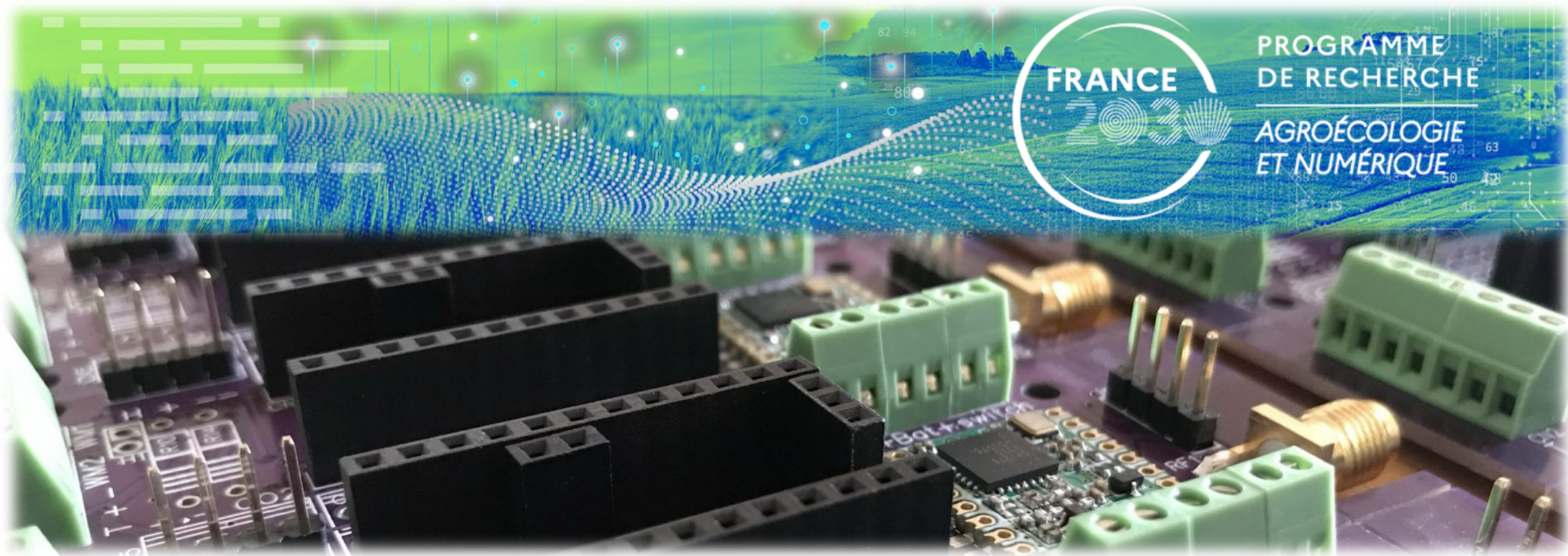




PROGRAMME
DE RECHERCHE
AGROÉCOLOGIE
ET NUMÉRIQUE

Performance of LoRaWAN CSMA in Dense Configuration

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

Congduc.Pham@univ-pau.fr



Capacity-building
with **Erasmus+** 
R.A.D.I.O.
Research And Development International Offices



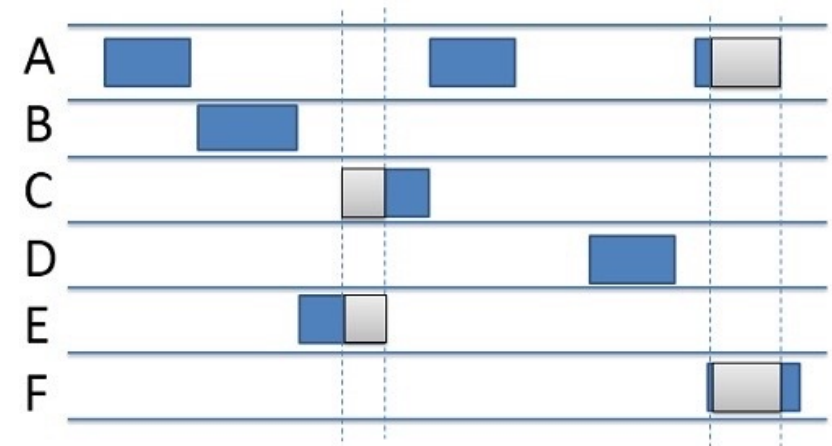
Wireless Sensors Made Simple
for agroecology & sustainable agriculture

Powered by technologies developed in  Intel-IrriS



LoRa CSS still dominant!

