

THE LPWAN TECHNOLOGIES ECOSYSTEM FOR UBIQUITOUS AND MASSIVE IOT

KEYNOTE AT EDIS'2026
NOV. 2nd, 2026

IOT-SENSING-SYSTEM

Internet-of-Things and Sensing System Research Activities at University of Pau, France

Prof. Congduc Pham

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

Université de Pau, France

Congduc.Pham@univ-pau.fr



European Commission | Horizon 2020 European Union funding for Research & Innovation

WAZIUP

WAZIHUB

IoT – from idea to reality

HUBiquitous

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

PRIMA

PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Intel-IrriS

RESILINK

Advanced and disruptive IoT/AI technologies targeting the smallholder community for increased resilience

FRANCE 2030 | PROGRAMME DE RECHERCHE AGROÉCOLOGIE ET NUMÉRIQUE | anr

AgriFutur

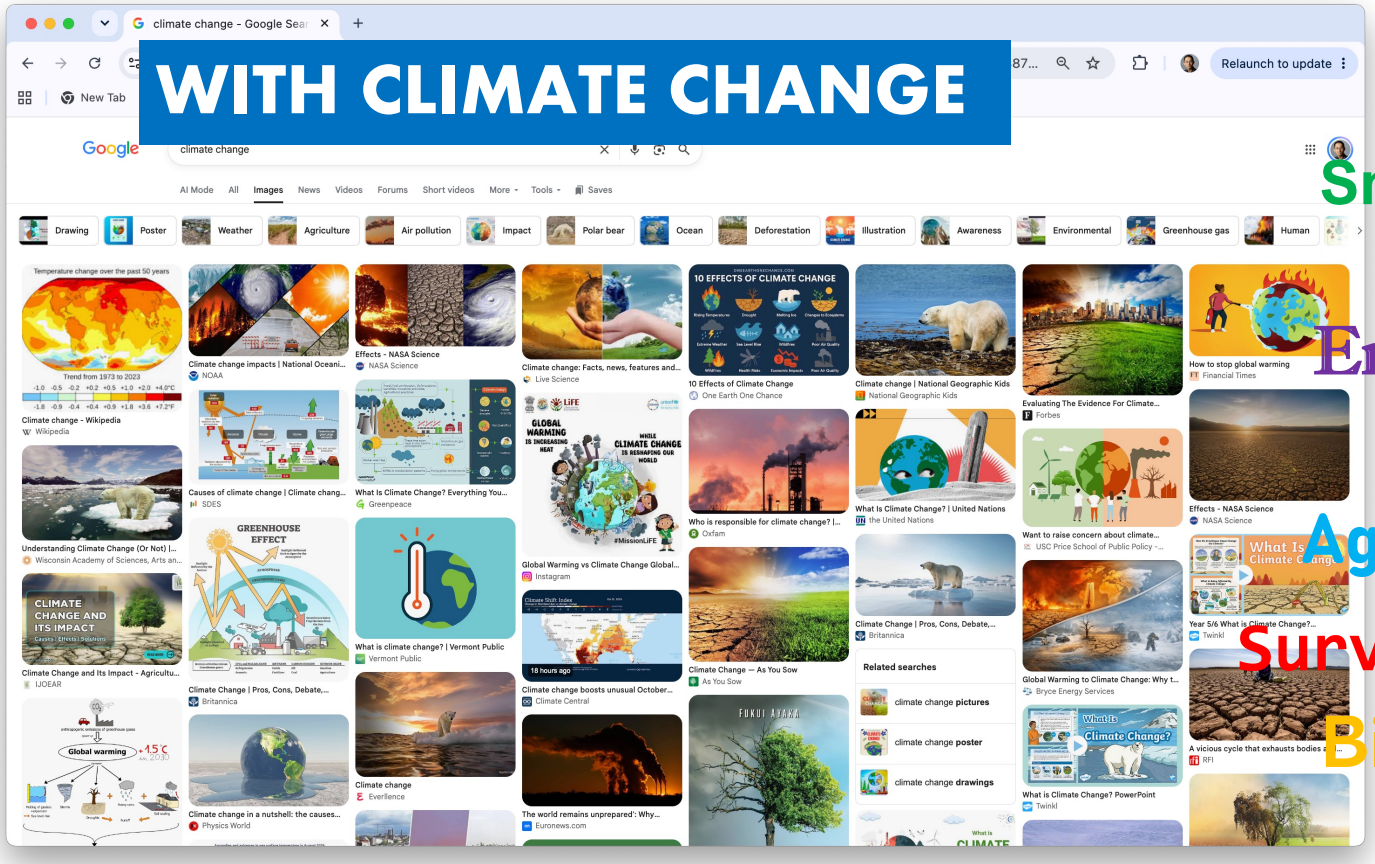
Wireless Sensors Made Simple for agroecology & sustainable agriculture

“UBIQUITOUS & MASSIVE IOT”?



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

“UBIQUITOUS & MASSIVE IOT”?



Small-scale agriculture

Environment

Wildlife

Agroecology

Surveillance

Biodiversity

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AGRI FUTUR
Toward Future Agroecology
Technological Integration and Ecosystem Modeling for Adaptive Management

FRANCE 2030 PROGRAMME DE RECHERCHE AGROÉCOLOGIE ET NUMÉRIQUE

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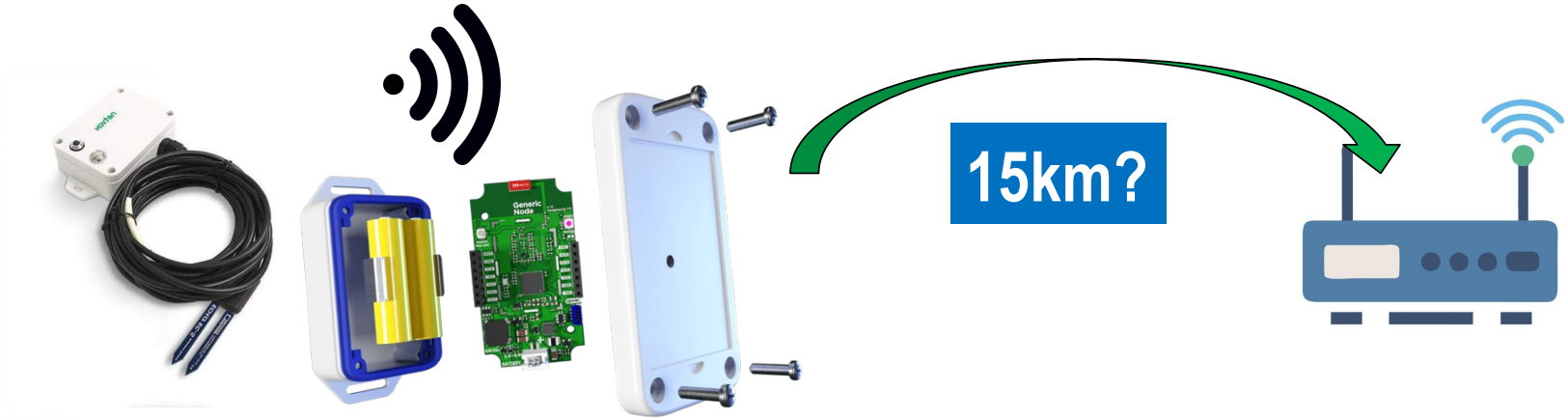
"UBIQUITOUS & MASSIVE IOT"?



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Energy – Range dilemma

ENERGY **RADIO RANGE**



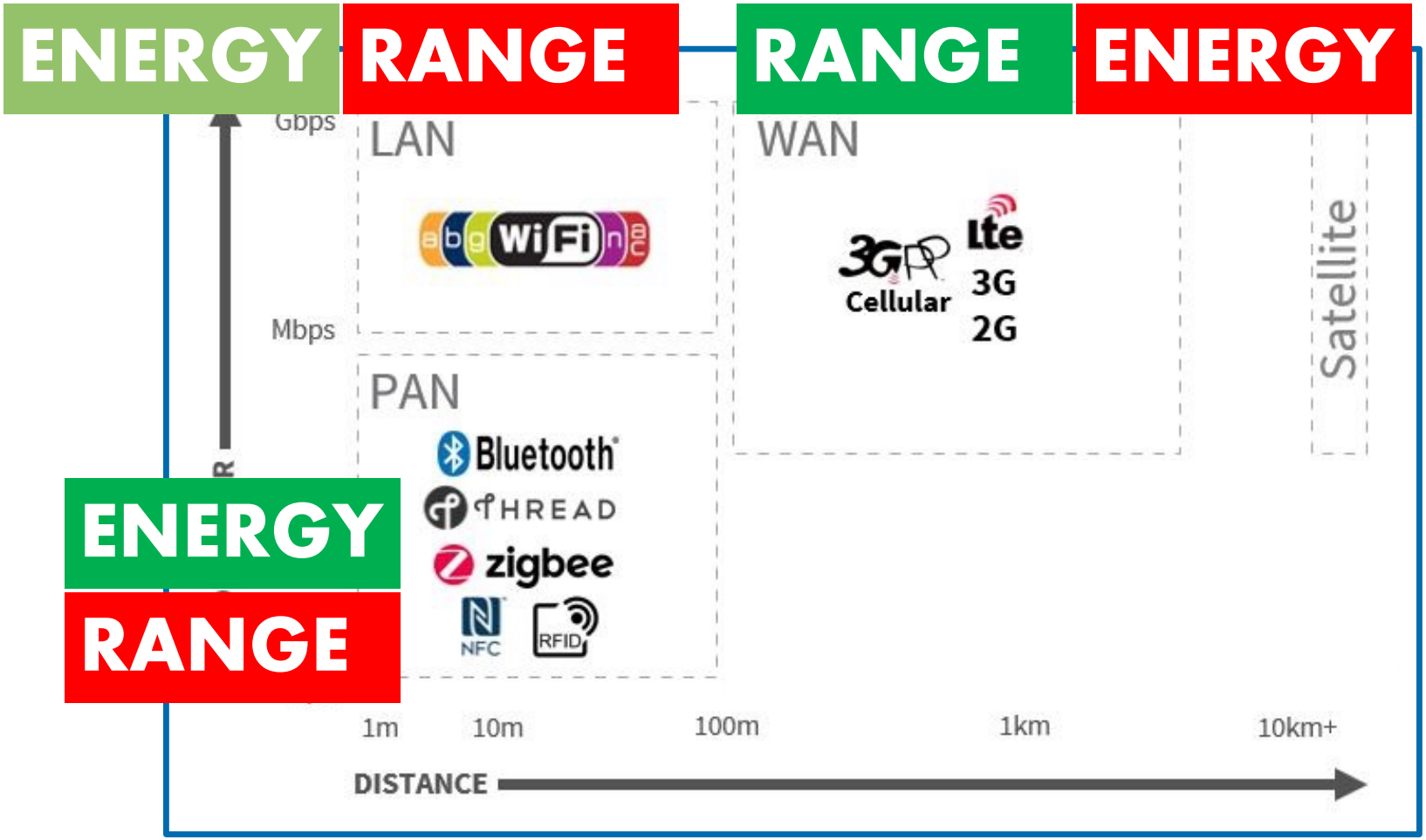


2500mA

CAN WE HAVE SEVERAL YEARS OF AUTONOMY?

