IoT RADIO CONNECTIVITY

GMES and Africa Incubation Challenge, Sep. 14th, 2021

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UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

WAZIUP
IoT – from idea to reality
WAZIHUB

HUBiquitous
Paving for the next 10 years of innovation in IoT and AI

IoT: communicating objects!

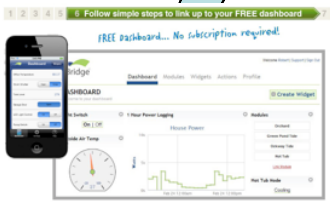
Sense, Monitor, Optimize & Control

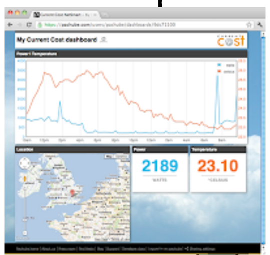
DATA ANALYSIS,
OPTIMIZATION & CONTROL

MONITORING

SENSING
PHYSICAL WORLD INTERACTION

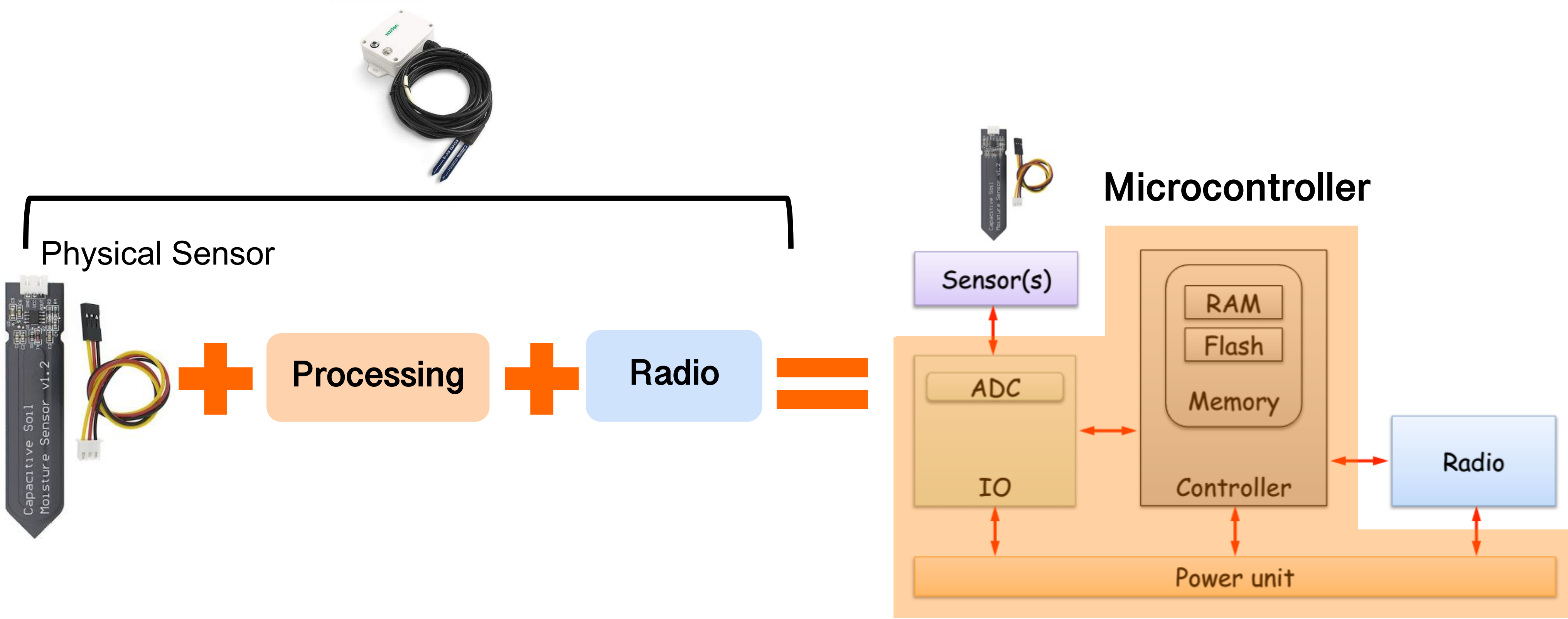
APPLICATION DOMAINS



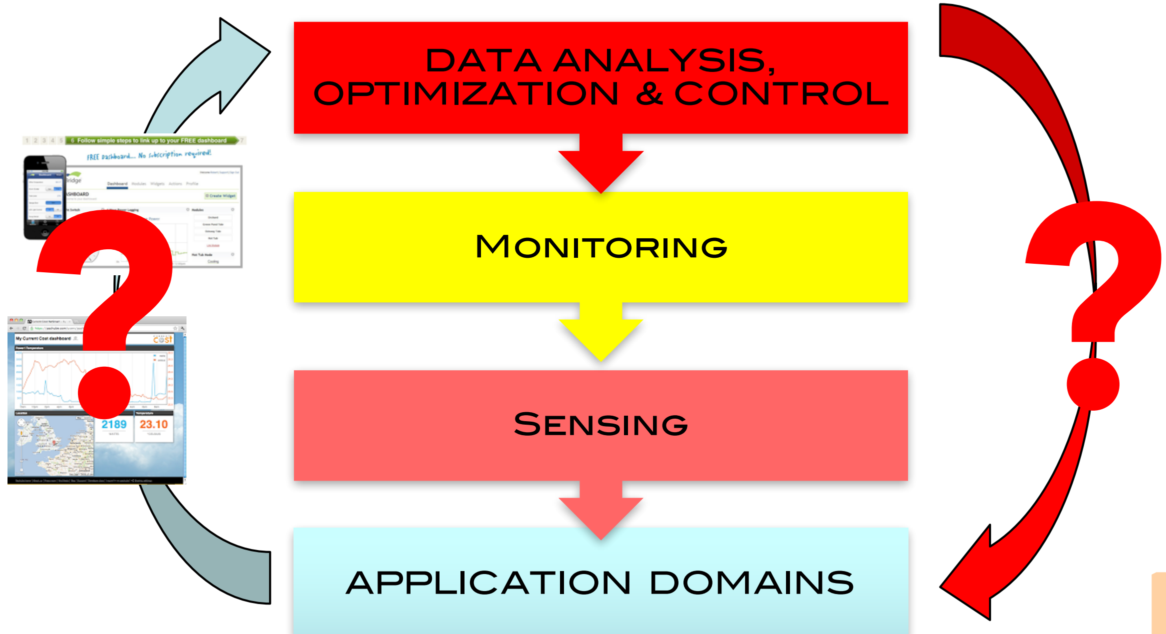


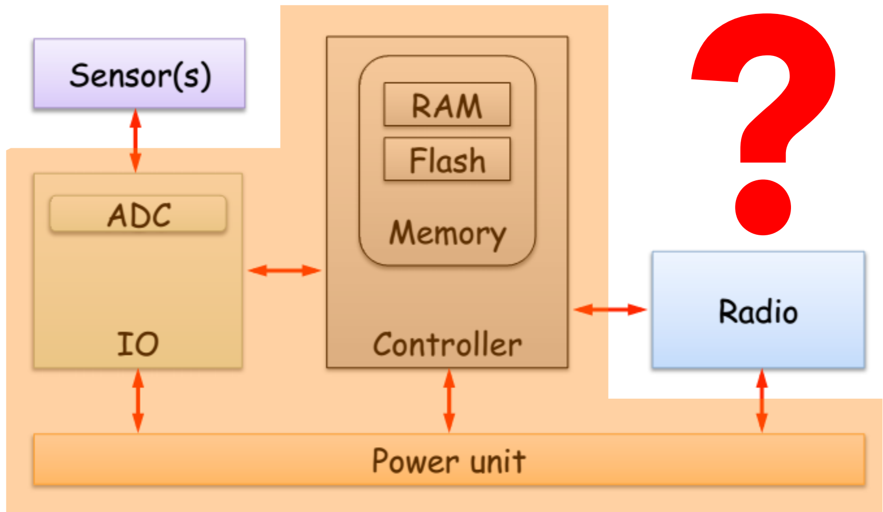
Typical IoT device

- IoT device can be viewed as a simple Embedded System



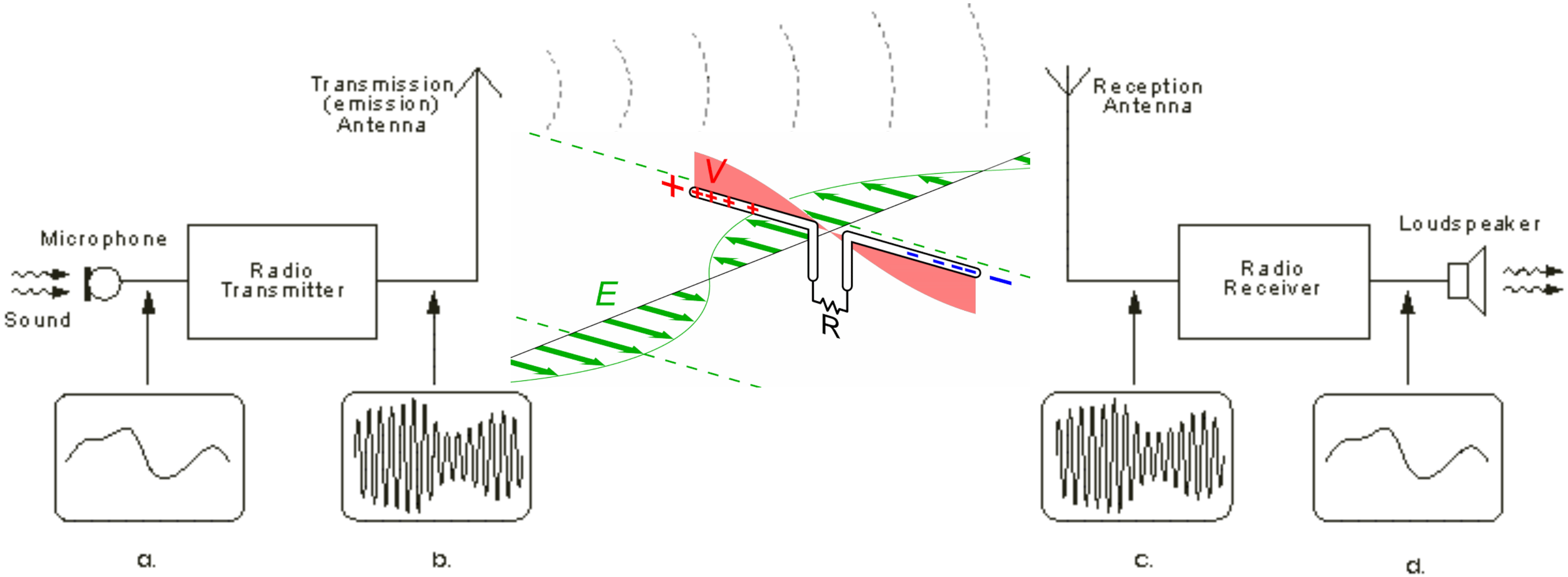
How to collect data?