- Almost all deployed LoRaWAN devices today still use LoRa CSS. LR-FHSS is standardized and commercially available, but its deployment remains very limited
- LoRa CSS will probably remain the dominant PHY for conventional terrestrial IoT
- LoRa CSS uses an ALOHA-based medium access
- Competition, with no rules;
basically anybody can talk at any time
- Sub-GHz regulations can help ALOHA to better scale
- LoRaWAN standard imposes additional limitations to the ETSI's sub-GHz duty-cycle & off-time

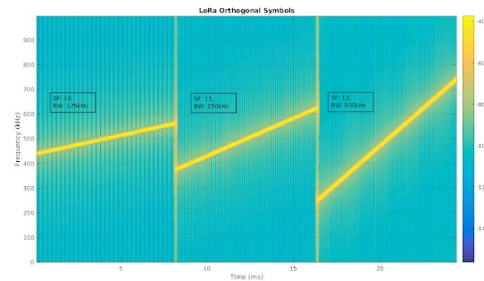




Is ALOHA still working for LoRa?

- Everybody knows that ALOHA is not efficient but it is simple!
- LoRa relies on frequency & SF diversity as well as on gateway density

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	



- LoRaWAN's Adaptive Data Rate mechanism (ADR) uses SF diversity to reduce collisions
- Nowadays, LoRaWAN has matured from sparse to denser deployments where collisions can become the dominant performance bottleneck**
- Capture Effect? Successive Interference Cancellation? Advanced Signal Processing?

Capacity-building
with **Erasmus+**

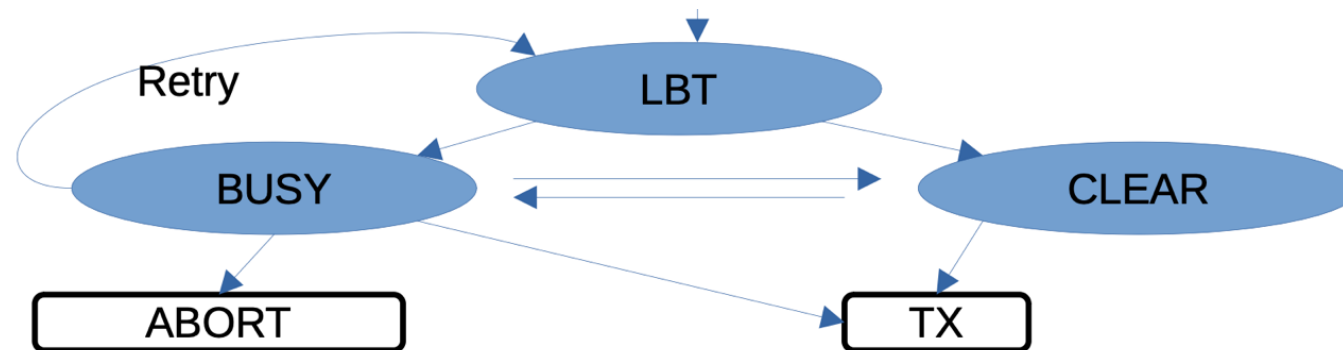


Co-funded by
the European Union



CSMA in a nutshell

- Carrier Sense Multiple Access → try to reduce collisions
- Implement a **Listen Before Talk** approach
- Usually start by a Carrier Sense "is channel **Clear**/**Busy**?"
- If **Clear**, usually transmit
- If **Busy**, usually backoff (e.g. random) to retry later
- Widely used in **IEEE 802.3** (wired Ethernet, CSMA/CD), **IEEE 802.11** (WiFi, CSMA/CA), **IEEE 802.15.4**