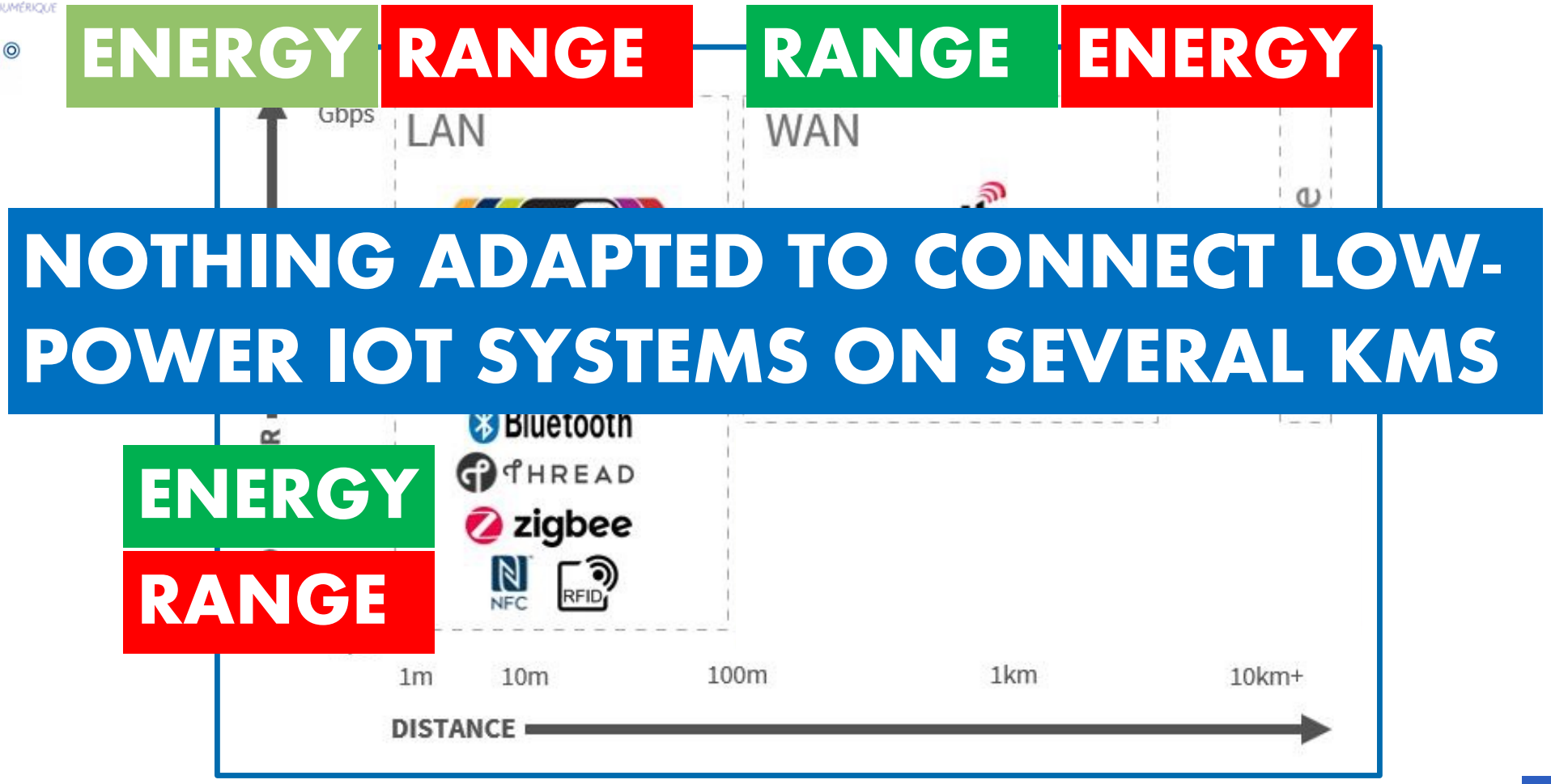
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Wireless technologies



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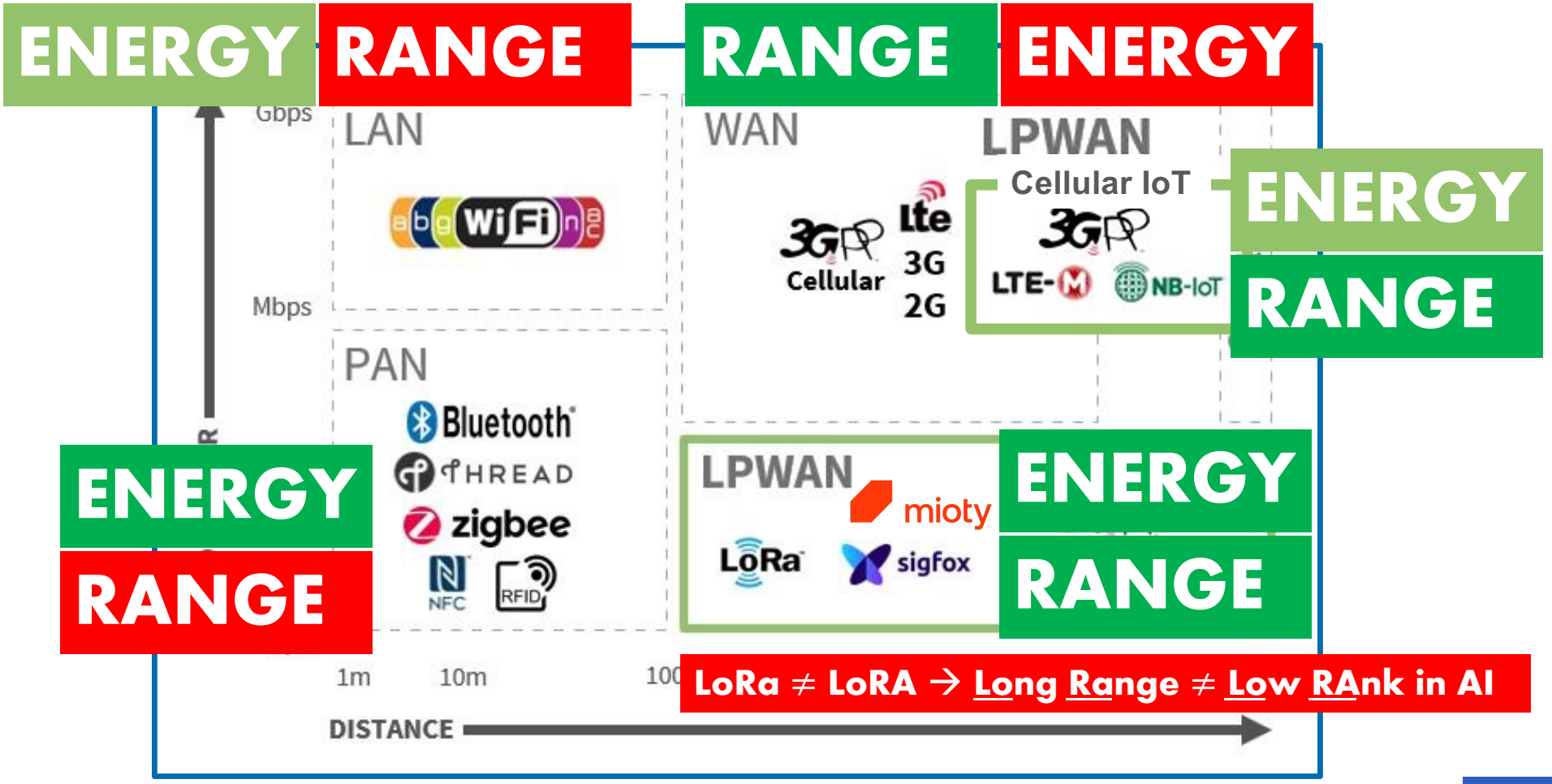
Wireless technologies



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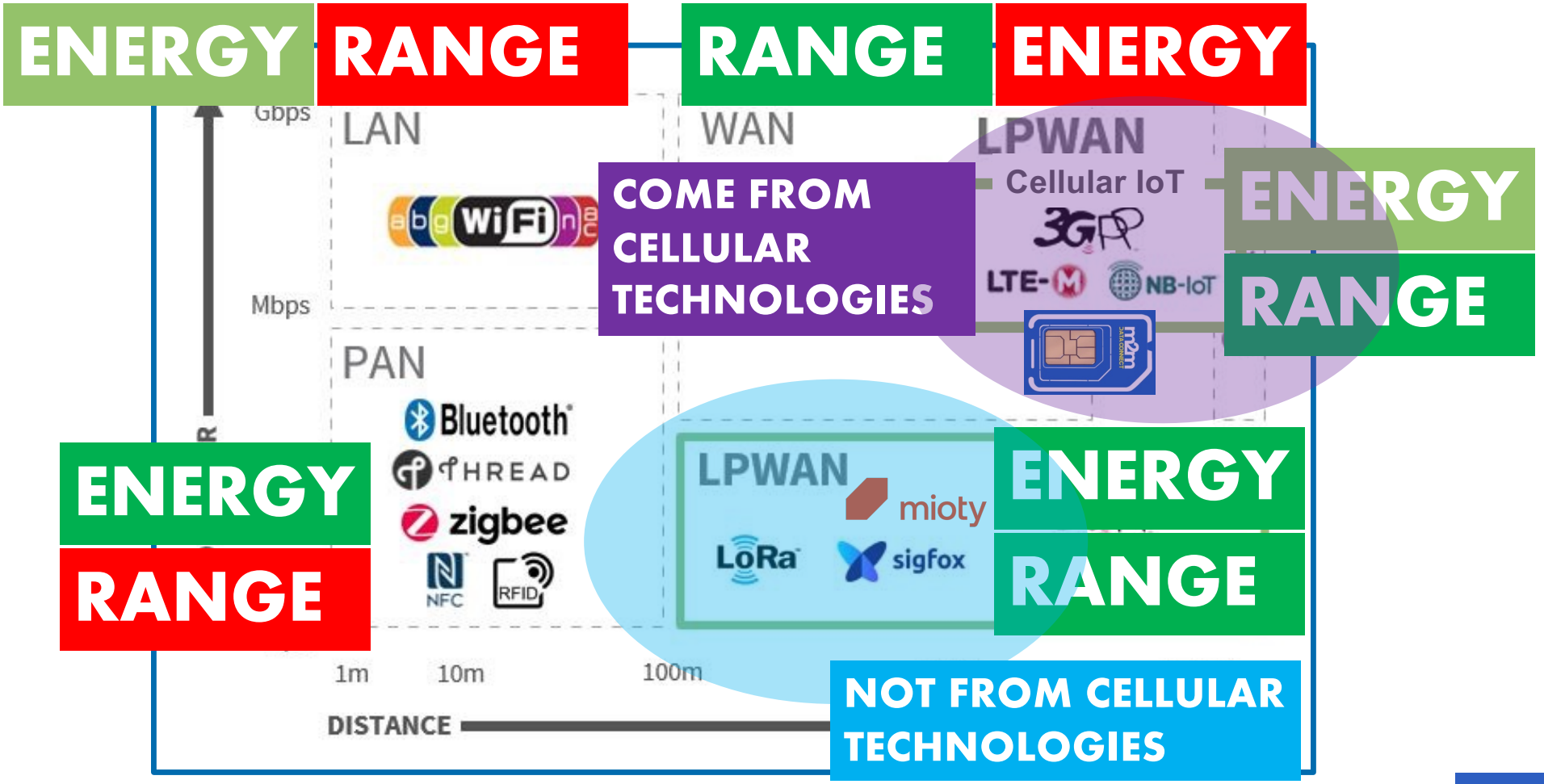
From 2015: LPWAN!

Low Power Wide Area Network



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From 2015: LPWAN! Low Power Wide Area Network