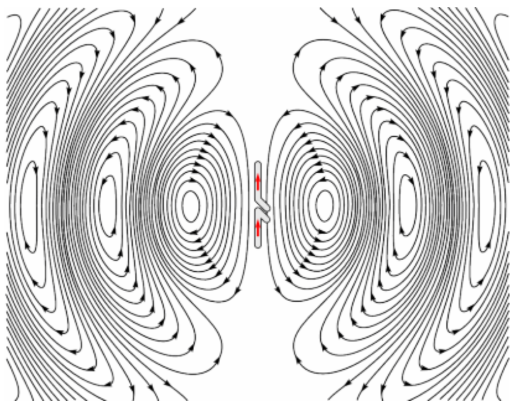


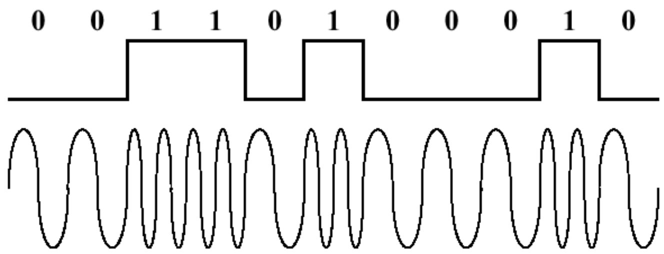


Microcontroller

Wireless (radio) transmission basics







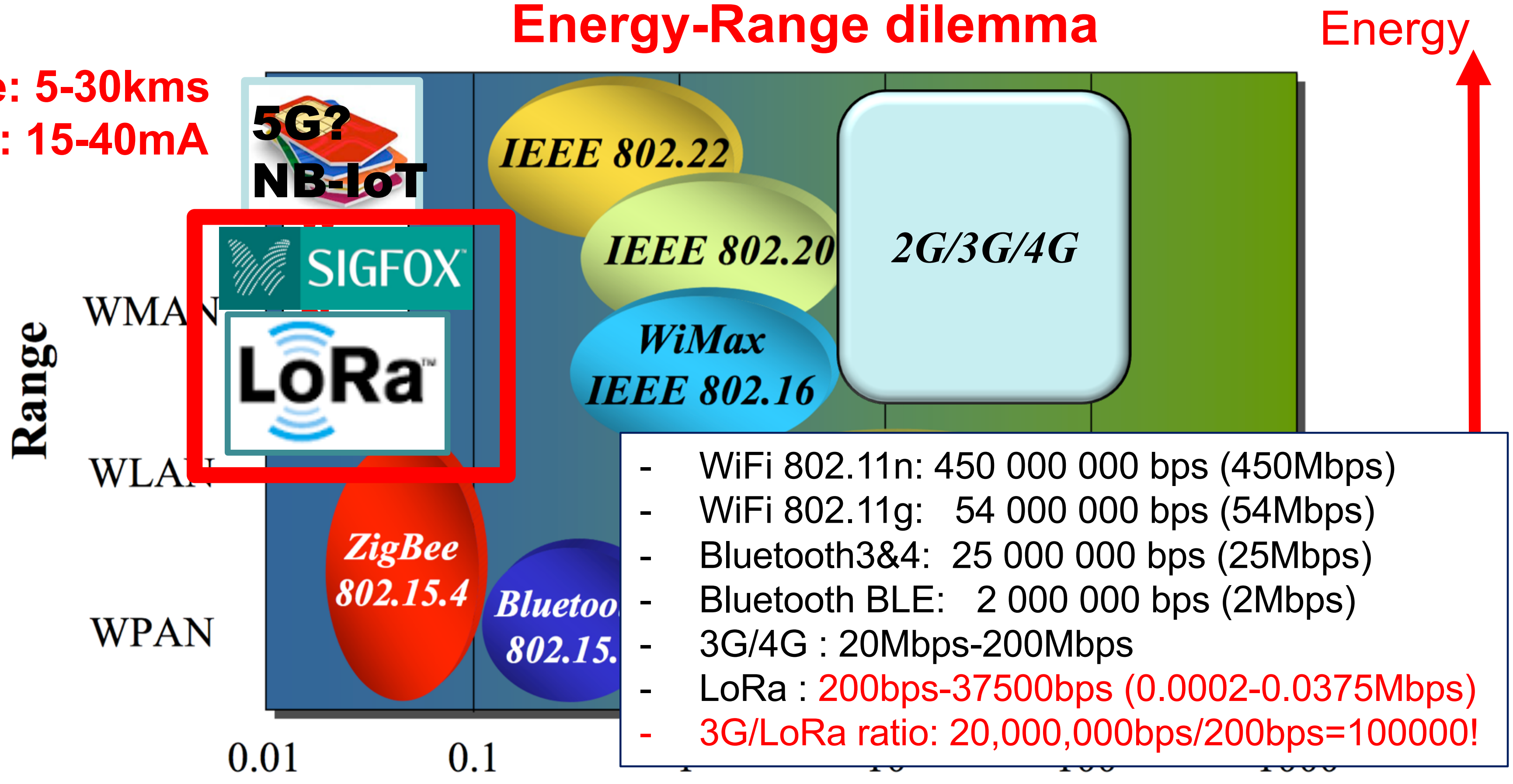
(b) Frequency-shift keying

Q: Can we have Gbps in wireless?

Low-power & long-range radios

Energy-Range dilemma

Long-range: 5-30kms
Low-power: 15-40mA

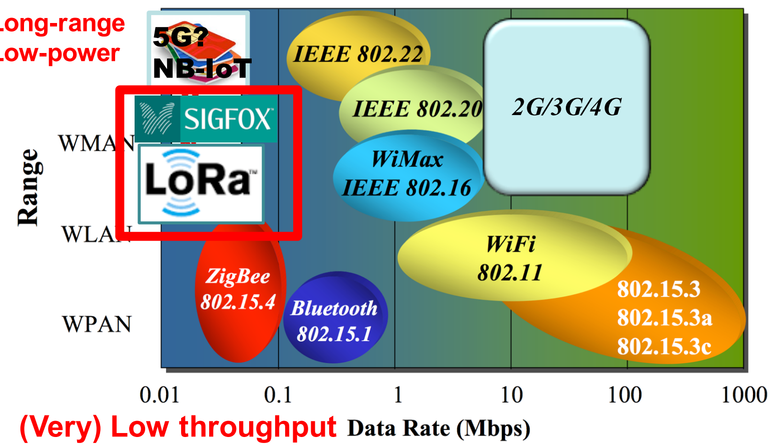


- WiFi 802.11n: 450 000 000 bps (450Mbps)
- WiFi 802.11g: 54 000 000 bps (54Mbps)
- Bluetooth3&4: 25 000 000 bps (25Mbps)
- Bluetooth BLE: 2 000 000 bps (2Mbps)
- 3G/4G : 20Mbps-200Mbps
- LoRa : 200bps-37500bps (0.0002-0.0375Mbps)
- 3G/LoRa ratio: 20,000,000bps/200bps=100000!

(Very) Low throughput: bps

Transmitting: `TC/22.5/HUM/67.7` ; about 20 bytes with packet header
Time on air can be 1.44s with LoRa

Energy consumption comparaison



Energy ↑

2G	3G	LAN	ZigBee	Lo Power WAN
N/A	N/A	O: 300m I: 30m	O: 90m I: 30m	Same as 2G/3G
200-500mA	500-1000mA	100-300mA	18mA	18mA-40mA
2.3mA	3.5mA	NC	0.003mA	0.001mA

2500mA

TX power: 500mA. Mean consumption: (8sx500+3592sx0.005)/3600=1.11mA

2500/1.11=2252h = 93 days = 3 months ☹

In most cellular networks, the device is still maintaining communication with BS even if it is inactive

