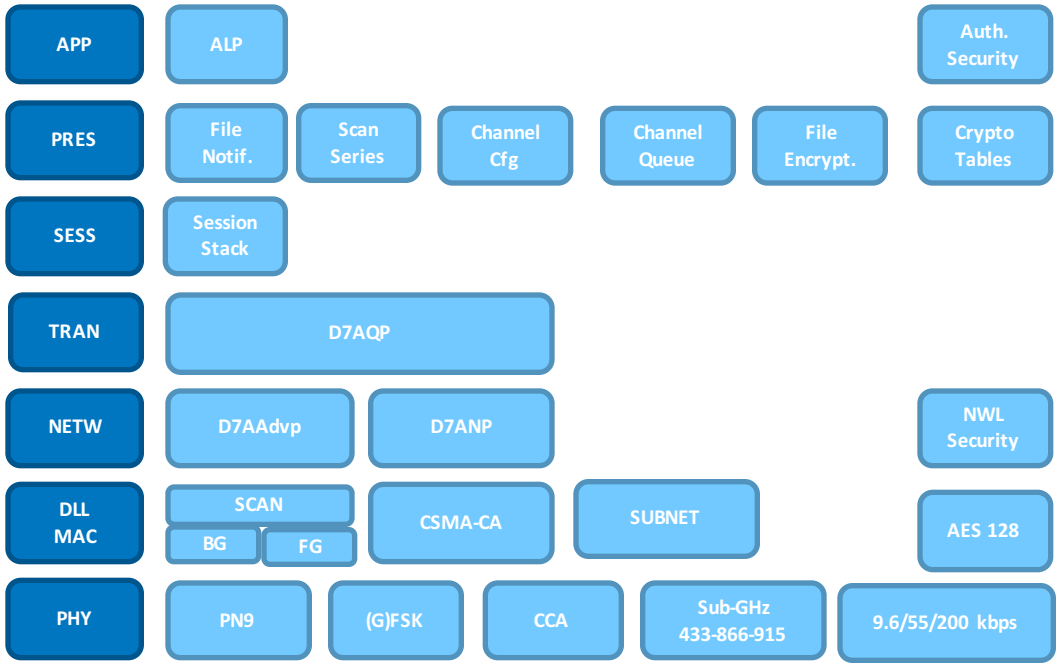


Mesh
Range depends on number of router nodes

Congestion – Routing Complexity – Latency
Routers need to be powered
Each hop consumes energy

Distance – Complexity – Energy – Latency

FULL STACK SPECIFICATION



OSI Layer		D7AComponent	Description
7	Application	File Access	File management via Application Layer Programming Interface (ALP). Property-based queries.
		D7AActP	Pre-registered application actions, triggered conditionally on file access.
6	Data Elements	D7A Files	A user-driven file system that supports read, write, create, delete, modify of executable, encryptable files.
			Native attributes allowing to configure D7AActP actions triggered on file access.
5	Session	D7ASP	Session FIFOs, priorities and QoS management.
4	Transport	D7ATP	Request-Response and group acknowledgment.
3	Network	D7ANP	Routing (no-hop & one-hop), foreground scan automation
		D7AAdvP	Ad-hoc synchronization
		Addressing	Access Profile
		Security	AES-128 authentication and encryption
2	Data Link	Frame Addressing Data	Unicast, Broadcast
		Transmission	Upper-layer event driven
		Data Reception	Upper-layer event driven, or via configurable, sequential automated channel scan
		Channel Access	CSMA-CA, with static channel guarding rules, multiple supported flow/congestion control models and frequency diversity.
1	Physical	Channel QoS	Clear Channel Assessment
		Encoding	1/1 PN9, 1/2 convolutional Code
		Rates	9.6 kb/s, 55.55 kb/s, 166.667 kb/s
		Modulation	± 4.8 kHz 2-(G)FSK, ± 50 kHz 2-(G)FSK or ± 41.667 kHz 2-(G)FSK
		Channel spacing	25 kHz or 200 kHz
		Spectrum	433.060 – 434.785 MHz 863.000 – 870.000 MHz 902.000 – 928.000 MHz

APPLICATION LAYER PROTOCOL

EVERYTHING IS A FILE

Structured data

- Everything is a file (sensor values, system configuration, encryption keys…)
- Any application action, data exchange method or protocol is mapped exclusively onto manipulation of Structured Data Elements (D7A Files) and their properties.