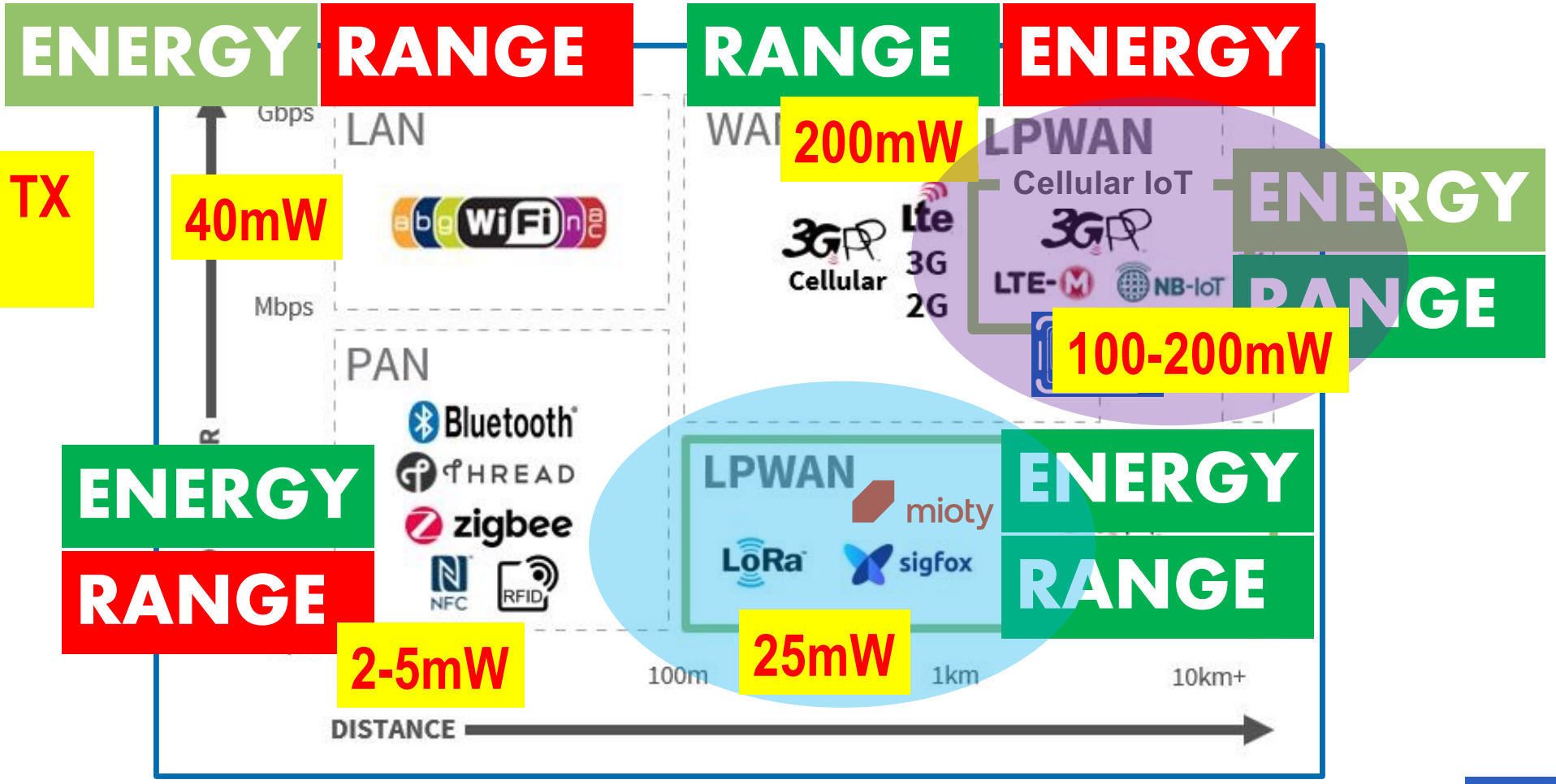
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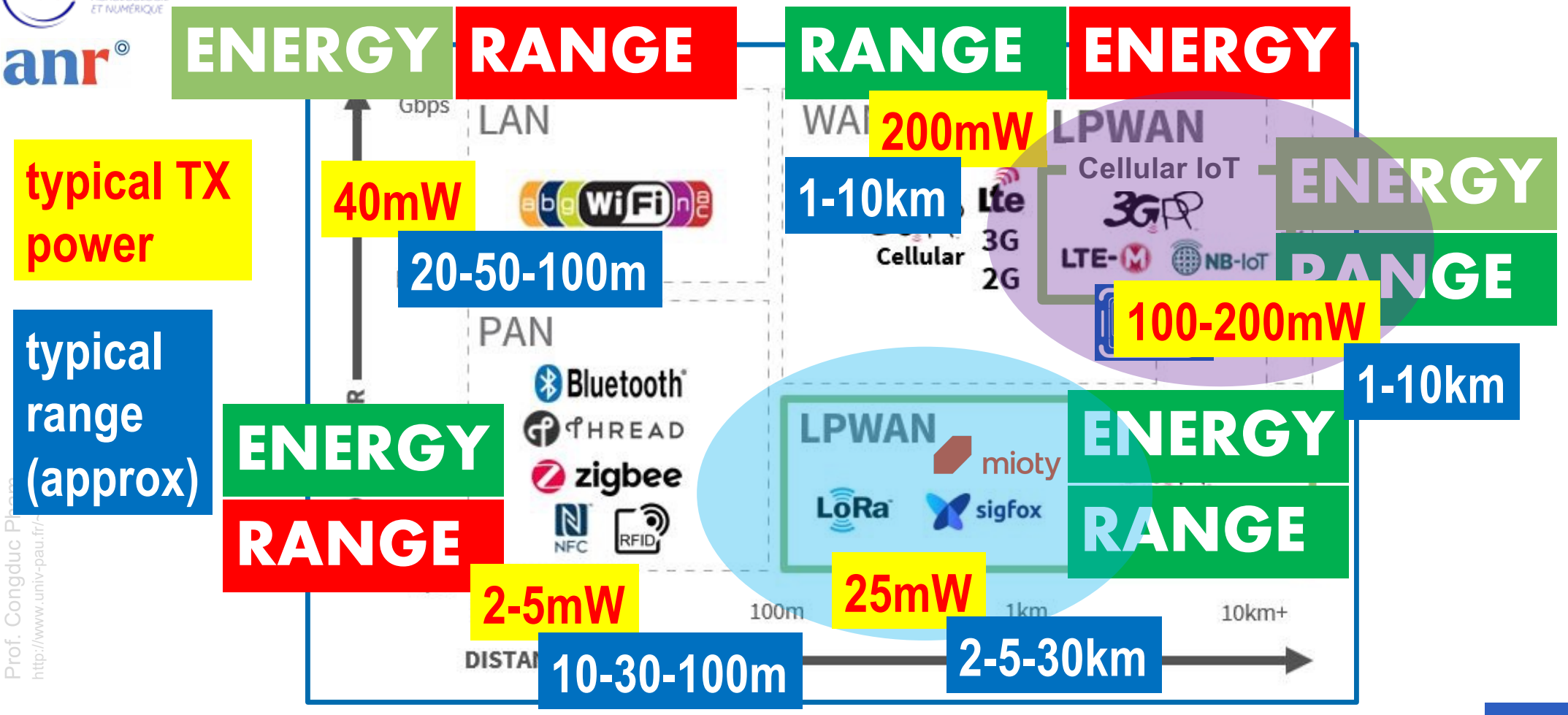
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LOW POWER Wide Area Network : how low?



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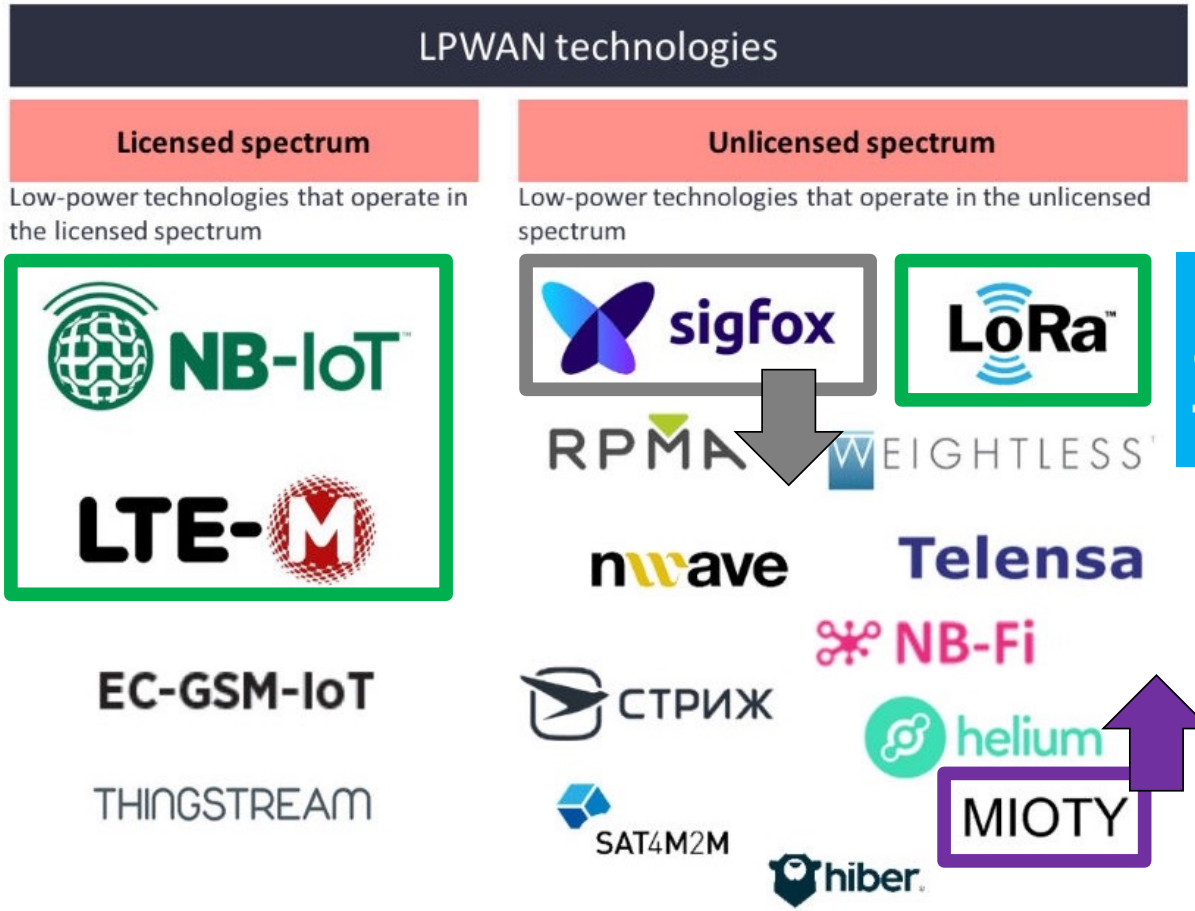
Low Power WIDE AREA NETWORK : what range?



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The leaders…
and the other technologies





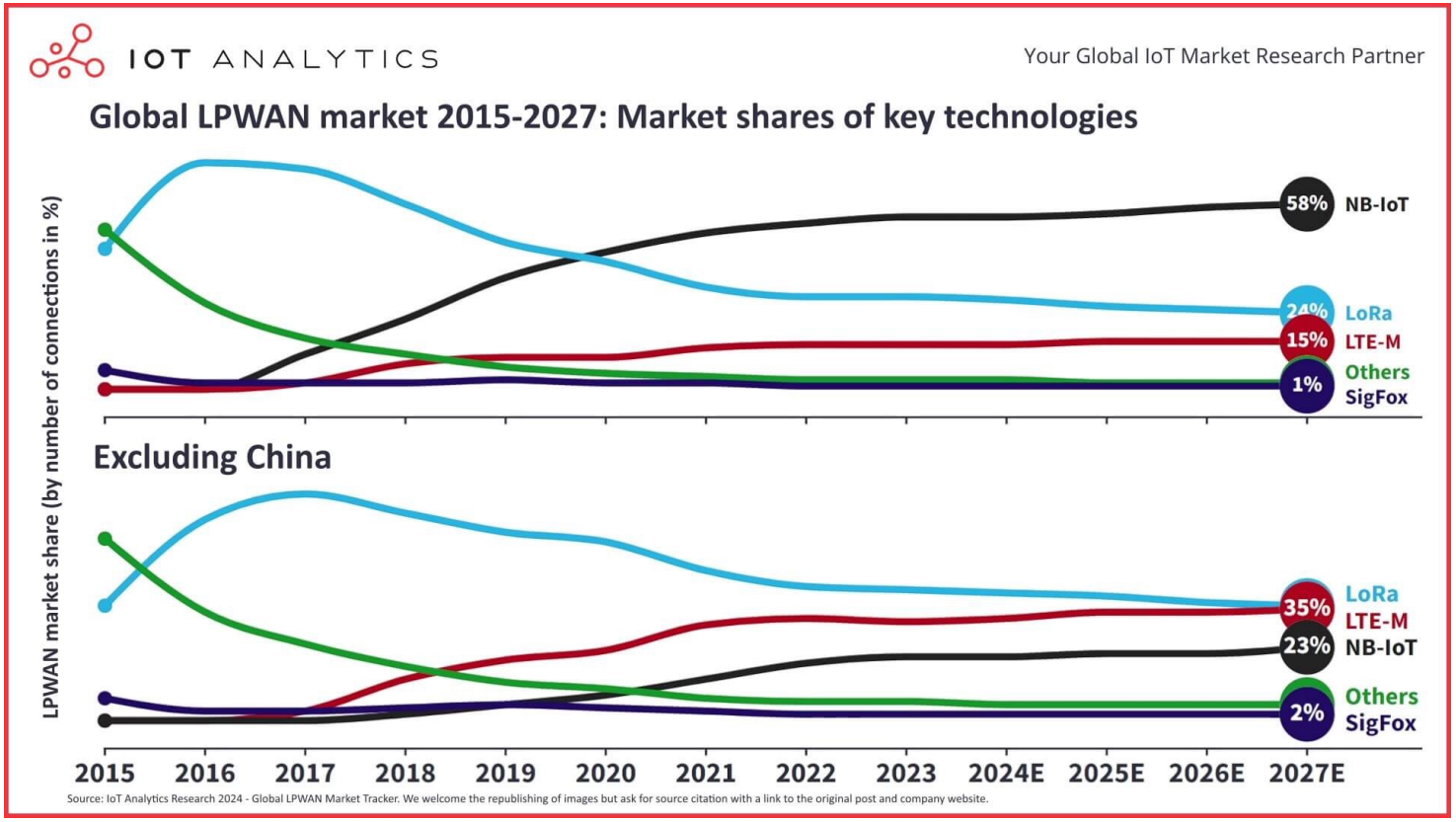
COME FROM CELLULAR TECHNOLOGIES

NOT FROM CELLULAR TECHNOLOGIES

Source: IoT Analytics LPWAN Market Report 2018 - 2023

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2026: the 3 that counts!