TX power: 40mA. Mean consumption: (2sx40+3598sx0.005)/3600=0.027mA

2500/0.027=92592h = 3858 days = 10 y. ☺

LPWAN does not need to maintain connection if not in used

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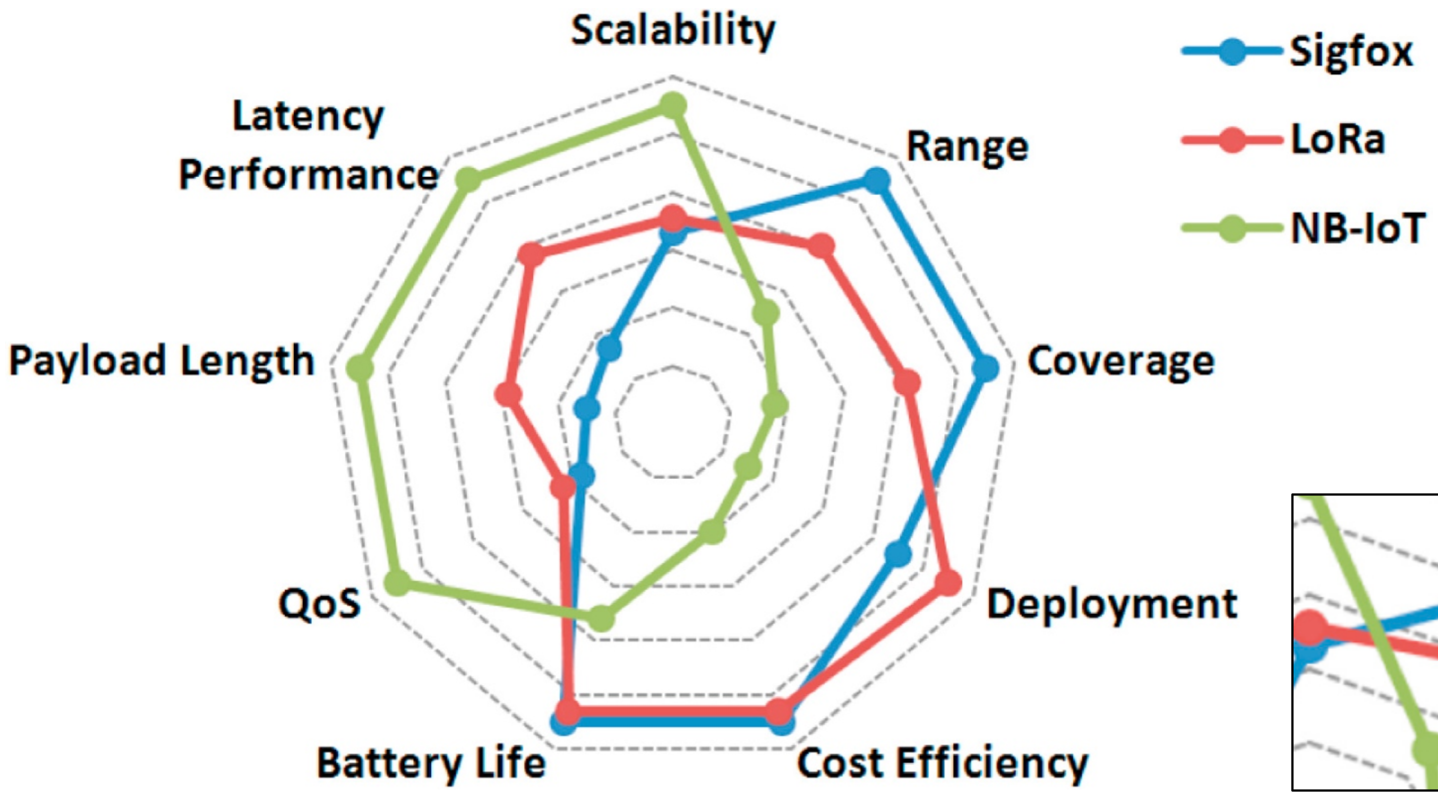
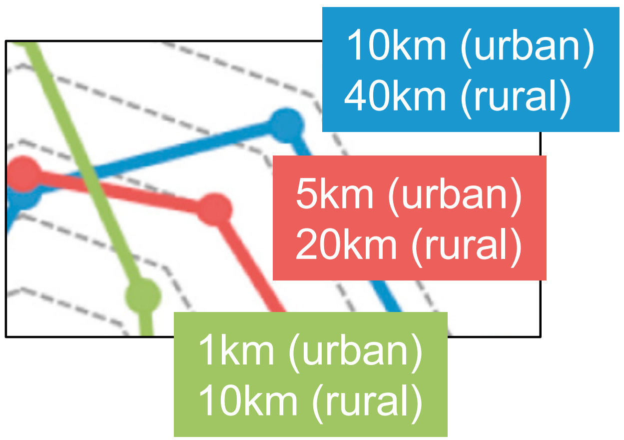
http://www.univ-pau.fr/~

LPWAN Expected range?





Attenuation in general

- Depends mainly on distance

$$P_r = P_e d^{-\alpha}$$

- with :
  - P_e = transmitted power
  - P_r = received power
  - d = distance between antennas
  - α from 2 to 4

10

Attenuation in practice

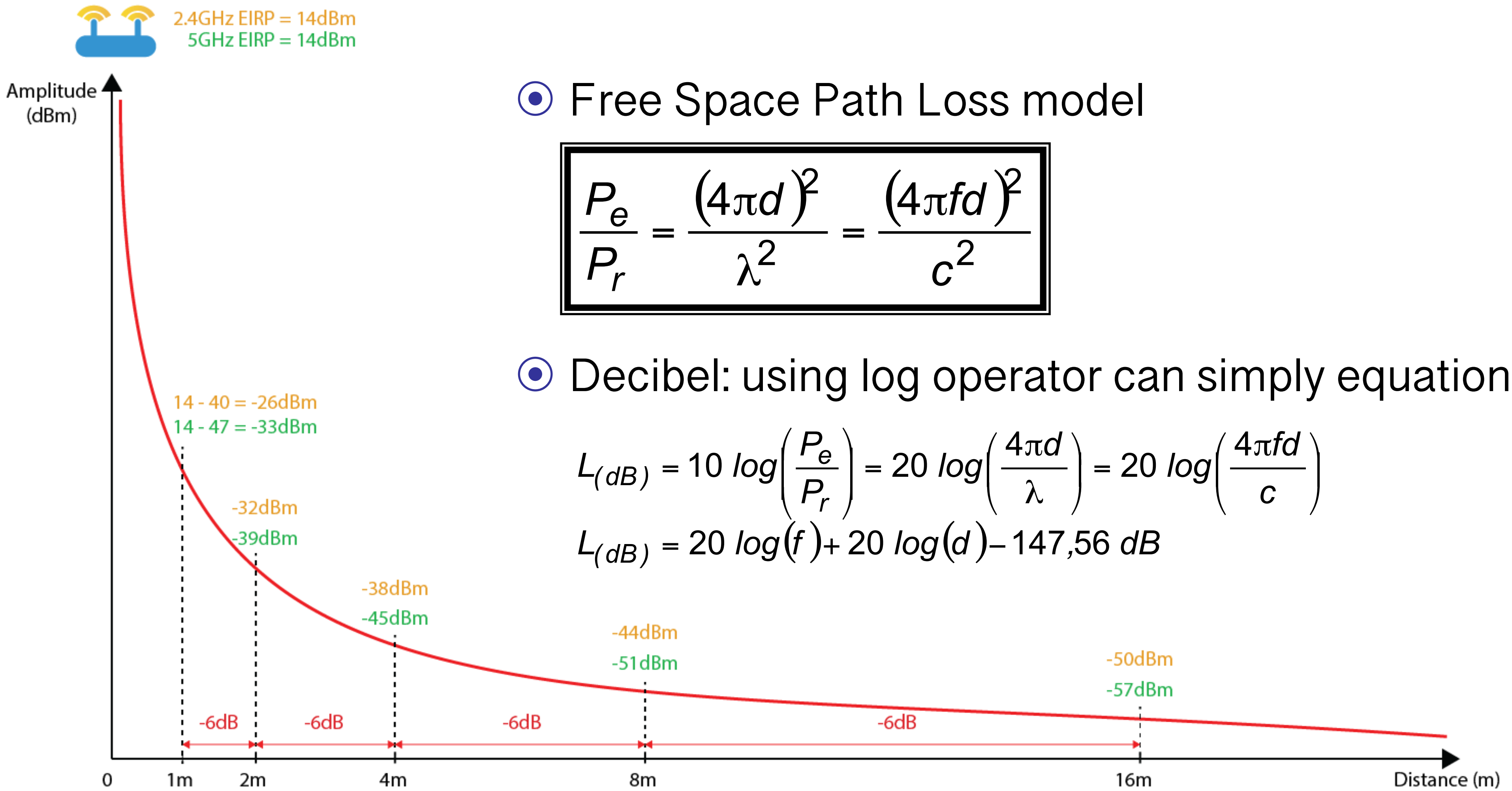
- For an ideal antenna (theoretic)

$$\frac{P_e}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

  - P_e = transmitted power
  - P_r = received power
  - d = distance between antennas
  - c = light speed in space 3.10^8 m/s
  - λ= wave length of the signal=c/f

11

Attenuation in image



- Free Space Path Loss model

$$\frac{P_e}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

- Decibel: using log operator can simply equation

$$L_{(dB)} = 10\ log\left(\frac{P_e}{P_r}\right) = 20\ log\left(\frac{4\pi d}{\lambda}\right) = 20\ log\left(\frac{4\pi f d}{c}\right)$$

$$L_{(dB)} = 20\ log(f) + 20\ log(d) - 147{,}56\ dB$$

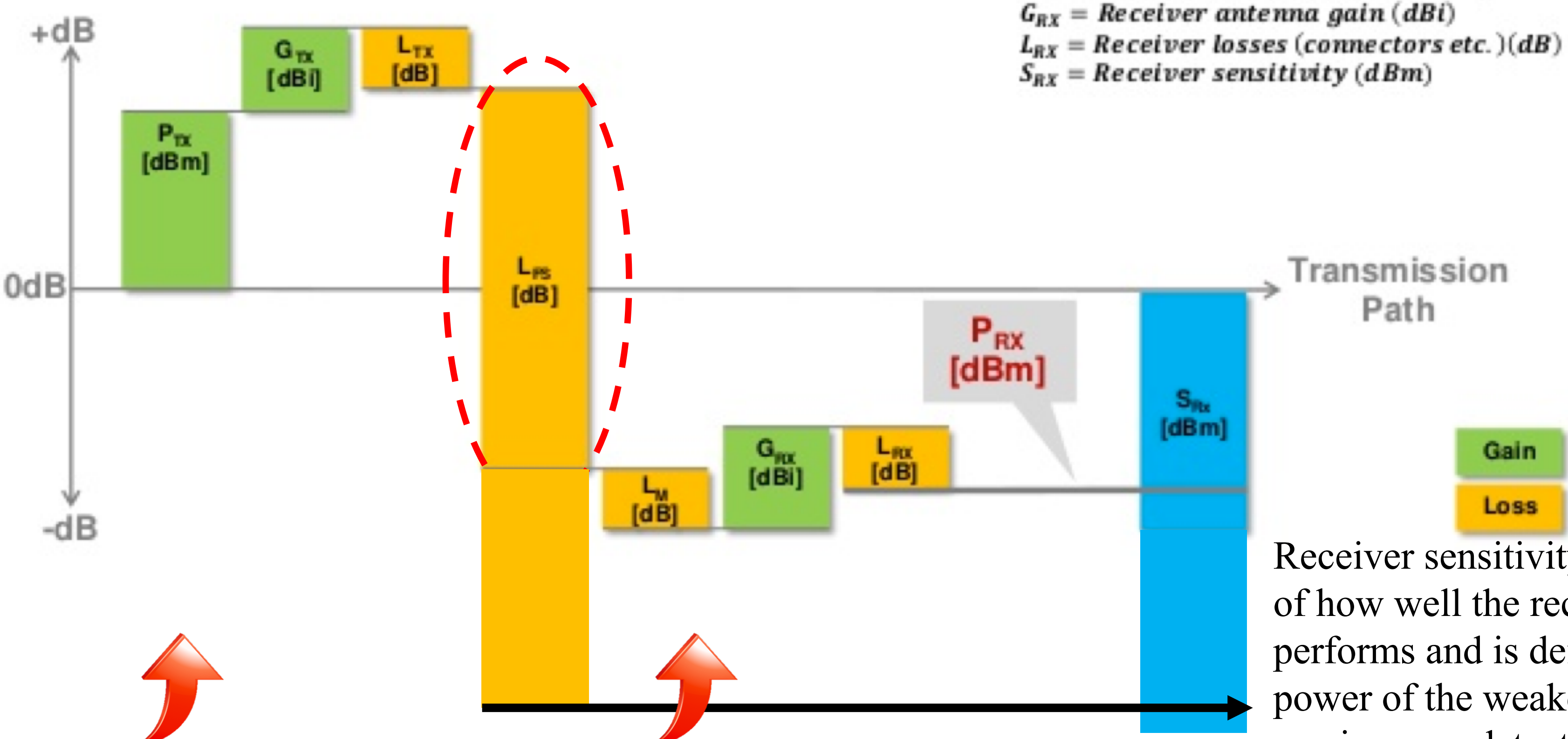
Additional advantage of log scale: very large and very small values can be plotted on the same graph

