INTEL-IRRIS

Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

Intel-IrriS

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

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Wireless Communication Essentials

Understanding radio & LoRa technologies in IoT

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UNIVERSITÉ DE PAU ET DES PAYS DE L'ADOUR

LIUPPA

WAZIUP
IoT – from idea to reality
WAZIHUB

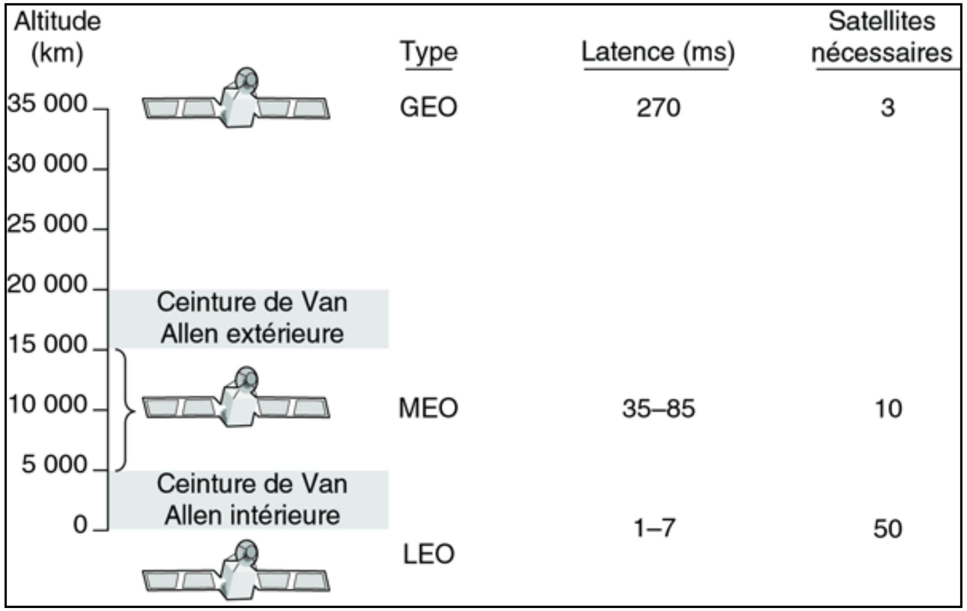
Wireless networks: WiFi

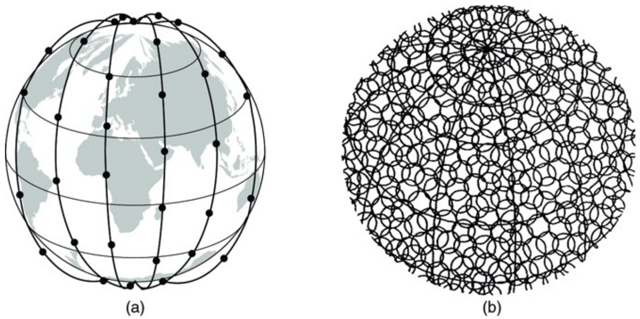
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

Wireless networks: 2G/3G/4G/5G/…

Wireless networks: Bluetooth

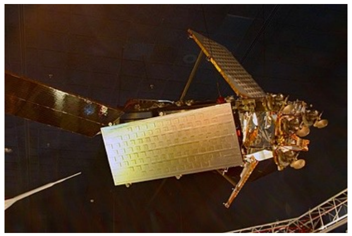
Wireless networks: Satellites

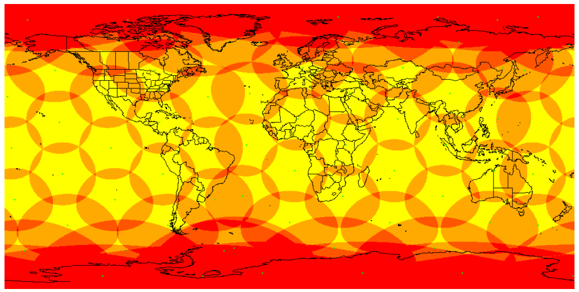




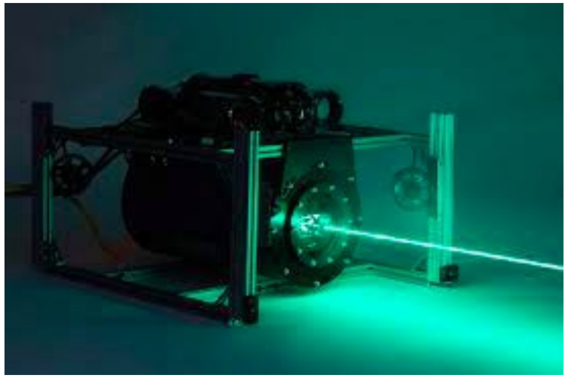
Iridium, 66 satellites

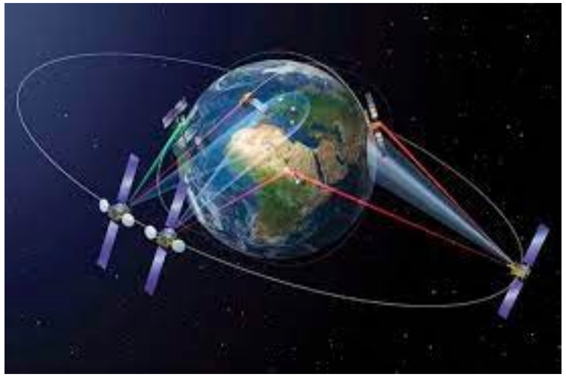
Initially 77

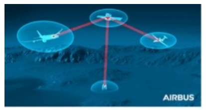




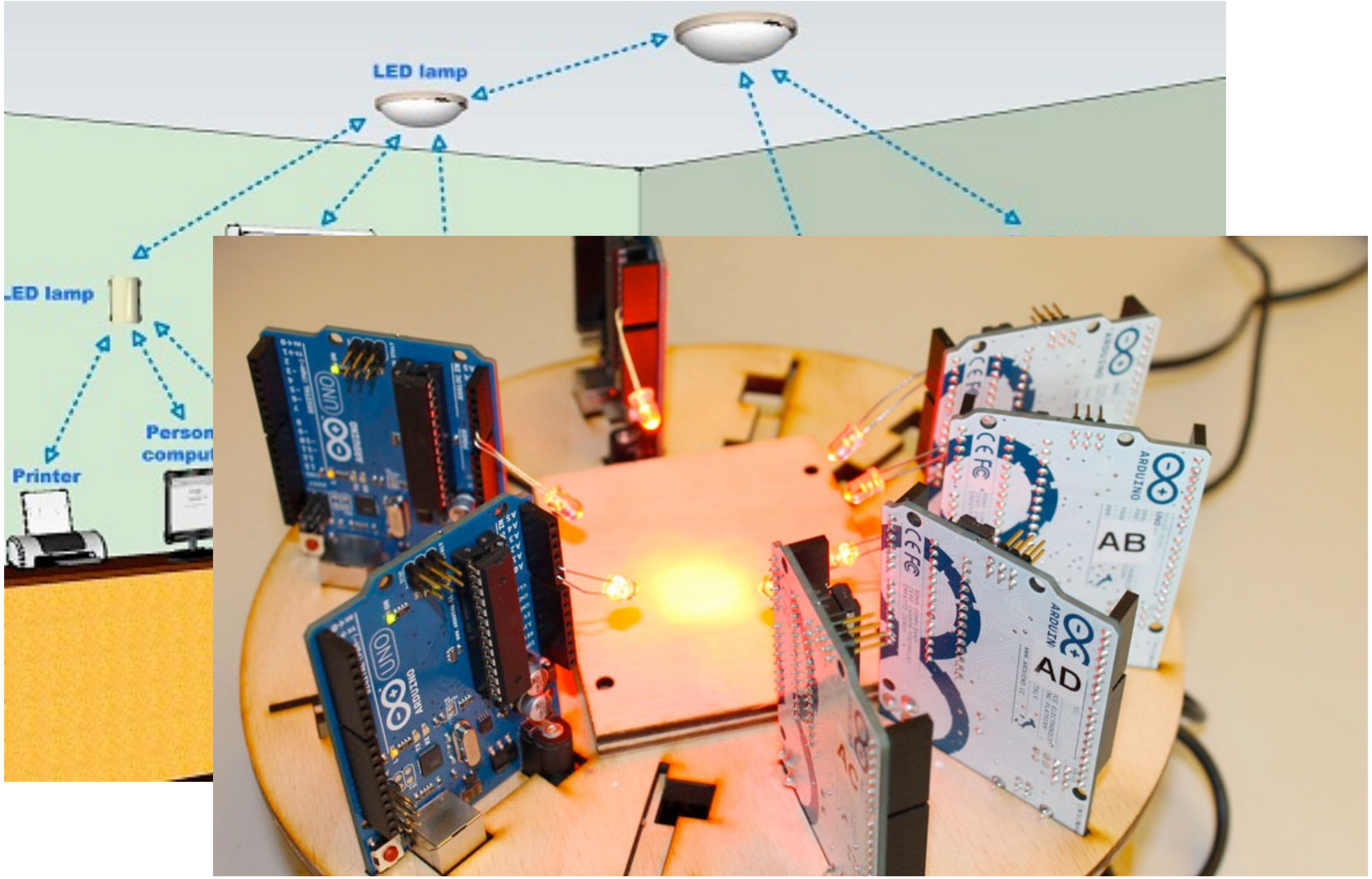
Wireless networks: Laser/Optical





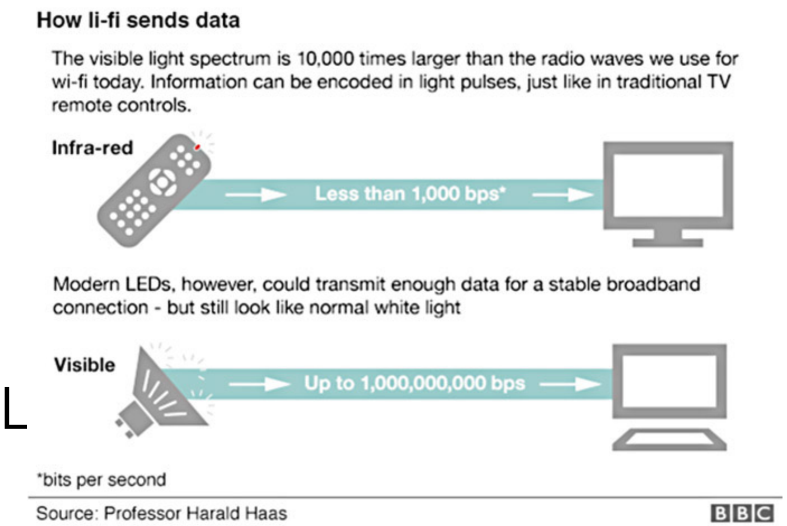


Wireless networks: Visible Light



Visible Light Communications, con't

- High throughput is "easy"
- Bi-directionality is still an issue
- VR is a perfect application for VL



