CSMA for LoRa: choose which?

CSMA pour LoRa: quelle variante choisir ?

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Presented on July 3rd, 2025

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FRANCE 2030 PROGRAMME DE RECHERCHE AGROÉCOLOGIE ET NUMÉRIQUE

PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

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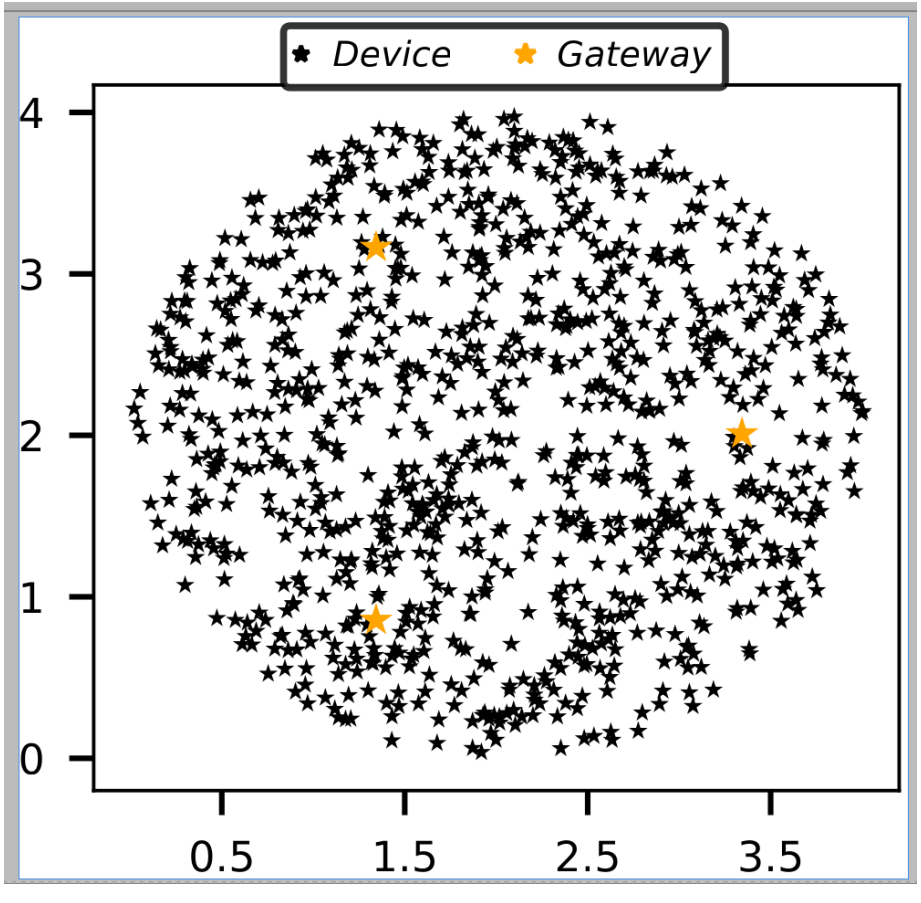
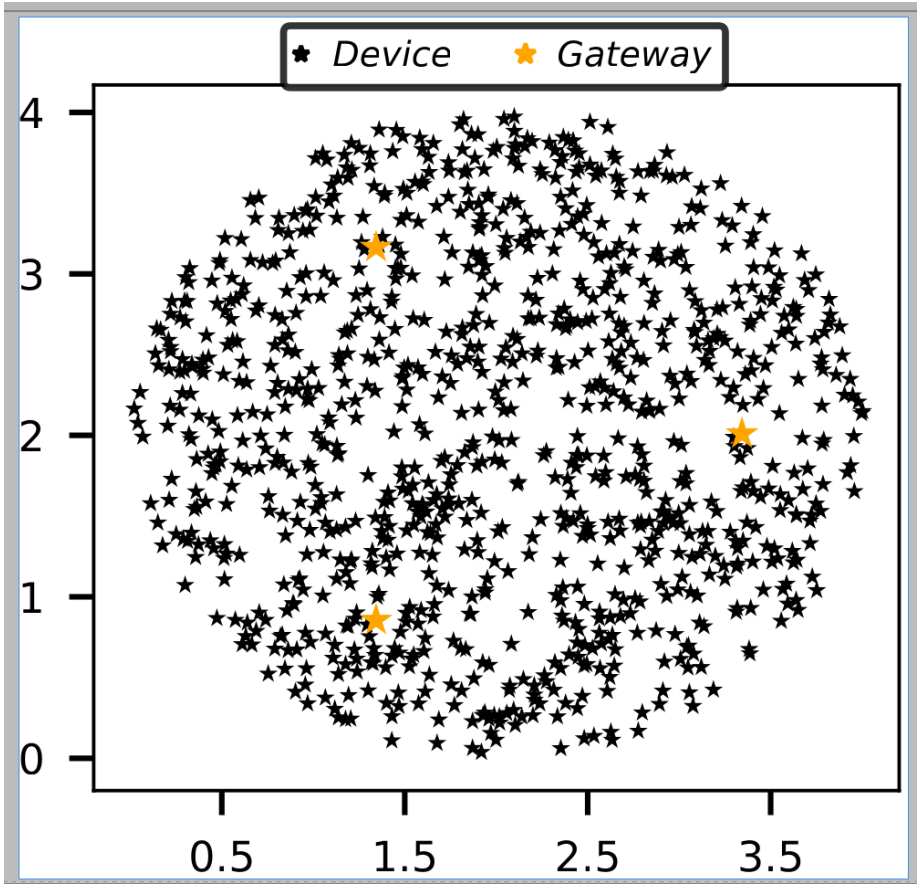
LoRa(WAN) in a dense collision domain



- Collisions
  - More devices
  - More traffic
- ALOHA → CSMA
  - Many versions
  - Many mechanisms
  - Which one is best choice?

LoRa(WAN) in a dense collision domain



- ALOHA =
  - No Collision Avoidance
  - Transmit when ready
- Collision at a GW =
  - 2 or + transmissions
  - Same channel
  - Time overlap (on critical zone)
  - Not enough SINR
- Spares
  - Capture Effect
  - Hidden terminal

Carrier Sense Multiple Access (CSMA)

