# Some remarks on mioty, LoRa (and LPWAN capacity)

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# What is this talk about?

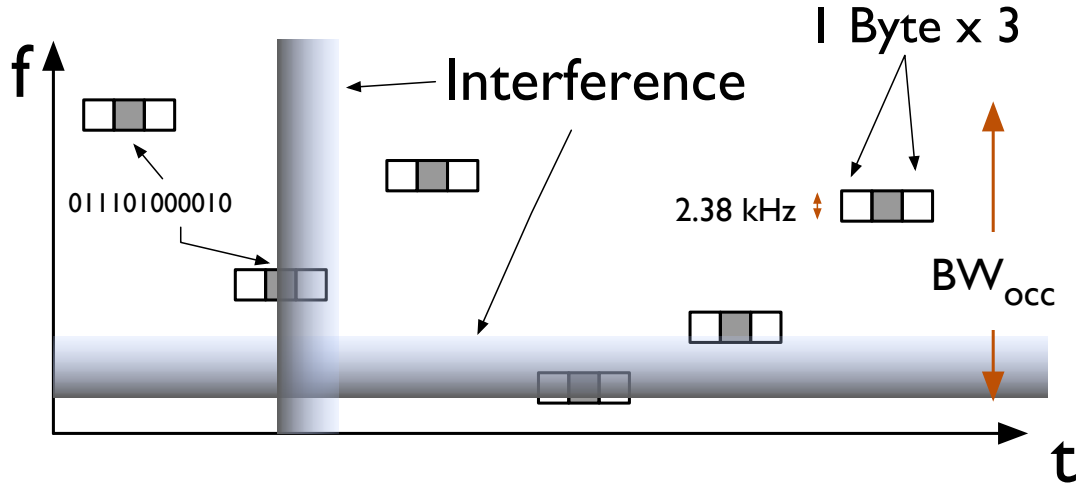
(Do not expect a black and white opinion on mioty vs. LoRa)

😄

- Short presentation of mioty
- Reflect on the arguments put forward in the "mioty Comparative Study Report" [RL23] and **focus on a few points**
  - ✓ 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 in a nutshell




- Frequency hoping, **error correction** between fragments (CR=1/3)
  - ✓ Bandwidth: 57 kHz × 2 + margin (→184 kHz: EU1) or 684 kHz × 2 + margin (1.44 MHz: EU2) (LR-FHSS: 39 kHz to 1.57 MHz)
  - ✓ Modulation rate: 2 380 Bd (LR-FHSS: 488 Bd, mioty raw instantaneous bit rate between that of SF8 and SF9)
  - ✓ At least 24 fragments / packet (occupied BW: 57 kHz or 684 kHz)
- mioty **instantaneous** throughput: $2.38 \times \frac{2}{3} \times \frac{1}{3} =$**529b/s** ($\frac{2}{3}$=midamble overhead, $R = \frac{1}{3}$) > LoRa SF11

# mioty in a nutshell (cont.)

- Claimed Sensitivity -138 dBm ($\simeq$ SF11, SF12) ($\gtrsim$ 8 dB below Shannon capacity for 2.38 kHz band, 2.38/3 kb/s)

  (**Better** than LR-FHSS?)
- (Elegant) **distributed sync**hronization (LR-FHSS: explicit header)

High channel capacity and/or resistance to noise:
as long as at least $\gtrsim$ **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]

(As for Sigfox or LR-FHSS)

# GW radios

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# GW radios (cont.)

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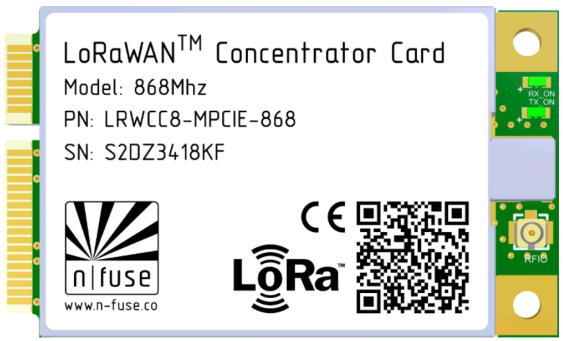


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Variant SX1308, 868Mhz

SKU lrwcc8-mpcie-868

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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…)
  (They are working on it: use freq. hopping for DL as well)
- **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)