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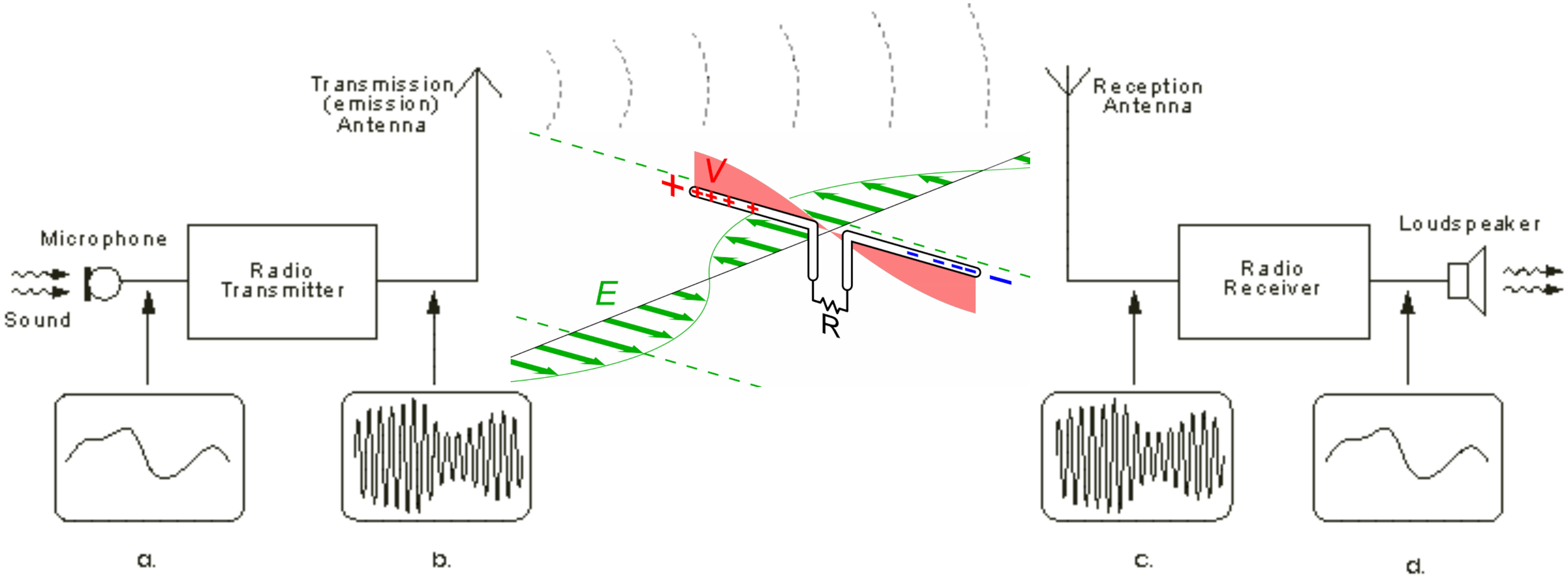
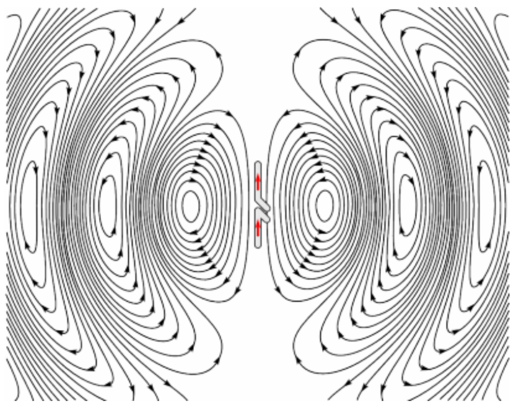
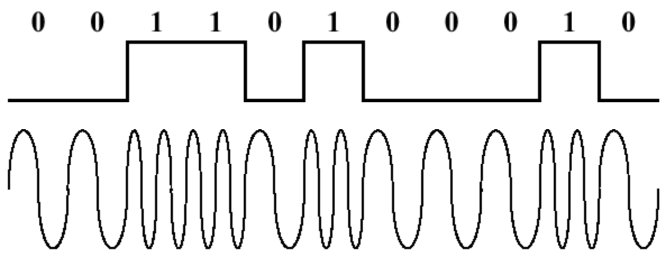
Wireless radio transmission basics





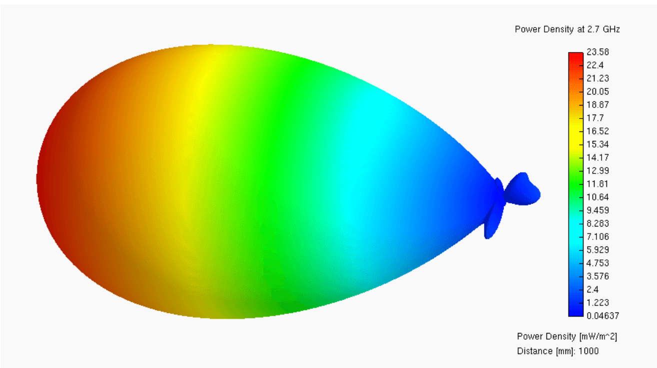
datal modulation

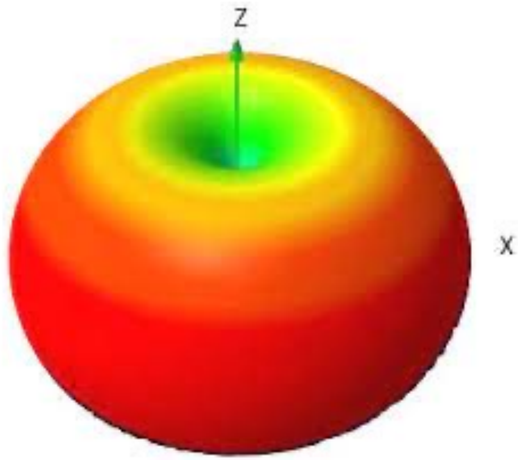


(b) Frequency-shift keying

Antenna types

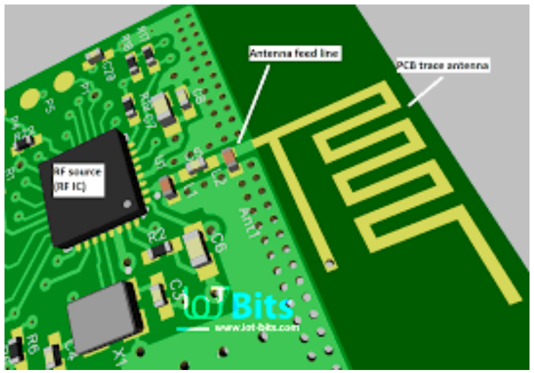
Omni-directional antennas

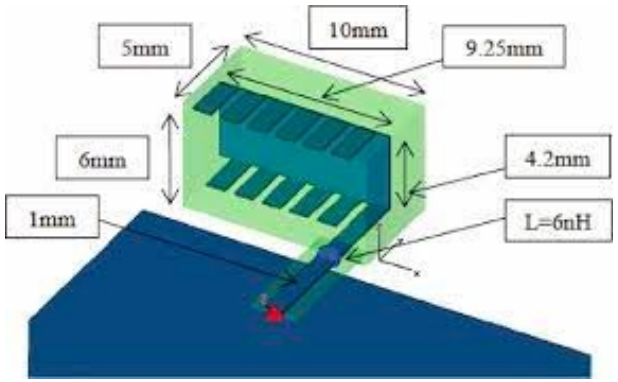




Directional antenna

PCB, patch, ceramic,...