ALP

- ALP is a generic API for manipulating D7A files. The interface can be D7A, but also UART, BTLE
- **ALP commands** are composed of **ALP Actions**
- Actions can be read, write, create, delete, execute, condition (query), grant permission, etc...
- Local or OTA

QUERIES + ACTIONS + D7A

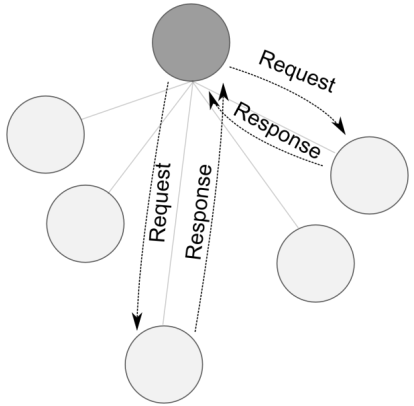
=

DISTRIBUTED DATABASE

Communication Model

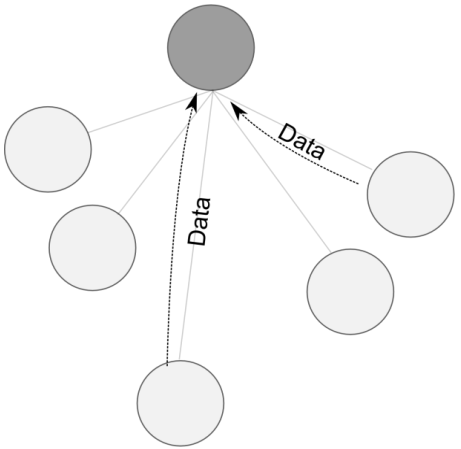
Pull

To obtain tag sensor data
To set actuator data



Unsollicited – Tag Talk First

For alarms and periodic data

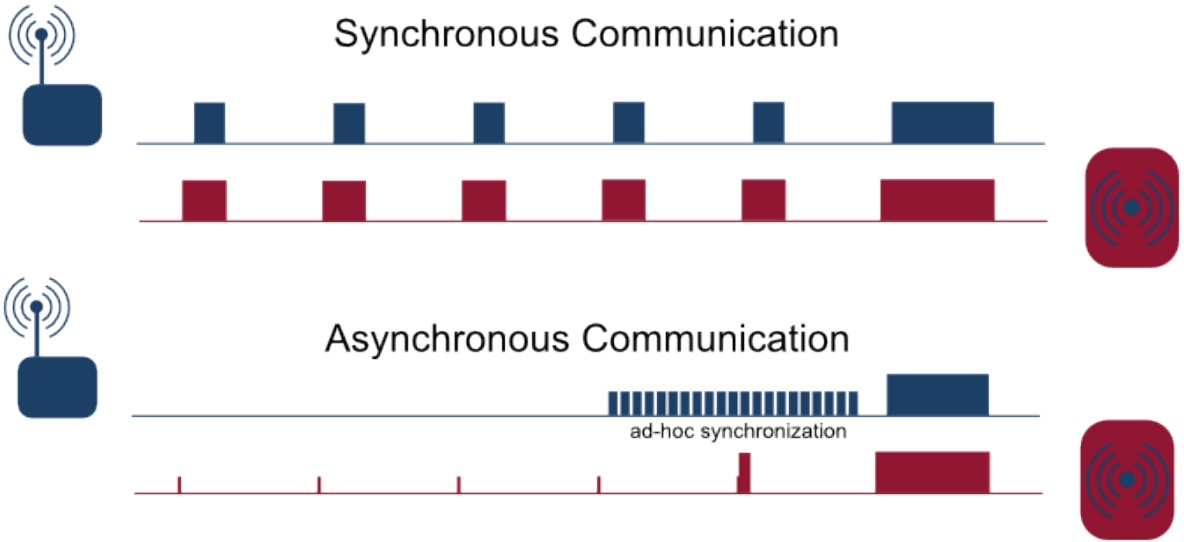


- Polling data using D7AP Advertising Protocol
- Pushing data using D7AP Action Protocol
- Dormant sessions (wait for the tag to talk first)

COMMUNICATION SCHEMES

D7AADVP

- Advertisement protocol
- Gateway queries endpoints
- Low power wake—up



COMMUNICATION SCHEMES

D7AACTP

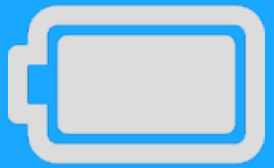
- Action protocol
- Notification / tag-talks-first
- ALP command preregistered on endnodes
- Filesystem can be configured to activate ALP command upon file access

COMMUNICATION SCHEMES

D7AACTP – APPLICATION EXAMPLE

Humidity Notification

Send a message to 0x23BE with the humidity and the battery level when the humidity changes.