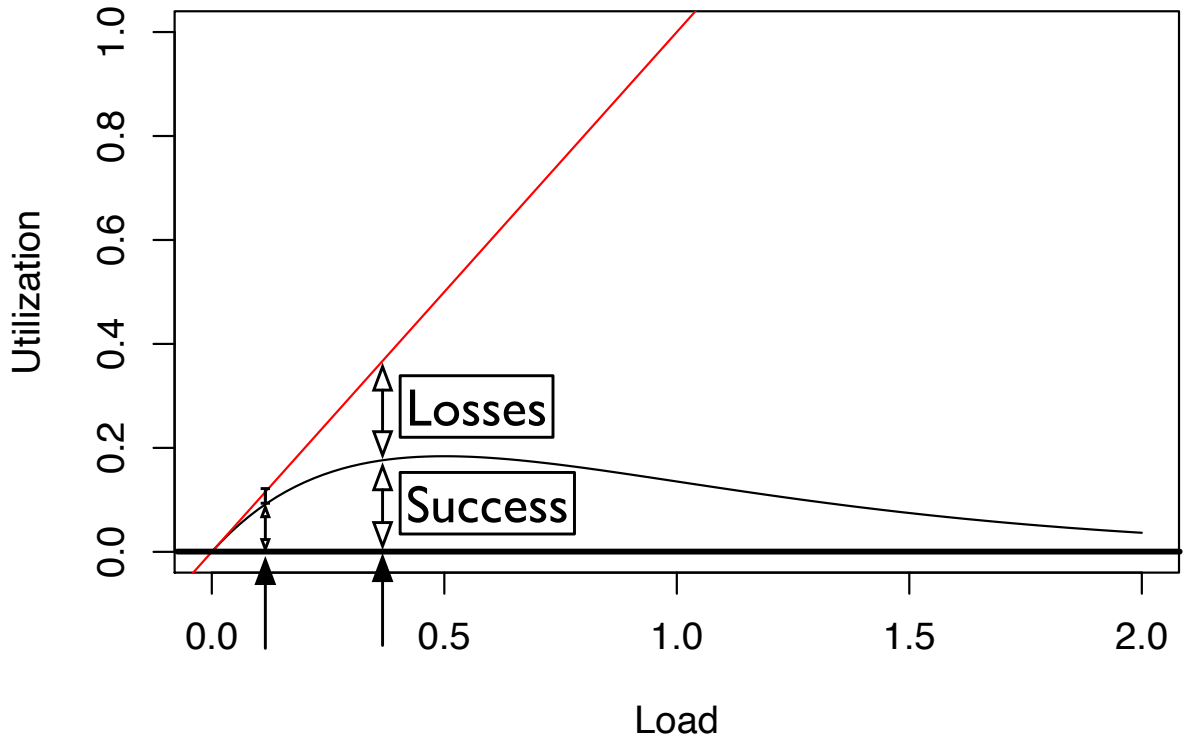
- **This assumes no LoRaWAN packet repetition!**
  - ✓ Unslotted Aloha: $PER_{\text{Aloha}} = 1 - e^{-2\mu D} \Rightarrow$

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

  - ✓ SF12, 10B packets, 99% PDR, $\mu D = 0.5\% \Rightarrow$ 0.2 packet/min

[2] 125 kHz vs 184 kHz

# Raw Aloha capacity




- **We all know Aloha calls for collision management**
  $\rightarrow$ Simply Assuming **R transmissions** of each data packet, if we want $PER_{Appli} = 1\%$
  $\Rightarrow PER_{Aloha} = \sqrt[3]{PER_{Appli}} = 21{,}65\%$ (46,4% for $PER_{Appli} = 10\%$)

$\Rightarrow$ mioty advantage is more like 3000 (or 550) times better than LoRaWAN (still a lot… But not as phenomenal…)

# More on LoRaWAN 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 sending **at the SF12 DC limit**…
- Keep in mind 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
- The only way this capacity argument could gain any traction is that we naturally tend to forget that:

