# Internet-of-Things and How to Connect Things

**ENSA Webinar on Internet-of-Things**

**Presented on July 1st, 2020**

**Prof. Congduc Pham**

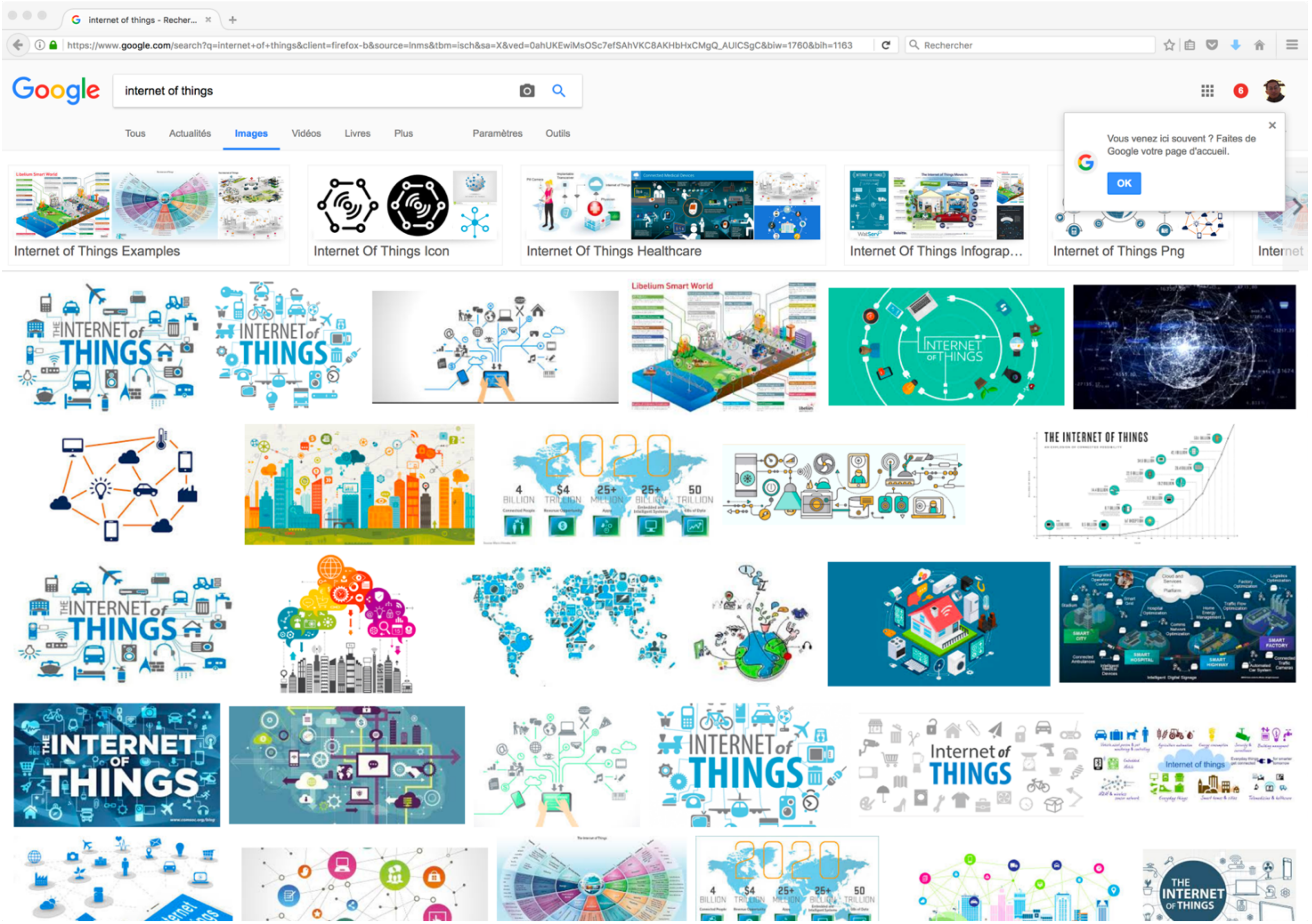
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham
Université de Pau, France

IVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

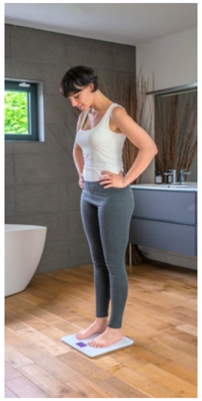
HORIZON 2020

WAZIUP
IoT – from idea to reality
WAZIHUB

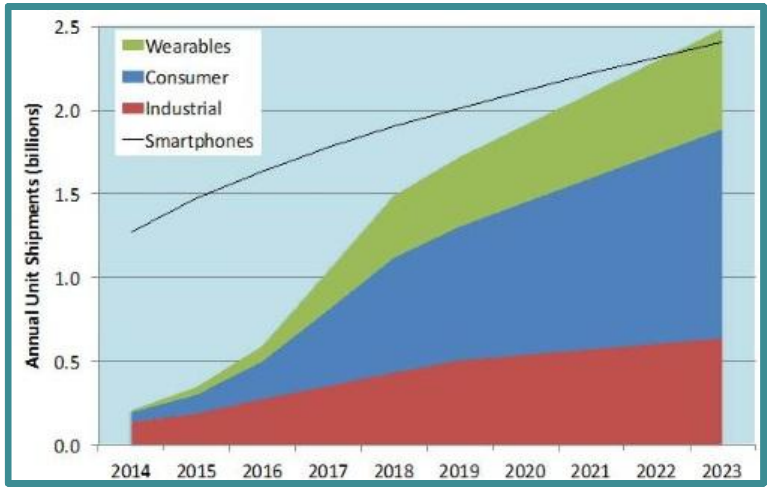
# Googling for « Internet of Things »



# ...shows communicating objects





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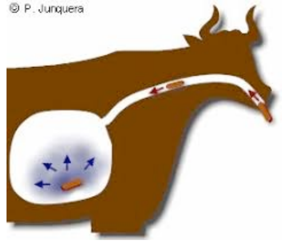
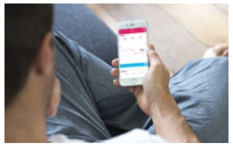