Battery Alarm

Broadcast battery alarm when battery below 20% and send all latest sensor values.

Sensor on Presence

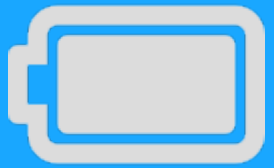
When the presence is detection from a mobile device and temperature is below 21°C, send ‘on’ command to local heating.

COMMUNICATION SCHEMES

D7AACTP - IMPLEMENTATION IN APPLICATION FIRMWARE

Humidity Notification

Measure humidity at x sec interval and write value to file with ID 0x34



Battery Alarm

Measure battery at x sec interval and write value to file with ID 0x25

Sensor on Presence

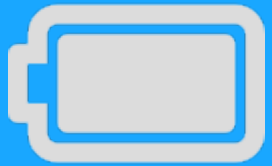
Measure temperature at x sec interval and write value to file with ID 0x33

COMMUNICATION SCHEMES

D7AACTP - CONFIGURATION OF FILE SYSTEM

Humidity Notification

Configure notification header for file 0x34 and set query to condition different from previous value. Set 0X23BE and 0x34 in notification file.



Battery Alarm

Configure notification header for file 0x25 and set query to condition
< 20. Set 0x25, 0x34 and 0x33 in notification file.

Sensor on Presence

Configure notification on file 0x19 (localisation file) and set 0x33 in in the notification file.

COMMUNICATION SCHEMES

TRADE-OFFS

D7AAdvP

Ideal for ad-hoc data gathering, not for periodic or sensor triggered.

Tradeoff between energy consumption and latency

D7AActP

Ideal for periodic sensor data transmission or sensor triggered

- Dormant sessions
- Use case specific, combinations possible
- Network behavior over-the-air updatable