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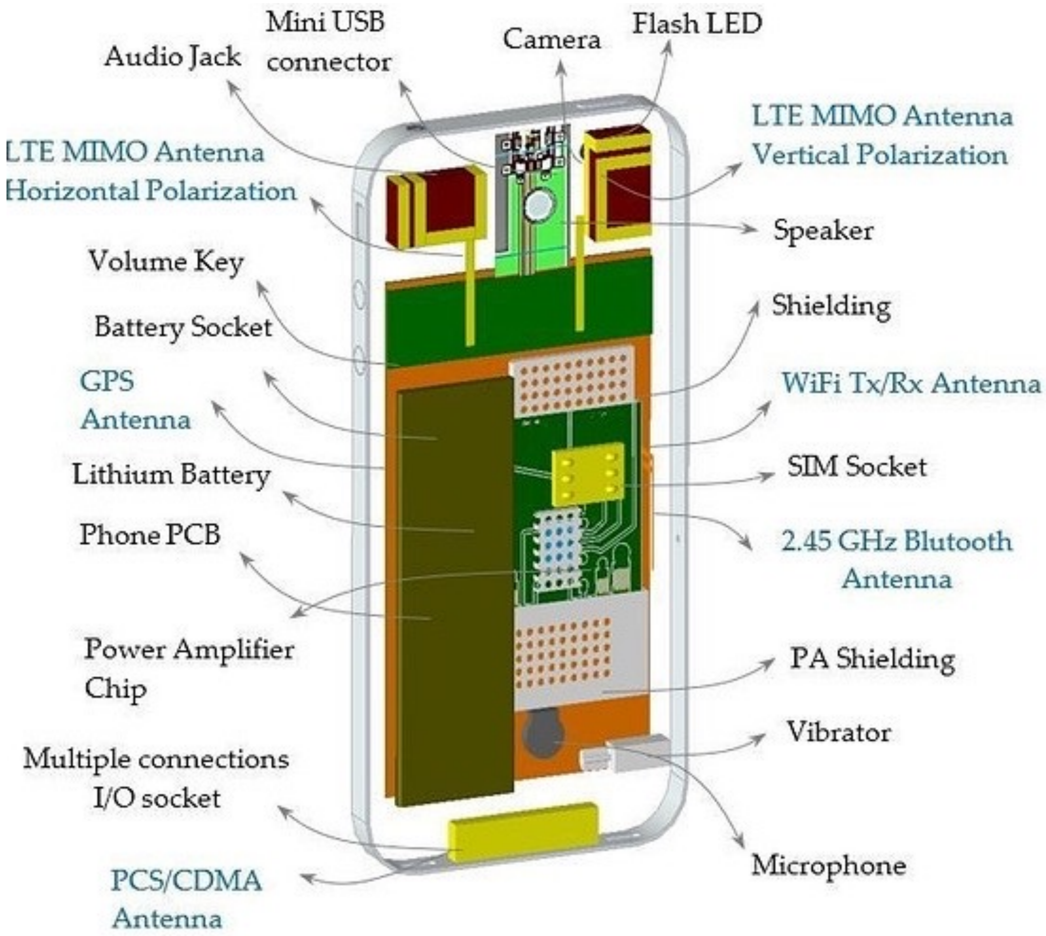
Antennas in a smartphones!



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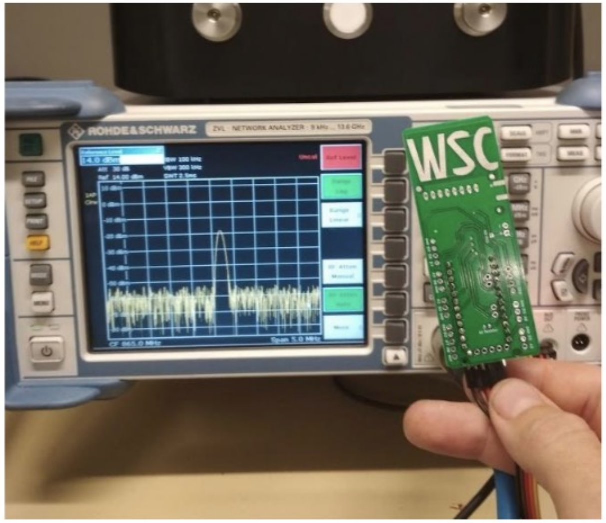
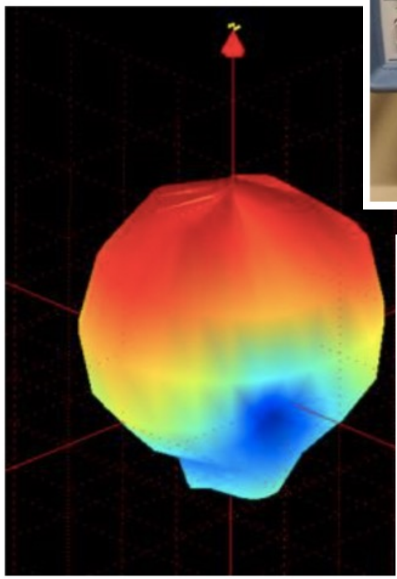
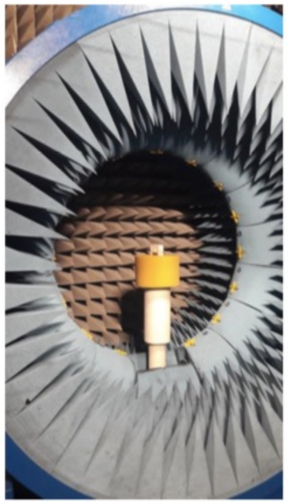
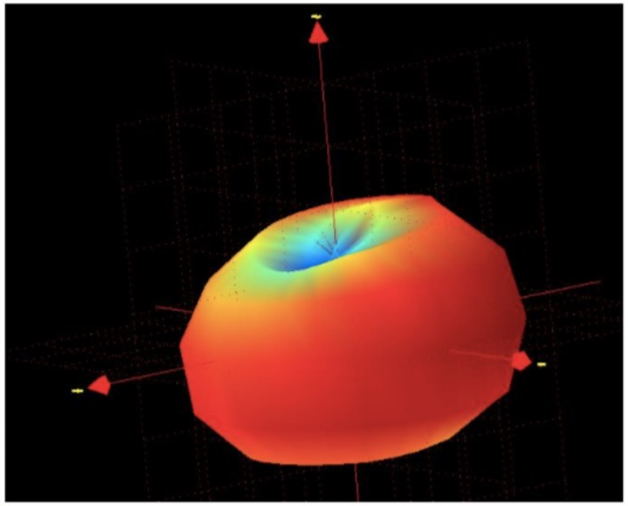
Testing antennas

- Source: F. Ferrero, University of Nice



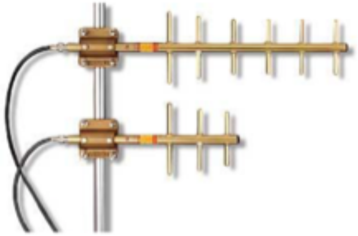


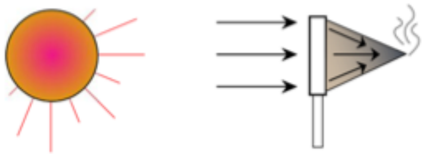




Antenna gain (1)

- Antenna gain
  - Directional antennas FOCUS energy: they DO NOT ADD energy





- Antenna Gain
  - Omni-directional antennas FOCUS energy: they DO NOT ADD energy

RF Essentials from Digi

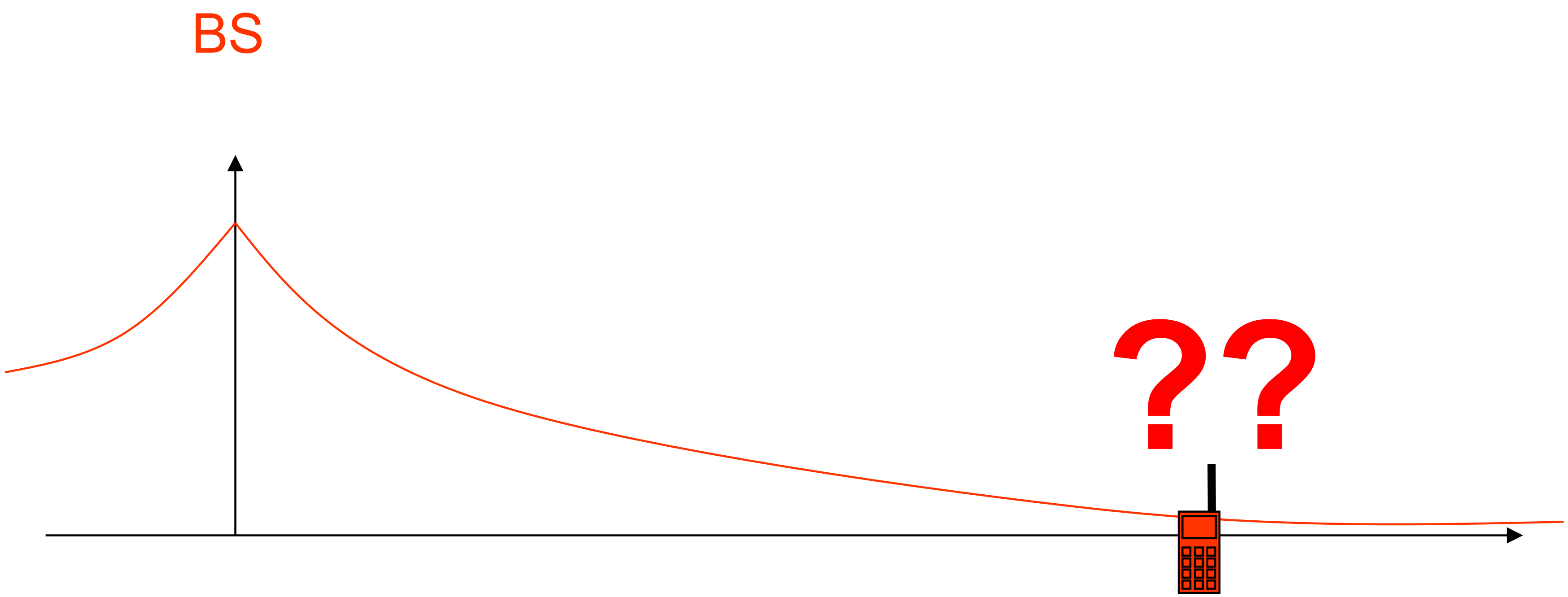
Antenna gain (2)

- Antenna gain and its effective surface

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f A_e}{c^2}$$

- with
  - G = gain
  - A_e= effective surface
  - f = signal frequency
  - c = light speed in space 3.10^8 m/s
  - λ= wave length of the signal=c/f

1st challenge: signal attenuation



Attenuation limits the range!