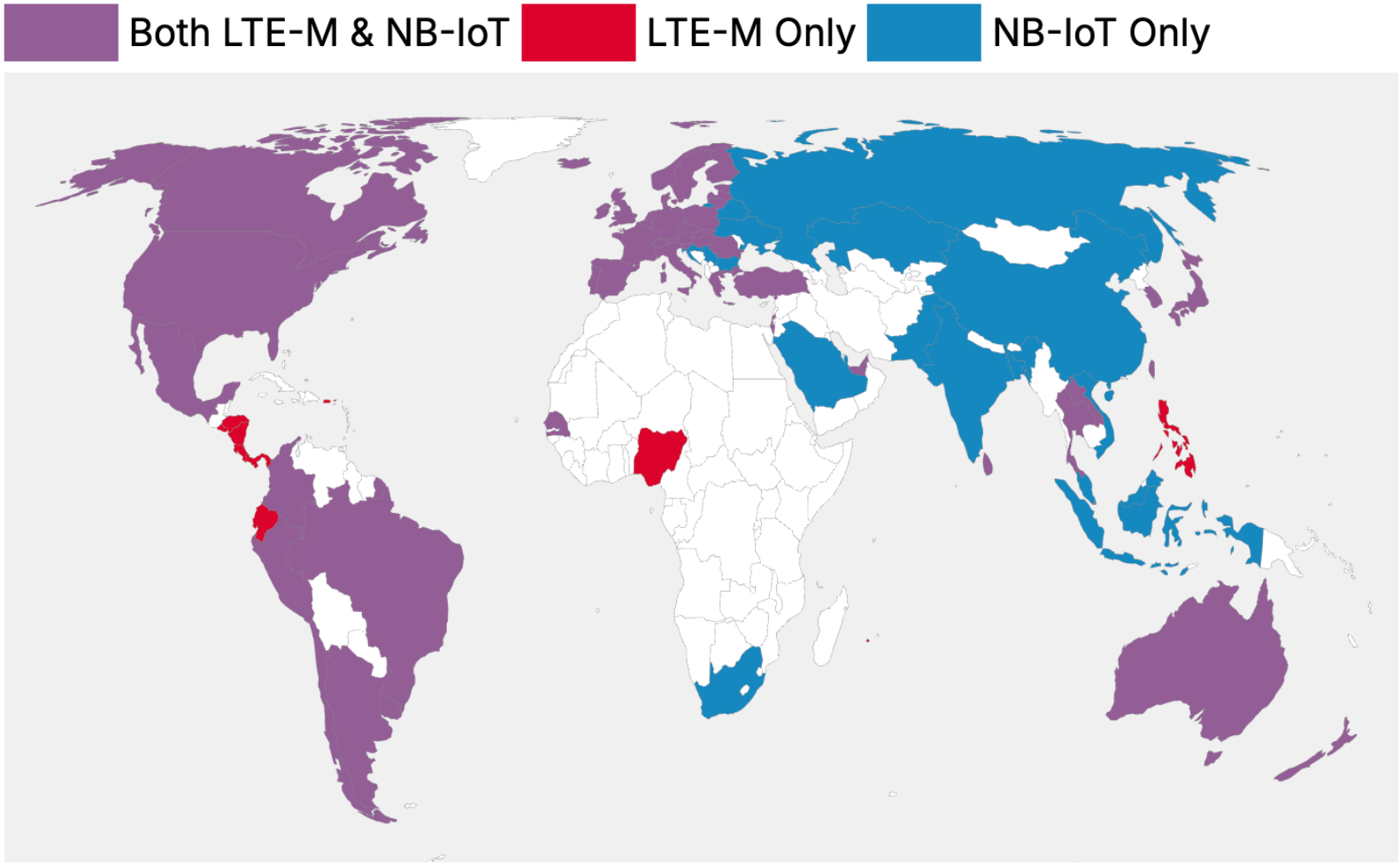






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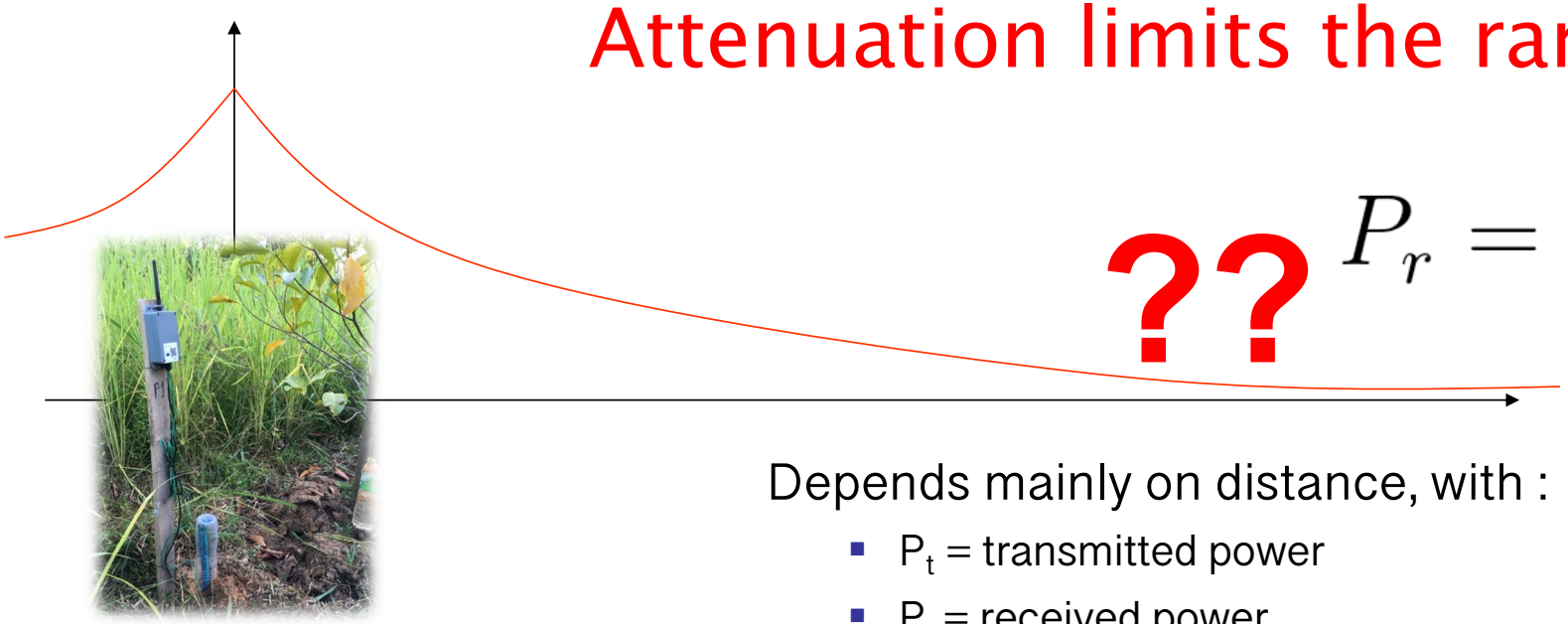
LTE-M and NB-IoT: not everywhere…



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LPWAN: attenuation is the main challenge!

X watts



Attenuation limits the range!

??

$$P_r = \frac{P_t}{d^\alpha}$$

Depends mainly on distance, with :

- P_t = transmitted power
- P_r = received power
- d = distance between antennas
- α from 2 to 4

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Wireless attenuation, let's take a quizz!

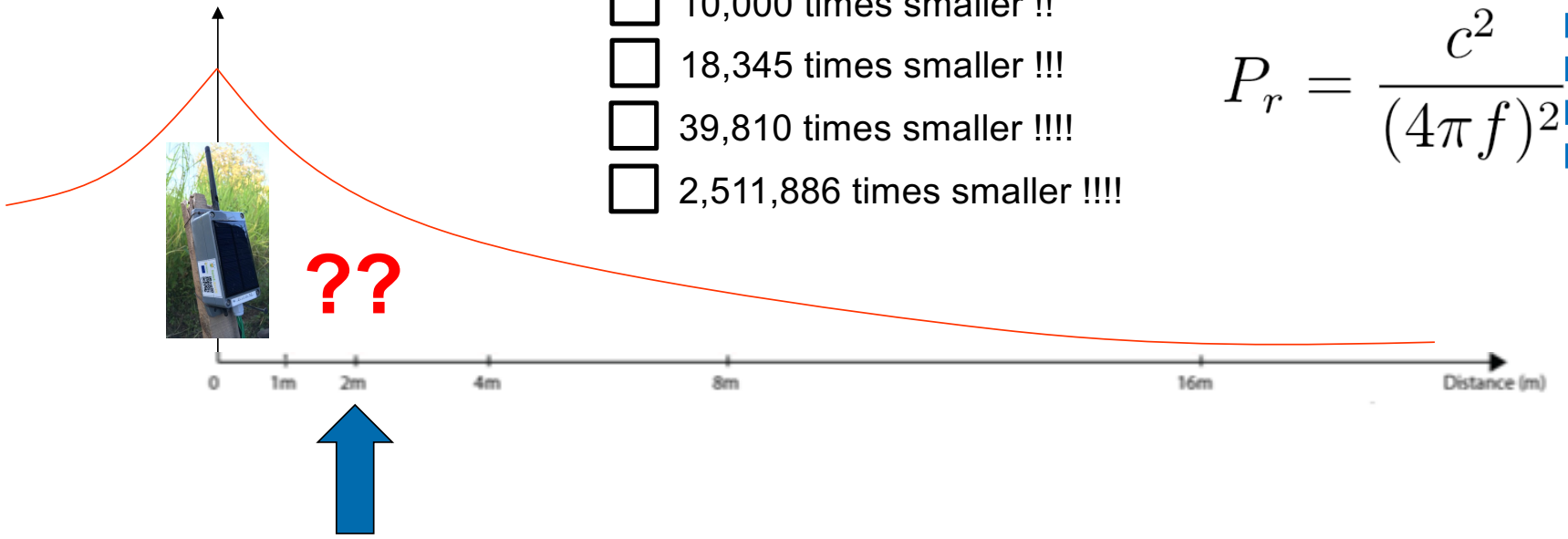
FOR A 2.4GHZ SIGNAL AT 2m

25mW

- ☐ 3,500 times smaller !
- ☐ 10,000 times smaller !!
- ☐ 18,345 times smaller !!!
- ☐ 39,810 times smaller !!!!
- ☐ 2,511,886 times smaller !!!!

Free Space Path Loss model

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



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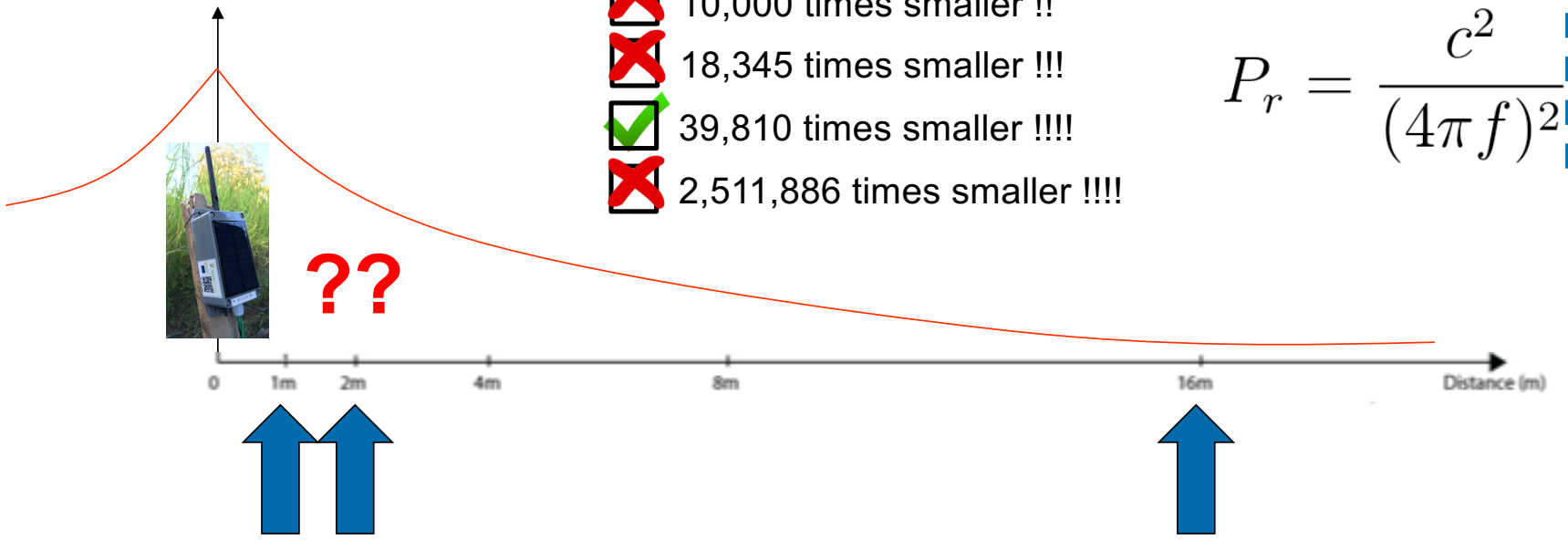
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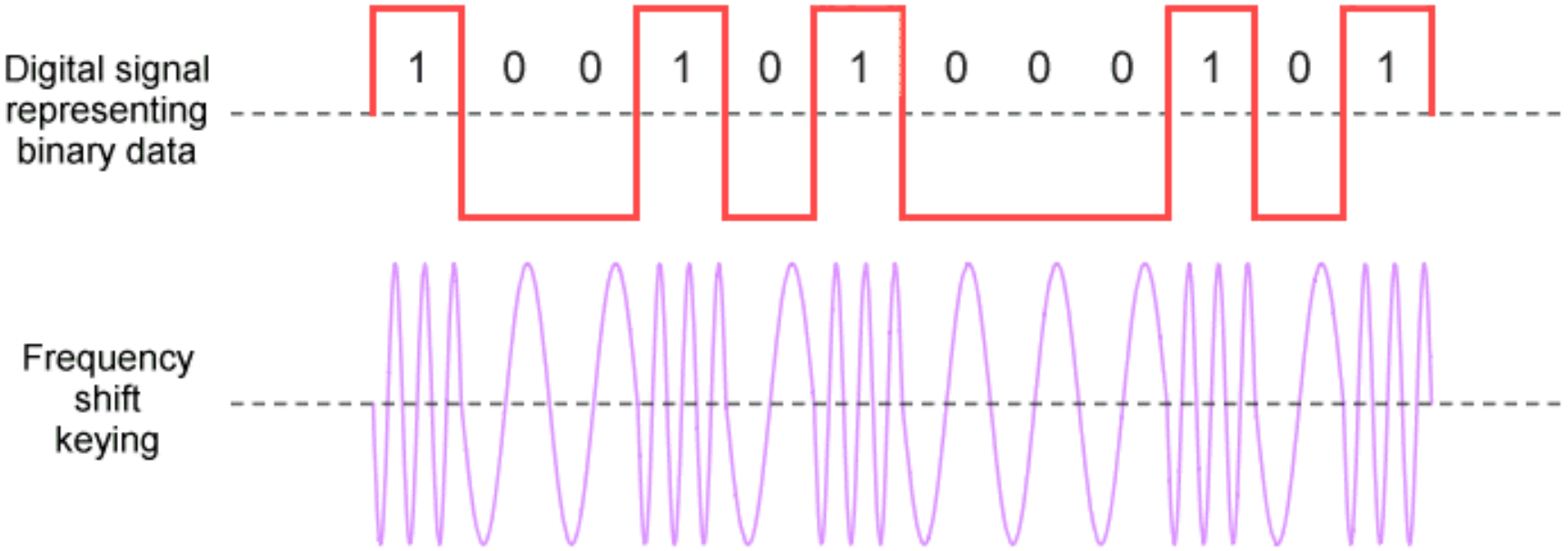
0.0025mW x10,000 smaller!