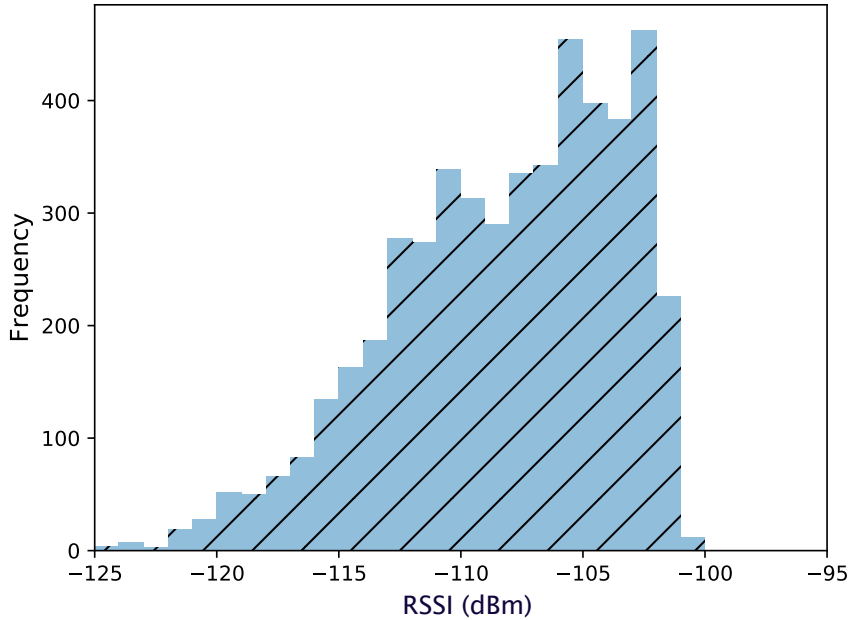
SF adjustments are not a means to have low ($\lesssim 30\%$) frame losses (also, see below)

**Having low losses** (with no redundancy), **kills all hopes** for traffic capacity (and/or coverage) to scale-up in your vicinity
**Not losing frames** should be a **red flag**!

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

LoRa RSSI distribution ⇒ (Experimental)