To avoid collisions

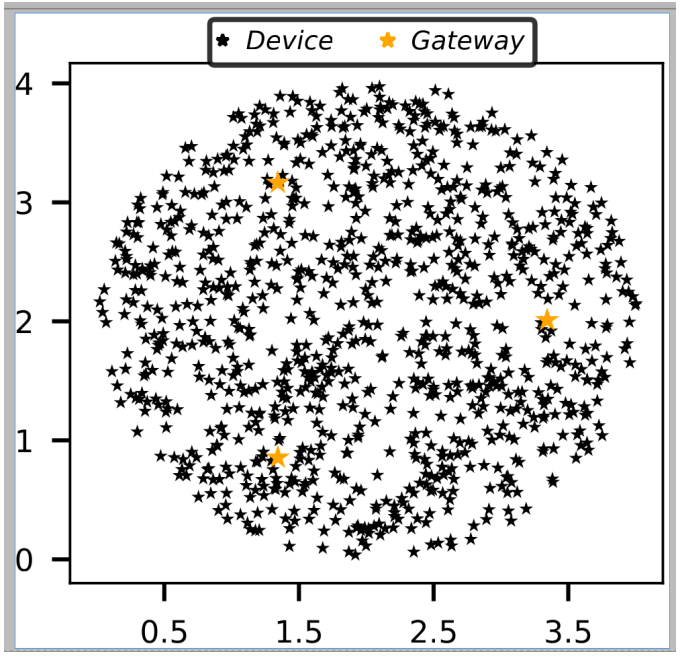
- In our context, only local info, no feedback
- A device can “only”:
  - “Listen”
  - “Wait” (Back off BO)
  - Change channel
  - Transmit
  - Discard

and retry/repeat (Max #r tries)

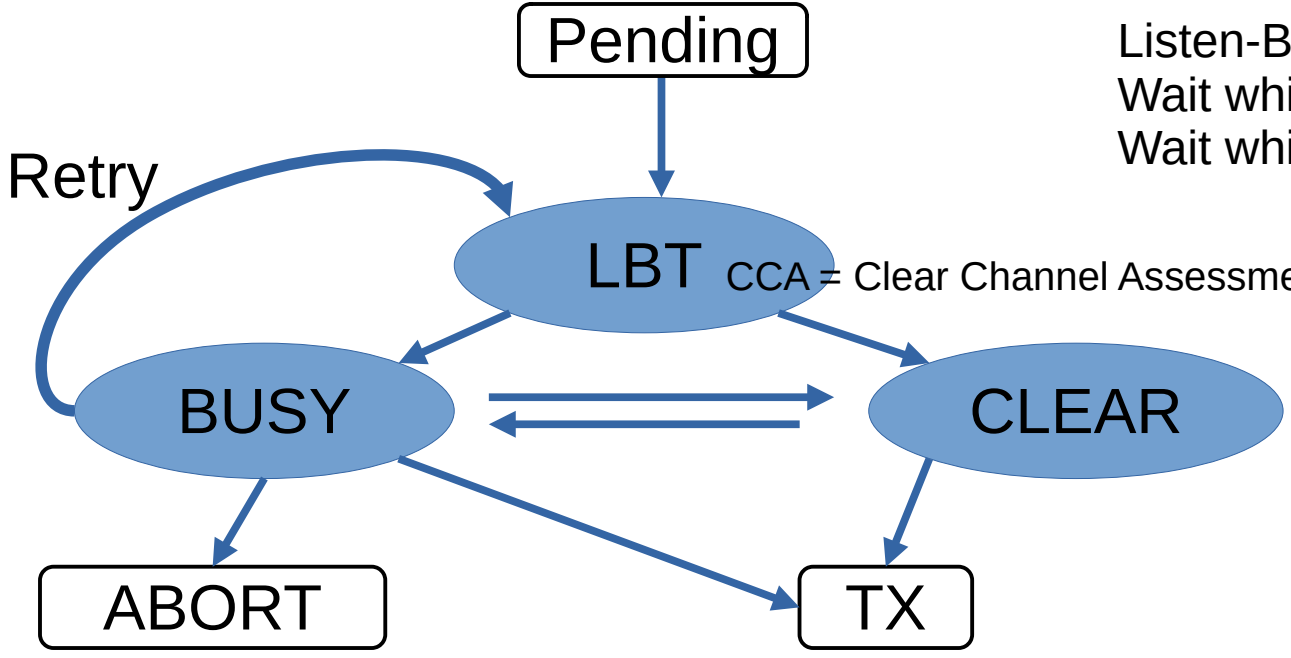
CSMA: listen, contention and retries

Other than CSMA?

- ALOHA → Collisions
- CS is not ideal, though (hidden terminal, near-far problem, etc.)
- Resource allocation requires sync and downlink
- Resolution techniques at GW are complementary

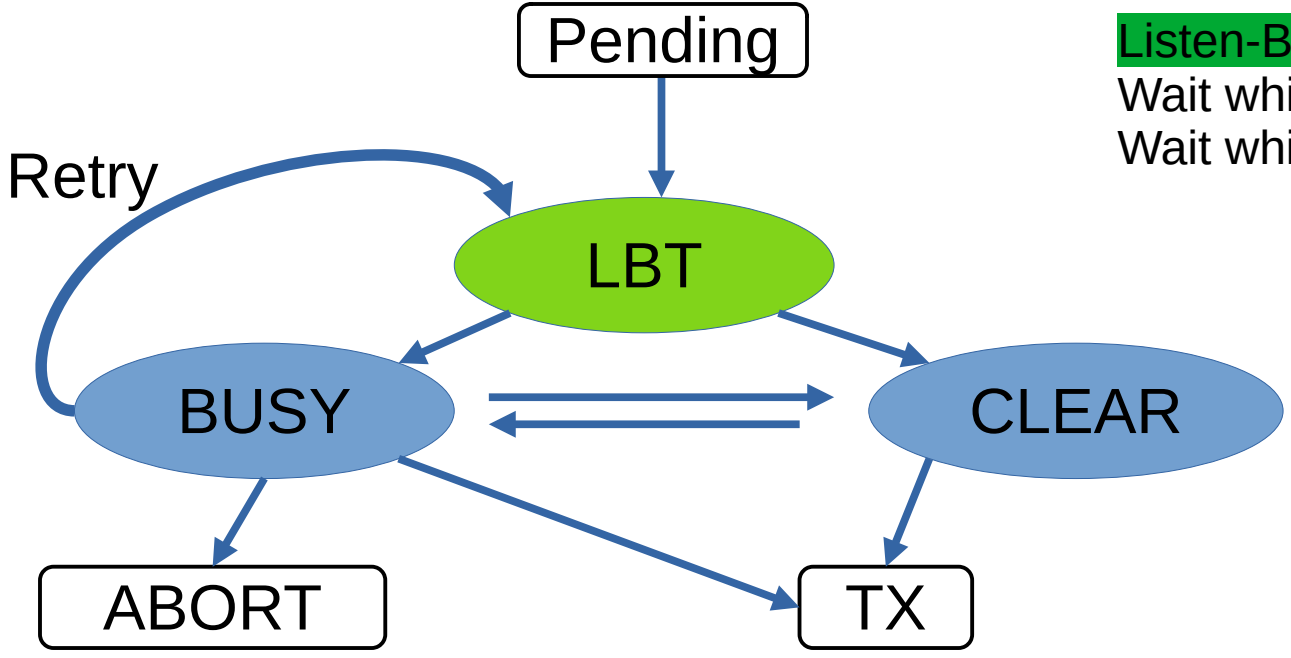


State machine of CSMA



Listen-Before-Talk
Wait while Busy
Wait while Clear

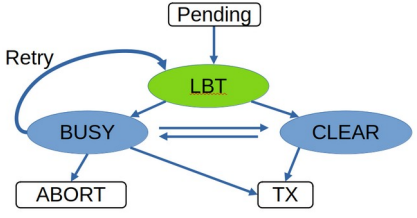
State machine of CSMA



Listen-Before-Talk
Wait while Busy
Wait while Clear

How do LoRa devices “Listen”?