Waste Container connected sensor


HORIZON 2020

# Sense, Monitor, Optimize & Control

WAZIUP WAZIHUB

Firebase FIWARE Axeda ioBridge ThingSpeak GroveStreams SensorCloud freeboard dweet.io OpenRemote TempoIQ

iOT

DATA ANALYSIS, OPTIMIZATION & CONTROL

MONITORING

SENSING
PHYSICAL WORLD INTERACTION

APPLICATION DOMAINS

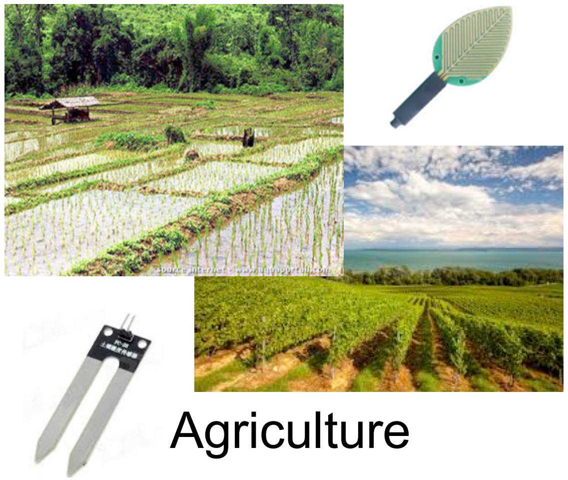

# IoT for development!

Irrigation

Livestock farming

Fish farming & aquaculture

Logistic, Storage,
Asset Tracking



Agriculture

Fresh water

Prof. Congduc Pham
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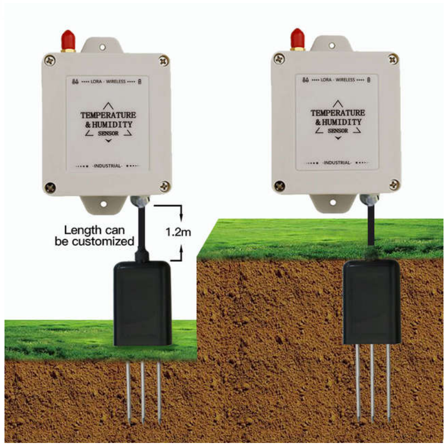
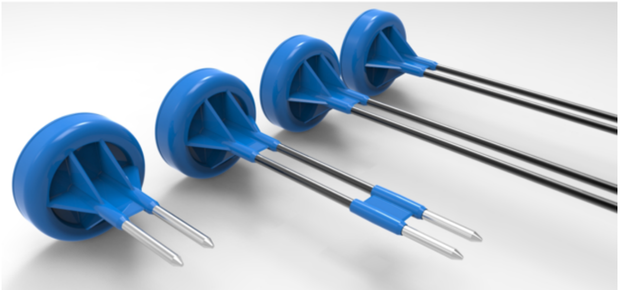
# Example: Smart Agriculture









# Typical IoT device

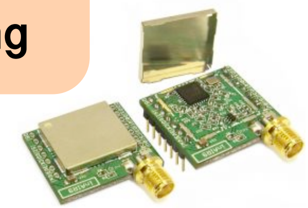
- IoT device can be viewed as a simple Embedded System

Soil Humidity Sensor


+

Some electronics & processing

Radio modules



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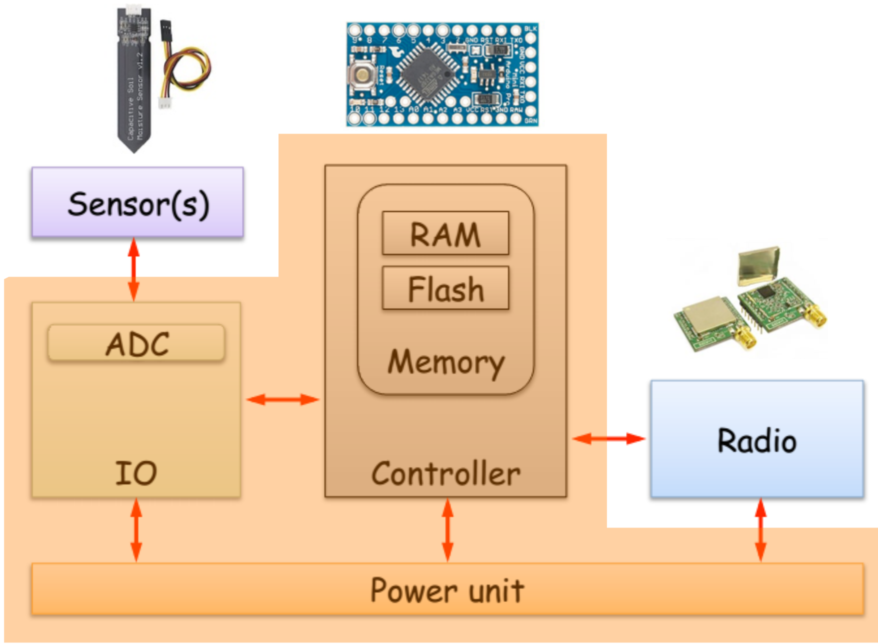
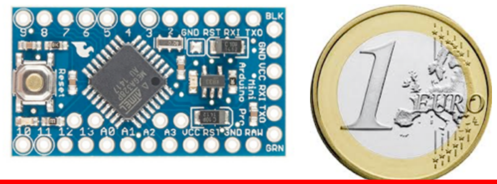



**Microcontroller**

# Low-cost microcontroller boards

Arduino Pro Mini

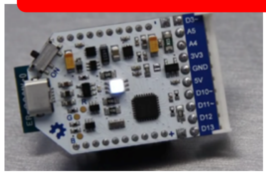


LoPy

http://blog.atmel.com/2015/12/16/rewind-50-of-the-best-boards-from-2015/

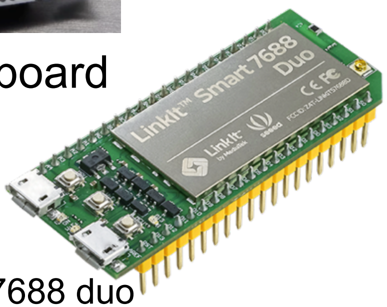
http://blog.atmel.com/2015/04/09/25-dev-boards-to-help-you-get-started-on-your-next-iot-project/