Link budget in wireless system

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{RX}$$

P_{RX} = Received power (dBm)
P_{TX} = Sender output power (dBm)
G_{TX} = Sender antenna gain (dBi)
L_{TX} = Sender losses (connectors etc.)(dB)
L_{FS} = Free space loss (dB)
L_M = Misc. losses (multipath etc.)(dB)
G_{RX} = Receiver antenna gain (dBi)
L_{RX} = Receiver losses (connectors etc.)(dB)
S_{RX} = Receiver sensitivity (dBm)

Adapted from Peter R. Egli, INDIGOO.COM

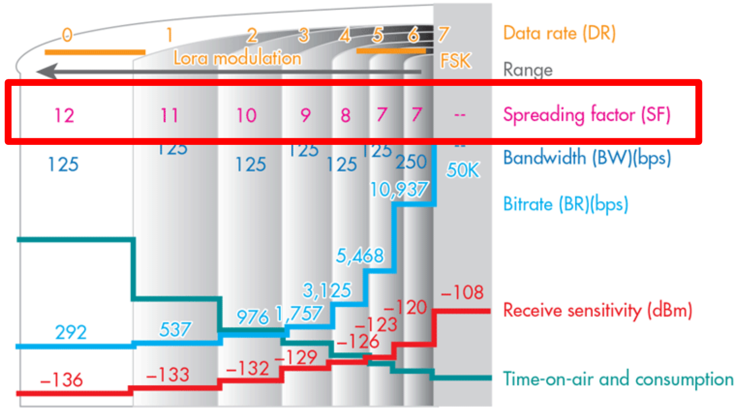


Receiver sensitivity is a measure of how well the receiver performs and is defined as the power of the weakest signal the receiver can detect

$$L_{(dB)} = 20\log(f) + 20\log(d) - 147{,}56\ dB$$

How can we increase range?

- Increase TX power and/or improve RX sensitivity
- Generally, RX sensitivity (~robustness) can be increased when transmitting (much) slower (like speaking slower!)
- LoRa uses spread spectrum approach to increase RX sensitivity
  - Spreading Factor defines how many chips will be used to code a symbol. More chip/symbol=longer transmission time ➠ more robustness
- **The price to pay for LPWAN**
  - LoRa has very low throughput: 200bps-37500bps (0.2-37.5kbps)



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Spreading factor in image

- Higher spreading factor means lower data rate but increased receiver sensitivity -> speaking slower!

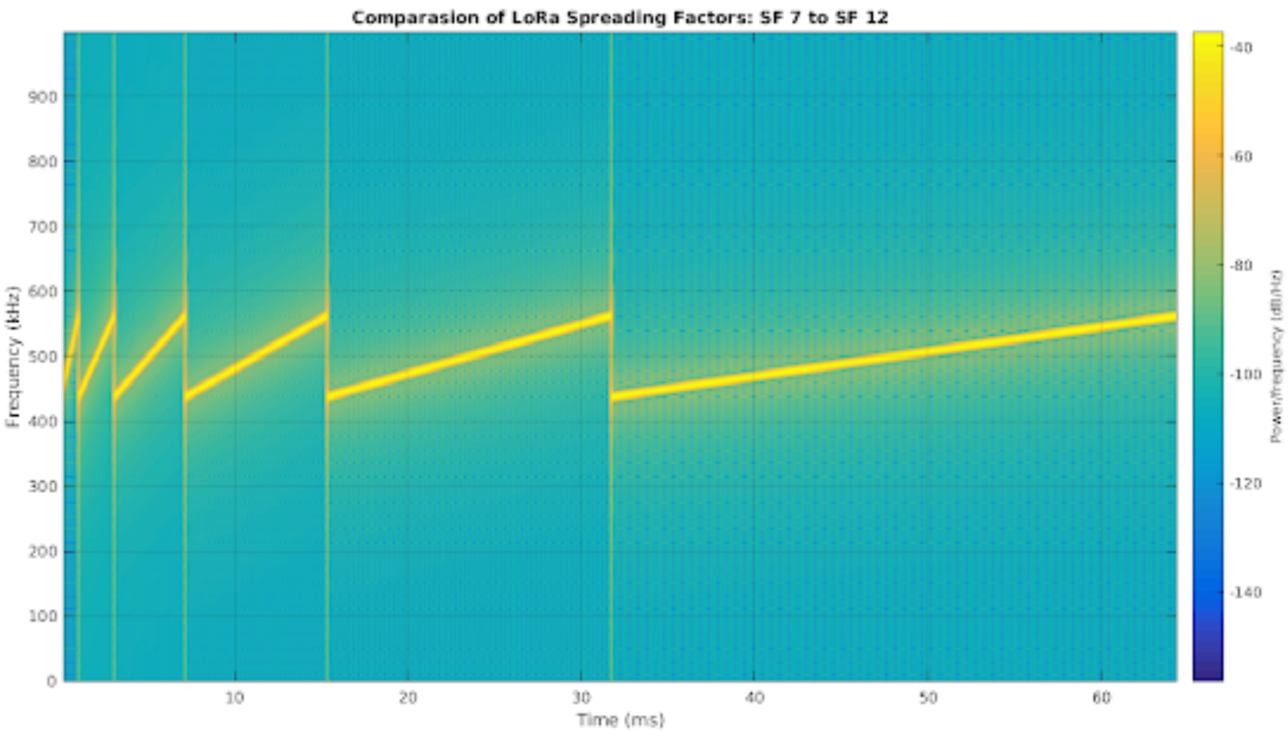
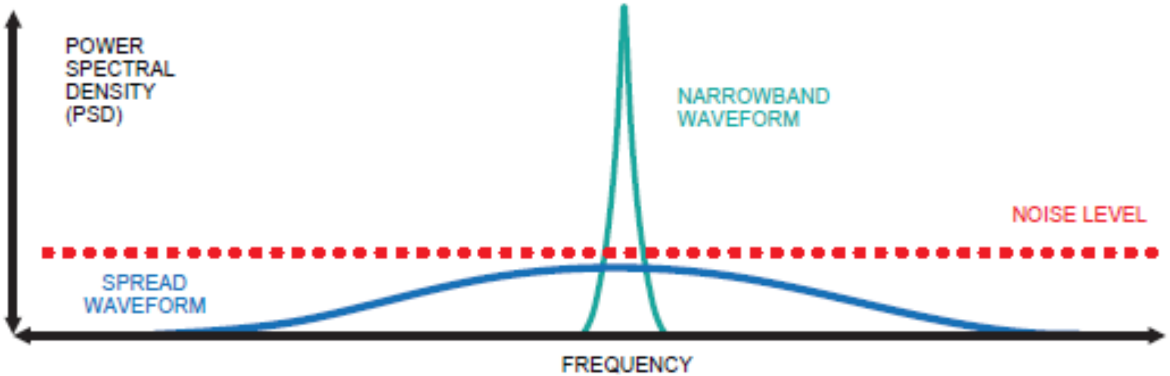
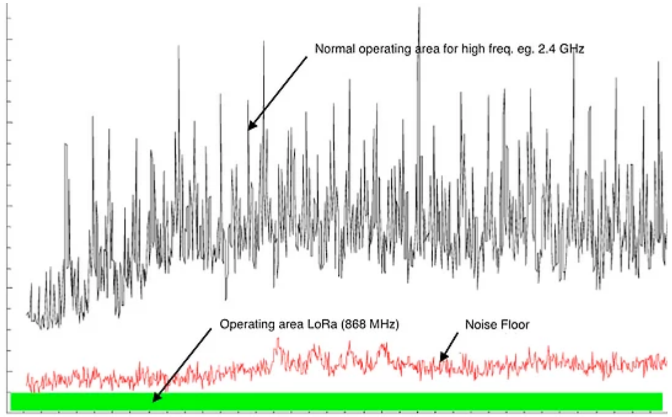