- RSSI-based?
  - But LoRa operates/interferes/collides below noise floor
- => 1) Semtech’s Channel Activity Detection (CAD)
- => 2) RX mode
  - Proposal 2023 too energy expensive
  - => CAD+RX outside LBT



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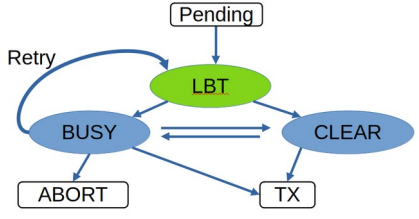
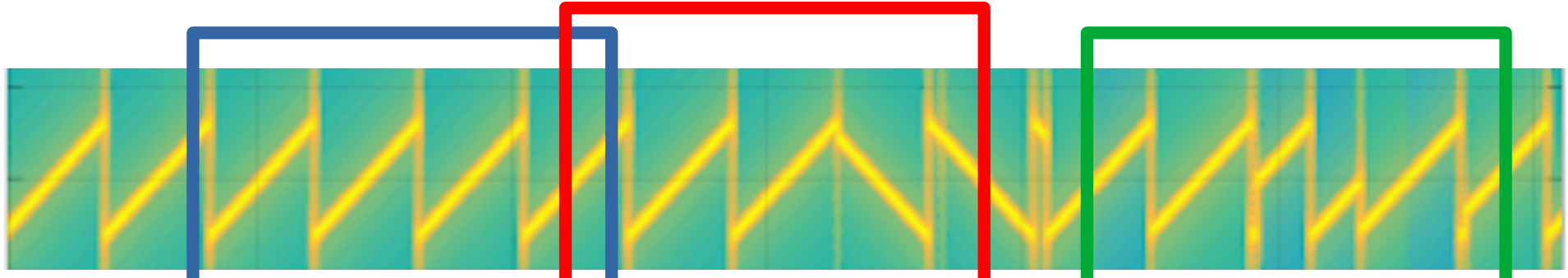
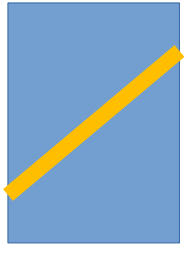


1) Channel Activity Detection (CAD)



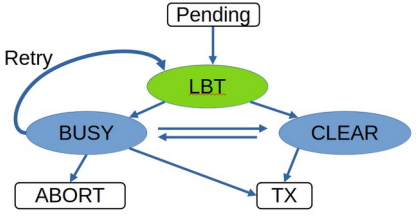
Correlate with



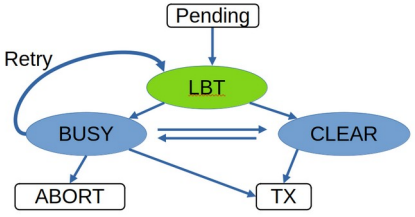
=> True/False

Slope-specific, asynchronous, not limited to preamble

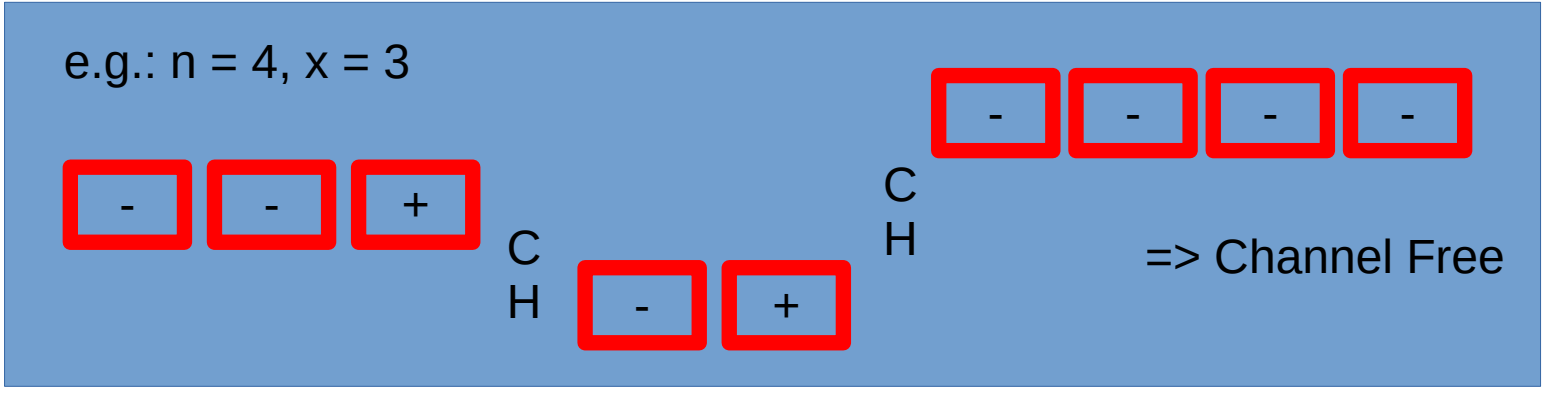
Overlaps, down chirps, degraded signals?



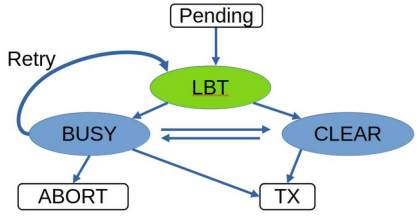
CADs in sequence



- Min #n negative CADs on a given channel
  - All negative => channel is free
  - Increase reliability
- Max #x channel changes per try
  - Until one is free
  - Each requires a radio config change