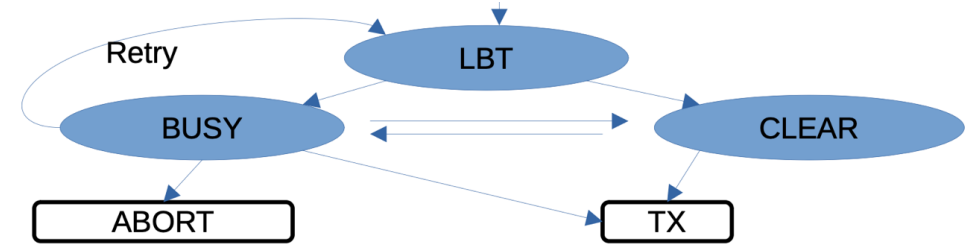


Research And Development International Offices



There are lot's of CSMA variants!

- ⦿ Random, exponential backoff?
- ⦿ Backoff when busy or clear?
- ⦿ Active or passive backoff?
- ⦿ With active backoff, residual backoff or not?
- ⦿ Frequency agility or not?
- ⦿ If frequency agility, black list or not?
- ⦿ If hop to another frequency, backoff or not?
- ⦿ RX then Network Allocation Vector (NAV) or not?
- ⦿ Final CCA before transmit or not?
- ⦿ Ultimately, abort or force transmit?
- ⦿ ...





LoRaWAN CSMA

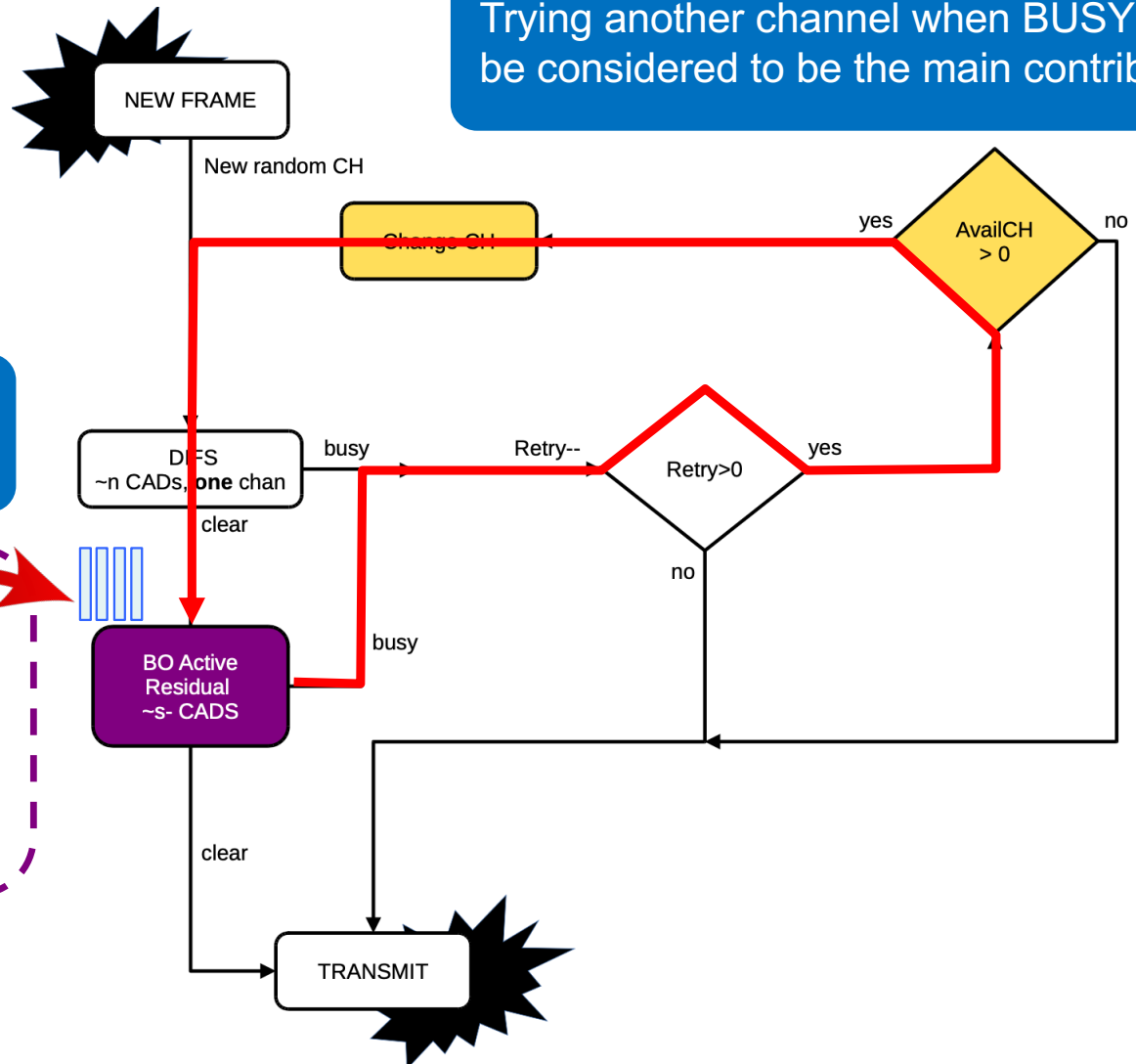
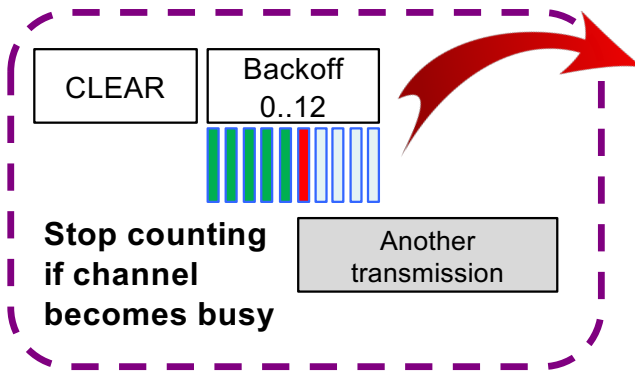
“LoRaWAN CSMA Technical Recommendation TR013-1.0.0, Enabling CSMA for LoRaWAN,” 2023.

