Some remarks on mioty, LoRa and capacity

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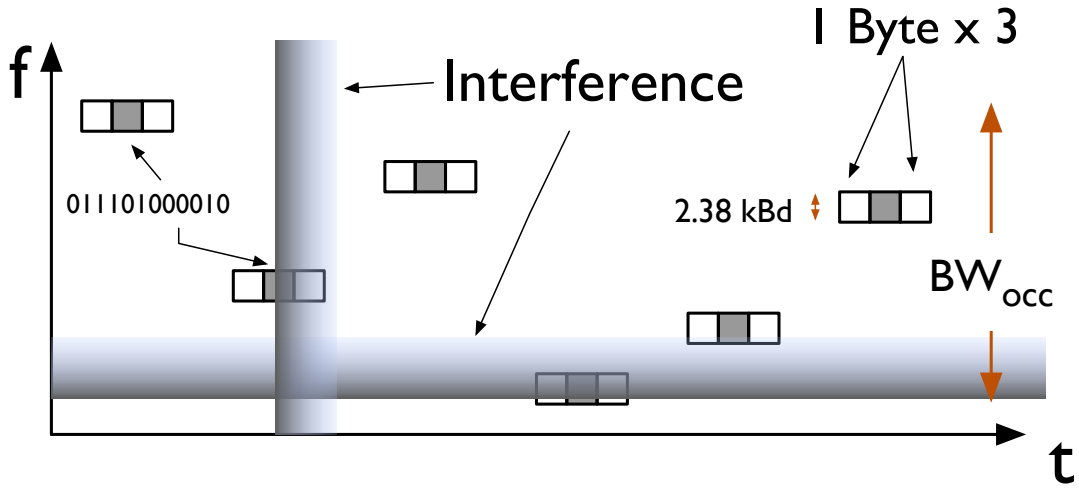
What is this talk about?

- Do not expect a black and white opinion on mioty vs. LoRa

- Reflect on “mioty Comparative Study Report” [RL23] and **focus on a few facts**
  - ✓ Downlink communication
  - ✓ Aloha and capacity
  - ✓ Multipath fading

Joerg Robert and Thomas Lauterbach.
Mioty comparative study report.
Technical report, Technische Universität Ilmenau, 2023.
https://mioty-alliance.com/mioty-vs-lora-study-report/.

mioty



- Frequency hoping, **error correction** between fragments (CR=1/3)
  - ✓ Bandwidth: 57 kHz × 2 + margin (→184 kHz: EU1) or 1.44MHz (EU2) (LR-FHSS: 39 kHz to 1.57 MHz)
  - ✓ Modulation rate: 2 380 Bd (LR-FHSS: 488 Bd, mioty raw instantaneous bit rate between SF8 and SF9)
  - ✓ At least 24 fragments / packet
- Claimed Sensitivity -138 dBm (≃ SF11, SF12) (≳ 2 dB above noise power in 2.38 kHz band) (**Better** than LR-FHSS?)

mioty (cont.)

- (Elegant) **distributed sync**hronization (LR-FHSS: explicit header)
- mioty **instantaneous** throughput: $2.38 \times \frac{2}{3} \times \frac{1}{3} = 529$b/s ($\frac{2}{3}$=midamble overhead, $R = \frac{1}{3}$) > LoRa @SF11

High channel capacity and/or resistance to noise:
as long as at least $\approx$ **1/3** of **fragments** are "safe",
reception may be successful

(Relatively) **high** GW complexity: "Generally, the gateway is based on a software defined radio (SDR)" [RL23]

(Like Sigfox or LR-FHSS)

GW radios

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GW radios (cont.)

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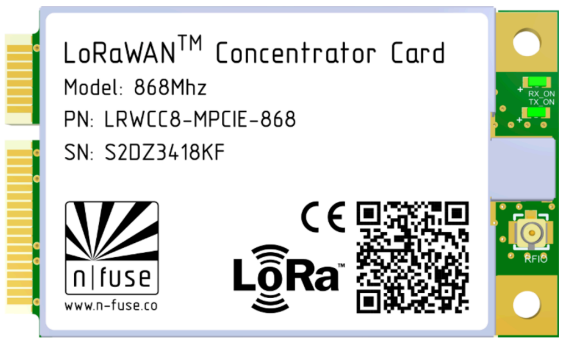

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Downlink commmunication

- If the device does no have an SDR, sensitivity is reduced by 9dB[1] (Or 40% less range for $\#\, d^4$ path loss…)
- **But** mioty does not need any form of ADR!
  So it is much less dependent on DL transmissions
- **ButBut** what about network provisioning, activation, OTA configuration, roaming, updates?
- **ButButBut** There are ways to improve DL reception: repetition etc.
- Macro diversity allows **concurrent UL/DL** traffic for both mioty and LoRaWAN

[1] Short Range Devices; Low Throughput Networks (LTN); Protocols for radio interface A, ETSI TS 103 357, Rev. 1.1.1, Jun. 2018; cited in [RL23]

Raw Aloha capacity

For a single LoRaWAN channel and a single mioty channel[2],
theoretical mioty capacity is about
26 000 times higher than LoRaWAN capacity for 99% PDR;
3 400 for 90% PDR ([RL23] pages 27, 28)

- **Yes, for no LoRaWAN packet repetition!**
  - ✓ Unslotted Aloha: $PER_{\text{Aloha}} = 1 - e^{-2\mu D} \Rightarrow$

$$PER_{\text{Aloha}} = 10\% \leftrightarrow \mu D = 5\%$$
$$PER_{\text{Aloha}} = 1\% \leftrightarrow \mu D = 0.5\%$$