0.00062mW x39,810 smaller!

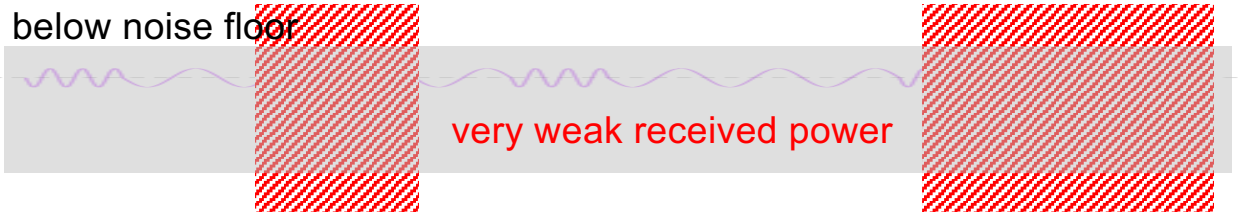
0.0000099526mW x2,511,886 smaller!

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Attenuation in image – simplified



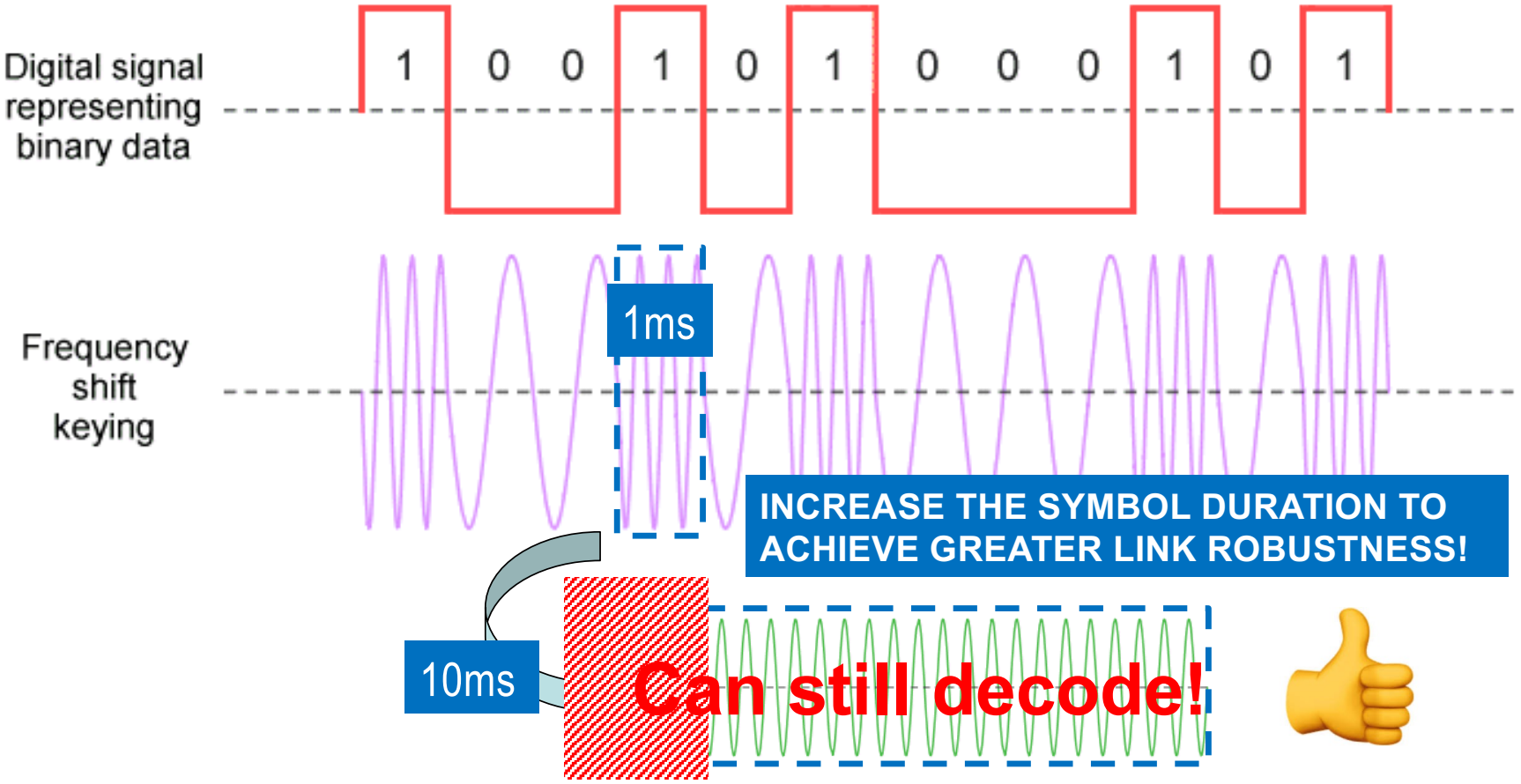
LOT'S OF ATTENUATION!!!



???

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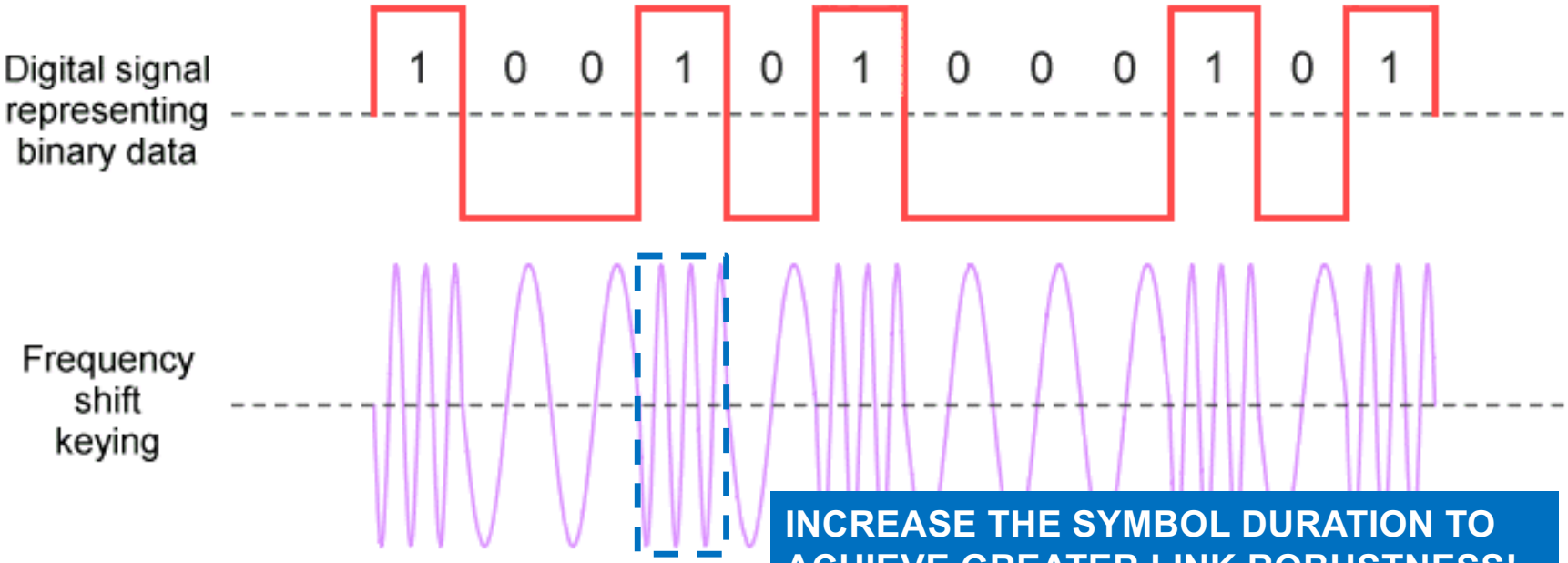
Increase receiver sensitivity?



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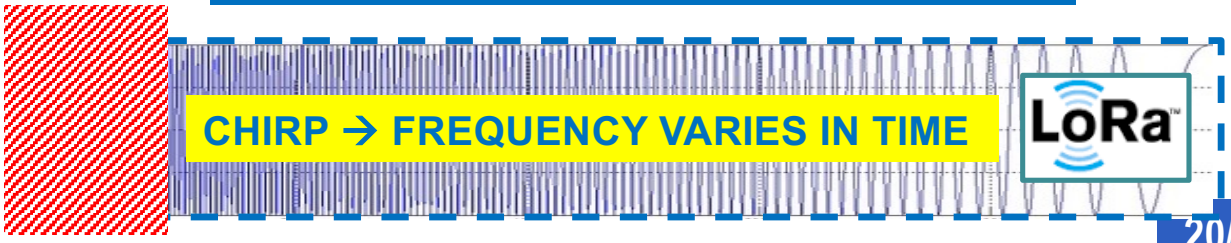
Chirp for even more robustness!





INCREASE THE SYMBOL DURATION TO ACHIEVE GREATER LINK ROBUSTNESS!

Immunity to Interference & Jamming
Resistance to Multipath Fading
Doppler Shift Tolerance

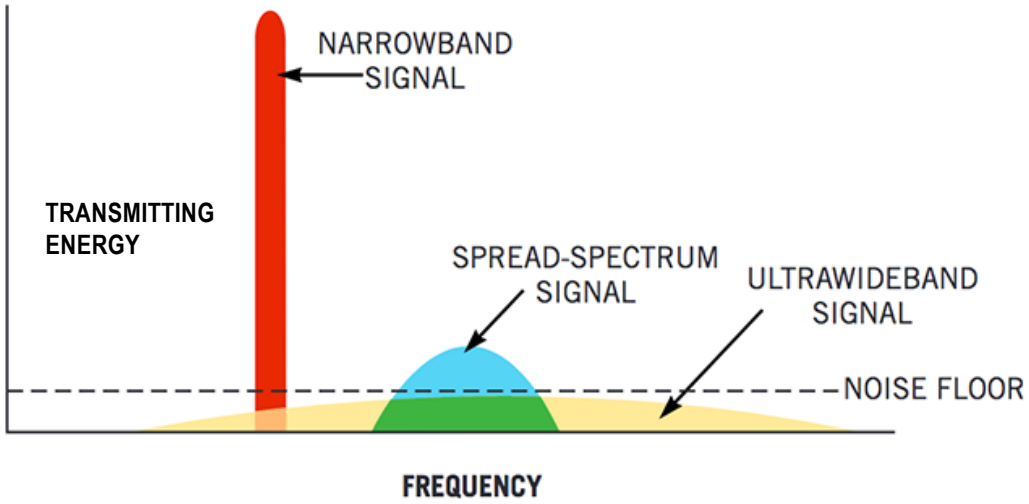


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Another solution: BE INVISIBLE!