CADs in sequence



- Min #n negative CADs on a given channel
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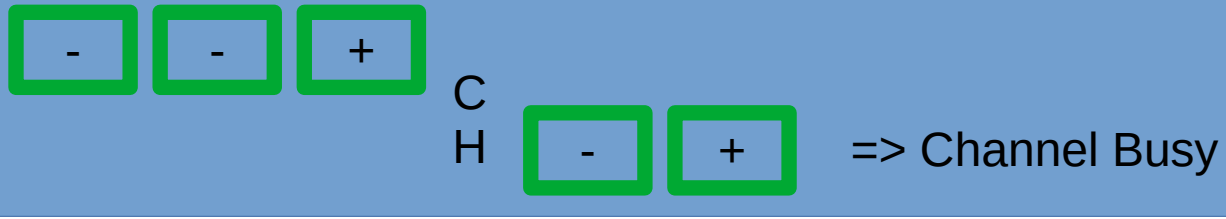
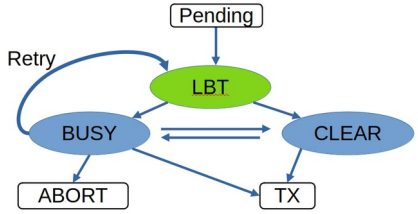
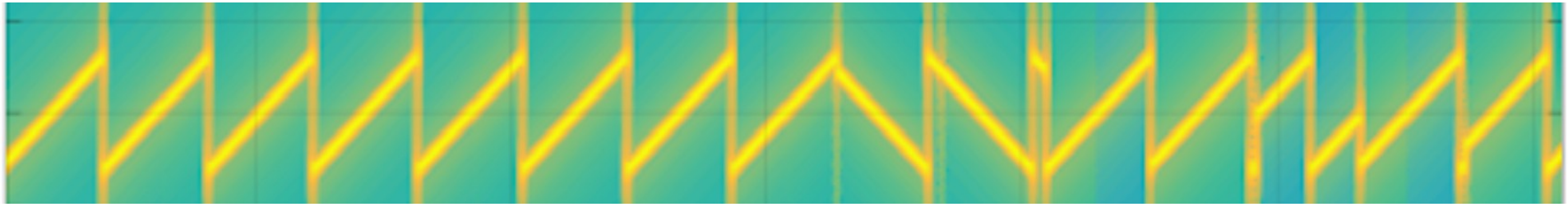
Same e.g. but: n = 4, x = 2



2) Listen with RX mode





Requires a min (6) of those to phase with signal

Decode header info

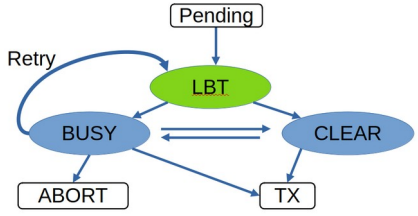
Slope-specific

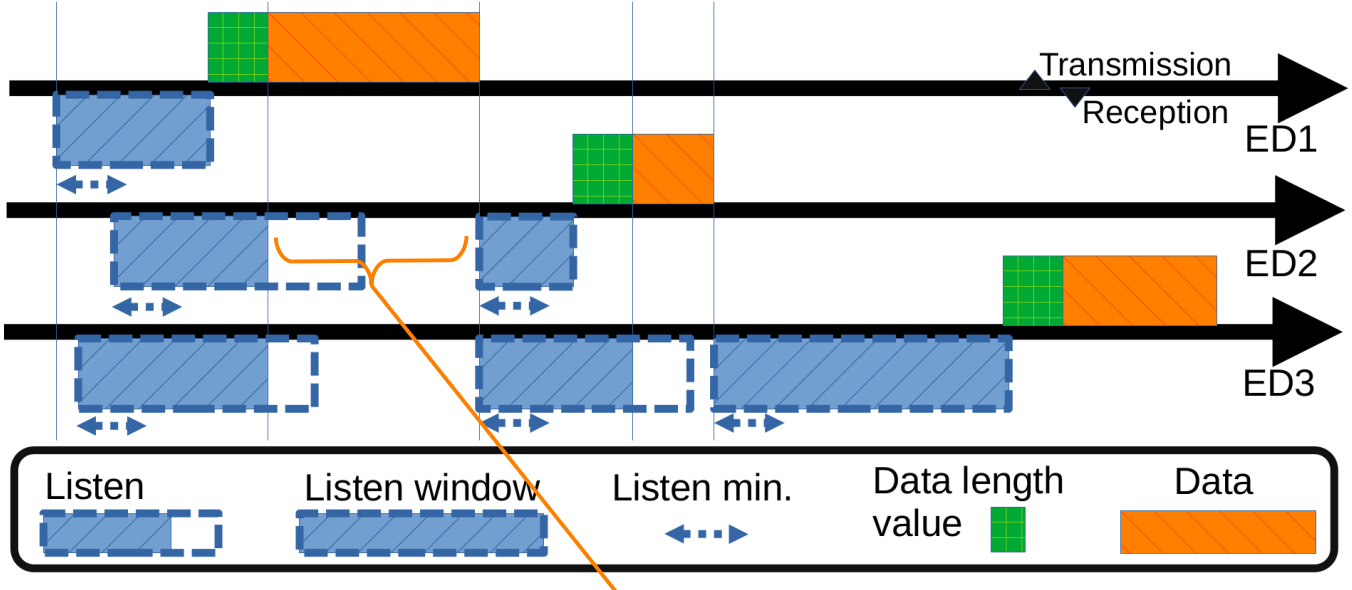
More complex, may miss preamble, longer, energy hungrier than CAD