CONTEXT AWARE SENSOR AND ACTUATOR DATA PROPAGATION

Write and read from files

Configure system through configuration files

Configured through file system

Handles scheduled scan cycles

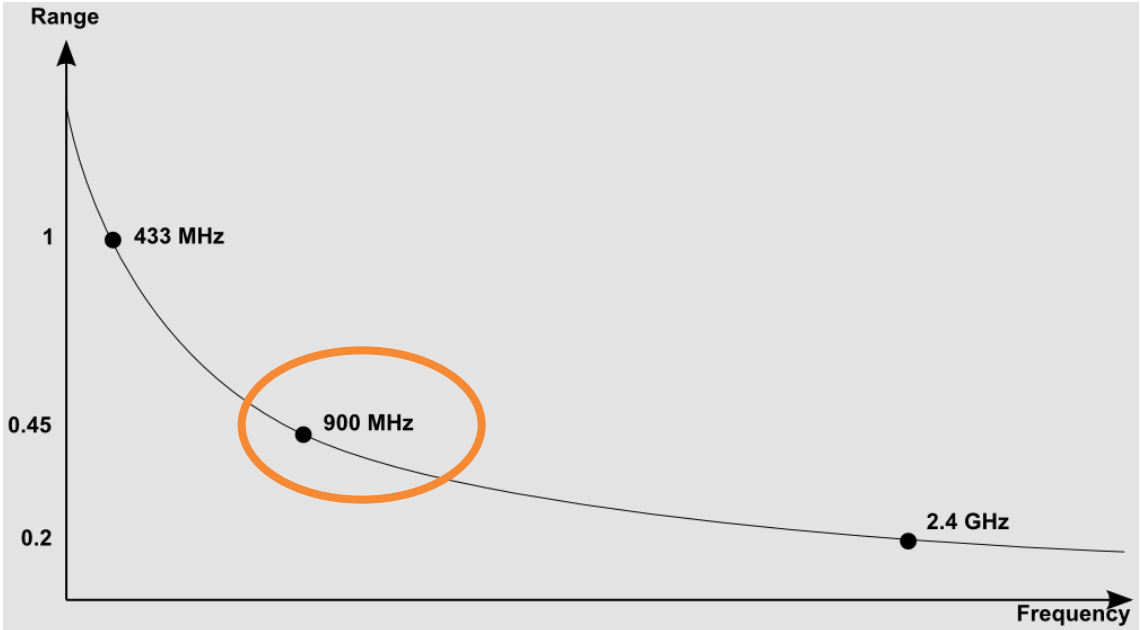
Handles queries from other devices

Handles queries and notifications on file changes

File system configurable over the air

THE MATCH

FREQUENCY

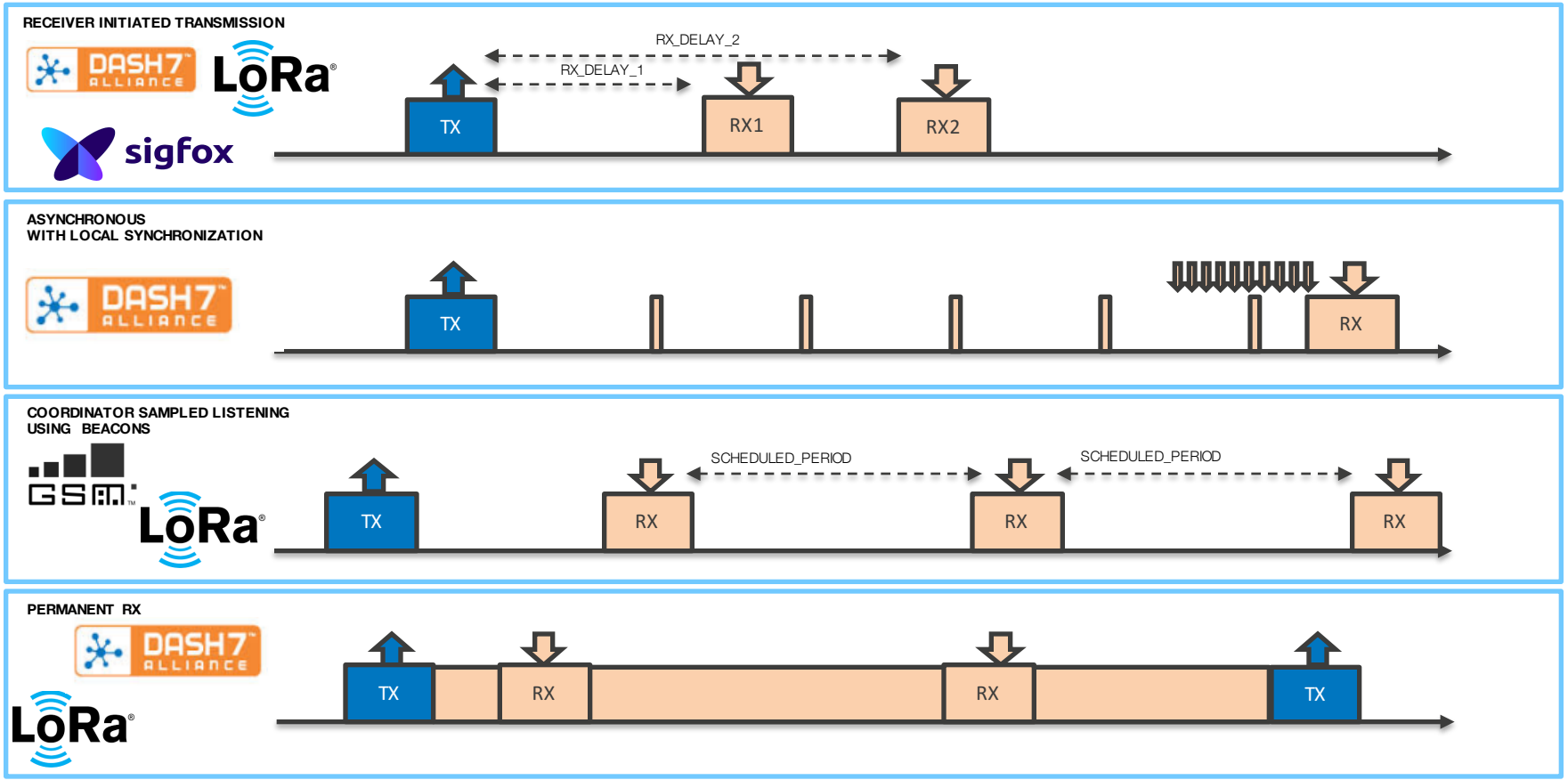


+-	+-	Antenna options	++
++	+	Permitivity	-
-	+	Bandwidth	++
++	+	NLOS Options	-

DATARATE ⇔ RX/TX DURATION VS RANGE

sigfox	100bps	-156dBm	12 bytes payload	6 seconds
LoRa®	250bps - 10kbps	-155dBm	max payload 50 bytes	50 ms – 2 seconds