- ⦿ A Technical Recommendation by LoRa Alliance
- ⦿ Shift on CSMA by LoRa Alliance can be driven by
 - ⦿ sparse to denser deployments → collisions can become the dominant performance bottleneck
 - ⦿ ADR's efficiency collapses in congested urban topographies → majority of EDs revert to maximum SF configurations, effectively neutralizing SF diversity.
 - ⦿ Newer chips (SX126x, LR11xx) provide improved detection reliability for a busy channel (Channel Activity Detection, CAD)
- ⦿ What LoRaWAN CSMA does?
 - ⦿ Several channels are considered for Carrier Sense, which is quite new
 - ⦿ Start by a Carrier Sense "is channel **CLEAR**/**BUSY**?" → nCAD on a channel
 - ⦿ If **CLEAR**, start an active backoff → sCAD & freeze on detected activity
 - ⦿ If **BUSY**, decrease retry (r=6 initially) and change to another channel, residual
 - ⦿ If retry==0, transmit in ALOHA



LoRaWAN CSMA in image

Active & residual backoff
is similar to WiFi



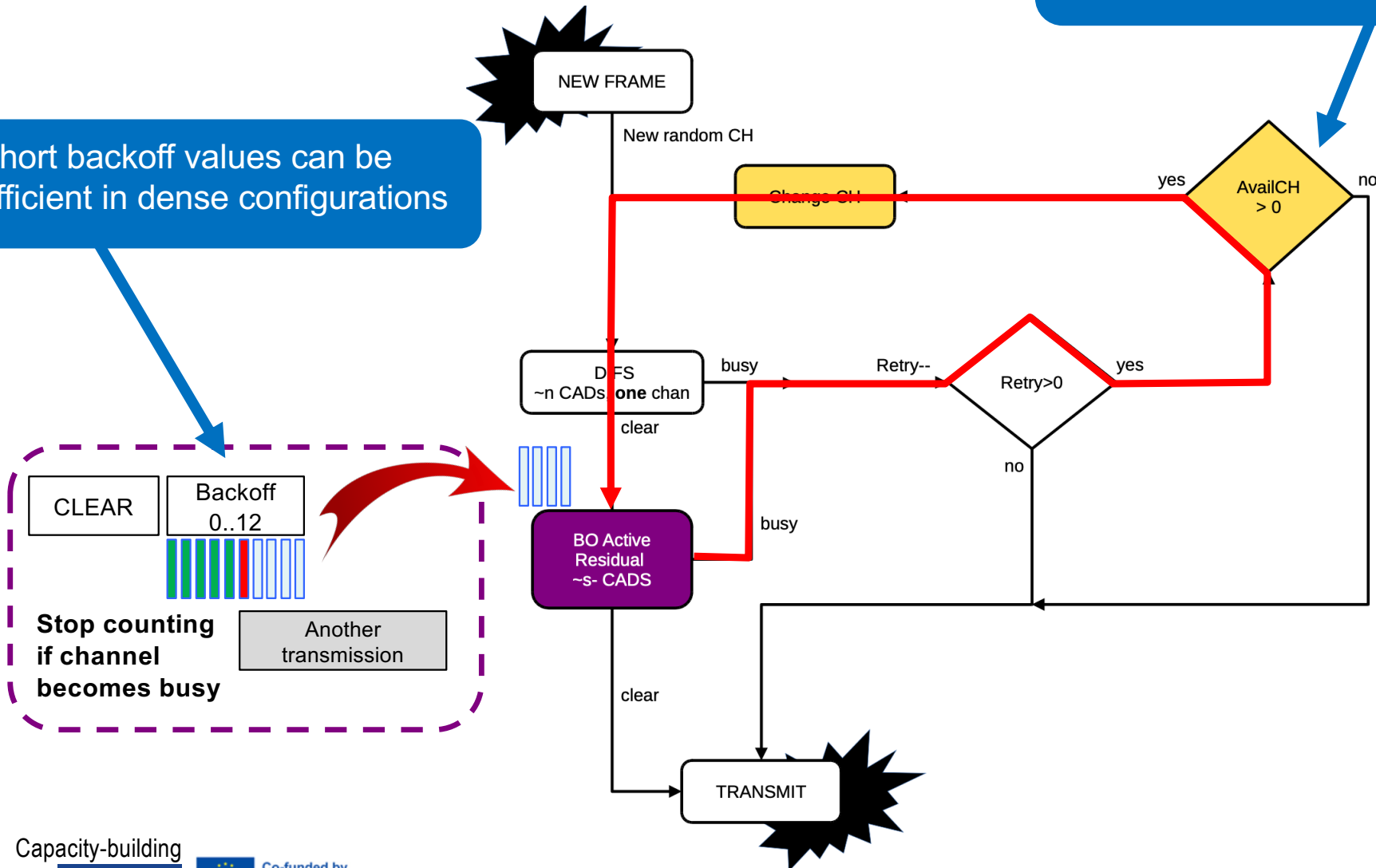
Trying another channel when BUSY can be considered to be the main contribution