Teensy 3.2



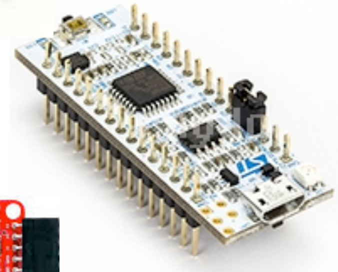
Theairboard

Expressif ESP32



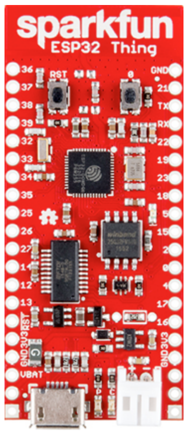
LinkIt Smart7688 duo

STM32 Nucleo-32



Heltec ESP32 + OLED

Adafruit Feather



Sparkfun ESP32 Thing

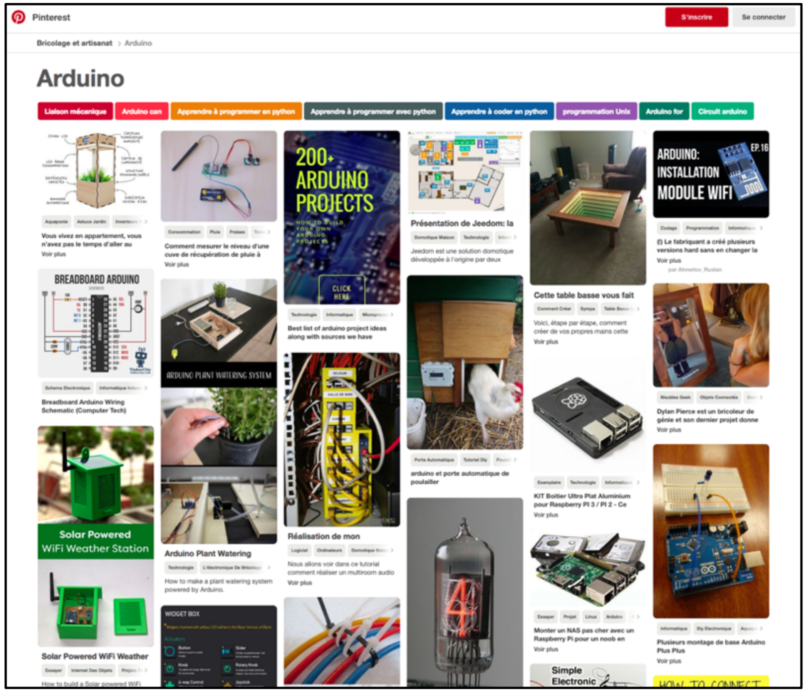
Tessel

SodaqOnev2

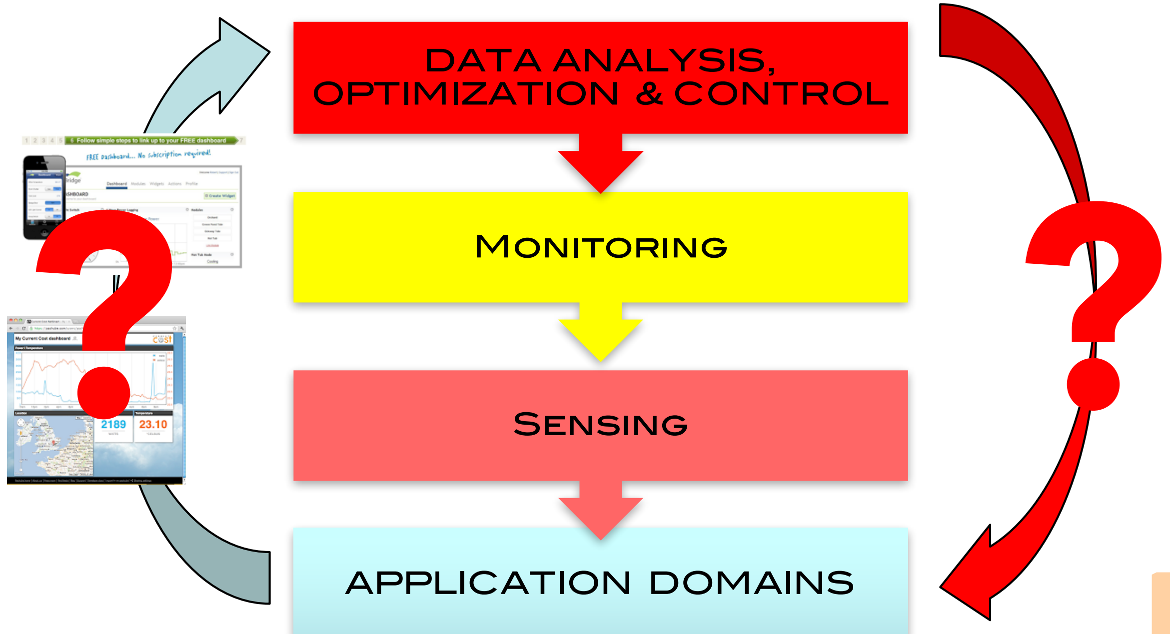
Tinyduino

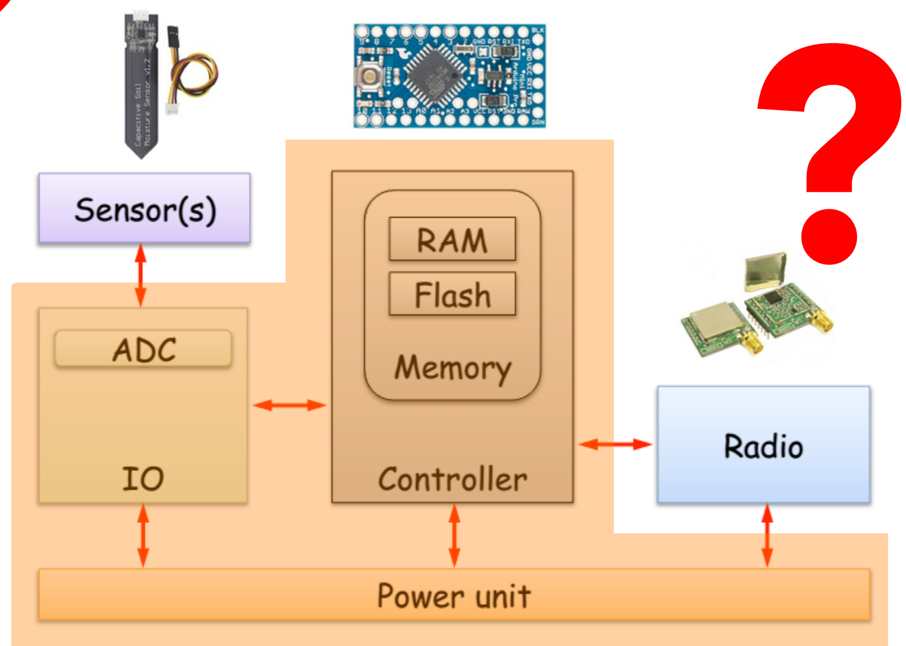
# … for Do-it-Yourself IoT projects

- DIY usually means
  - More open-source software from larger community
  - More flexibility