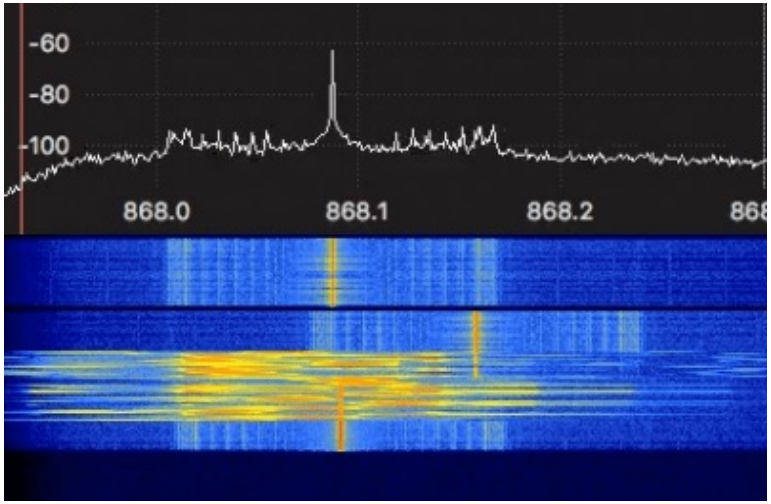


- Ultra-narrow band (UNB) of about only 100Hz (e.g. SIGFOX)
- **But decoding is much more complex…**



Credit: https://www.edn.com/ultrawideband-the-next-wireless-panacea/

Credit: disk91.com – the IoT blog



100Hz → 1250 times smaller!

LoRa 125000 Hz

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ALMOST INVISIBLE: where to search?

- Decoding is much more complex
- The "needle in a haystack" problem
- You need to have some clue
  - Top? Bottom?
  - Left? Right?
  - Middle?

- Sigfox base stations operate with very wideband receivers (typically tens of kHz to several MHz).
- **Continuously monitor the whole usable ISM band → need high-end & costly hardware!**



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Time matters!

- Decoding is much more complex
- The "needle in a haystack" problem
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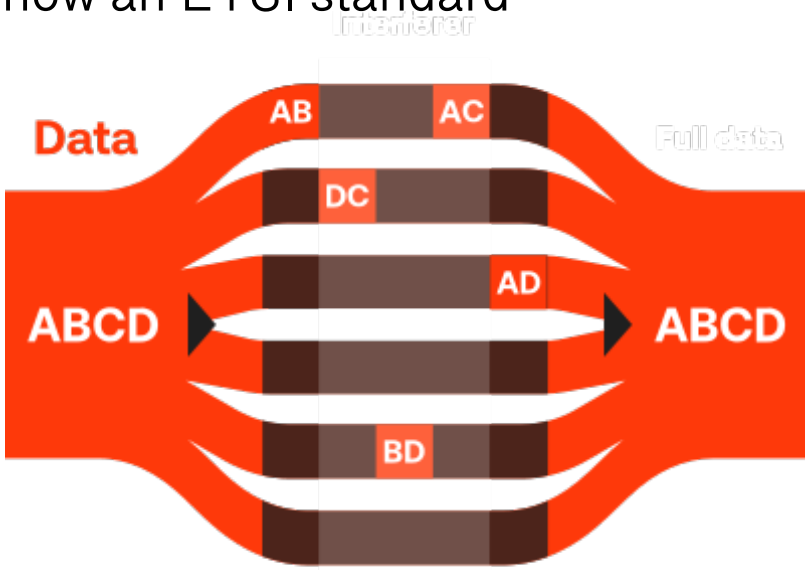
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Distribute AND try to be invisible!



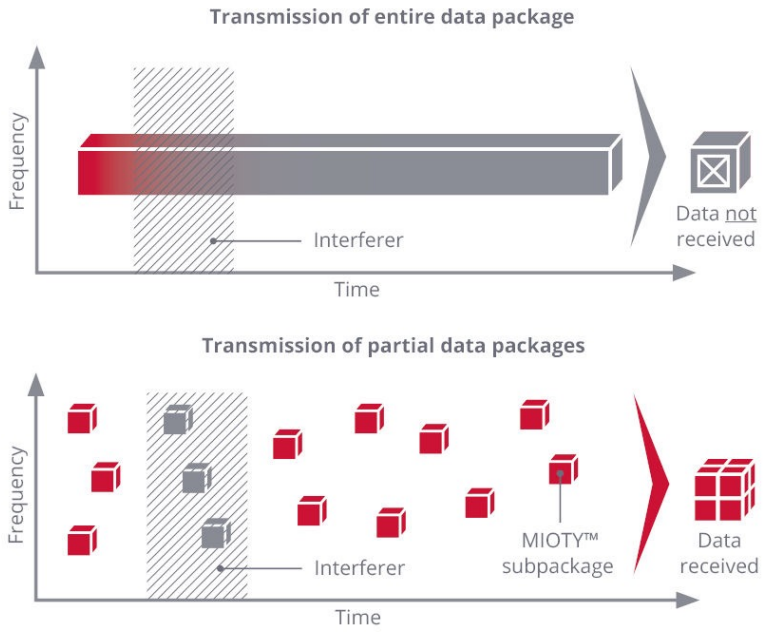
- A new comer: mioty technology based on Telegram-Splitting-UNB
- Developed by Fraunhofer IIS – now an ETSI standard

mioty



ADD REDUNDANCY FOR MORE ROBUSTNESS

subpackets



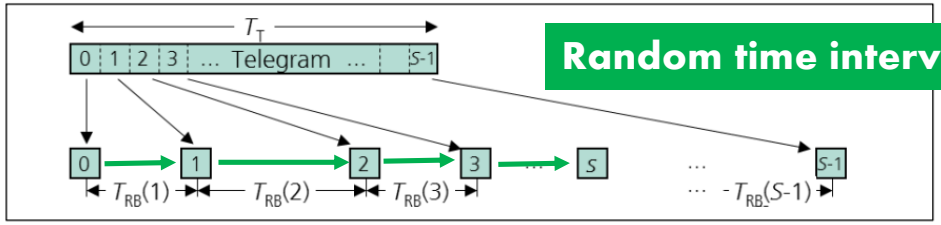
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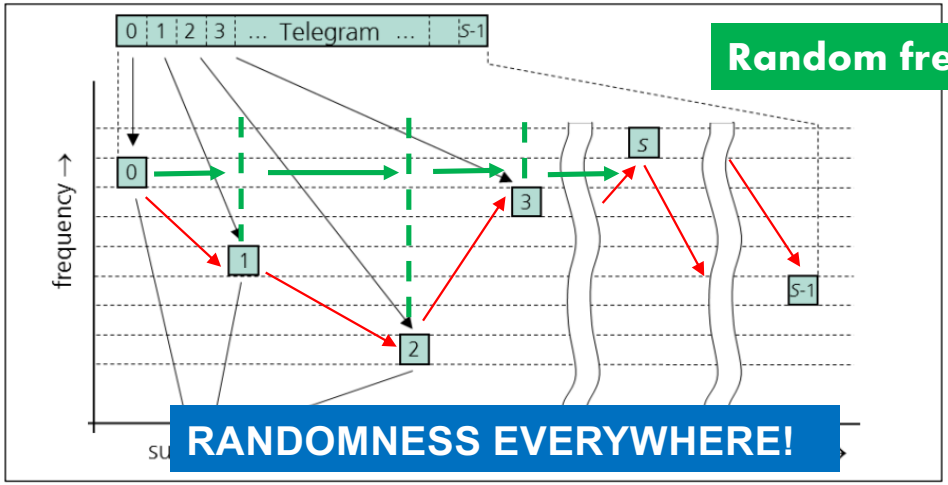
Telegram-Splitting



- Random time intervals & frequency carriers
- **Decoding is more complex…but mioty uses 8 pre-defined time-freq patterns**

- **Packet (telegram) split into a minimum of 24 burst (core frame)**
- **Each burst is sent on a different frequency (up to 34)**
- **Each burst is separated from the others by a certain time**
- **Each burst includes 1/3 of sync data (but no identification)**
- **Information is triplicated to support collision**
- **Creates time and frequency diversity with redundancy**

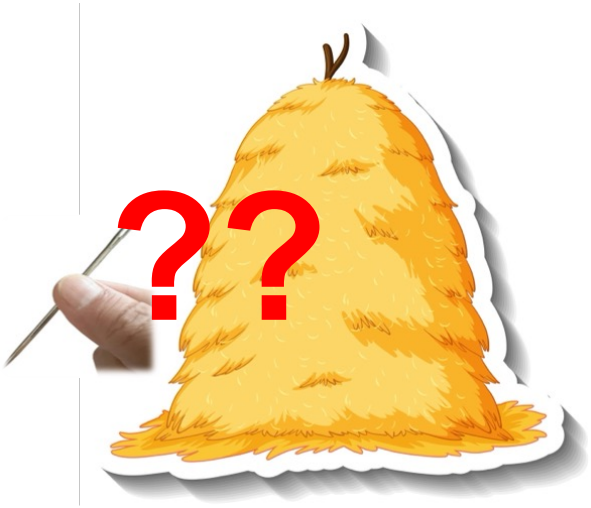


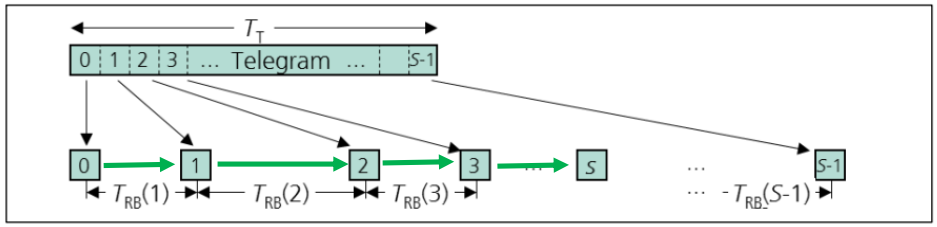


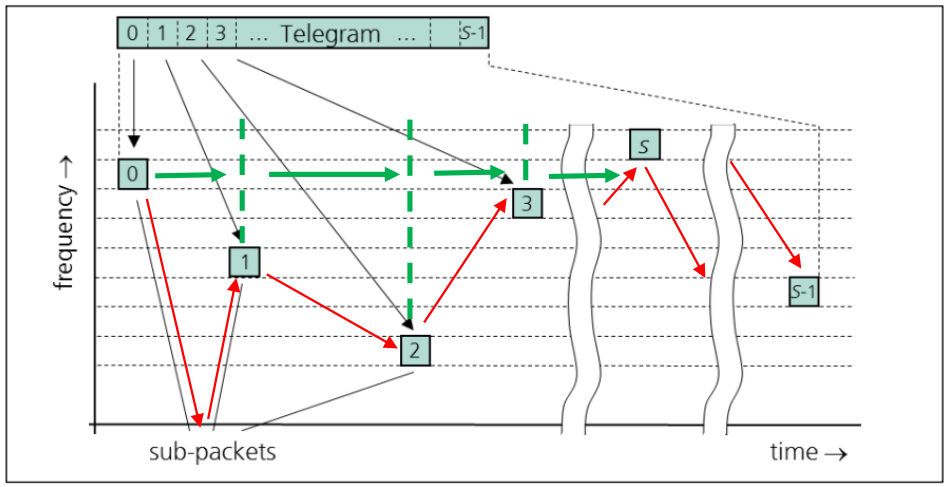
Author – Paul Pinault / Disk91.com
Prof. Congduc Pham
http://www.univ-pau.fr/~cpham

Needle in a haystack?