What can be good What might be not that good

Short backoff values can be efficient in dense configurations

Carrier Sense with Channel Hopping is an interesting idea

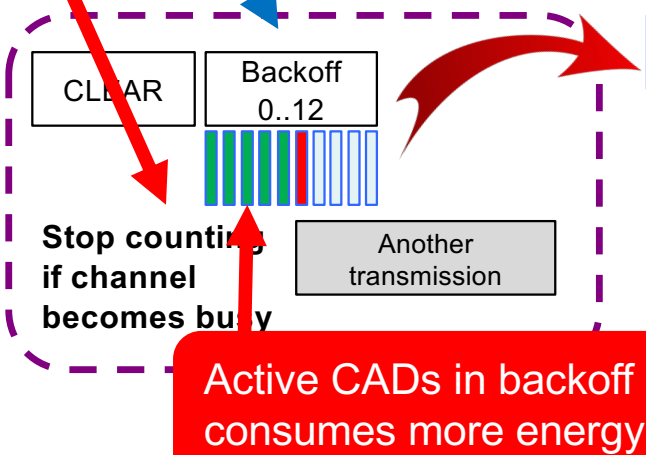




What can be good What might be not that good

Short backoff values can be efficient in dense configurations

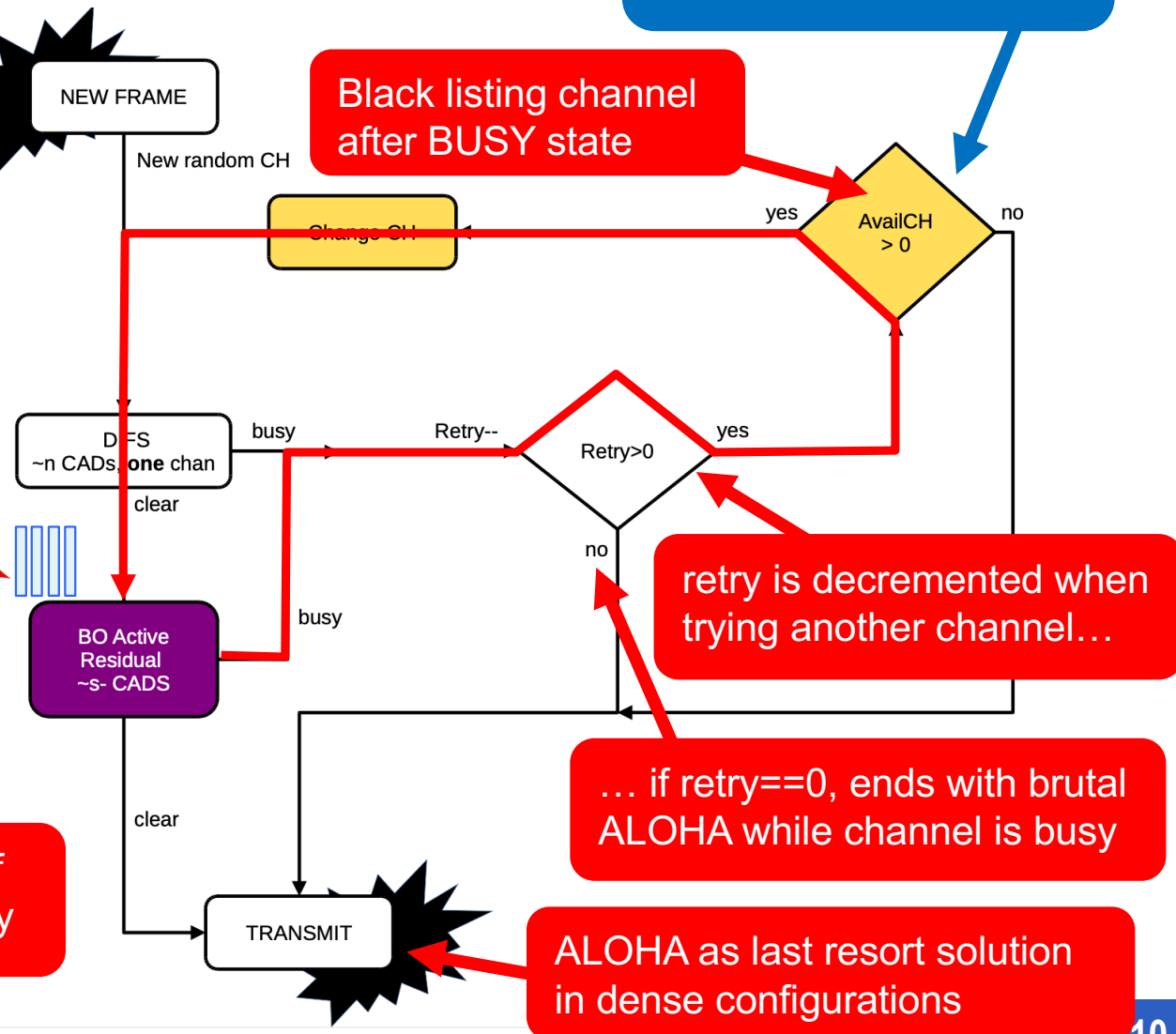
Active backoff when there can be limitations on CAD's reliability