# How to collect data?

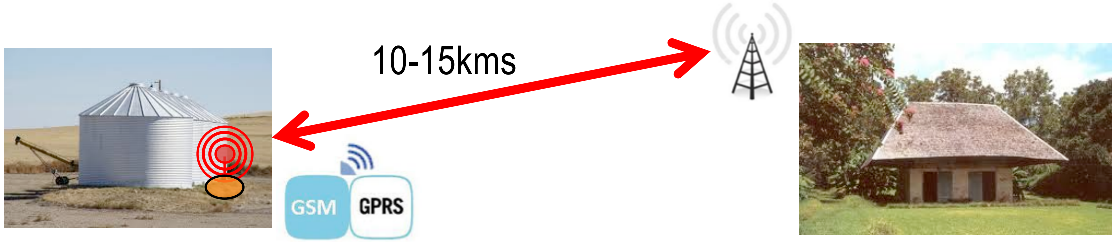


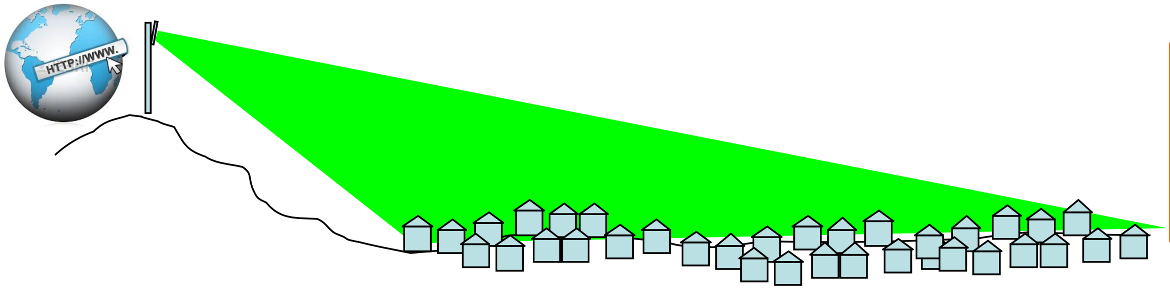




Micro-processor
Micro-controller

# Wireless transmission cost

Moisture/
Temperature of
storage areas



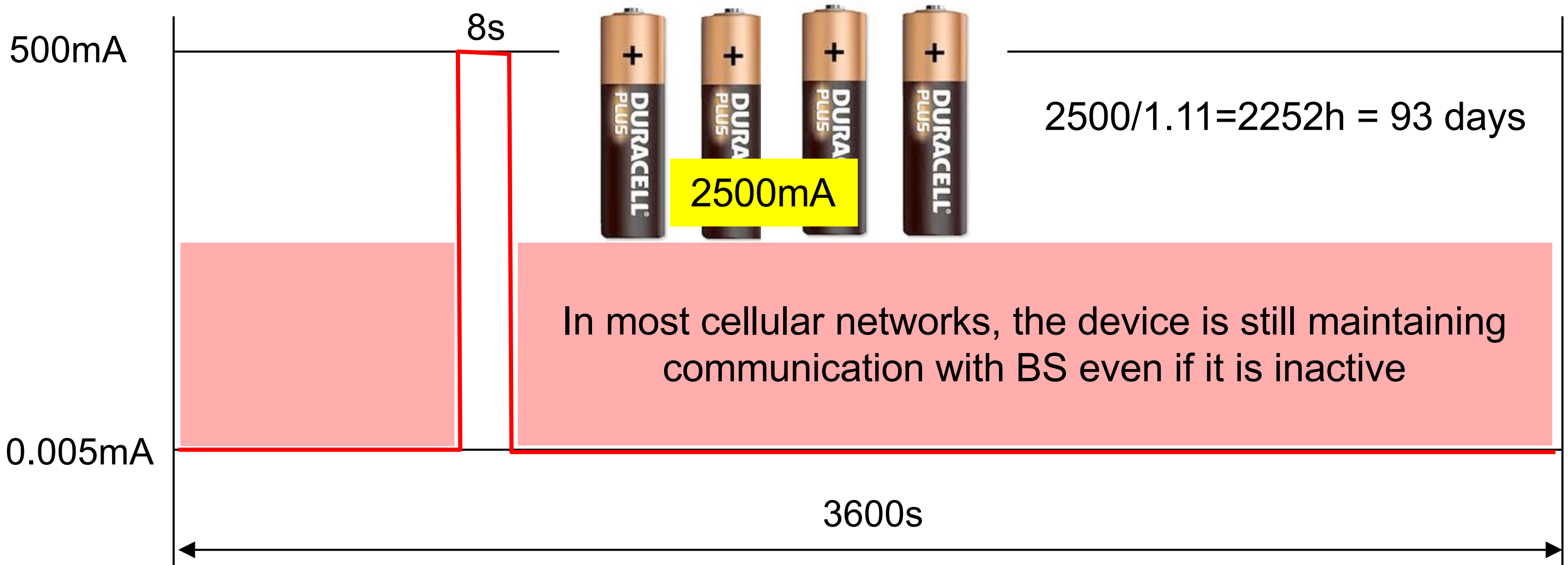



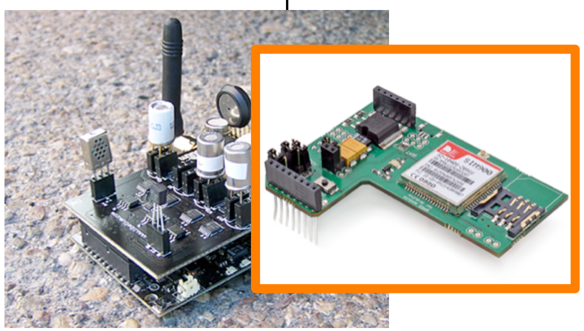

| Technology | 2G | 3G | LAN |
|---|---|---|---|
| Range (I=Indoor, O=Outdoor) | N/A | N/A | O: 300m<br>I: 30m |
| Tx current consumption | 200-500mA | 500-1000mA | 100-300mA |
| Standby current | 2.3mA | 3.5mA | NC |

Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

# Energy consideration

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

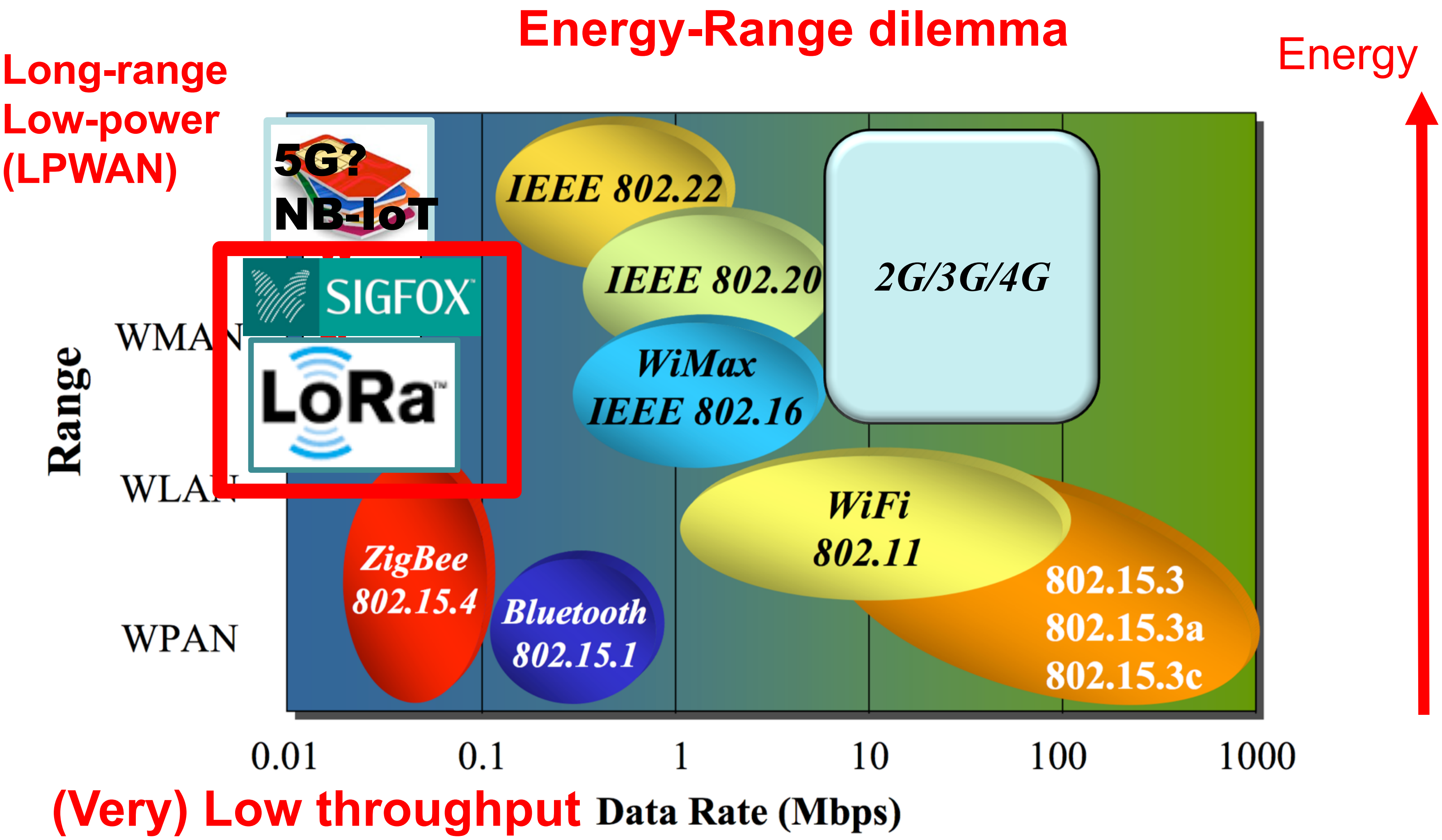


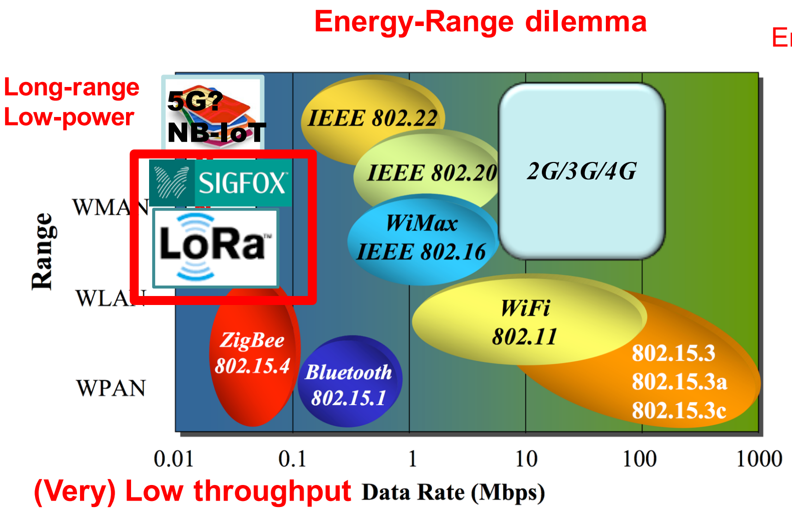
2G/3G/4G

| Technology | 2G | 3G | LAN |
|---|---|---|---|
| Range (I=Indoor, O=Outdoor) | N/A | N/A | O: 300m I: 30m |
| Tx current consumption | 200-500mA | 500-1000mA | 100-300mA |
| Standby current | 2.3mA | 3.5mA | NC |