To be interrupted at end of header

Gives MAC info, size of payload

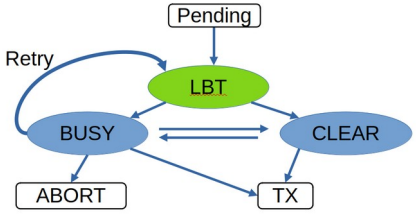
2) Listen with RX mode



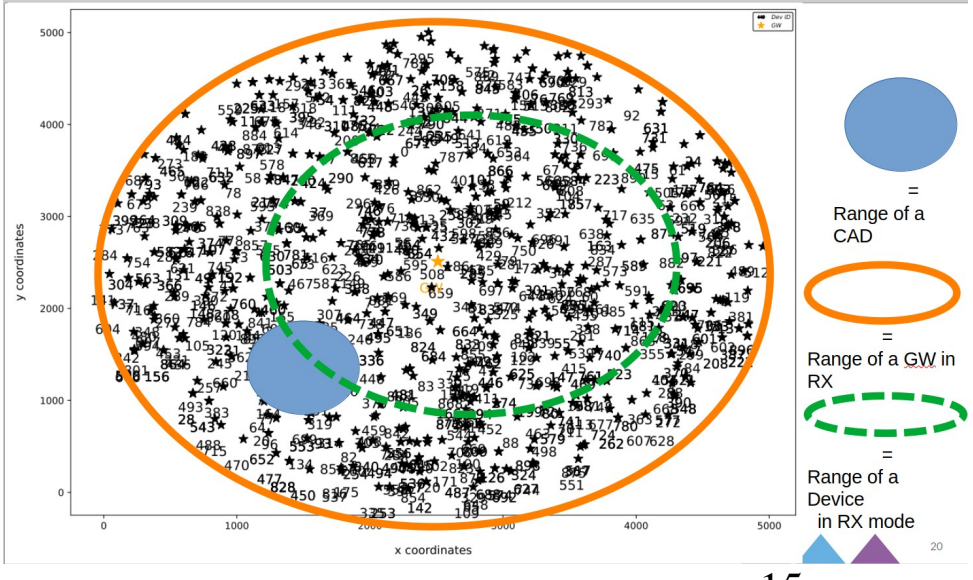


Known size = know wait time = NAV
Network Allocation Vector

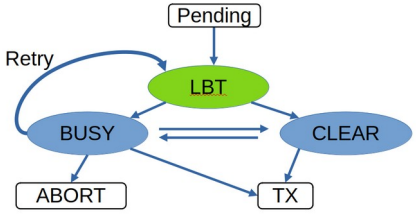
2) Listen with RX mode



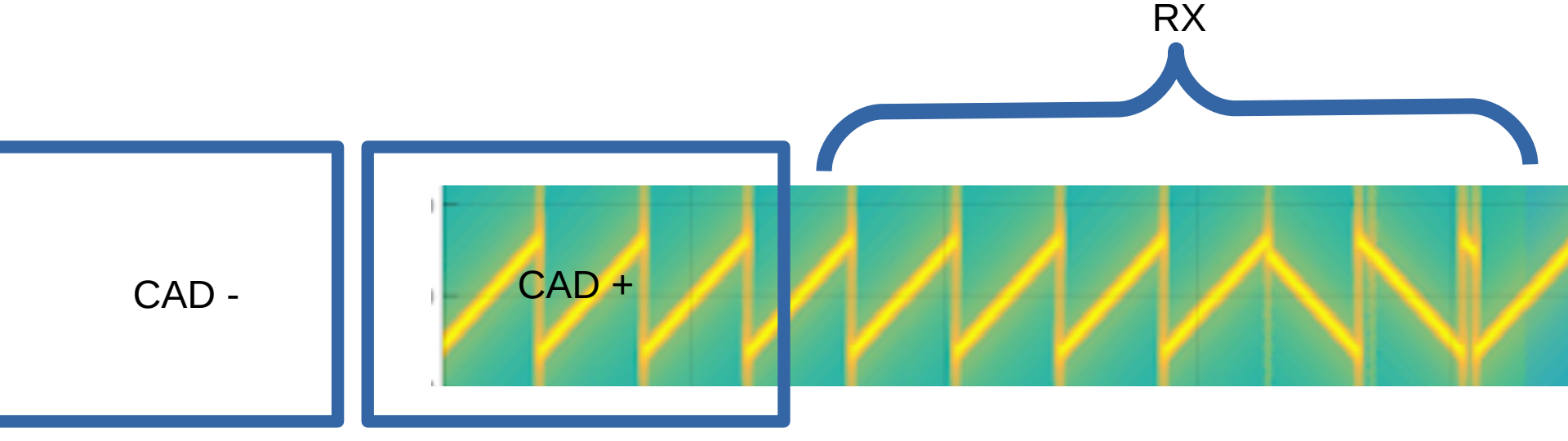
- CANL 2023:
  - Collision Avoidance by Neighbor Listening for Dense LoRa Networks. ISCC, Jul 2023
  - RX in LBT
  - Assume CAD not reliable
- Too energy expensive
  - in LBT



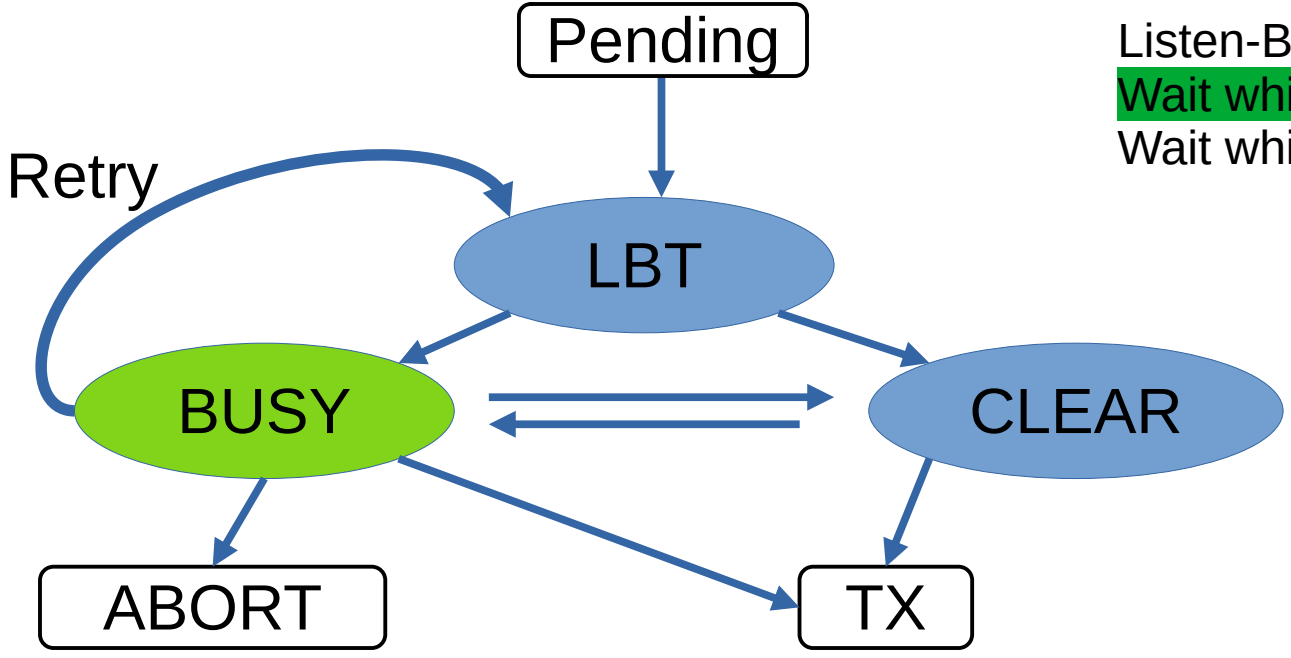
Proposal: CAD + RX



- RX only when a CAD switches Busy
  - Target preamble only
- Get NAV length



State machine of CSMA



Listen-Before-Talk
Wait while Busy
Wait while Clear

What to do when channel is Busy

- (Binary exponential) passive Back Off

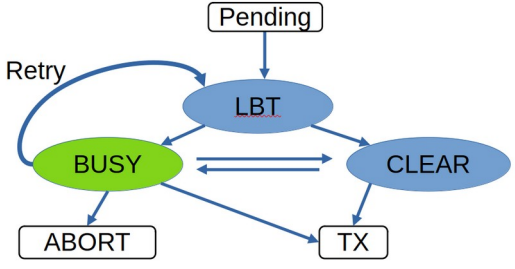
  = wait passively an (increasing) random time

  = non persistent CSMA

- Change to another channel
- Actively check channel remains busy

  from persistent CSMA

And retry



What to do when channel is Busy

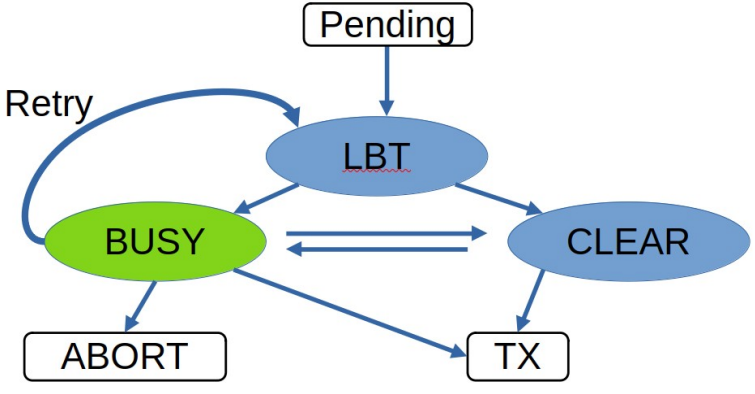
And max #r retries reached

- (Ultimate) passive Back Off

  = you know it is busy => wait

  => And transmit

- Discard (abort)