Figure from "All About LoRa and LoRaWAN", https://www.sghoslya.com

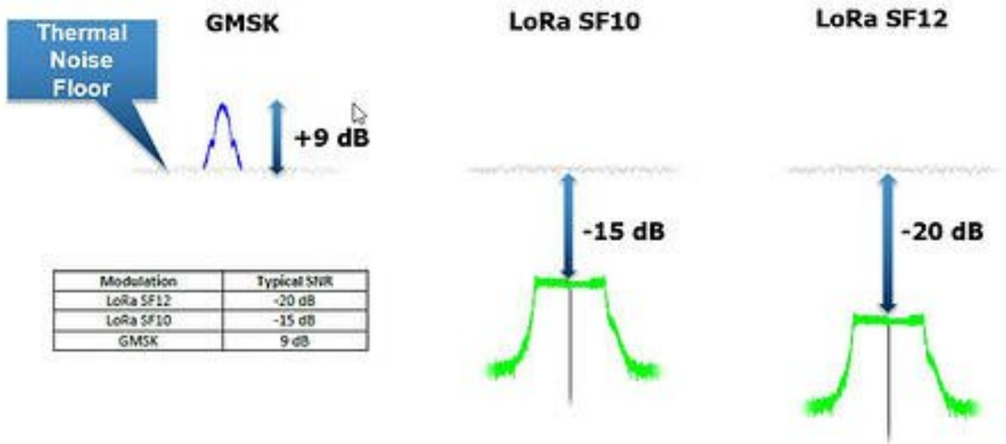
Advantage of Spread Spectrum

- Spread Spectrum techniques are usually more robust to noise





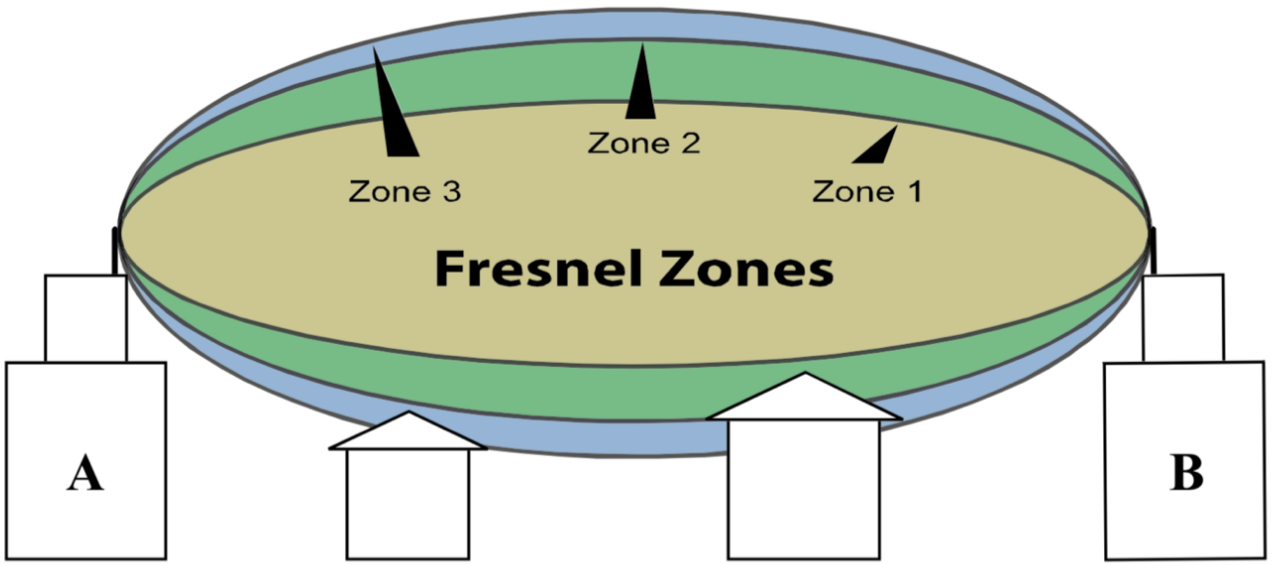
- LoRa signals can be decoded below noise floor



SpreadingFactor (RegModulationCfg)	LoRa Demodulator SNR
6	-5 dB
7	-7.5 dB
8	-10 dB
9	-12.5 dB
10	-15 dB
11	-17.5 dB
12	-20 dB

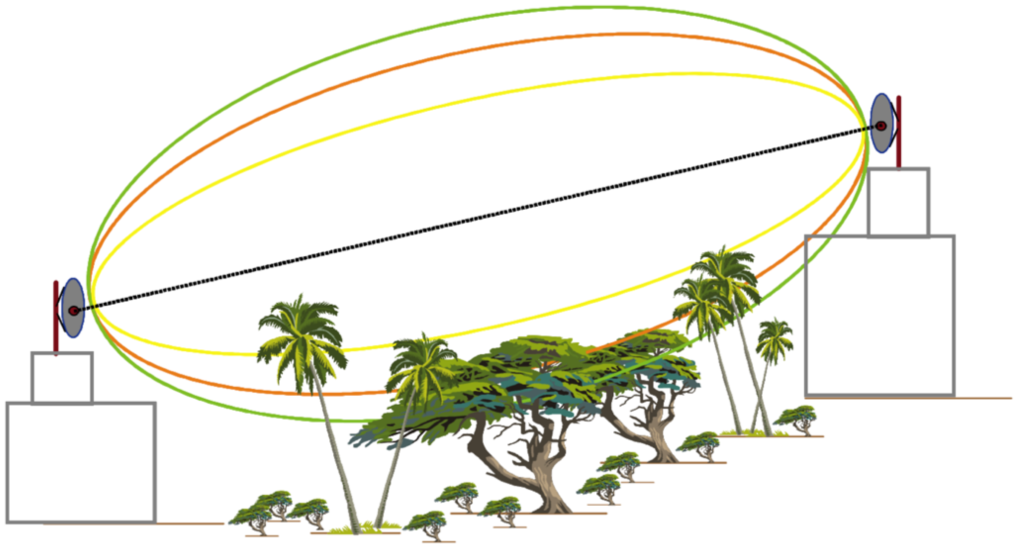
Line-of-Sight & Fresnel zone

- LoS means clear Fresnel zone
- Football (american) shape
- Acceptable = 60% of zone 1 + 3m



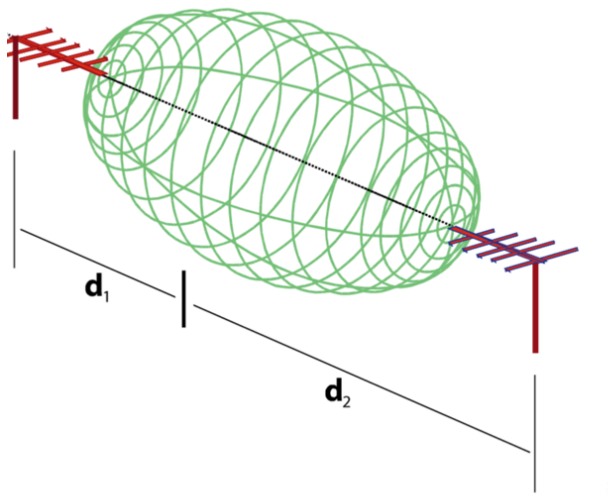
RF Essentials from Digi

Clearing the Fresnel zone? Raise antennas!



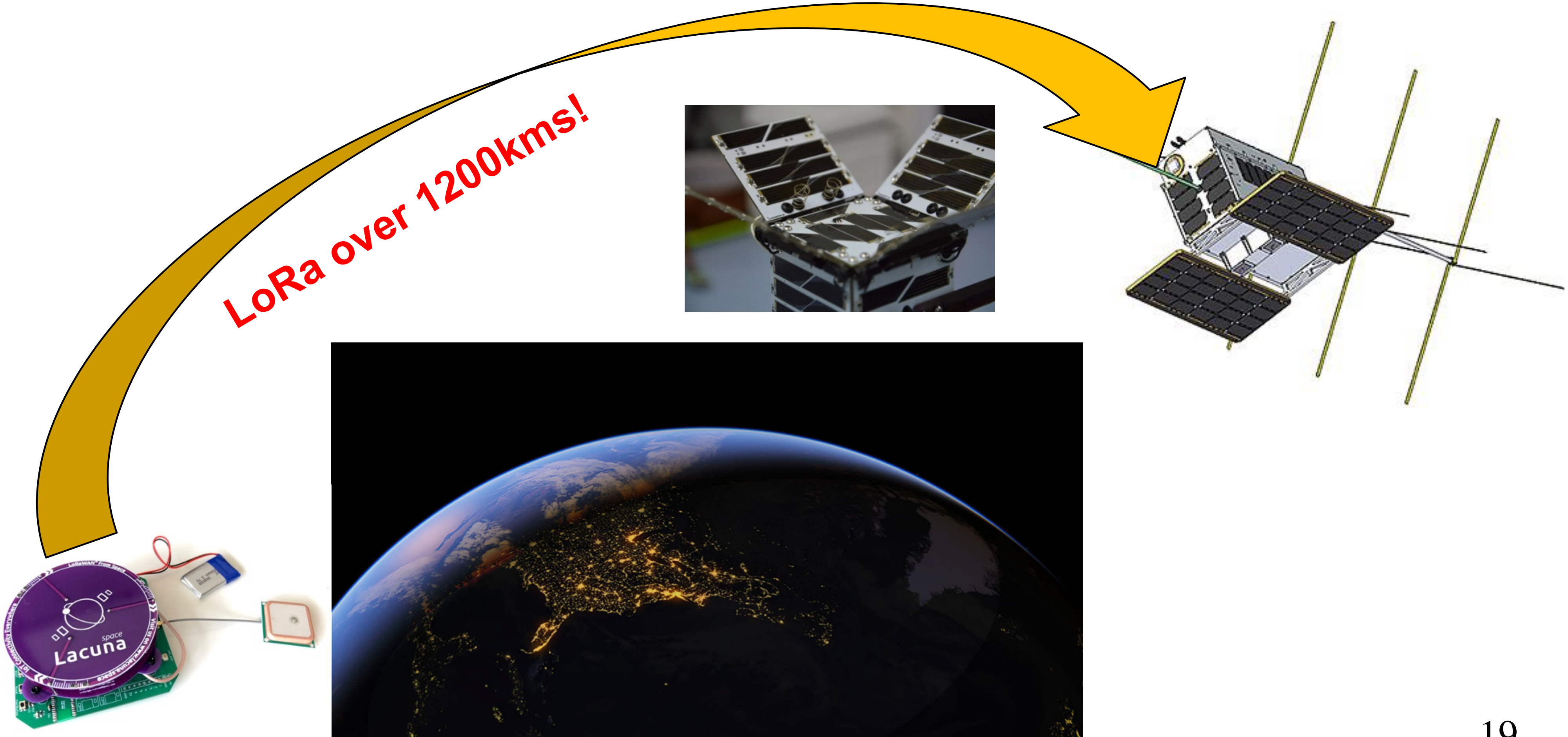
$$r_n = \sqrt{\frac{\quad}{d_1 + d_2}}$$

Range Distance	900 MHz Modems Required Fresnel Zone Diameter	2.4 GHz Modems Required Fresnel Zone Diameter
1000 ft. (300 m)	16 ft. (5 m)	11 ft. (3.4 m)
1 Mile (1.6 km)	32 ft. (10 m)	21 ft. (6.4 m)
5 Miles (8 km)	68 ft. (21 m)	43 ft. (13 m)
10 Miles (16 km)	95 ft. (29 m)	59 ft. (18 m)

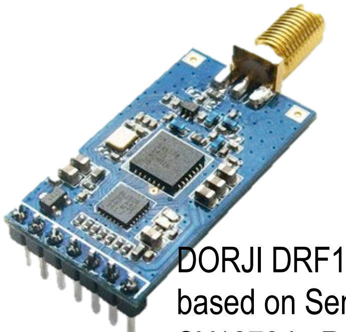


Clearing the Fresnel zone? Let's use satellite!