# Low-power & long-range radios



# Energy consumption comparaison




Energy ↑

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

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

2500/0.027=92592h = 3858 days = 10 years

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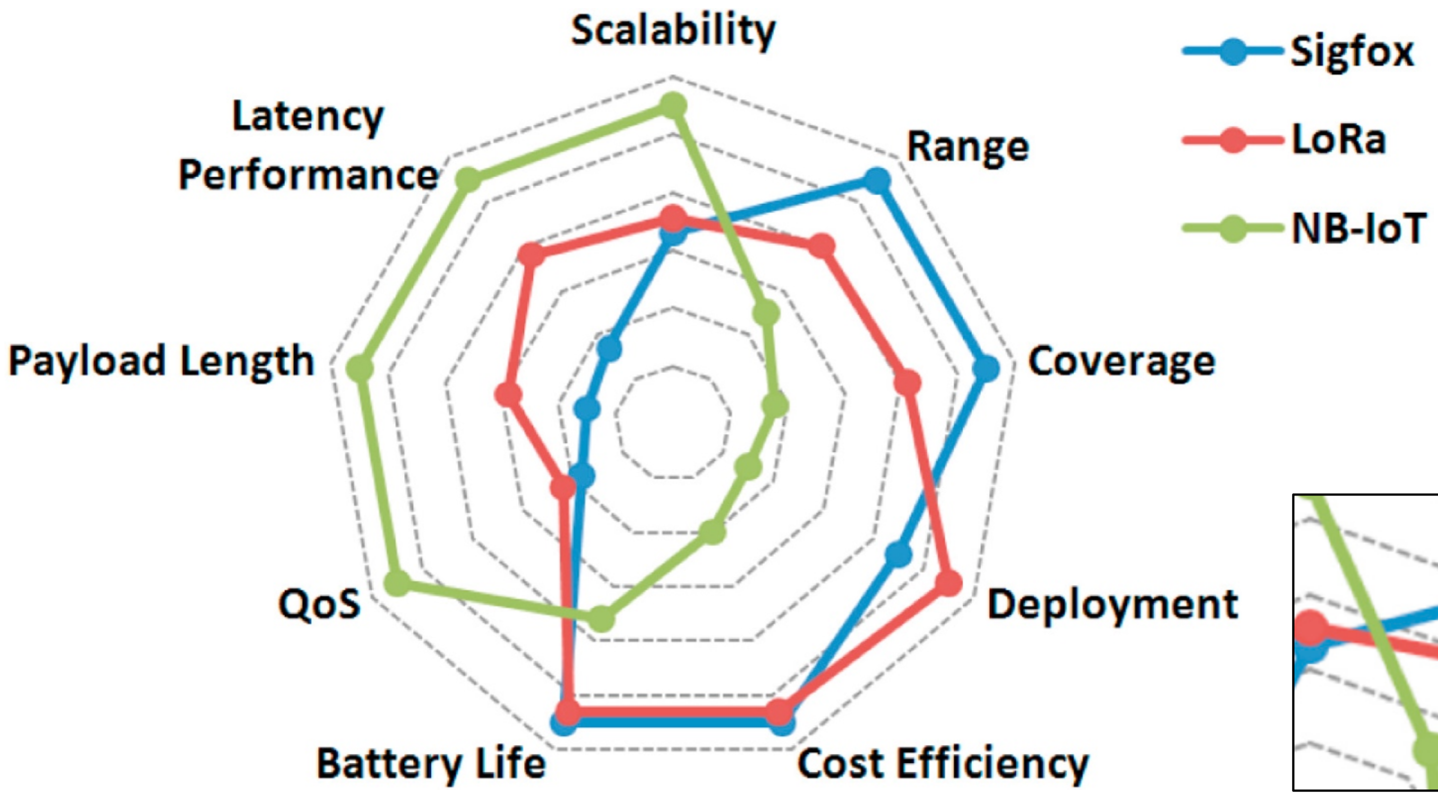
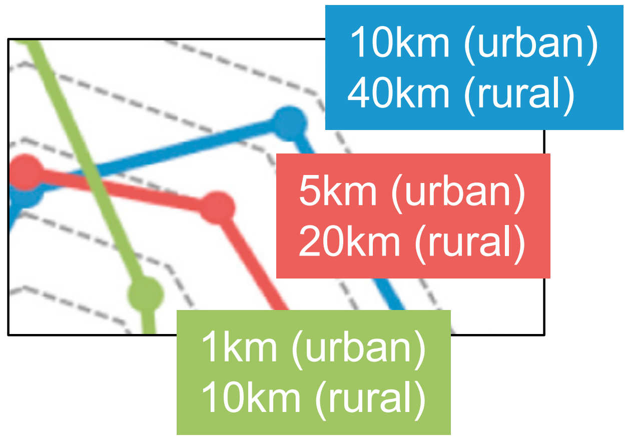
# Expected range?



# Main problem: attenuation!

- Depends mainly on distance

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

- with ideal antenna (theoretic)

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

- notation
  - $P_e$ = transmitted power
  - $P_r$ = received power
  - d = distance between antennas
  - α from 2 to 4
  - c = light speed in space $3.10^8$ m/s
  - λ= wave length of the signal=c/f

Simple Free Space Path-Loss (FSPL) model

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

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

# 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)*

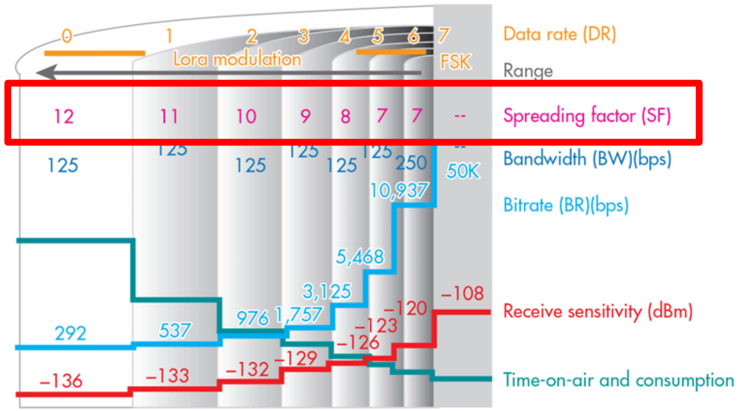
Adapted from Peter R. Egli, INDIGOO.COM


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)