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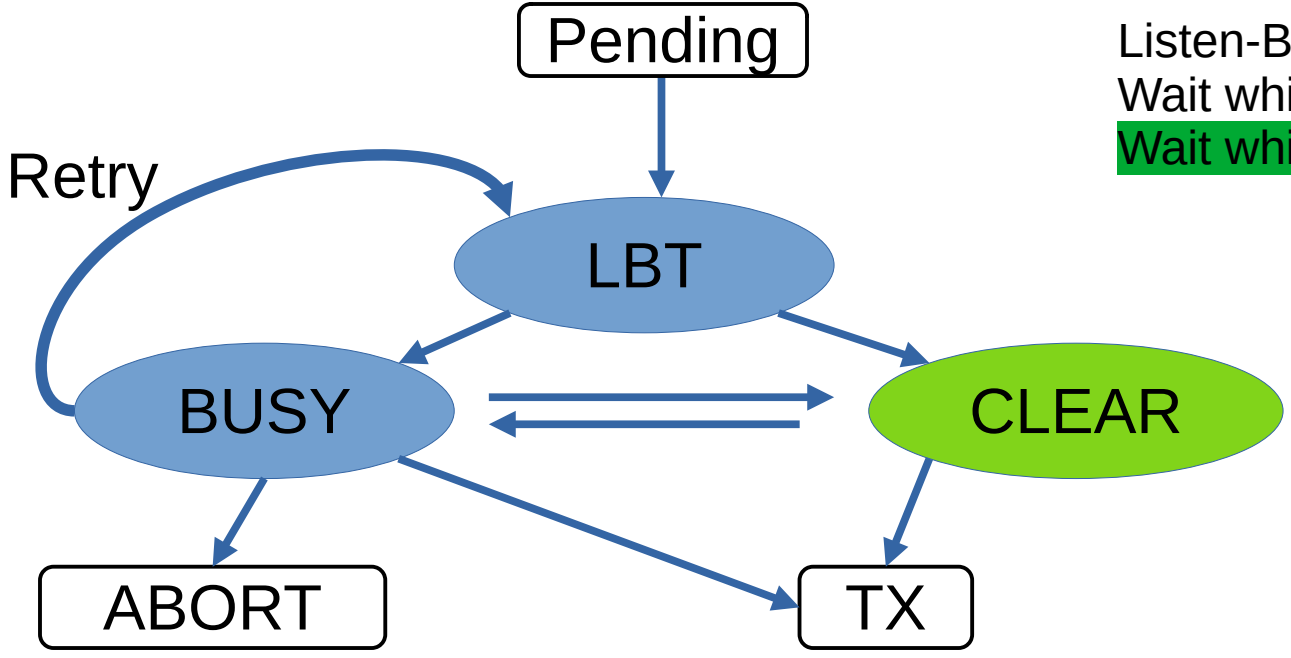


Listen-Before-Talk
Wait while Busy
Wait while Clear

What to do when channel is Clear

- (Residual) active BO

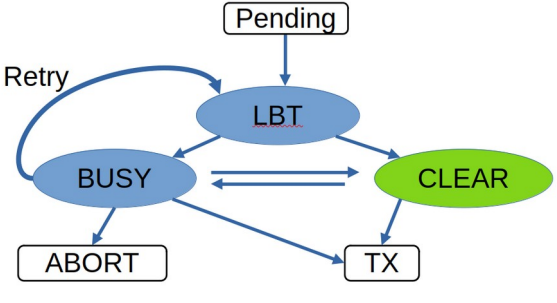
  = Check while waiting, do not reset

- Passive BO and recheck

  = wait passively, recheck with n CADs

=> And transmit

- Transmit directly
- Do n CADs+RX
  - RX if last CAD true
  - Then NAV+CH (threshold)



Combine all these?

Protocol name	LBT	BUSY	CLEAR
basic	sCADs	epBO	
full_basic	mCADs	epBO	
BEB_passive	sCADs	epBO	pBO+CADs
full_BEB_passive	mCADs	epBO	pBO+CADs
BEB_active	sCADs	epBO	raBO
full_BEB_active	mCADs	epBO	raBO
CH_passive	sCADs	CH	pBO+CADs
LoRa_CSMA	sCADs	CH	raBO
wait_passive	sCADs	waBO	pBO+CADs
full_wait_passive	mCADs	waBO	pBO+CADs
wait_active	sCADs	waBO	raBO
full_wait_active	mCADs	waBO	raBO
xCANL_CAD	mCADs	NAV/CH	pBO+CADs