- Attenuation 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

Attenuation in practice

- For an ideal antenna (theoretic)

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

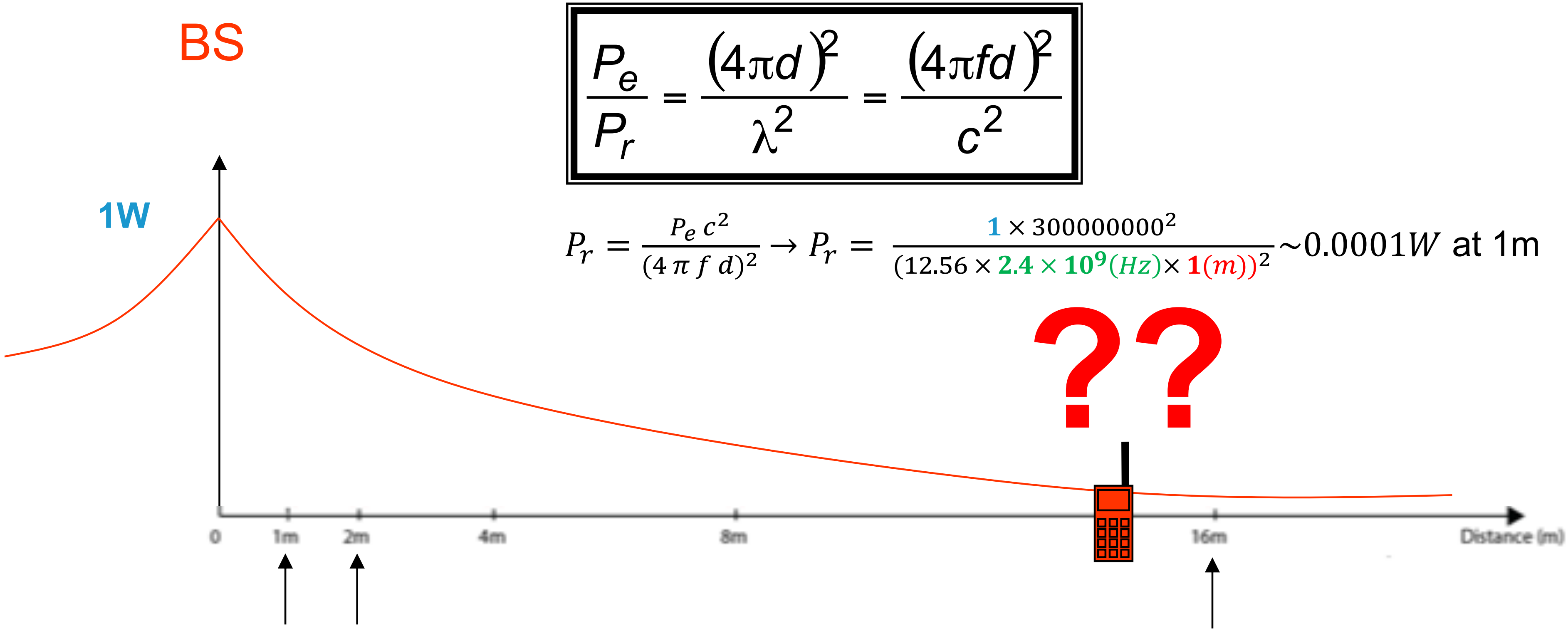
- P_e = transmitted power
- P_r = received power
- P_e / P_r is high when P_r is small → high attenuation
- d = distance between antennas
- c = light speed in space 3.10^8 m/s
- λ= wave length of the signal=c/f
- Higher frequencies f means higher attenuation!

Attenuation, values in watts

- Free Space Path Loss model

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

$$P_r = \frac{P_e\, c^2}{(4\,\pi\, f\, d)^2} \rightarrow P_r = \frac{1 \times 300000000^2}{(12.56 \times 2.4 \times 10^9 (Hz) \times 1 (m))^2} \sim 0.0001W \text{ at 1m}$$



0.0001W
x10000 smaller!

0.00002476W
x40384 smaller!

0.0000003869W
x2584634 smaller!

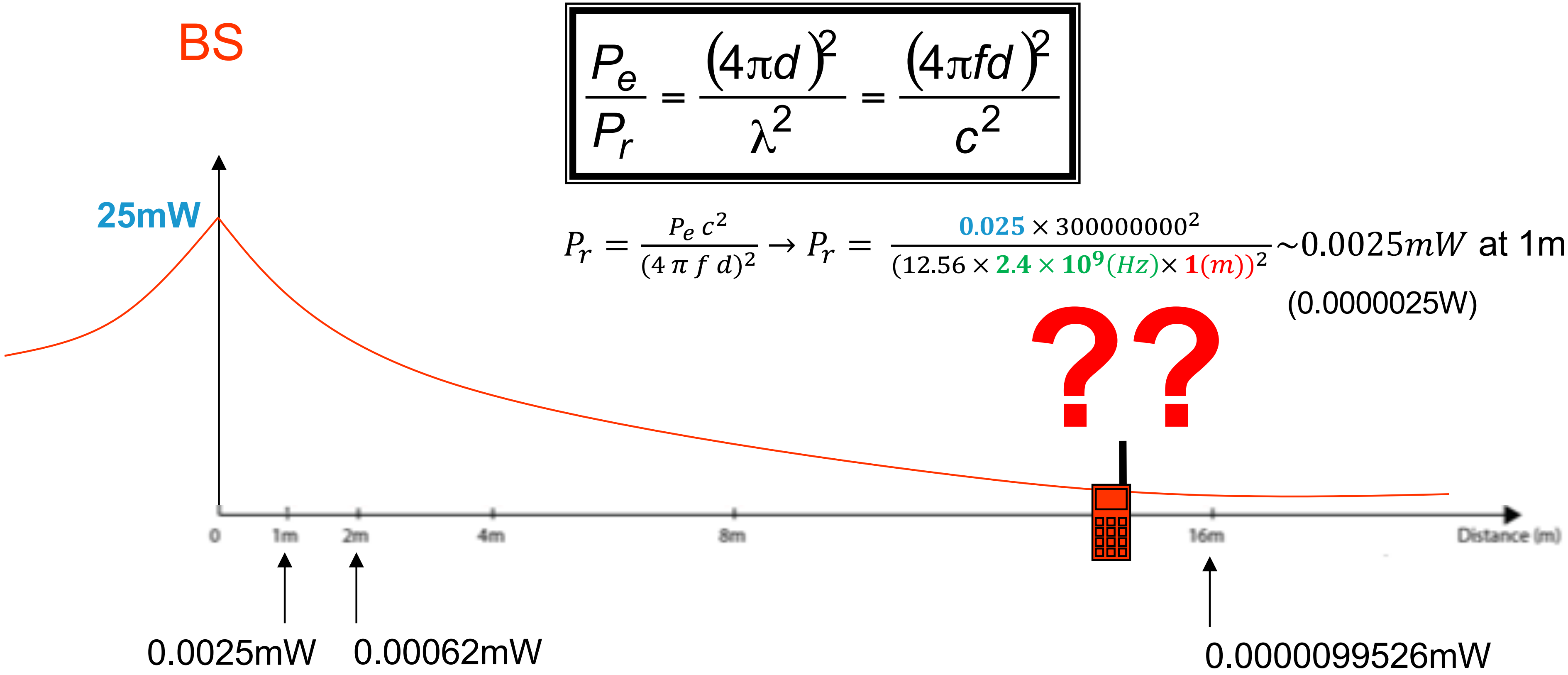
Attenuation, values in watts

- Free Space Path Loss model

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

$$P_r = \frac{P_e\, c^2}{(4\,\pi\, f\, d)^2} \rightarrow P_r = \frac{0.025 \times 300000000^2}{(12.56 \times 2.4 \times 10^9 (Hz) \times 1 (m))^2} \sim 0.0025 mW \text{ at 1m}$$

(0.0000025W)