- 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)

# Spreading factor in image

- Higher spreading factor means lower data rate but increased receiver sensitivity

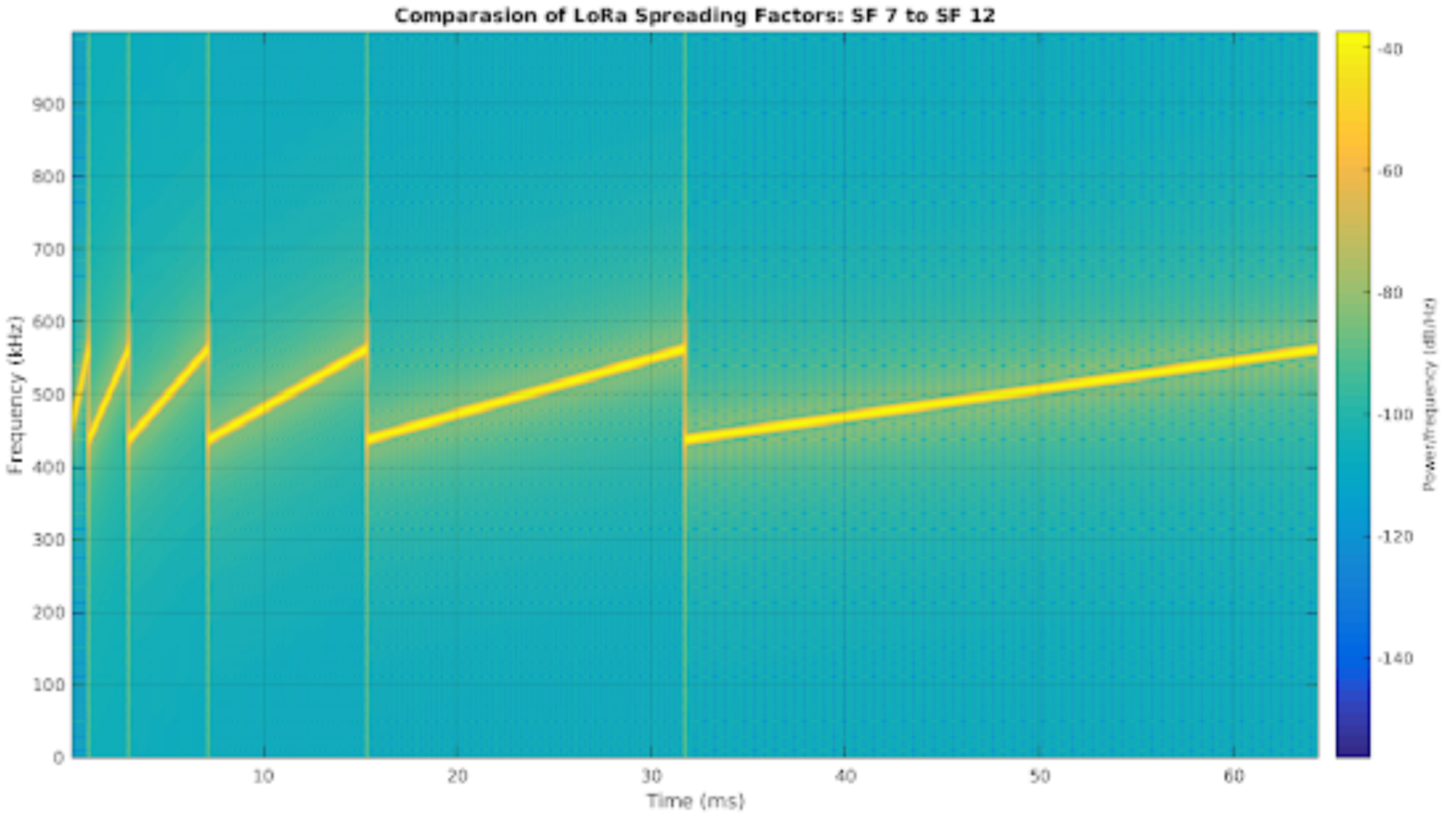
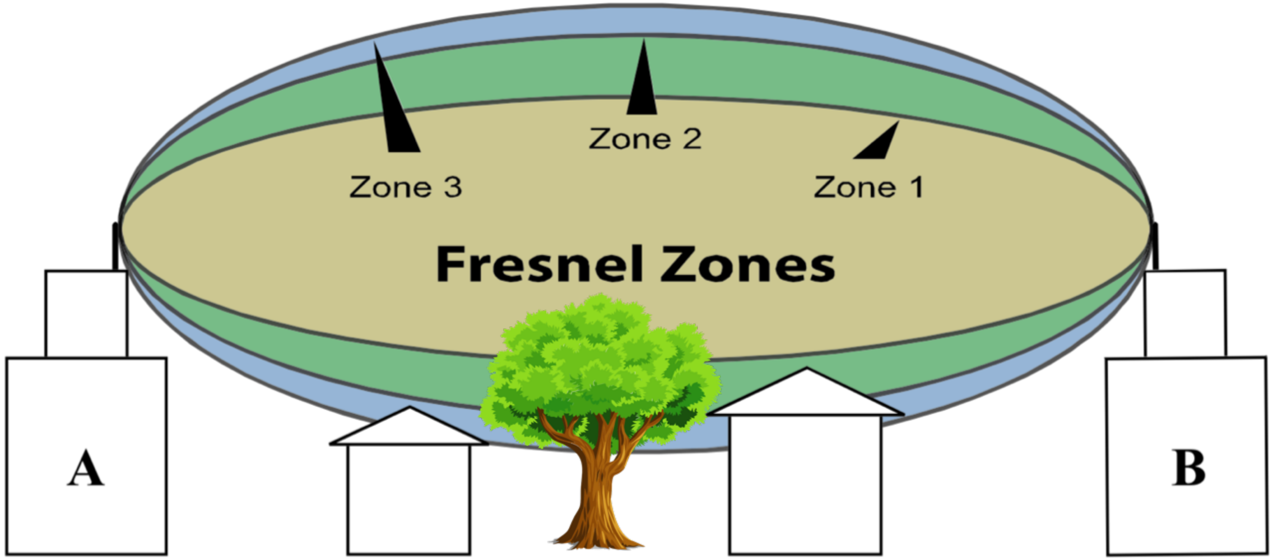