- Low-orbit, low-cost; compact satellite for global coverage



LoRa modules with Semtech's SX127x

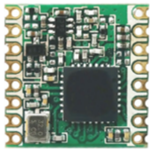


DORJI DRF1278DM is based on Semtech SX1278 LoRa 433MHz

Libelium LoRa is based on Semtech SX1272 LoRa 863-870 MHz for Europe

inAir9 based on SX1276

Froggy Factory LoRa module (Arduino)

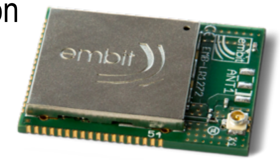


HopeRF RFM series

HopeRF HM-TRLR-D

LinkLabs Symphony module

IMST IM880A-L is based on Semtech SX1272 LoRa 863-870 MHz for Europe



Embit LoRa

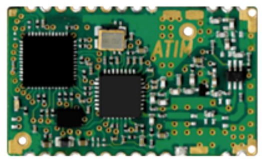
Microship RN2483

Adeunis ARF8030AA- Lo868

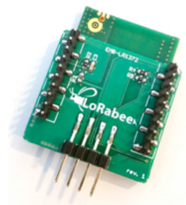
habSupplies

Multi-Tech MultiConnect mDot

AMIHO AM093



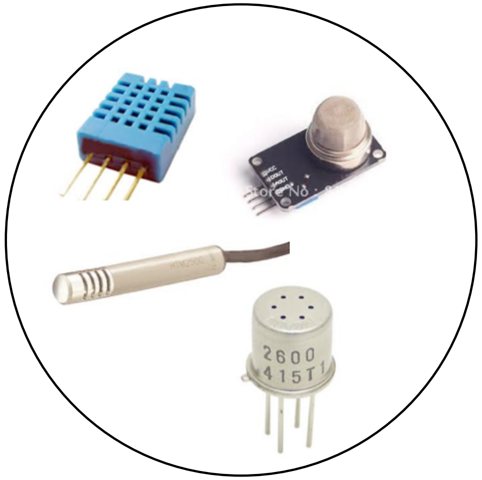
ARM-Nano N8 LoRa module from ATIM

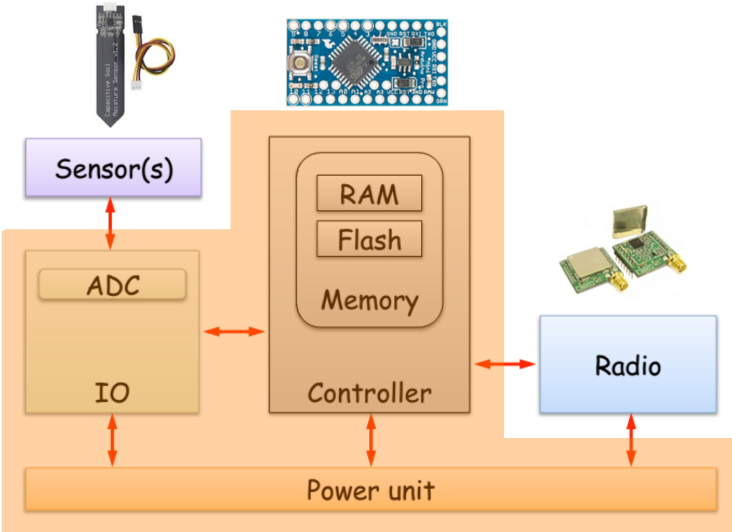


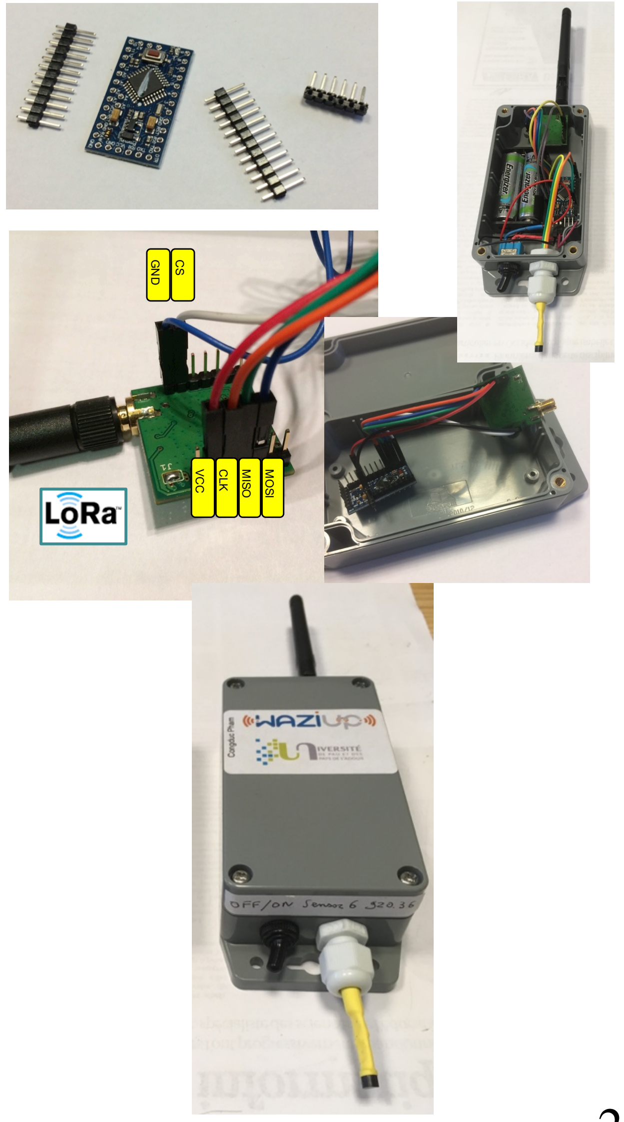
SODAQ LoRaBee Embit

SODAQ LoRaBee RN2483

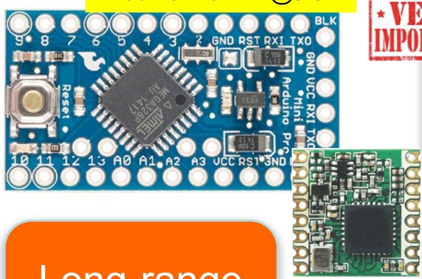
Do-It-Yourself IoT







Arduino Pro Mini @3.3V



- Physical sensor mgmt
- VERY IMPORTANT Activity duty-cycle, low power
- VERY IMPORTANT AES encryption
- Long-range transmission
- Logical sensor mgmt

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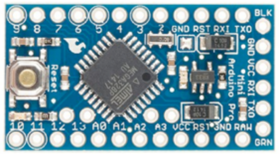
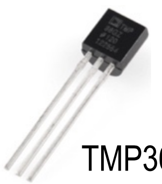
A simple temperature sensor example

