POLYMORPHICAL WIRELESS COMMUNICATION FOR CONNECTED AGRICULTURE

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Future ubiquitous networks

CONTEXT

Sencrop

Automatic ultra-precise data collection to assist agriculture workers

[1] Sencrop. url: https://sencrop.com/.

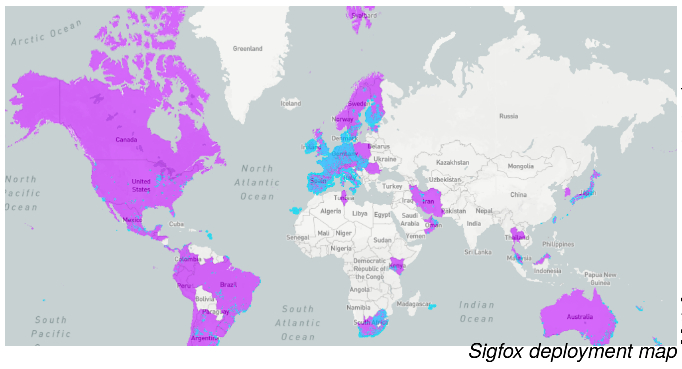
Goal: Extend geographical range of operation & over-the-air firmware upgrades

sigfox

100 bytes per second

140 x 12 bytes / day upstream

4 x 8 bytes / day downstream



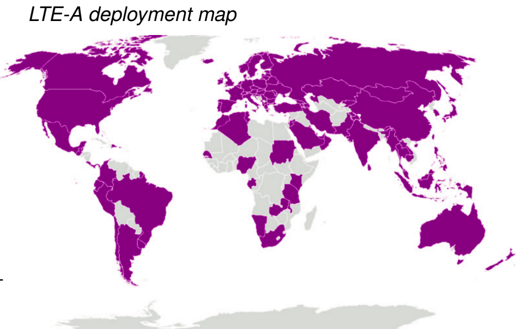
Sigfox deployment map

[4] Sigfox coverage map. Dec. 2018. url: https://www.sigfox.com/en/coverage.

Idea: Multiple radio technologies & multi-hop networks

CELLULAR NETWORKS

LTE-A deployment map



[5] Global mobile Suppliers Association (GSA). Evolution from LTE to 5G: Global Market Status. Tech. rep. Nov. 2018.

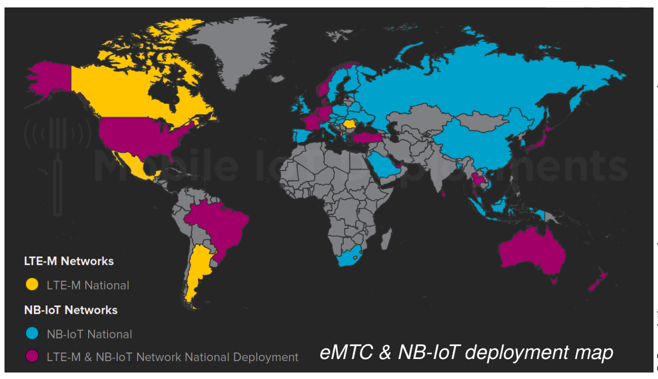
Enhanced Machine Type Communication (eMTC a.k.a. LTE-M)

- Based on 4G (LTE)
- 1 Mbps bit-rate
- 1,4 MHz bandwidth
- eDRX & PSM

Narrow-band IoT (NB-IoT)

- Also based on 4G
- 250 kbps down & 20 kbps up bit-rate
- 180 kHz bandwidth
- No handover

eMTC & NB-IoT only need a firmware upgrade of the base stations to be deployed



eMTC & NB-IoT deployment map

[6] Mobile IoT Deployments. Dec. 2018. url: https://www.gsma.com/iot/deployment-map/.

LOW POWER WIDE AREA NETWORK

LoRa

- 0,3-50 kbps bit-rate
- 3 classes of device

Ingenu

- 2,4 GHz ISM band
- 78 kbps up
- 19,5 kbps down

Weightless

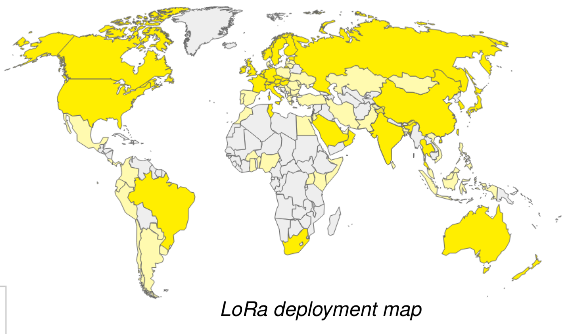
- 3 standards: W/P/N
- 0,2-100 kbps
- Ack & FotA

100 Network Operators

68 Alliance Member Operators

51 Countries operating in

100 Countries with LoRaWAN Deployments



LoRa deployment map

[9] LoRaWAN coverage map. Dec. 2018. url: https://lora-alliance.org/.