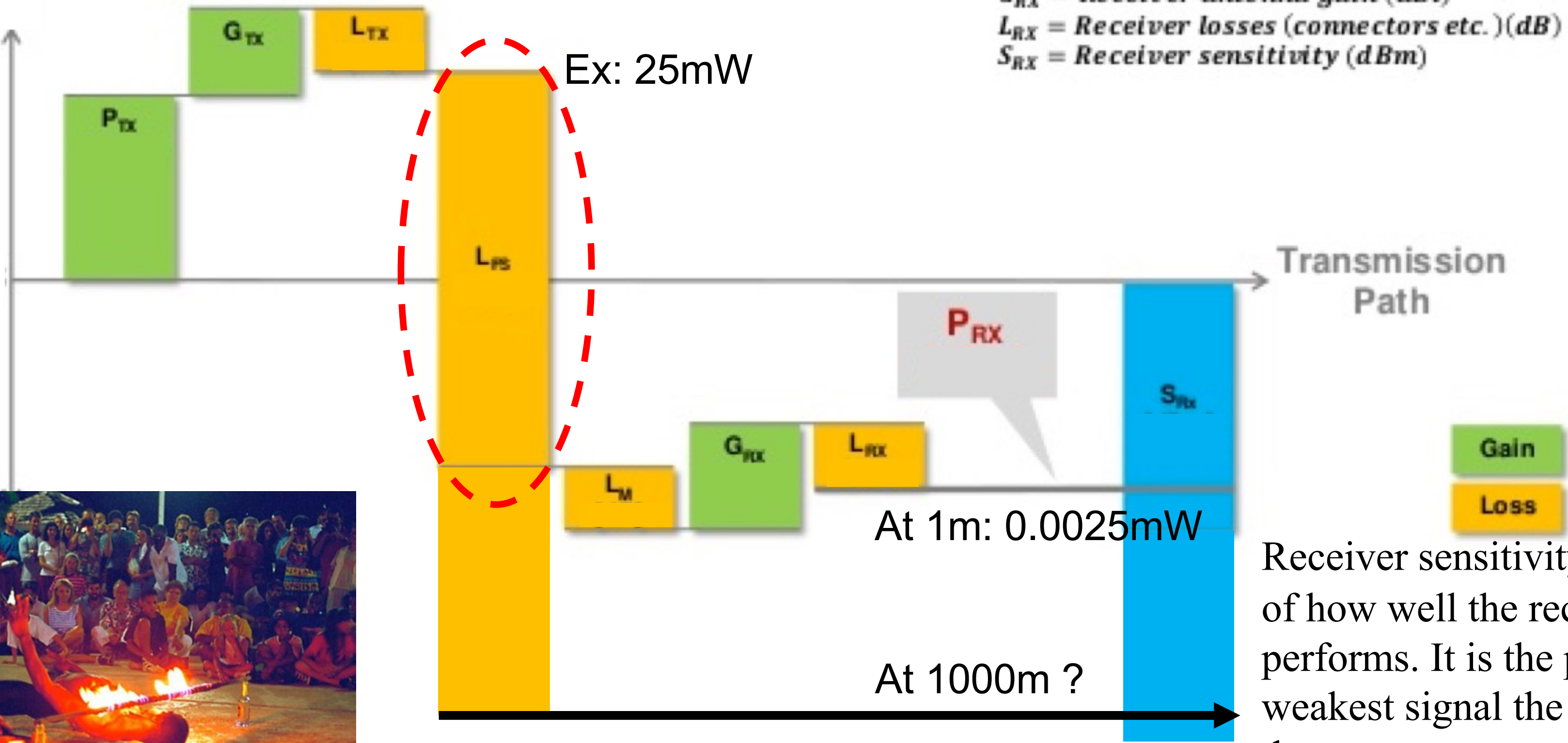


Link budget in wireless system – (simplified)

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

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

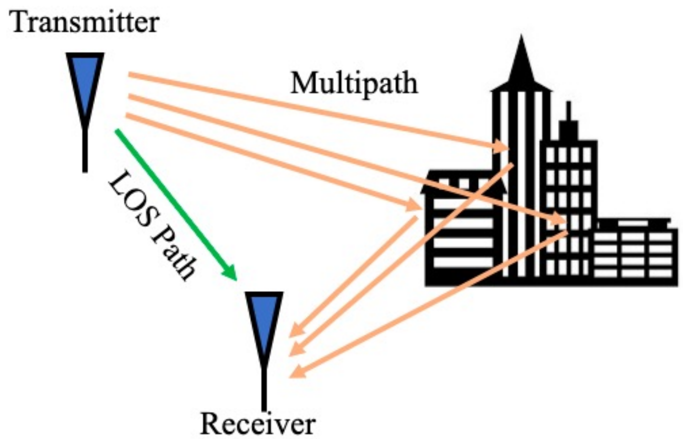


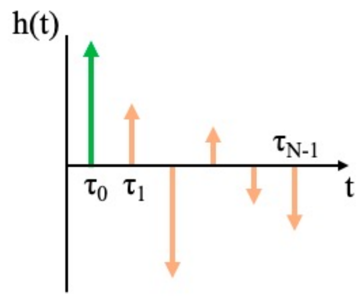
Receiver sensitivity is a measure of how well the receiver performs. It is the power of the weakest signal the receiver can detect

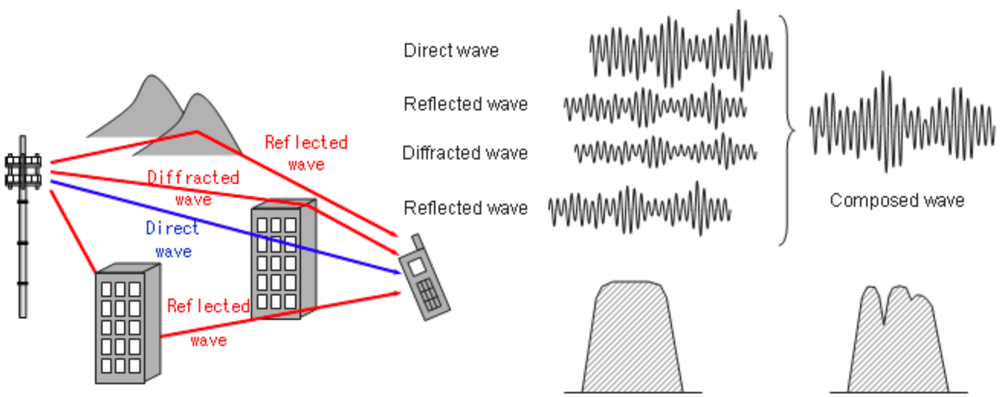
How low can you go?

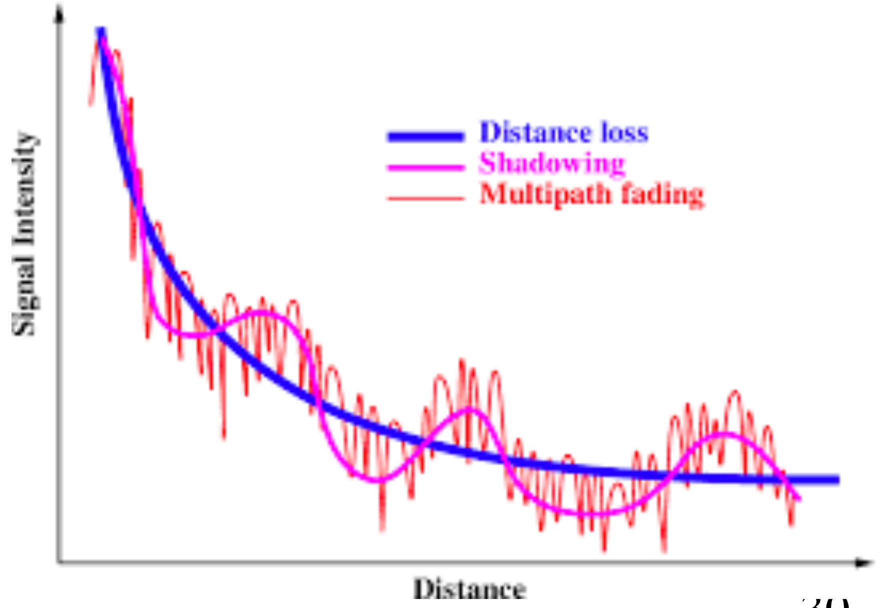
Shadow fading & Multi-path fading

- Things are getting even worse!
- Shadow fading by obstacles
- Multi-path fading
- …



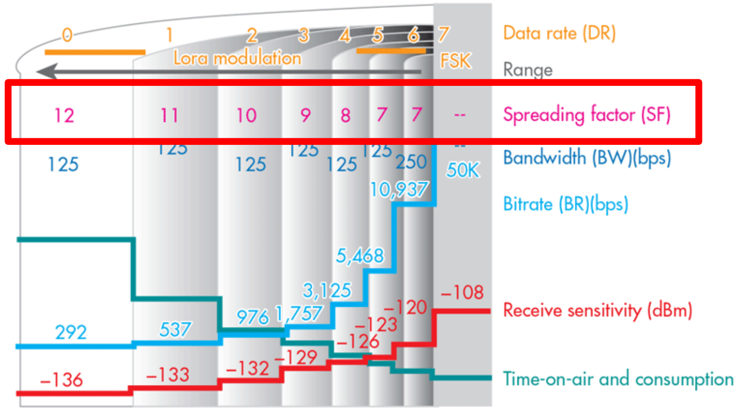






How can we increase range?

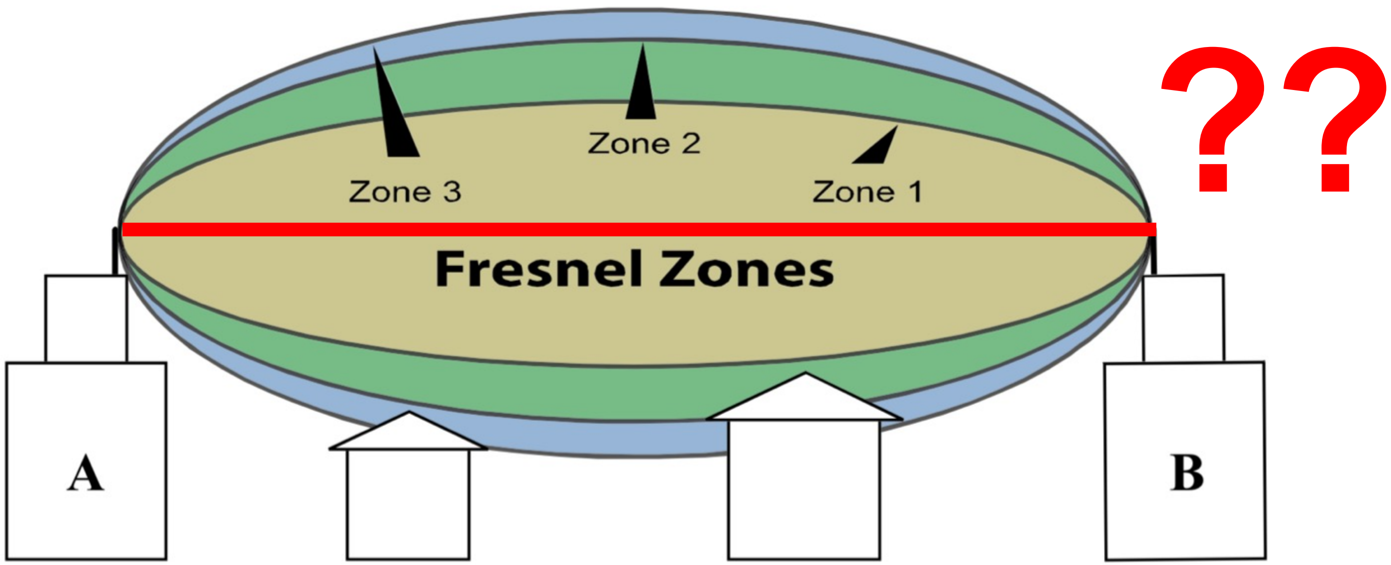
- Increase TX power and/or improve RX sensitivity
- Generally, RX sensitivity (~robustness) can be increased when transmitting (much) slower (like speaking slower!)
- LoRa uses spread spectrum approach to increase RX sensitivity
  - Spreading Factor defines how many chips will be used to code a symbol. 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)
- 3G/LoRa ratio: 20,000,000bps/200bps=100000!