  - ✓ SF12, 10B packets, 99% PDR, $\mu D = 0.5\% \Rightarrow$ 0.2 packet/min
- **We all know Aloha calls for collision management**
  $\rightarrow$ Simply Assuming **R transmissions** of each data packet, if we want $PER_{\text{Appli}} = 1\%$
  $\Rightarrow PER_{\text{Aloha}} = \sqrt[3]{PER_{\text{Appli}}} = 21{,}65\%$ (46,4% for $PER_{\text{Appli}} = 10\%$)

$\Rightarrow$ mioty advantage is more like 3000 (or 550) times better than LoRaWAN (still a lot)

[2] 125 kHz vs 184 kHz

More on capacity

- LoRaWAN collisions are not symmetrical (with **capture**, one packet often survives the collision)
- **Other SFs** are often usable (SF7 ToA is $\frac{1}{22}$ that of SF12)
- With all SFs, Rayleigh fading, 60% PDR ($\lesssim$ 1% app. layer loss), **10B** (+5 header) packets, typical LoRaWAN capacity would be **500 to 1000**[3] unique packets per min (with only 6 LoRa channels, 3 transmissions)[4]
- That's thousands of nodes… Knowing 10B is a very detrimental payload size for LoRaWAN
- In EU1/184kHz, mioty gives 7 000 pkts/min, or 55 000 pkts/min in EU2/1.4MHz

[3] for 20 or 90 nodes/km^2

[4] **Adapted from** Martin Heusse et al. "Performance of unslotted Aloha with capture and multiple collisions in LoRaWAN", IEEE Internet of Things Journal, 2023.

Final word on capacity

So mioty capacity typically exceeds that of LoRaWAN by **one order** of magnitude

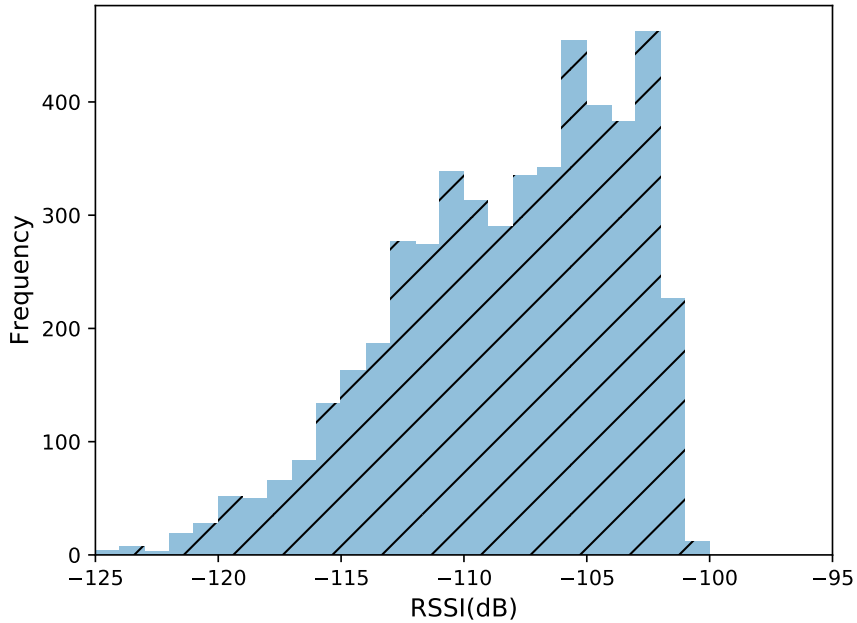
…and by **several orders of magnitude** if…

- we assume no **retransmission** (not the subject of enough attention);
- we assume LoRaWAN is just unslotted Aloha;
- use only SF12

Multipath fading (a.k.a. Rayleigh or fast fading)

LoRa RSSI distribution⇒

The gain follows an Exponential Distribution : 63% of values are below average



- In mioty, each transmission occupies a band of ≈ **60 kHz or 720 kHz** (Half of EU1 or half of EU2)
- The **Coherence** band is in the order of **200 kHz** for typical cellular range

  …to obviate fading, WCDMA uses a band of 5 MHz!
- **Deep fades** may well impact all/most mioty fragments, even using EU2

Diversity is key

- **mioty** provides frequency-time diversity in front of interference/collisions
- **Repetition** in **LoRaWAN** provides frequency-time diversity
  - ✓ Also effective against fast fading
  - ✓ An even better approach would be to use Inter-packet ECC (repetition is dummy ECC), and/or Piggybacking redundancy (1 packet, 3 data)?
- **Receive antenna diversity** (or even macro-diversity) would be beneficial for both LoRaWAN and mioty (but more expensive mioty radio…)
- LoRaWAN SFs are a form of CDMA, with **a lot** of unused multiplexing power

Conclusion

- Let's not lose track of the fundamentals
  - ✓ What is the focus/limitation of a given technology? (LoRaWAN only partially uses code-based multiplexing, DL is challenging for mioty etc.)
- As researchers: **please**, consider the PDR only as a preliminary calculation before **repetition/ECC**!
- It's a radio channel
  - ✓ Fast fading (when and where it applies…);
  - ✓ Antenna diversity, antenna placement
  - ✓ interferences
- Where should we go from here?
  - ✓ Work on mioty DL?
  - ✓ Improve LoRaWAN capacity? (at what cost?)