DASH7™ ALLIANCE	9.6 kbps 55 kbps 166 kbps	-105dBm	max payload 256 bytes	10 ms

RX SCHEDULING



WIRELESS TRADE-OFFS APPLIED TO LPWAN

Today – no licensed LPWAN solution deployed yet

Lower frequency bands
(with less bandwidth)

Simple coding, i.e. lower data rates
(→ low complexity, low cost)

Limit 'radio on time'
(sleep, low data usage, downlink after uplink)

Predominantly star topologies
(low installation & maintenance cost)

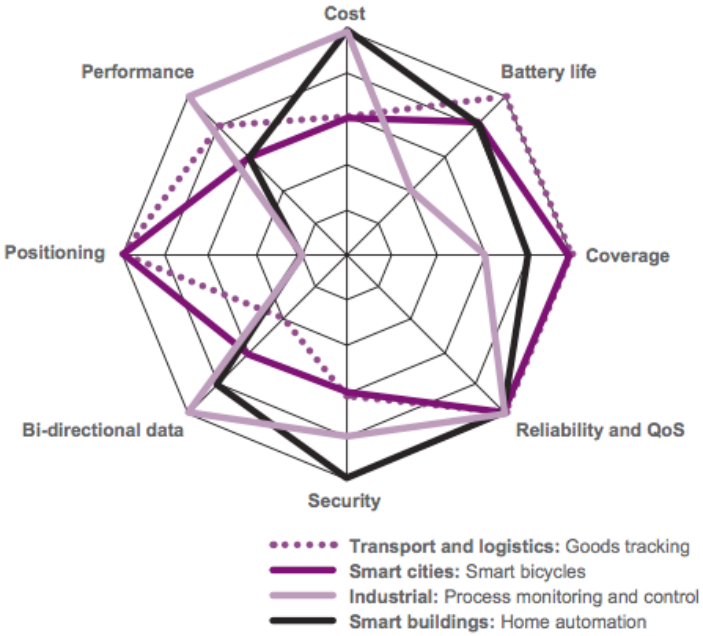
WHEN ONE RF TECHNOLOGY IS NOT ENOUGH

LPWAN

COMPETITION BETWEEN STANDARDS?

Yes, but room for multiple LPWAN technologies!