Line-of-Sight & Fresnel zone

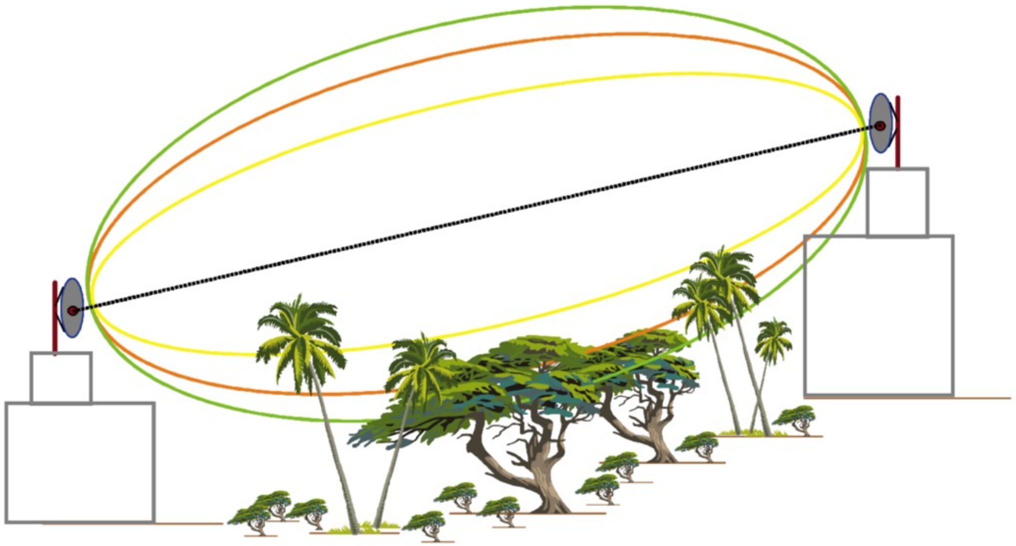
- LoS means clear Fresnel zone
- Football (american) shape
- Acceptable = 60% of zone 1 + 3m



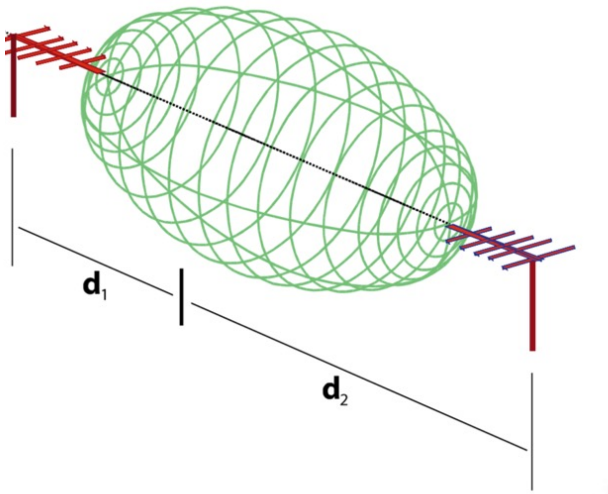
RF Essentials from Digi

In real environment!

Clearing the Fresnel zone? Raise antennas!



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

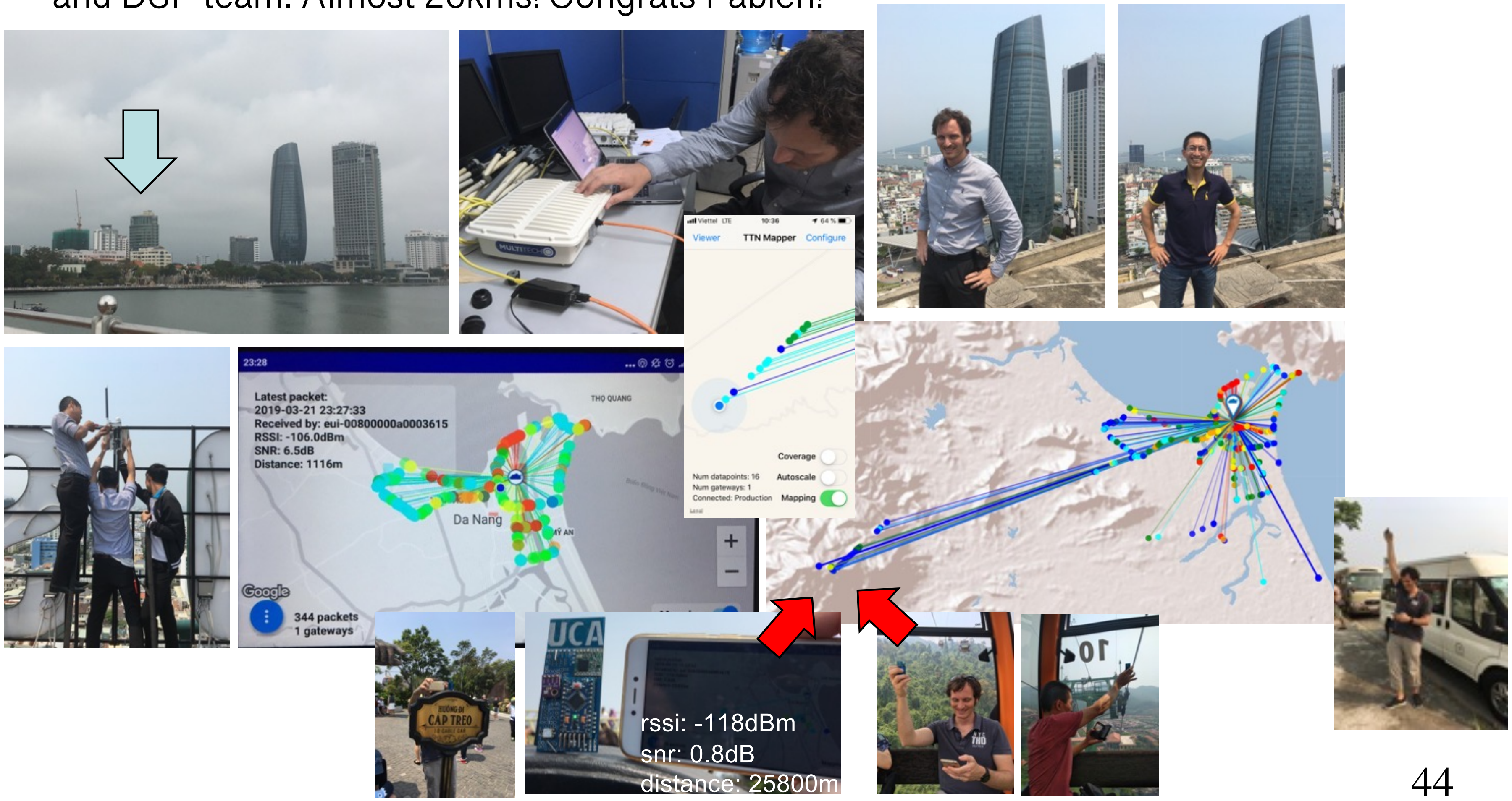


Range Distance	900 MHz Modems Required Fresnel Zone Diameter	2.4 GHz Modems Required Fresnel Zone Diameter
1000 ft. (300 m)	16 ft. (5 m)	11 ft. (3.4 m)
1 Mile (1.6 km)	32 ft. (10 m)	21 ft. (6.4 m)
5 Miles (8 km)	68 ft. (21 m)	43 ft. (13 m)
10 Miles (16 km)	95 ft. (29 m)	59 ft. (18 m)

RF Essentials from Digi

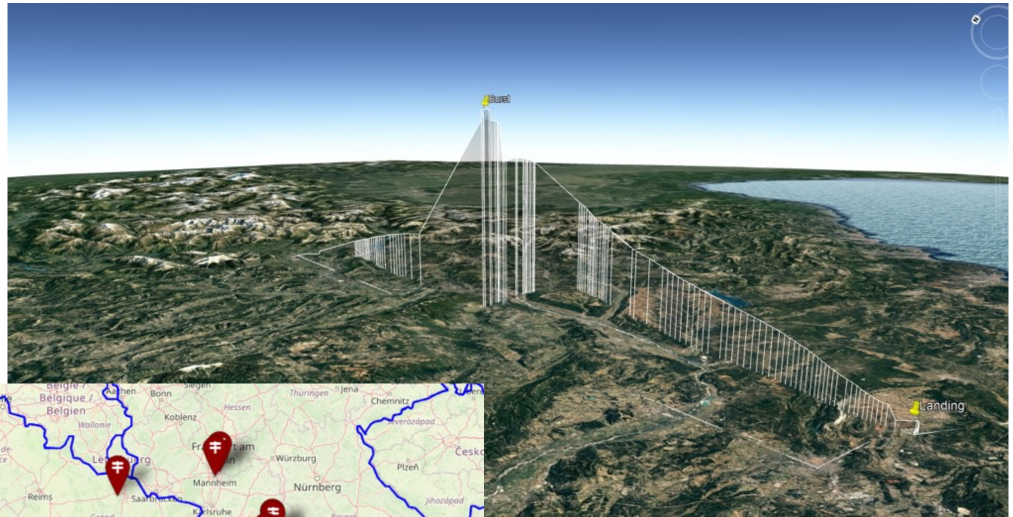
Coverage test by Fabien Ferrero on March 21-22, 2019