Figure from "All About LoRa and LoRaWAN", https://www.sghoslya.com

# Line-of-Sight & Fresnel zone

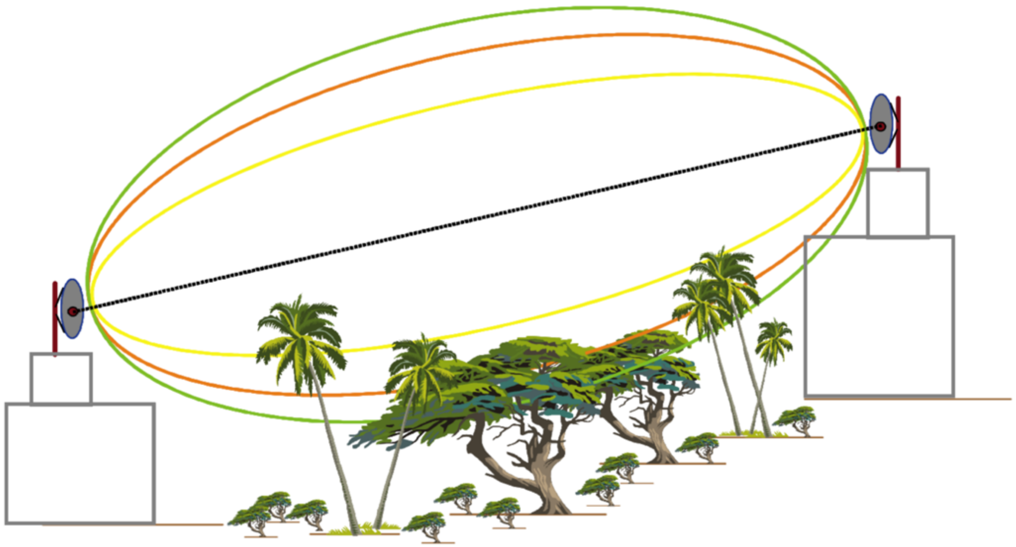
- LoS means clear Fresnel zone
- Football (american) shape
- Acceptable = 60% of zone 1 + 3m



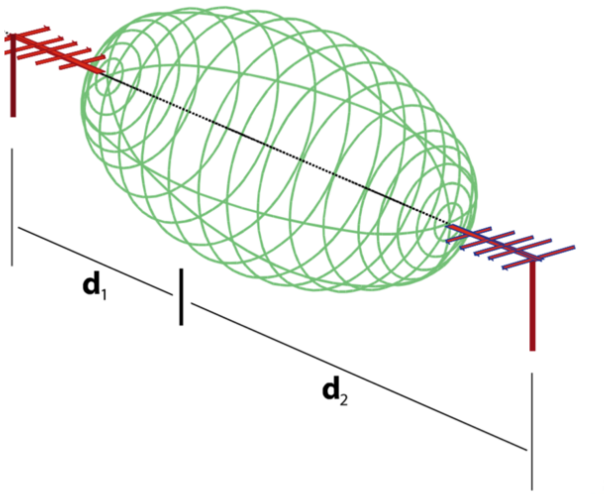



RF Essentials from Digi

# 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) |



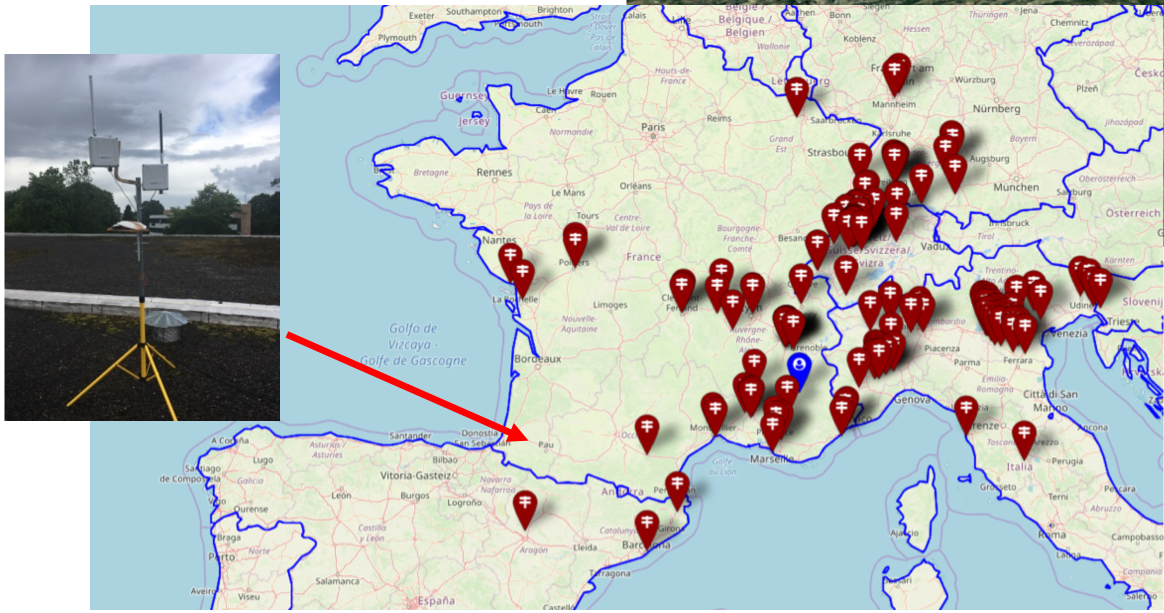
RF Essentials from Digi

# Coverage test by Fabien Ferrero on March 21-22, 2019

- LoRa gateway on top of Danang's DSP building by Fabien, U. Danang and DSP team. Almost 26kms! Congrats Fabien!

# Coverage test by Fabien Ferrero on June 11th, 2019

- High Altitude Ballon


- 31kms high
- Reception at 642km (Udine, Italy)!
- Current record at 702km with balloon at 38kms

https://github.com/FabienFerrero/HAB_Relay_STM32Contest