→ ref

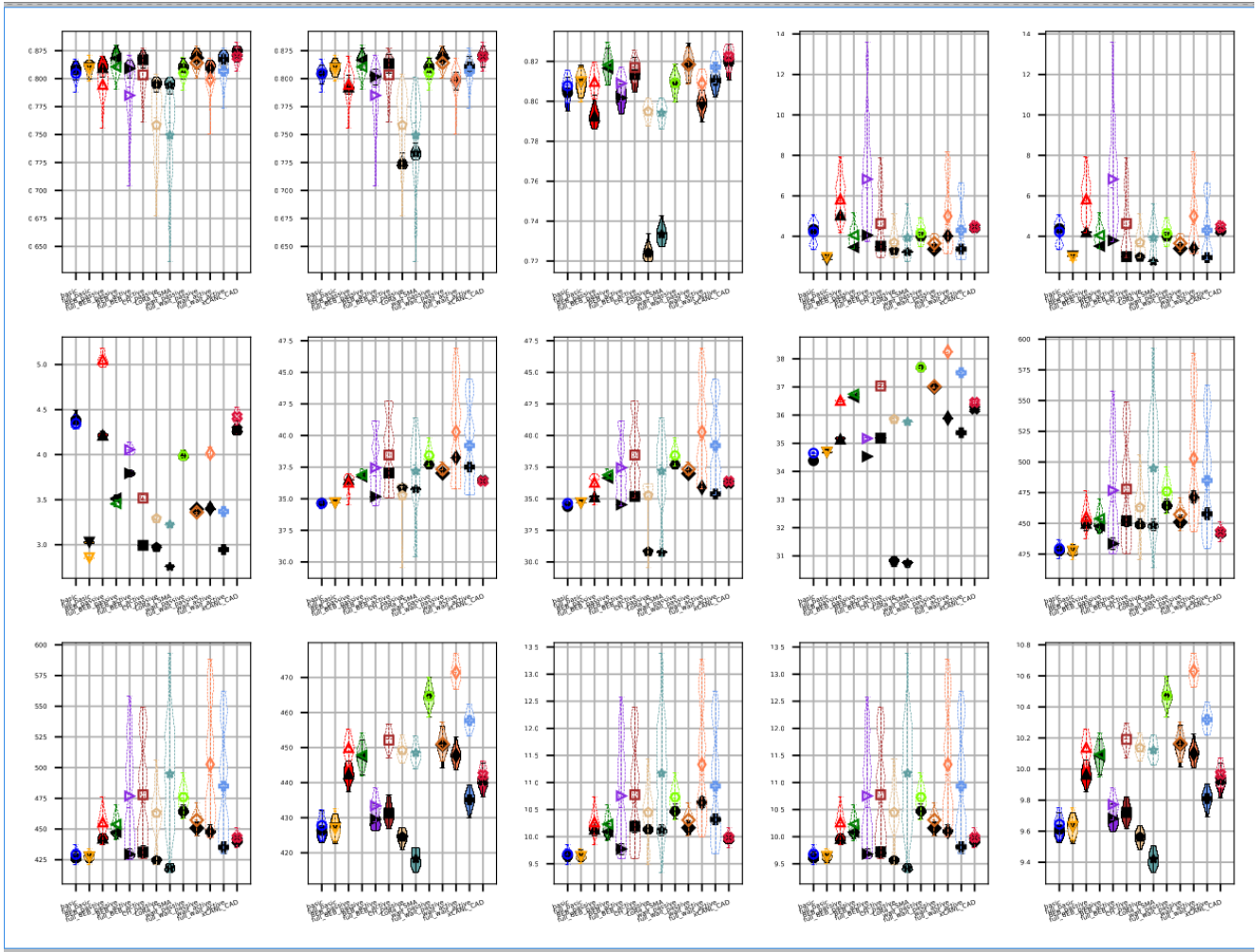
→ TR LoRa Alliance

→ prop

Which one is best?

- Depends
  - Conditions (density, scale, traffic load)
  - Objective (PDR, energy, delay)
  - Variants (BO sizes, LBT constraints)
- Evaluation
  - Simulation
  - 64 variants