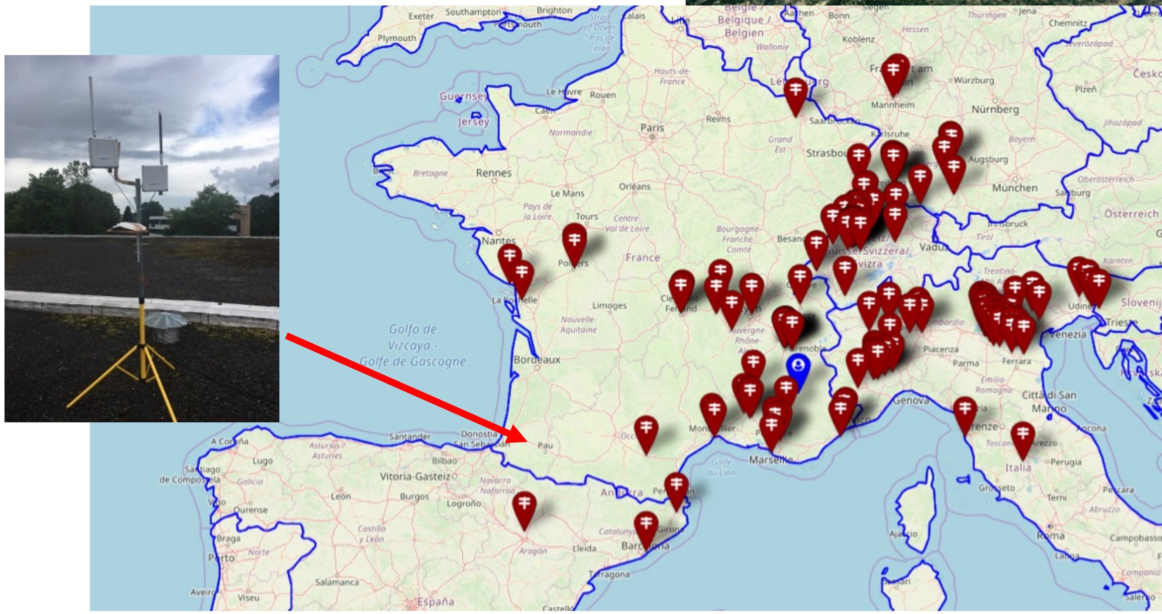
- LoRaWAN gateway on top of Danang's DSP building by Fabien, U. Danang and DSP team. Almost 26kms! Congrats Fabien!



Coverage test by Fabien Ferrero on June 11th, 2019

- High Altitude Ballon





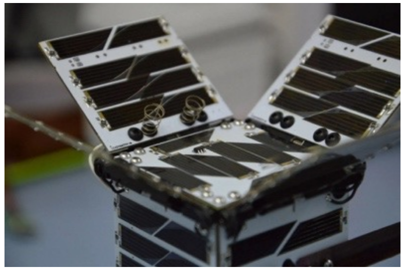
- 31kms high
- Reception at 642km (Udine, Italy)!
- Current record at 702km with balloon at 38kms

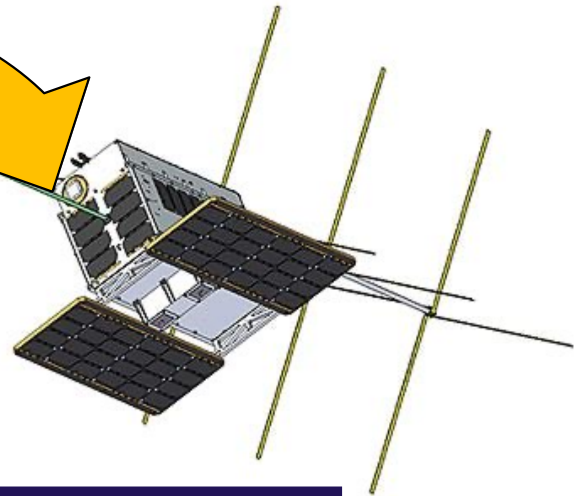
https://github.com/FabienFerrero/HAB_Relay_STM32Contest

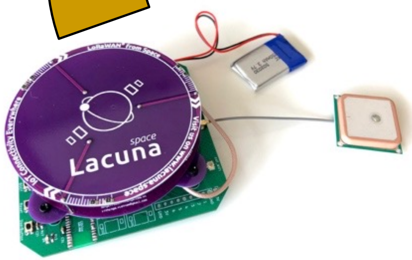
Clearing the Fresnel zone? Let's use satellite!

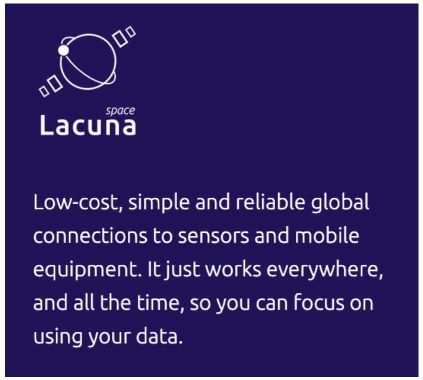
- Low-orbit, low-cost; compact satellite for global coverage

LoRa over 1200kms!