Device and connectivity requirements



Source: Ericsson

LPWAN - USE CASES

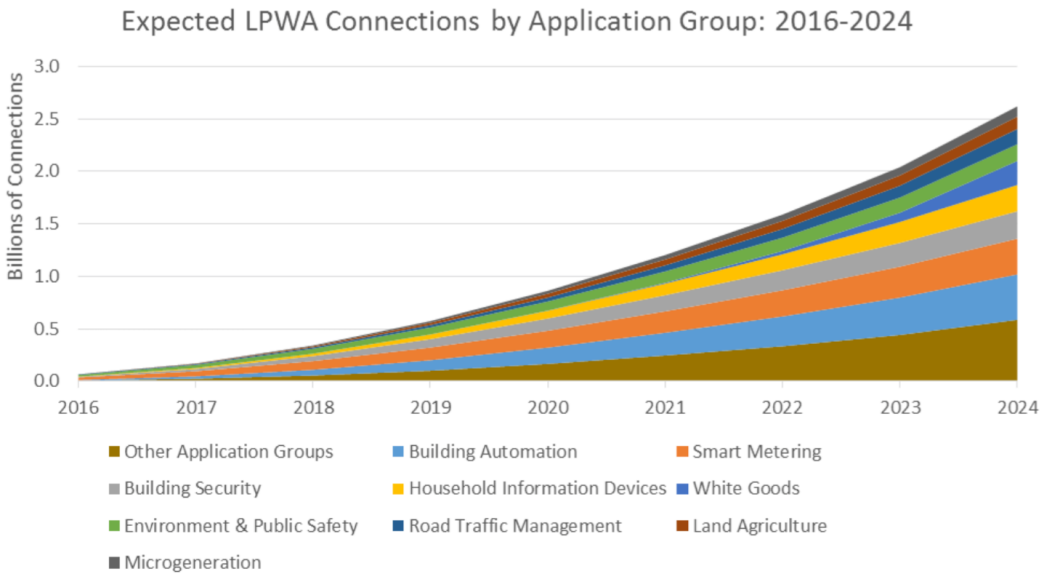
USE CASES INVOLVING

LOW DATA RATE, BATTERY-OPERATED DEVICES, LOW SENSOR DENSITY

Source: Actility

LPWAN FORECAST

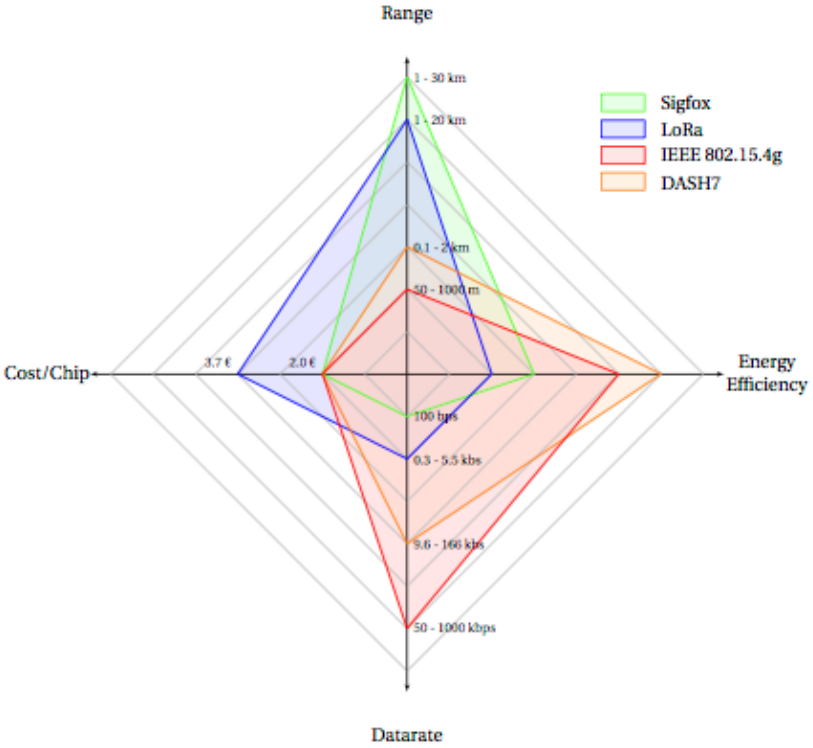
> 2.5 BILLION LPWAN CONNECTIONS BY END OF 2024*