- mioty uses TS-UNB, so do we have the "needle in a haystack" issue?
- mioty uses time and frequency diversity

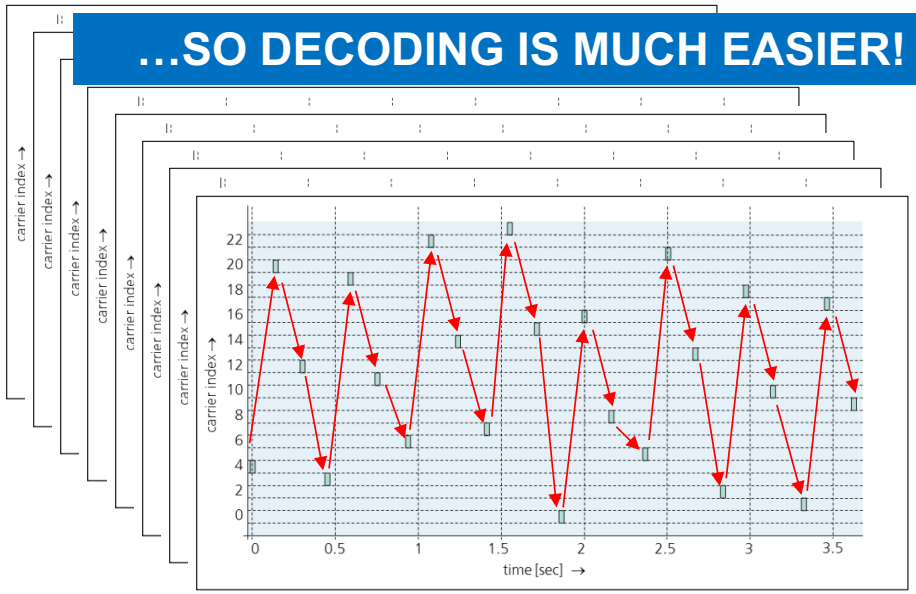






BUT USES 8 PRE-DEFINED PATTERNS

...SO DECODING IS MUCH EASIER!



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LoRa, Sigfox, mioty: common point?

- LoRa: Spread Spectrum with innovative use of chirp signals
- Sigfox: Ultra-Narrow-Band with complex decoders
- mioty: Ultra-Narrow-Band + Telegram Splitting

WHY ALL THESE HASSLES?

BECAUSE THEY USE UNLICENSED BANDS!

AND SO?

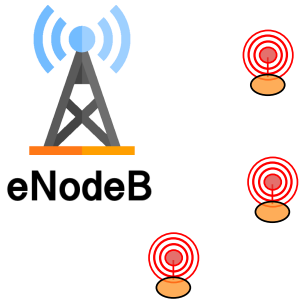
ANYBODY CAN USE THESE BANDS, NEED TO BE MORE ROBUST & SMARTER!

WHAT IF LICENSED BAND?

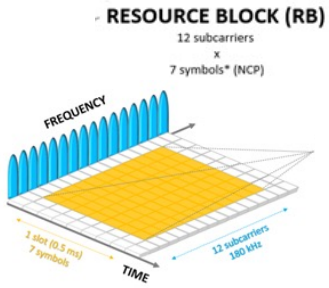
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NB-IoT & LTE-M solutions

LICENSED BAND!



- Coming from **mobile cellular**, they operate in **licensed bands** assigned to operators
  - → Can transmit at higher power e.g. **200mW** instead of 25mW
- They use **scheduled** channel access
  - → Devices **cannot transmit whenever they want**
  - → **eNodeB assigns radio resources** and transmission times
  - → When, how long, and on which subcarriers (e.g. frequency)



LTE-M is optimized for mobile, higher-data, low-latency IoT with support for voice and handover→ ~lightweight 4G for IoT

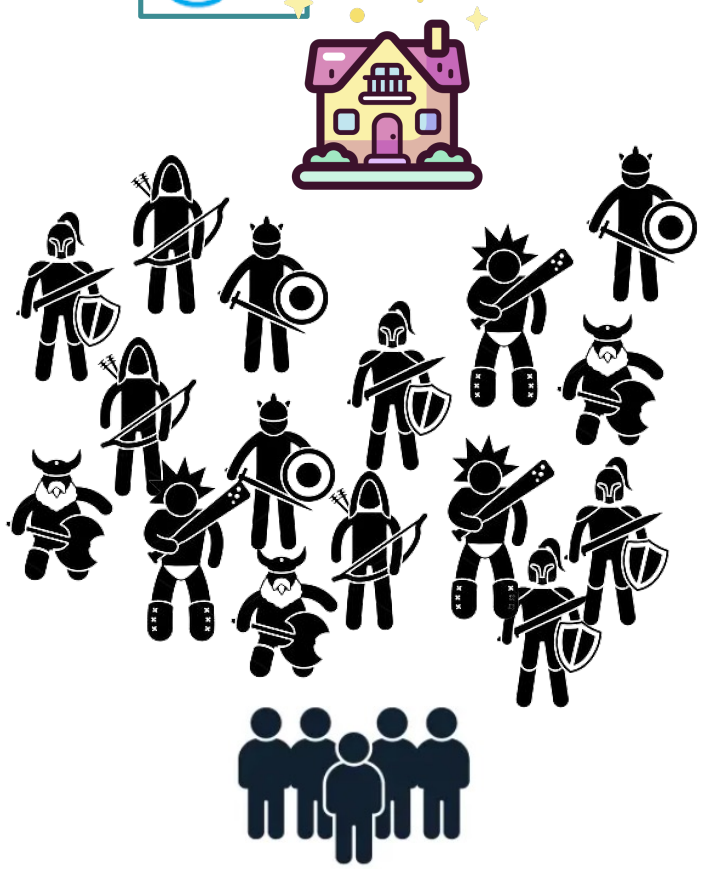
NB-IoT is optimized for massive, deep-coverage, low-power, low-data, static IoT → specifically designed for IoT

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Non-cellular vs Cellular

UNLICENSED BAND!

LoRa SIGFOX mioty



LICENSED BAND!

LTE-M NB-IoT

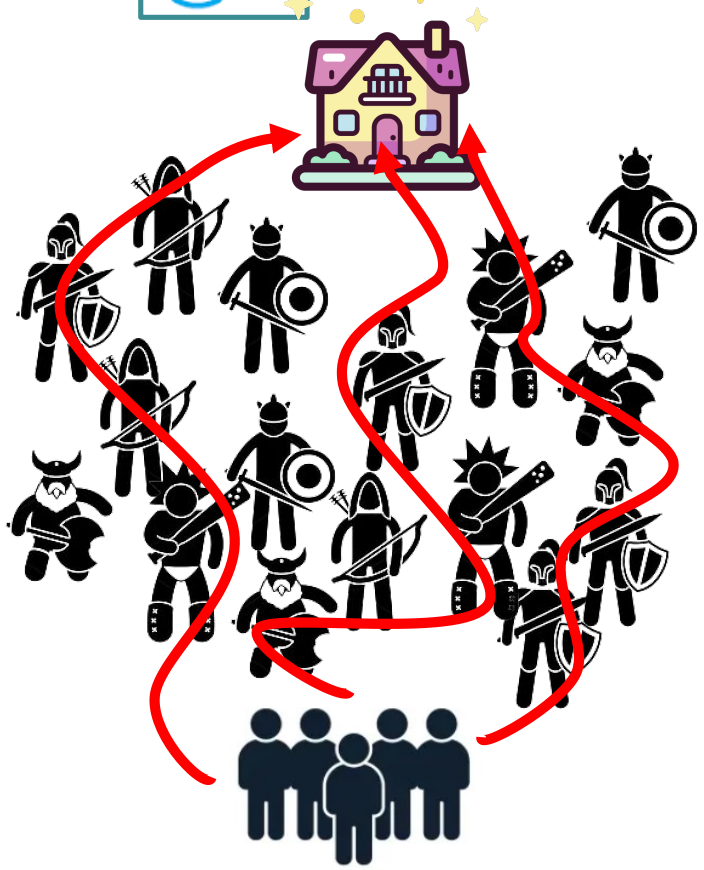


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LICENSED BAND!

LTE-M NB-IoT





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UNLICENSED BAND!

LoRa SIGFOX mioty

LICENSED BAND!

LTE-M NB-IoT



You need innovative tricks, including camouflage!

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Non-cellular vs Cellular

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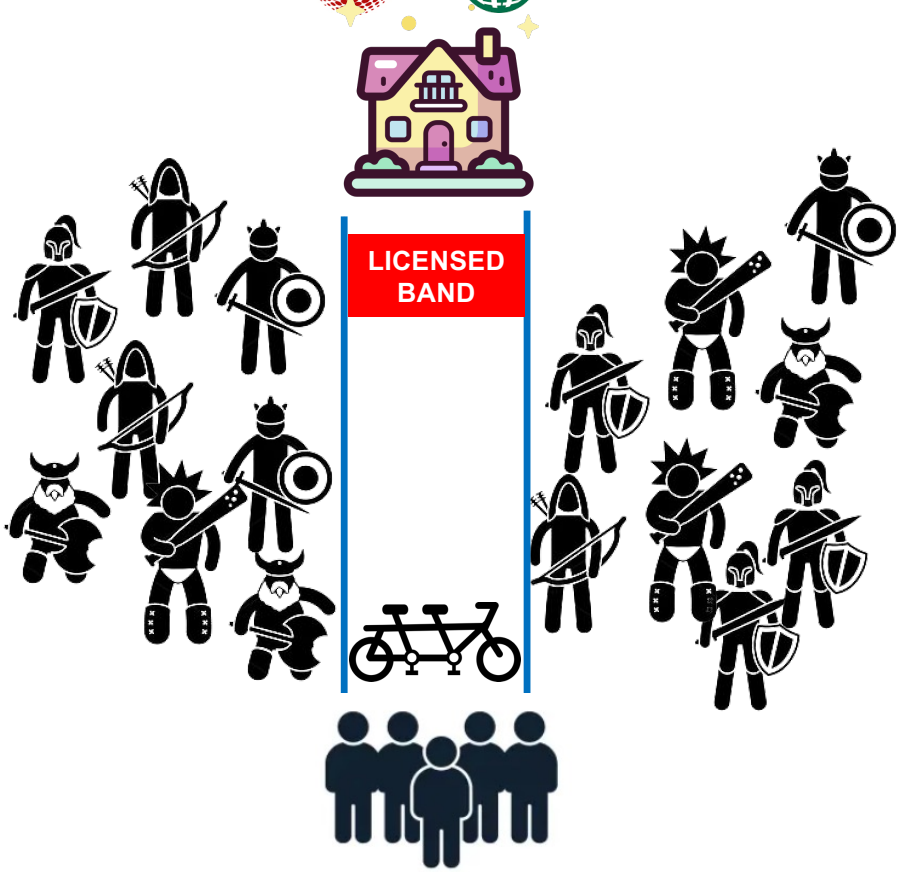
LoRa SIGFOX mioty



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Non-cellular vs Cellular

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LoRa™ SIGFOX mioty



You need innovative tricks, including camouflage!

LICENSED BAND!

LTE-M NB-IoT



You can use standard methods and make them low-power

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Understanding commercial IoT specs



WEENAT https://weenat.com/en/sensors/



Sonde Capacitive

Pilotage de l'irrigation



Sonde de Fertirrigation

Irrigation et nutriments



Anémomètre

Météo connectée



Capteur gel

Protection des cultures

Sending data to the Weenat application

Sensor data is transmitted in near real-time via low-speed Sigfox, LoRa or LTE-M NB-IoT (4G / 5G) networks, which are energy-efficient.

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LoRa vs mioty vs LTE-M vs NB-IoT

Dominant in

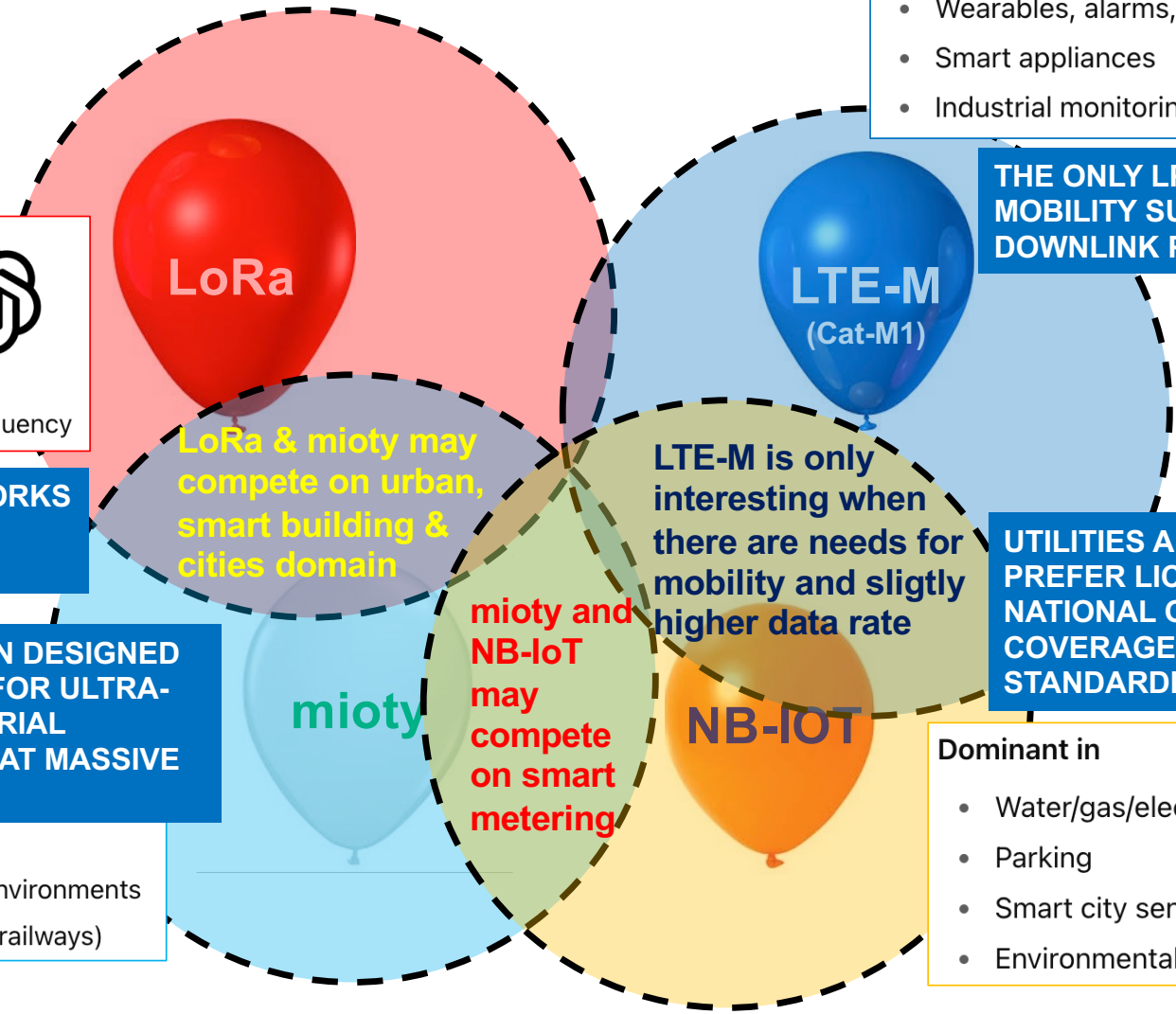
- Agriculture
- Municipal or campus networks
- Smart buildings
- Logistics sensors with low message frequency