Many more technologies: Telensa, DASH7, Qowisio, WAVIoT...

DISCUSSION

Energy consumption

- Hardware dependent
- Based on datasheets:

UNB < LoRa < Weightless-P < Cellular < Ingenu

- Ratio bit-rate / energy ?

Hologram coverage map

[13] Hologram. Dec. 2018. url: https://hologram.io/.

Coverage

- Highly dependent on the environment
- UNB > LoRa > Weightless-P >Cellular > Ingenu
- Penetration of natural environment ?

Financial cost

- Highly dependent on countries, operators and so on
- Cellular « brokers » e.g. Hologram (1$/month +40¢/MB)

	Module	Connectivity	Infrastructure
LTE-M	$10-15	$3-5 / mo for 1MB	
NB-IOT	$7-12	<$1 /mo for 100kb	
Sigfox	$5-10	<$1 / mo	
Ingenu	$10-15	?	
LoRaWAN Public	$9-12	$1-2 / mo	
LoRaWAN Private	$9-12	$0.25 / mo	$500
Symphony Link	$15	$0.25 / mo	$500

[12] Ray Brian. Cost of building with LPWAN technologies. Dec. 2018. url: https://www.link-labs.com/blog/

Deployment

- Cellular is by far the largest deployment
- LoRa can be deployed as a private network / not cellular
- Evolution in the future ?

Usage of the spectrum

- Many LPWANs on the sub-GHz ISM unlicensed band
- Cellular use licensed bands, but partly LTE bands

NETWORK INTERFACE SELECTION

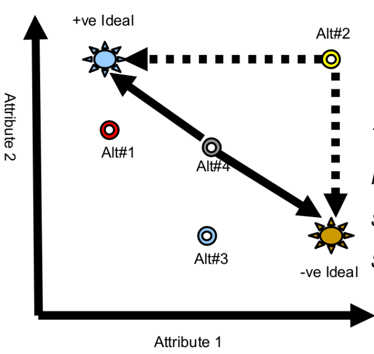
	C1 (w1)	C2 (w2)	.	.	Cm (wm)
A1	a11	a21	.	.	am1
A2	a12	a22	.	.	am2
.	.	.	.	.	.
.	.	.	.	.	.
An	a1n	a2n	.	.	amn

Multi Attribute Decision Making (MADM) matrix

F. Bari and V. Leung, "Multi-Attribute Network Selection by Iterative TOPSIS for Heterogeneous Wireless Access," 2007 4th IEEE Consumer Communications and Networking Conference, Las Vegas, NV, 2007, pp. 808-812

MADM problem

- A = {Ai, for i=1,2,...,n} the set of candidates
- C = {Cj, for j=1,2,...,m} the set of attributes
- w1, w2, ..., wm the weights of each attribute



Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

Problem: Complex calculations & ranking abnormalities

Euclidean normalization

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{N} a_{ij}^2}}$$

Distance from ideal position

$$S_i^+ = \sqrt{\sum_{j=1}^{m} \left(v_j^+ - v_{ij}\right)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} \left(v_j^- - v_{ij}\right)^2}$$

Ranking instability

- Alteration of the final ranking when removing worst candidates
- Caused by euclidean normalization
- Using alternative normalization methods can reduce the effect but not neutralize it

LIGHT TOPSIS FOR IOT

Simple and stable normalization

- Reduce complexity and eliminate rank reversal
- Application layer expresses needs in terms of bounds and weights
- Use fixed bounds for each attribute

For each attribute Cj :

if Cj is upward then we have :

Bj+ the upper bound

else if Cj is downward then we have :

Bj- the lower bound

$$if\ C_j\ upward\ r_{ij} = \frac{a_{ij}}{B_j^+}$$

$$if\ C_j\ downward\ r_{ij} = \frac{B_j^-}{a_{ij}}$$

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[3] Finnegan Joseph and Stephen Brown. "A Comparative Survey of LPWA Networking". In: (May 2017).
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Inria