Active CADs in backoff consumes more energy

Black listing channel after BUSY state

Carrier Sense with Channel Hopping is an interesting idea

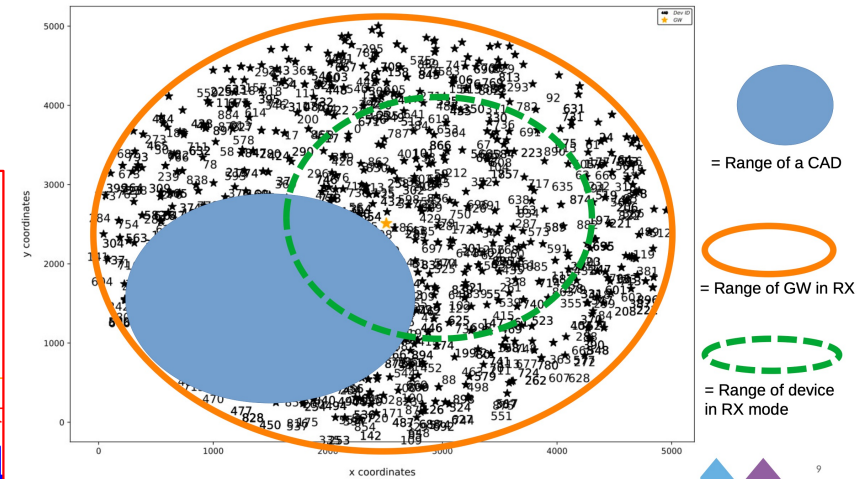
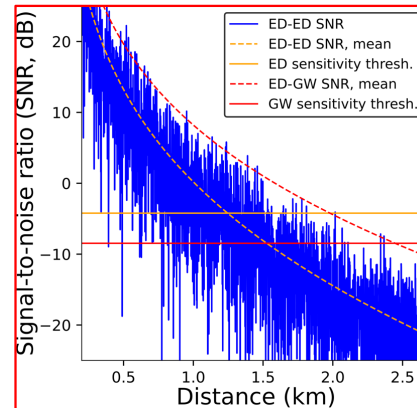




Simulation model

- ◉ We greatly extended LoRaSim to evaluate & compare MAC protocols in more realistic & elaborated settings

- ◉ CAD & more realistic Capture Effect
- ◉ multi-gateway, multi-channel
- ◉ more accurate energy & channel model (noise, fast fading, etc)
- ◉ asymmetric path-loss for ED-ED communications



- ◉ → LoRa-CSMA-Sim

<https://github.com/Guillaumegaillard/LoRa-CSMA-Sim>

- ◉ LoRa-CSMA-Sim is moving to **LPWAN-Sim** to compare various LPWAN technologies (such as LoRa, LR-FHSS, Mioty, etc)

Capacity-building
with **Erasmus+**





(Some) Analysis & Discussions

- ⦿ The analysis is for dense deployment scenarios, 3 GWs for up to 2000 EDs with varying traffic load
- ⦿ → limiting the number of channel hopping reduces the overhead, but impairs the PDR by forcing a transmission when the channel is busy
- ⦿ → impact of ending with brutal ALOHA is high! It can be better to actually discard transmission when thinking globally!
- ⦿ → active CADs in backoff-when-CLEAR obviously increases energy consumption, which could be justified, but...
- ⦿ → ...PDR can actually be lower compared to more "traditional" CSMA variants with a simpler, passive, no residual backoff-when-BUSY mechanism!



(Short) Conclusions

- Proposed LoRaWAN CSMA is found not optimal for urban dense deployment scenarios where both traffic density and long time-on-air are challenging issues
 - Active & residual backoff (à la WiFi) is not very convincing
 - Channel hopping is interesting but #retry is too small → ends with ALOHA
 - Black listing channels shows no evidence to be necessary → ends with ALOHA
 - Ending with ALOHA should be avoided
- Detailed results in G. Gaillard and C. Pham, "Performance of LoRaWAN CSMA in Dense LoRa Networks", Proceedings of the 27th International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM'25), Barcelona, Spain, 27-31 October, 2025
- The article suggests & evaluates variants that can be more adapted to very dense configurations