https://lacuna.space/first-successful-lacunasat-launch-in-2021/

LPWAN=star topology, gateway centric

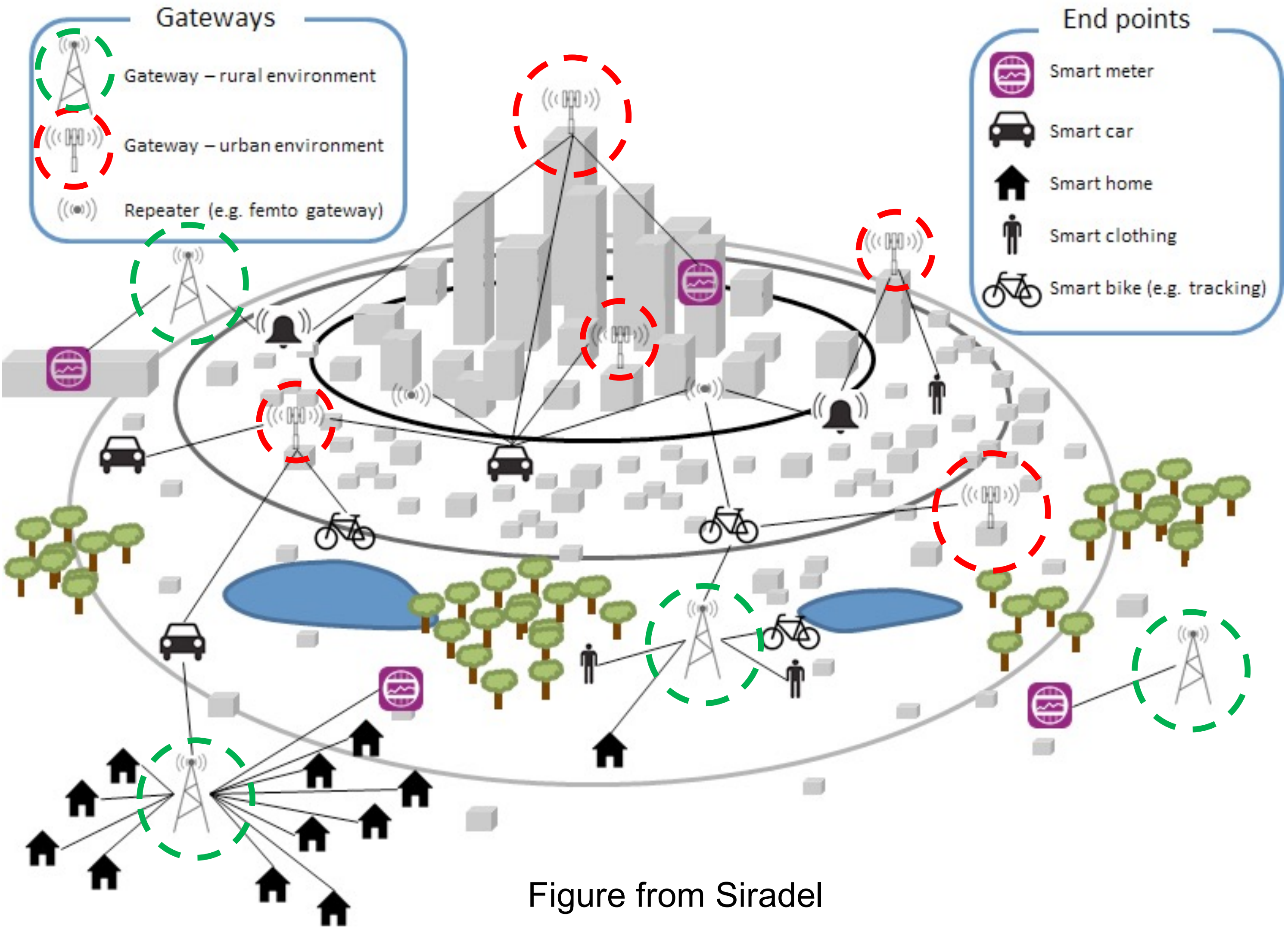
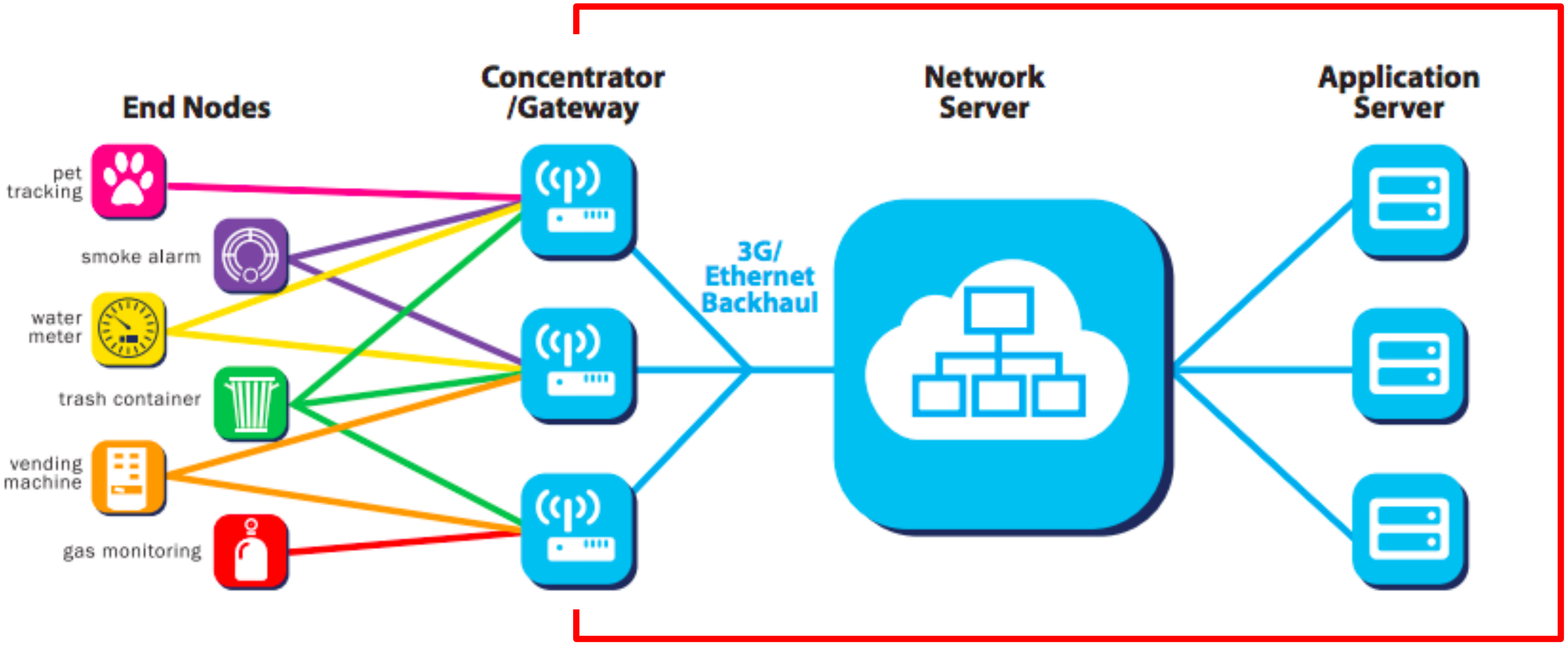
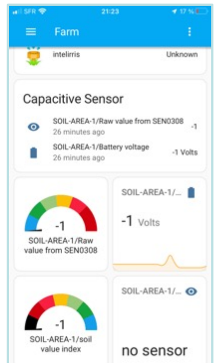


Figure from Siradel

LoRaWAN IoT networks

- LoRaWAN specifications/protocols run on top of LoRa physical networks. It is defined and managed by the [LoRa Alliance]
- Make possible to run large-scale, public LoRa networks



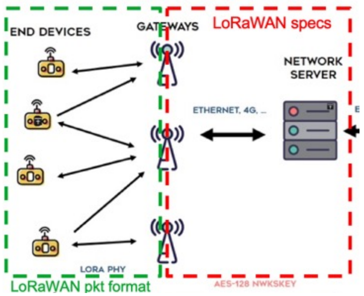


ThingsBoard

Undestanding LoRa vs LoRaWAN

- The physical layer, thus the long-range radio technology, is called LoRa
- A so-called 1-byte sync word is used to add a "filtering" level
- You can decide to transmit using only the LoRa physical layer and then define our own packet format
- With pure LoRa you can transmit from any device to any other device with same LoRa datarate, frequency and sync word
- LoRaWAN uses LoRa physical layer but defines its own packet format and uses sync word of 0x34 (public LoRaWAN)
- "In LoRaWAN, a gateway applies I/Q inversion on TX, and nodes do the same on RX. This ensures that gateways can talk to nodes and vice-versa, but gateways will not hear other gateways and nodes will not hear other nodes" [LMIC Arduino]

LoRaWAN gateway



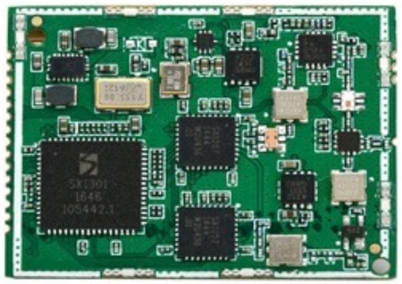
- A full LoRaWAN gateway should be able to listen on multiple channels and spreading factors

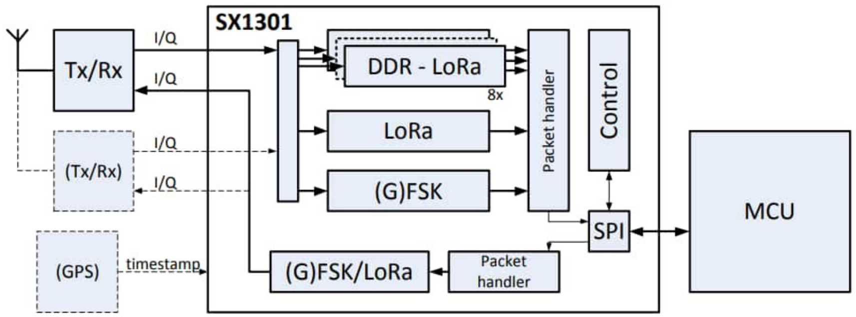
EU863-870

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

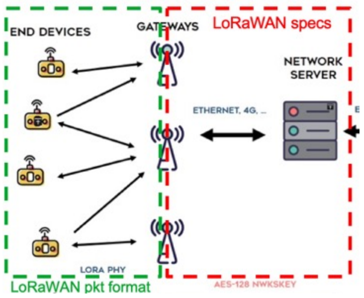




LoRaWAN gateway software

- Most of LoRaWAN gateways run the following software
  - the Semtech's concentrator gateway at the lowest level (https://github.com/Lora-net/lora_gateway)
  - The Semtech's LoRa packet forwarder on top of the low-level concentrator gateway (https://github.com/Lora-net/packet_forwarder)
- "*A LoRa packet forwarder is a program running on the host of a LoRa gateway that forwards RF packets receive by the concentrator to a server through a IP/UDP link, and emits RF packets that are sent by the server.*"
- The server is the so-called LoRaWAN Network Server (LNS) as described in the next slides
- The Network Server is usually linked to the Application Server which can be seen as a LoRaWAN cloud

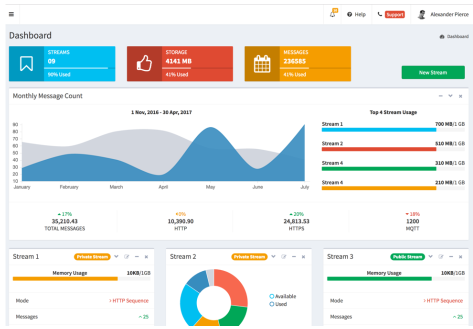
LoRaWAN Network Server (LNS)

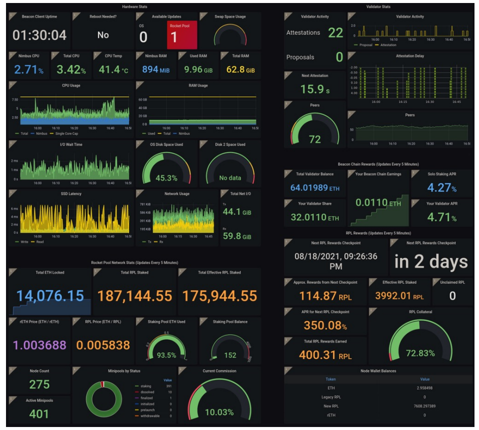


- LNS manages the state of the network, has knowledge of devices active on the network and is able to handle over-the-air-activation procedure (OTAA)
- When data is received by multiple gateways, the LNS can also de-duplicate this data
- When a message needs to be sent back to a device, the LNS forwards it to one of the gateways
- Currently, each LoRaWAN network provider will have their own LNS
  - The Packet Forwarder run on deployed gateways needs to identify an LNS
  - Therefore users need to be "bounded" to a particular LoRa network provider because end-devices need to be registered

TheThingNetwork (TTN)

- Popular LoRa Network Provider
- Provides the TTN Network Server





- Community-based deployment of LoRa gateways
  - User A can buy a LoRa gateway, register it and deploy it
  - User B then creates an account on TTN to register its devices
  - Messages from registered devices received by a TTN gateway will be made available for users on the TTN console

TTN user console