EASY TO DEPLOY, PRIVATE NETWORKS LOW COST, AND FLEXIBILITY THAT OPERATORS CANNOT MATCH

Dominant in

- Oil & gas
- Mining
- Industry 4.0
- High-noise or high-interference environments
- Large-area monitoring (pipelines, railways)

THE ONLY LPWAN DESIGNED FROM DAY ONE FOR ULTRA-ROBUST INDUSTRIAL ENVIRONMENTS AT MASSIVE SCALE



Dominant in

- Trackers (logistics, pets, assets)
- Wearables, alarms, emergency devices
- Smart appliances
- Industrial monitoring requiring more data

THE ONLY LPWAN WITH REAL MOBILITY SUPPORT AND DOWNLINK PERFORMANCE

UTILITIES AND GOVERNMENTS PREFER LICENSED SPECTRUM, NATIONAL OPERATOR COVERAGE, AND LONG-TERM STANDARDIZATION

Dominant in

- Water/gas/electricity smart metering
- Parking
- Smart city sensors
- Environmental monitoring

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What your mother never told you…

- **Despites all these smart mechanisms, obtaining several kms range at low power is still very challenging!**

HIGH OVERHEAD, LOW TRANSFER EFFICIENCY!

REDUNDANCY & REPETITION FOR ROBUSTNESS

LORAWAN RECOMMENDS 2-3 REPETITIONS, SIGFOX USES 3

MIOTY'S OVERHEAD IS USUALLY 300-500%

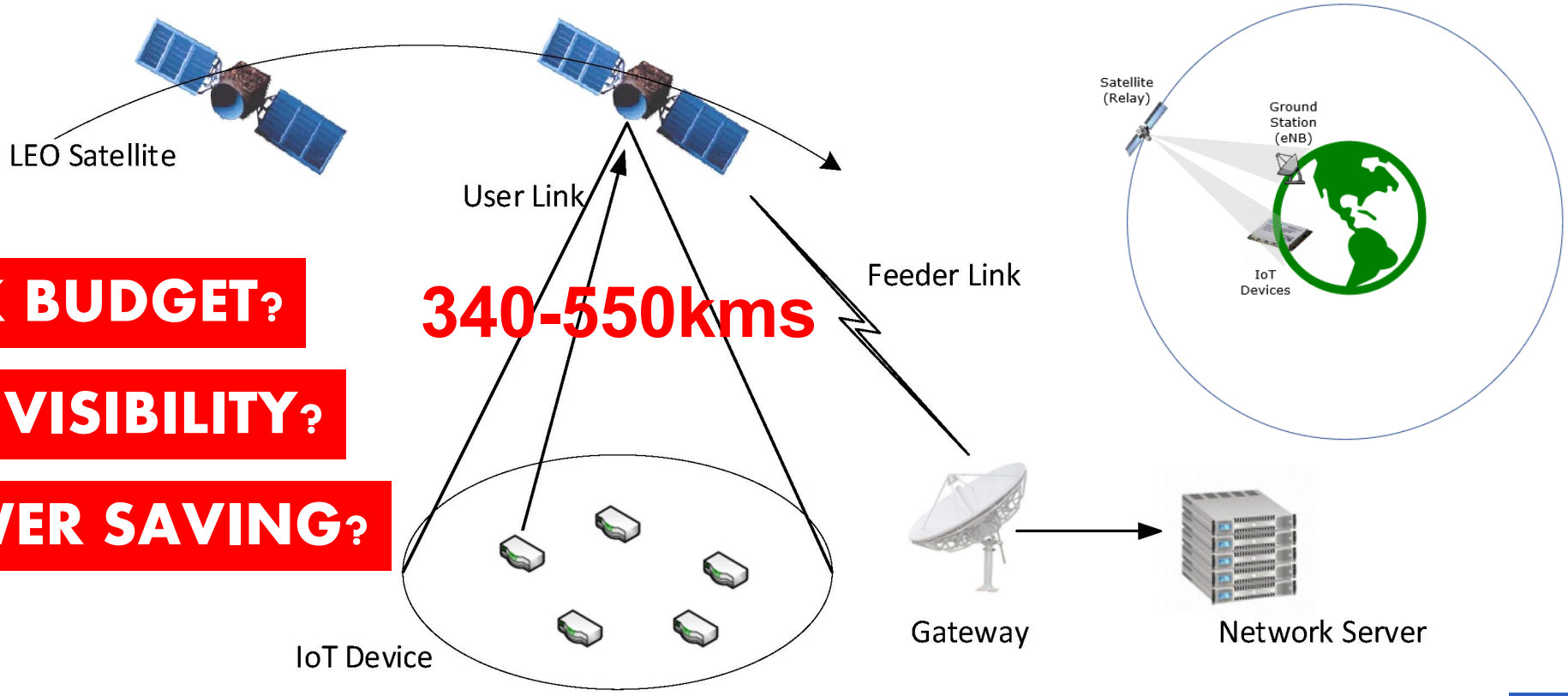
NB-IoT CAN HAVE FROM 2 TO 128 REPETITIONS (DEEP)

LTE-M CAN HAVE 2, 4 OR 8 REPETITIONS

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Really anywhere on Earth?

- Deployment of LEO satellite constellations make Satellite IoT a reality!



LINK BUDGET?

SAT. VISIBILITY?

POWER SAVING?

...

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IoT connectivity battle going to space!

- Satellites belong to so-called **Non-Terrestrial Networks** (NTN)
- **3 approaches** for Satellite IoT connectivity (mostly to LEO satellites)

1/ Use terrestrial LPWAN technologies: adaptations of terrestrial LPWAN technologies to satellite links

Direct-to-Satellite (DtS) means device → satellite

Indirect access means device → gateway → satellite

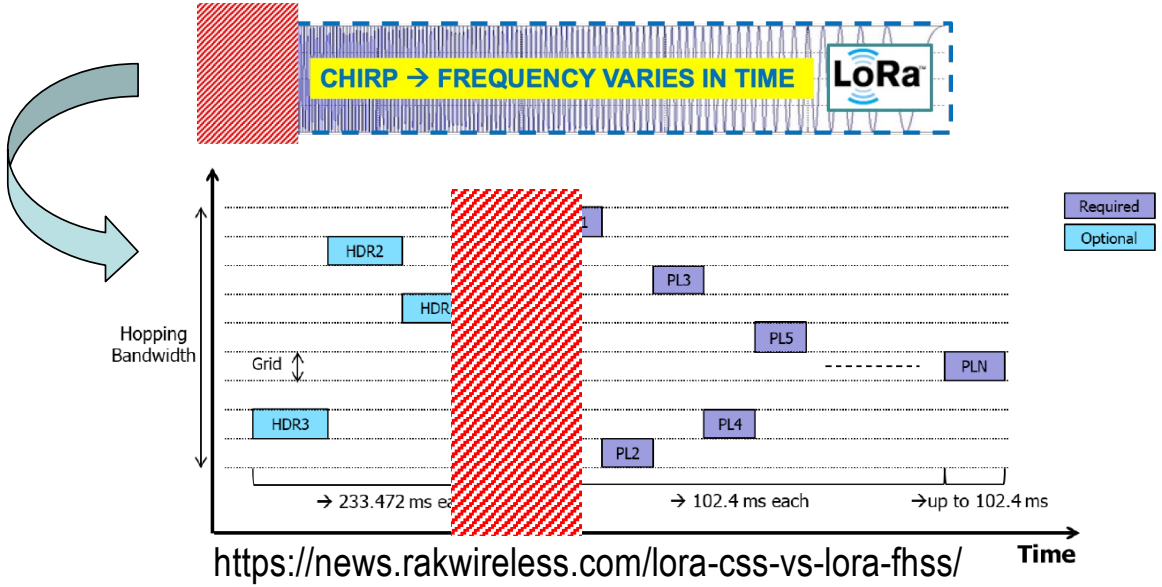
2/ Extending cellular technologies for NTN: satellites provide connectivity to ordinary or adapted cellular devices using spectrum traditionally associated with terrestrial cellular mobile networks

3/ Use satellite-native LPWAN: low-power devices communicate with satellites using protocols or waveforms specifically designed for satellite IoT

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1/ Terrestrial LPWAN technologies

- DtS version of LoRa CSS for more robustness → **LR-FHSS**
  Long-Range Frequency Hopping Spread Spectrum



https://news.rakwireless.com/lora-css-vs-lora-fhss/

10dB link budget improvement results in **3X free-space and 1.5X terrestrial range improvement**

- **mioty** can be more easily extended to DtS communications due to its native FHSS-like operating mode

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2/ Cellular technologies for NTN

- Extending 3GPP cellular technologies → NB-IoT NTN & LTE-M NTN
- **Advantage** → Can leverage compatible cellular IoT chipsets and standards
- **Main challenge** → Adapting cellular procedures and devices to NTN conditions
- **Adoption** → Utilities and governments prefer licensed spectrum, national operator coverage, and long-term standardization
- **E.g. Sateliot** (Spain): 11 LEO for 5G NTN

NB-IoT NTN is optimized for low-rate IoT communications

LTE-M NTN supports IoT applications requiring greater mobility or throughput

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3/ Satellite-native LPWAN, mostly LEO

- **Kinéis** (France): 25 LEO nanosatellites
- **Myriota** (Australia): ~30 nanosatellites
- **Astrocast** (Switzerland): 100 LEO nanosatellites
- **Iridium** (US); 66 LEO satellites, Short Burst Data (340 bytes) service
- **Apogeo Space** (Italy): 9 picosatellites, expanding
- **Globalstar** (US): 48 LEO satellites, with expanding plan!
- **Swarm**: 150 picosatellites. Bought by SpaceX in 2021. Now has ceased activity → included in Starlink
- **Starlink** (US): Jumps into satellite IoT but rather with LTE Direct-to-Device approach







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Satellite-native vs Adaptation of Terrestrial

ADAPTATION OF TERRESTRIAL LPWAN

- Terrestrial LPWAN have been designed to provide a **high link budget**
- In LoS conditions, this link budget can allow to reach a LEO satellite
- BUT, OTHER PARAMETERS ARE NOT EASY TO OPTIMIZE
  - Receiver synchronization, satellite constellation, ground infrastructures, collisions, protocols, …

SATELLITE-NATIVE LPWAN

- When designing a whole, new, satellite-native LPWAN solution, **all parameters** can be optimized altogether to reach higher system-level link performance and not only link budget

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Conclusions

- **~1999: Smart Objects and Internet-of-Things**
- **2026**: Technology maturation is here!
- From application perspective, it is great!
- From research perspective, well…**we can study, evaluate, propose**…
- … but probably marginal change to "standards"
- **Can contribute** to innovative applications with **more open technologies**
  - Collaboration between devices in P2P & mesh
  - Hybrid and continuity of access: multi-radio, terrestrial, non-terrestrial, …
- **Ad-hoc** deployments with **application-specific mechanisms** in **agriculture, agroecology, environment, wildlife, …**

STILL A LOT OF EXCITING RESEARCH BEFORE I RETIRE!

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