Arduino Pro Mini @3.3V

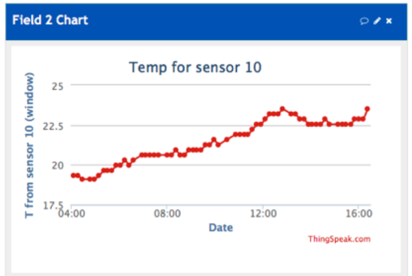


Modtronix inAir9



TMP36

Wakes-up every 10min, take a measure (temp) and send to gateway



5µA in deep sleep mode, about 40mA when active and sending

More than 1 year with 1 measure/10min

Can run several years with 1 measure/1h

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LPWAN = star topology

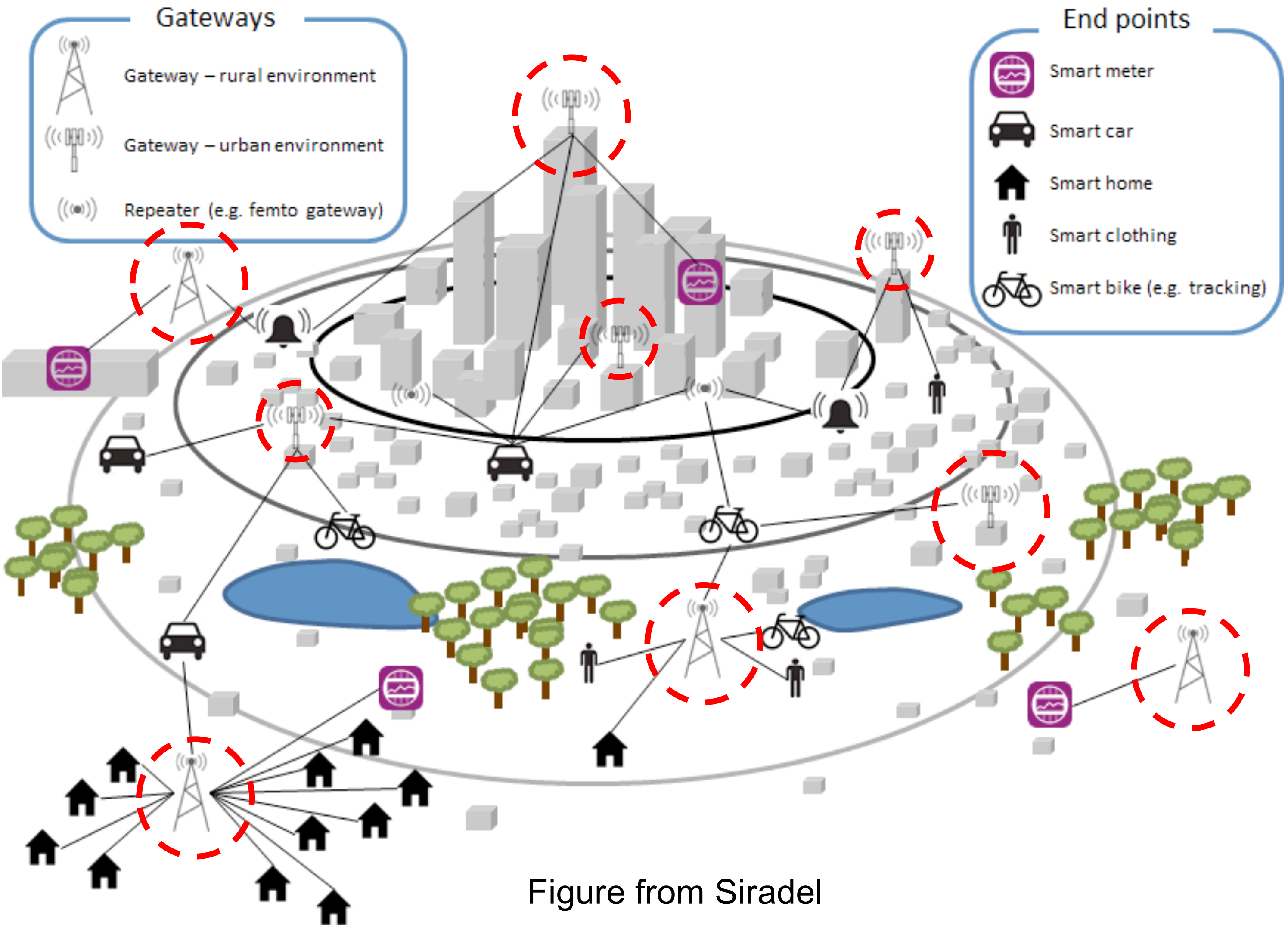
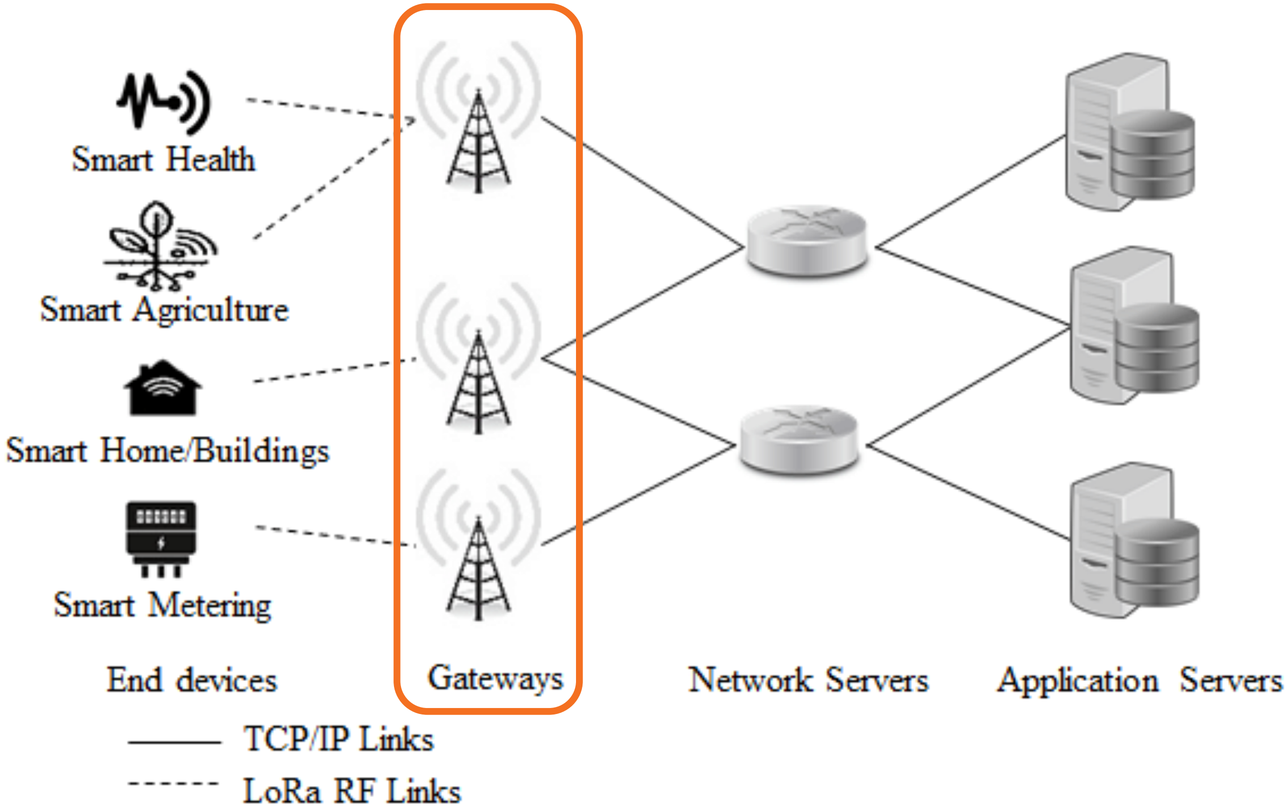


Figure from Siradel

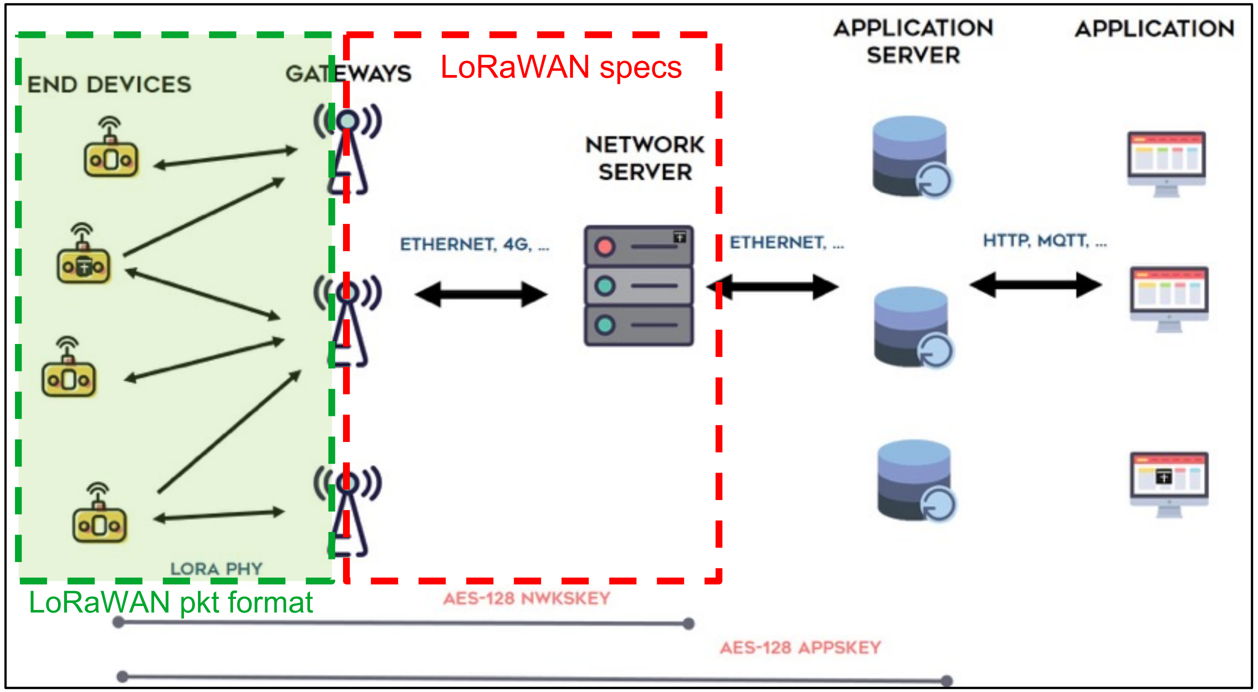
General LPWAN IoT architecture

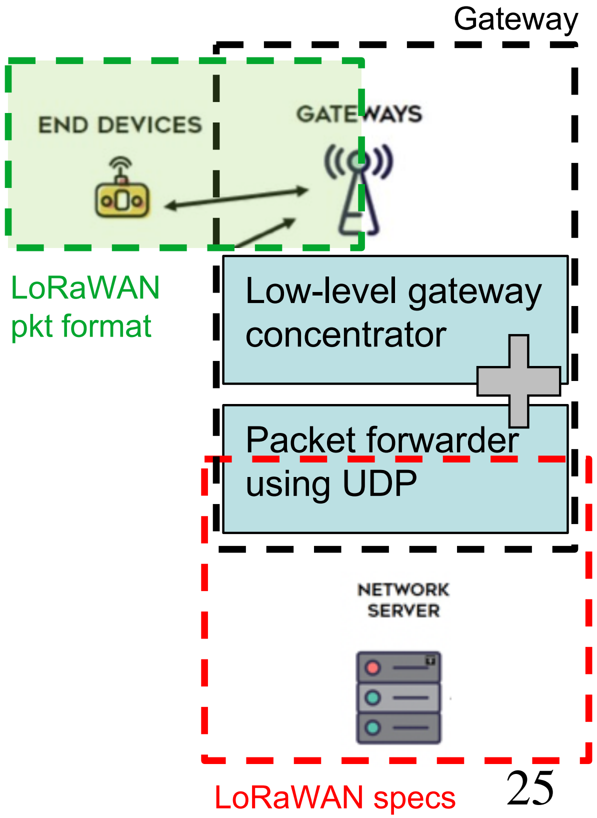
- LPWAN architecture is gateway-centric
  - IoT gateways are connected to Internet
  - They forward data from IoT device to Internet Servers