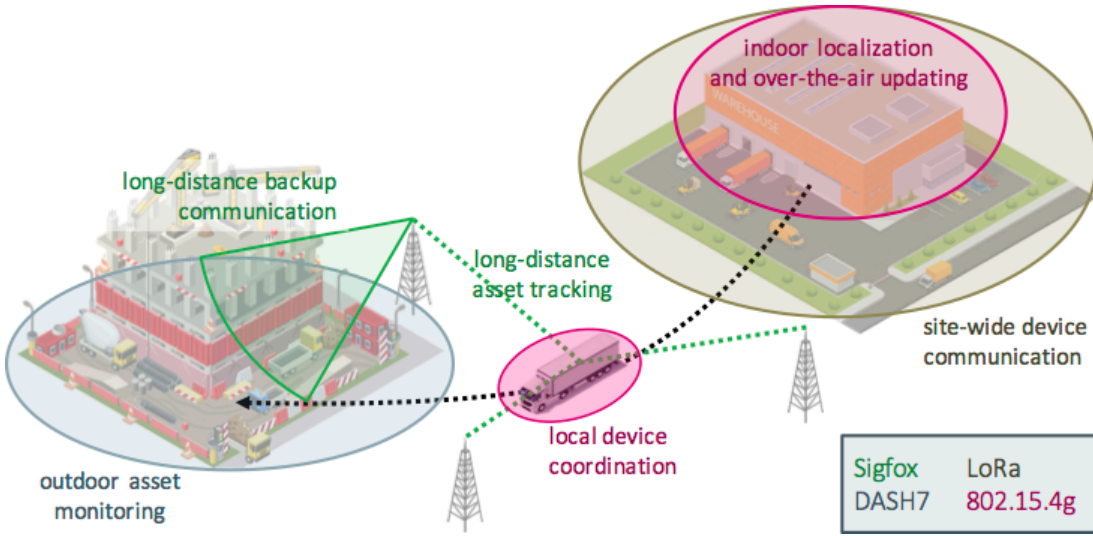


Source: Machina Research

***CAVEAT: Many other numbers circulate**

WHERE DASH7 MEETS LPWAN





LPWAN OPEX

They tell you LoRa® or sigfox devices are **CHEAP!**

None of these technologies allows to upgrade firmware over the air
What if:

- a security breach is found
- SigFox goes bankrupt
- A new building masks the nearest antenna and you loose coverage
- You find an algorithm to reduce power and gain 1 year of battery life

Most of these devices will be deployed for YEARS!

SECURE THE FUTURE

or

hardware is compatible with

Add a DASH7 stack and Upgrade Firmware Over The Air to

- Switch Connectivity
- Re-Configure Devices Remotely
- Apply security patches
- Switch between Public and Private Network

Avoid costly Maintenance

WHEN ACTIVE RFID MEETS PASSIVE RFID

APPLICATION LAYER PROTOCOL (ALP)

Everything is a file

Structured data

- Everything is a file (sensor values, system configuration, encryption keys…)
- Any application action, data exchange method or protocol is mapped exclusively onto manipulation of Structured Data Elements (D7A Files) and their properties.

ALP

- ALP is a generic API for manipulating D7A files. The interface can be D7A, but also UART, BTLE
- **ALP commands** are composed of **ALP Actions**
- Actions can be read, write, create, delete, execute, condition (query), grant permission, etc...
- Local or OTA

PROVISIONING, DEPLOYMENT, OPERATION

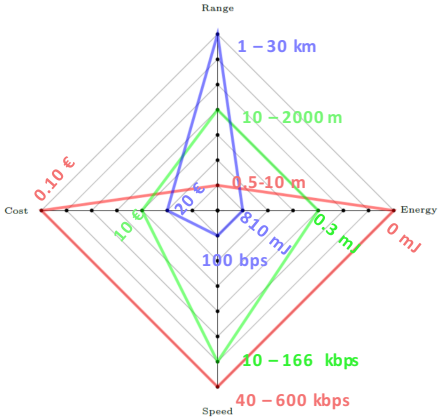
Long range is great but sometimes you want to:

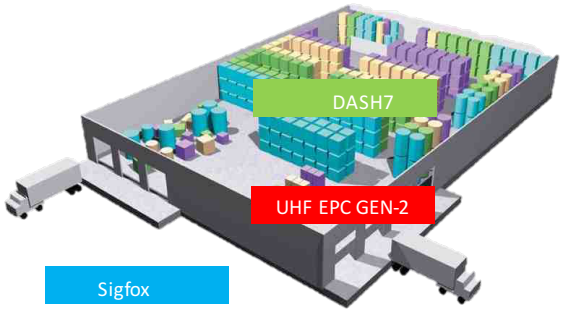
- Know which device is in your hand
- Trigger something on the device in front of you
- Distribute keys without being overheard

DASH7™ ALLIANCE

ALP over

UHF GEN-2


Range
1 – 30 km
10 – 2000 m
0.5-10 m
Energy
0 mJ
0.3 mJ
10 mJ
20 mJ
Cost
0.10 €
10 €
100 bps
10 – 166 kbps
40 – 600 kbps
Speed


DASH7
UHF EPC GEN-2
Sigfox


LoRa
SIGFOX
UHF gen-2

HOW TO CHOOSE THE RIGHT PROTOCOL?