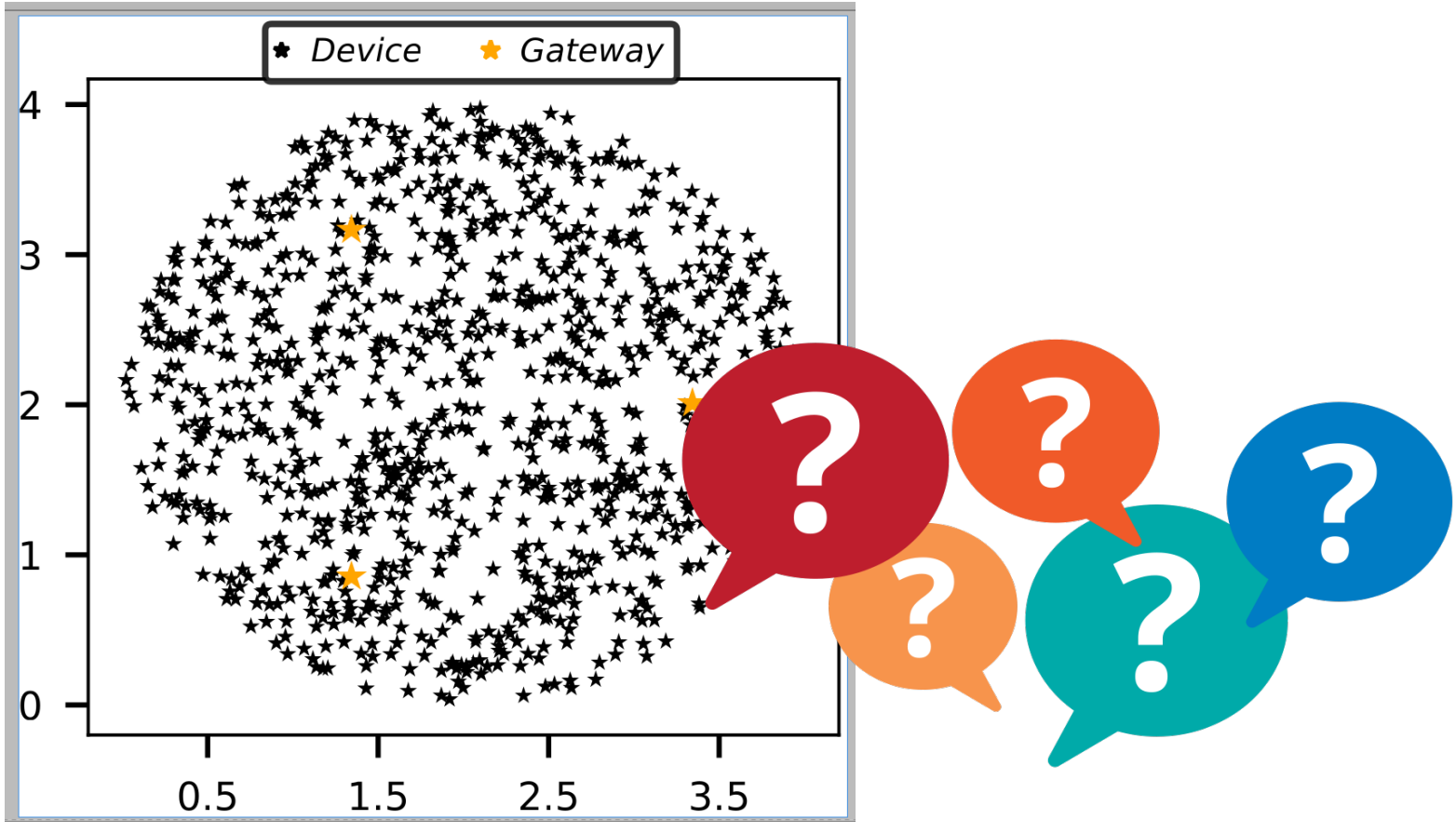
Many simulation results



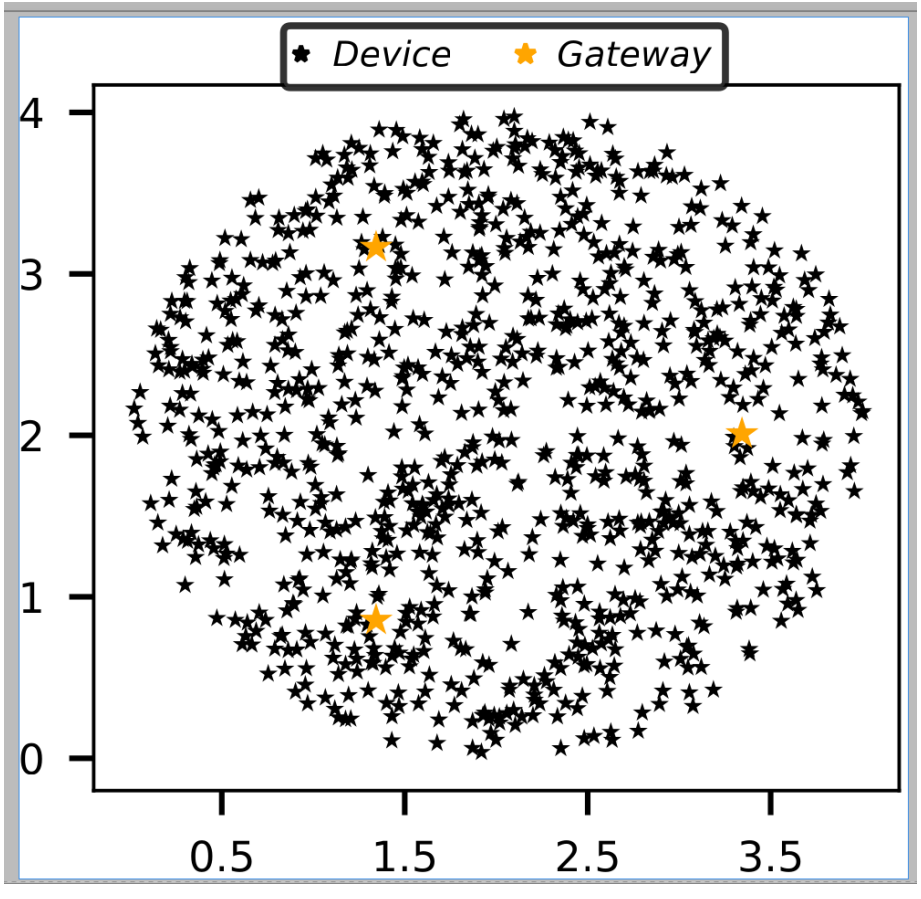
Objective	PDR	J/B	Latency	
Variant with best	PDR	J/B	PDR	J/B
basic		$\mathcal{V}$		
full_basic			$\mathcal{V}$	
LoRa_CSMA		($\mathcal{V}$)		$\mathcal{V}$
xCANL_CAD	$\mathcal{V}$			

Concluding remarks

- Avoid systematic channel hopping:
  - homogeneous channels
- Use simple approaches are energy efficient;
- Run complex ones if you target PDR performance.

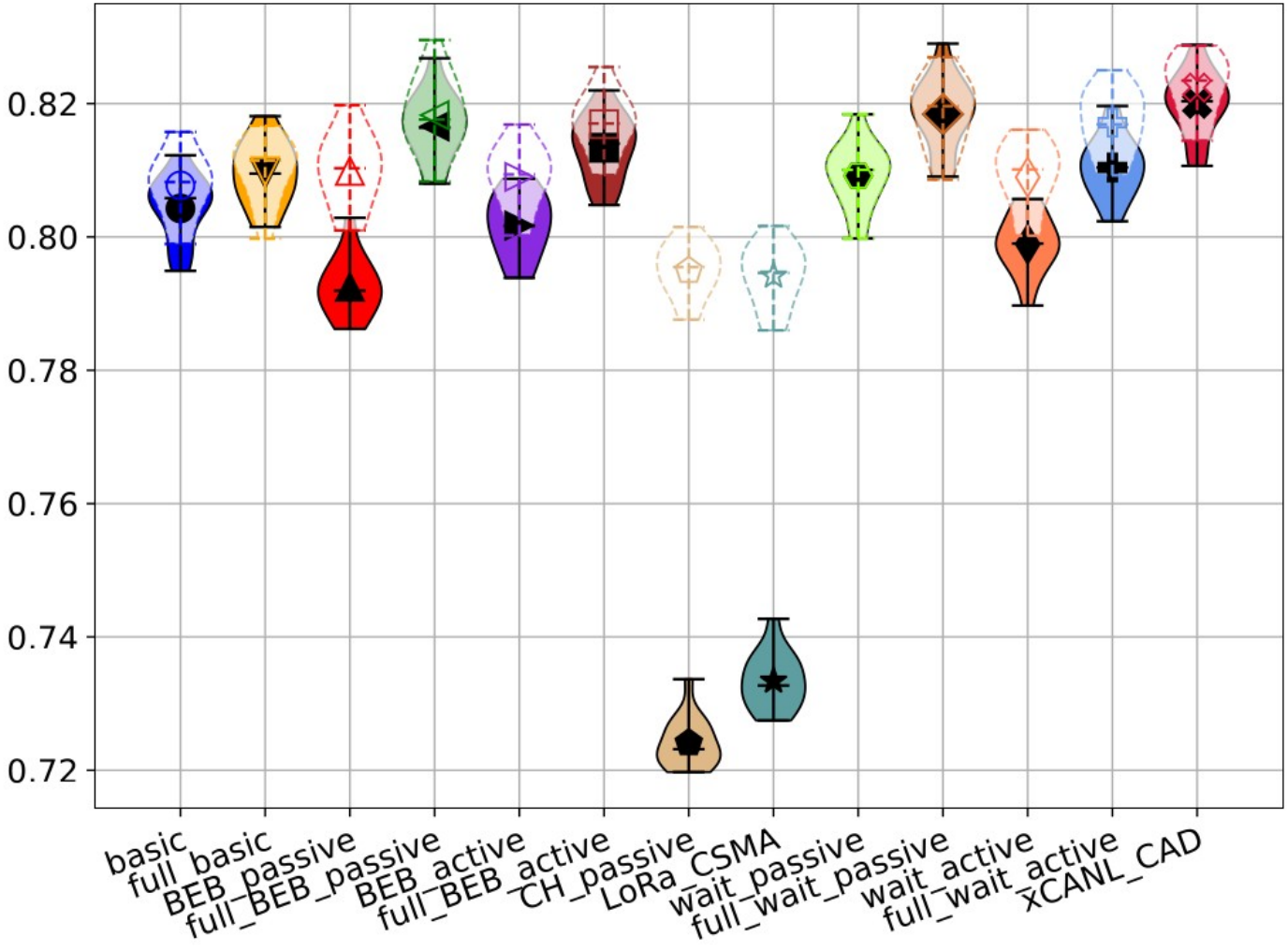

Device
Gateway
4
3
2
1
0
0.5
1.5
2.5
3.5
?
?
?
?
?

LoRa(WAN) in a dense collision domain



- Asynchronous
- No Downlink
- SF12
- Interference
- Obstruction
- 8 channels * 125 kHz
- Random CH sequence/dev
- Multiple GWs

PDR


0.82
0.80
0.78
0.76
0.74
0.72
basic
full_basic
BEB_passive
full_BEB_passive
BEB_active
full_BEB_active
CH_passive
LoRa_CSMA
wait_passive
full_wait_passive
wait_active
full_wait_active
xCANL_CAD

Energy efficiency