LoRaWAN specifications

- LoRaWAN protocols run on top of LoRa physical networks. It is defined and managed by the LoRa Alliance
- It specifies protocols to run large-scale, public LoRa networks





LoRaWAN gateway

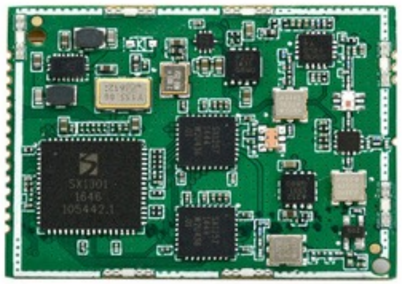
- A full LoRaWAN gateway should be able to listen on multiple channels (x8) and spreading factors (SF7-SF12)

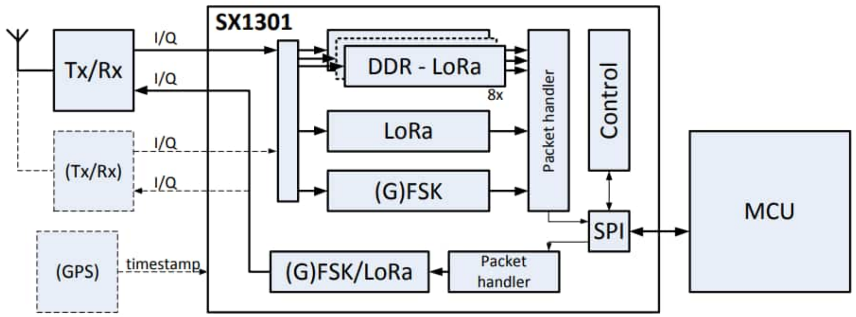
EU863-870

Uplink:

1. 868.1 - SF7BW125 to SF12BW125
2. 868.3 - SF7BW125 to SF12BW125
3. 868.5 - SF7BW125 to SF12BW125
4. 867.1 - SF7BW125 to SF12BW125
5. 867.3 - SF7BW125 to SF12BW125
6. 867.5 - SF7BW125 to SF12BW125
7. 867.7 - SF7BW125 to SF12BW125
8. 867.9 - SF7BW125 to SF12BW125
9. 868.8 - FSK

- They are mostly based on the Semtech SX1301 radio concentrator

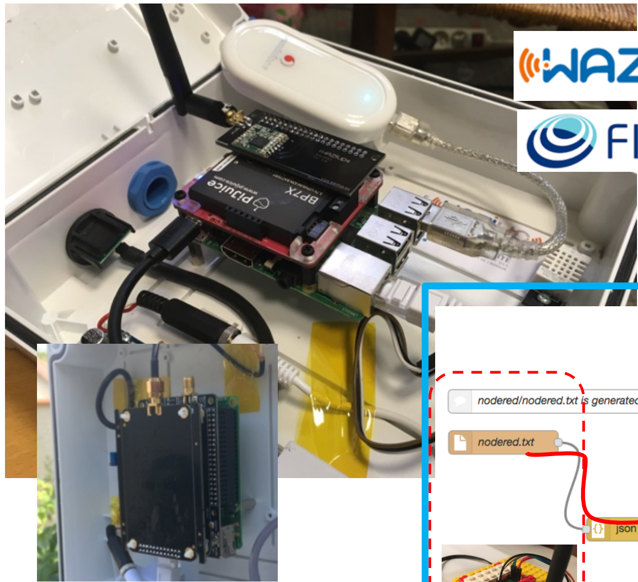




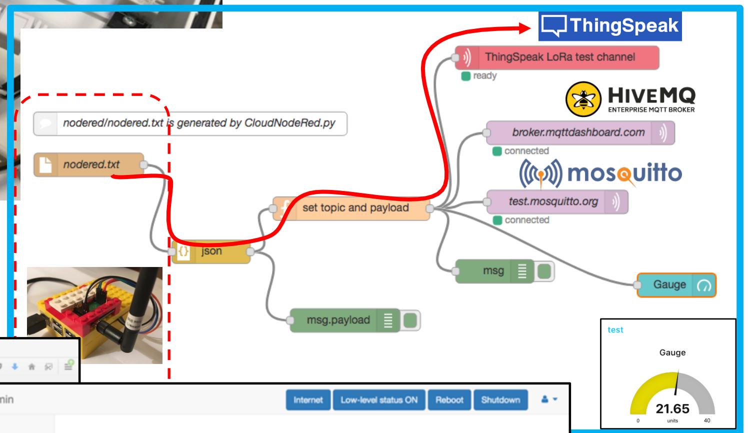
Open, DIY, versatile IoT gateway

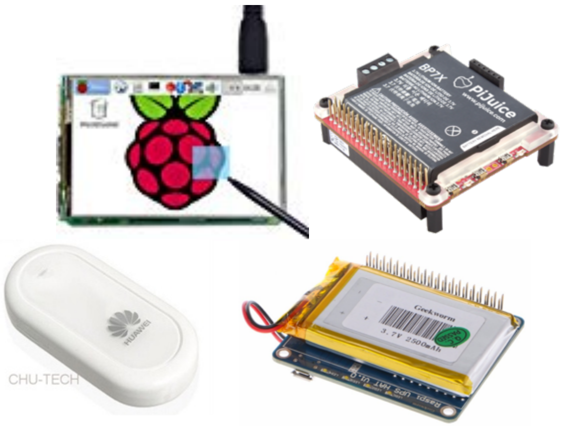
Large customization features!

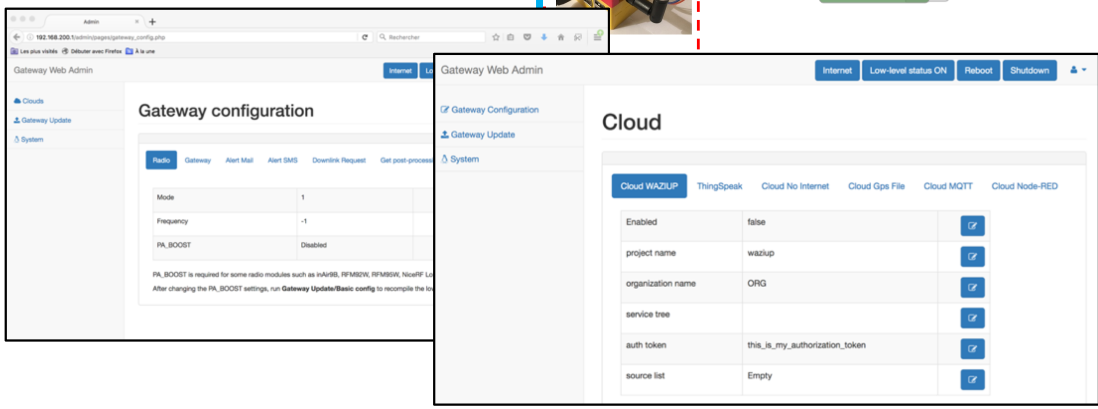
https://github.com/CongducPham/LowCostLoRaGw



Raspberry PI: lots of libraries, lots of software, lots of hardware, lots of shields,…

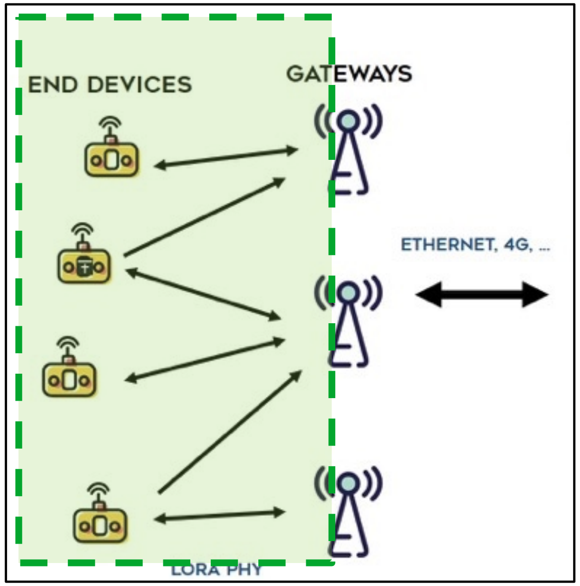


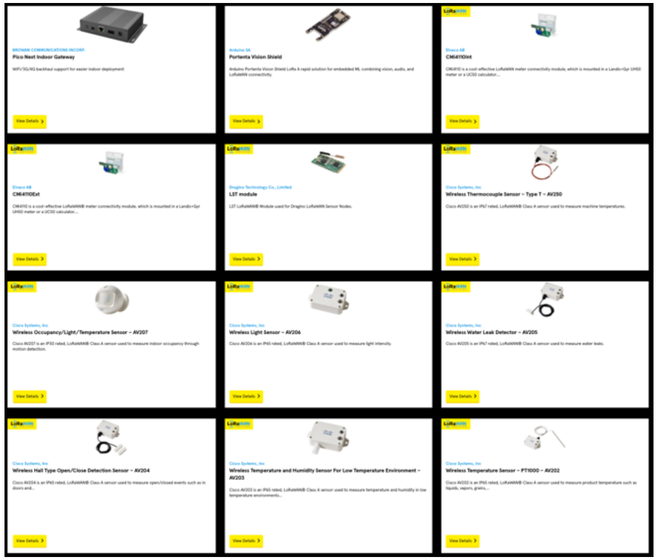




Conclusions

- Internet-of-Things provides the unique feature to make things "talk" to us
- Traditional radio technologies (3G/4G, WiFi, Bluetooth, …) are either too energy consuming or cannot deal with long distance
- Long-range radio technologies such as LoRa enable simple and efficient deployment of IoT devices
- LoRaWAN IoT ecosystem is growing very fast…
- But there is room for DIY IoT!





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UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

WAZIUP
IoT – from idea to reality
WAZIHUB

HUBiquitous
Paving for the next 10 years of innovation in IoT and AI