Some questions to ask

Your application

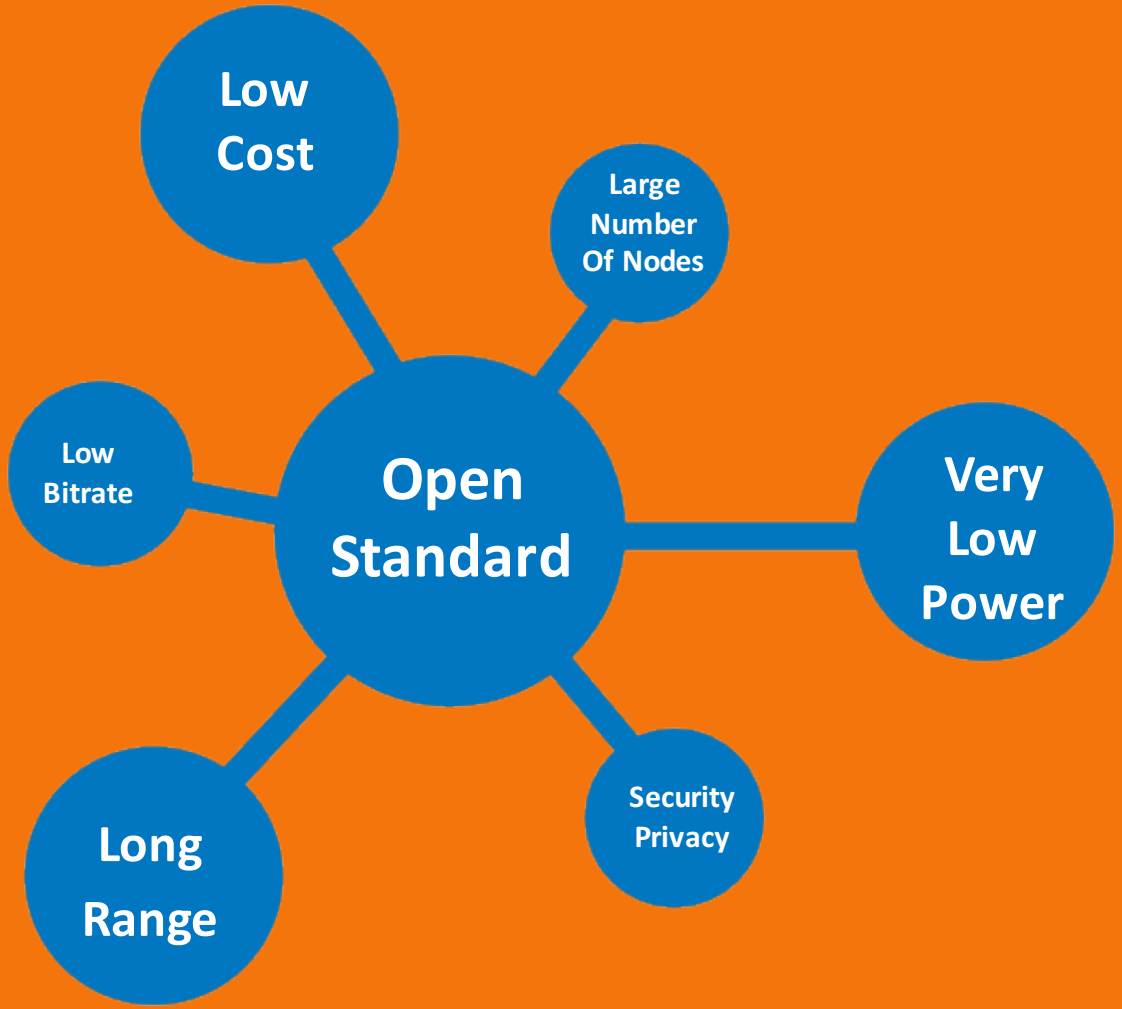
- Coverage?
  - Local
  - National
  - Worldwide
- Time to market?
- Outdoor, indoor, deep indoor?
- Security?
- Business model?
- Scalability/capacity?
- Vendor lock-in?

Your device

- Minimum viable lifetime?
- Device size and antenna design?
- Firmware updates needed (OTA)?
- Module or embedded chipset?
- Static or mobile device?
- Addressing?

Your data

- What is the size of data to send?
- What is the periodicity of transmissions?
- How critical is the data (reliability)?
- Downlink versus uplink communication?


Low Cost
Large Number Of Nodes
Low Bitrate
Open Standard
Very Low Power
Long Range
Security Privacy