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

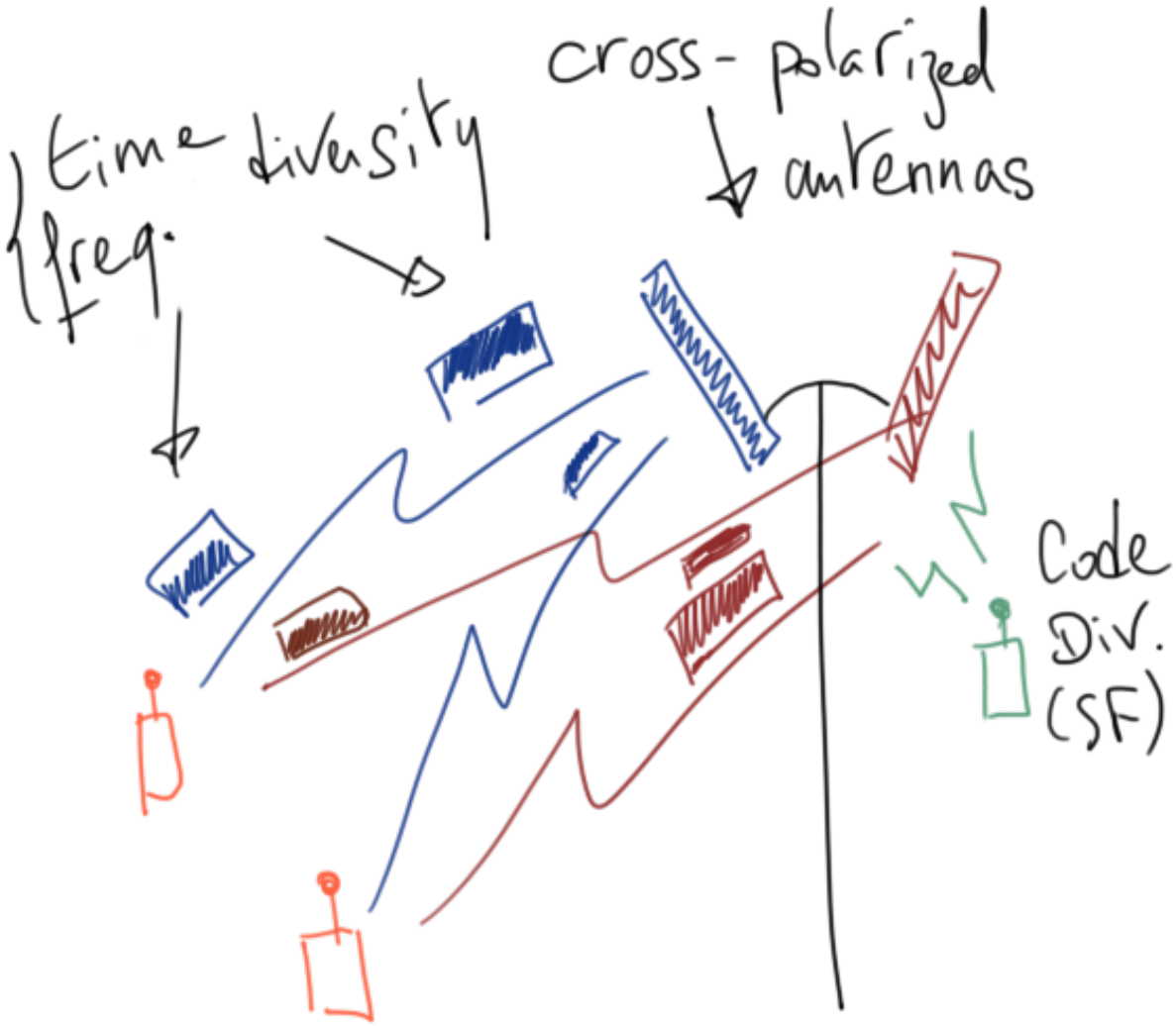



- In mioty, each transmission occupies a band of ≈ **60 kHz or 720 kHz** (Half of EU1 or half of EU2)
- The **Coherence** band is in the order of **200 kHz** for typical cellular range…
  which is why WCDMA uses a band of 5 MHz to obviate fading!
- **Deep fades** may well impact most/all mioty fragments, even using EU2

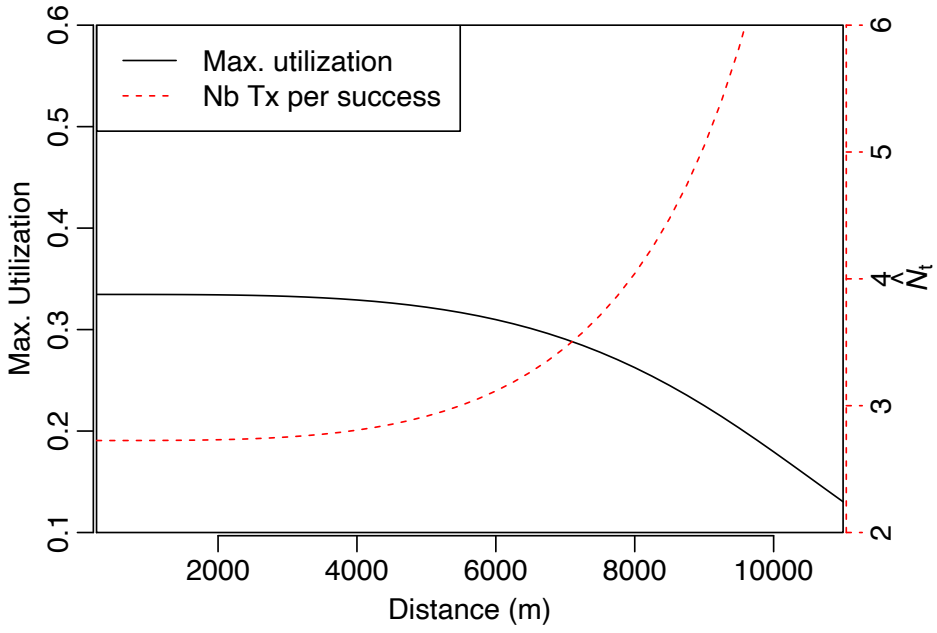
# Diversity is key

- **mioty** provides frequency-time diversity in front of interference/collisions
- **Repetition** in **LoRaWAN** provides frequency-time diversity
  - ✓ More effective against fast fading than mioty
  - ✓ An even better approach would be to use **Inter-packet ECC** (repetition is dummy ECC), and/or Piggybacking redundancy (Repeat same data in consecutive packets)?
- **Receive antenna diversity** (or even macro-diversity) is 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

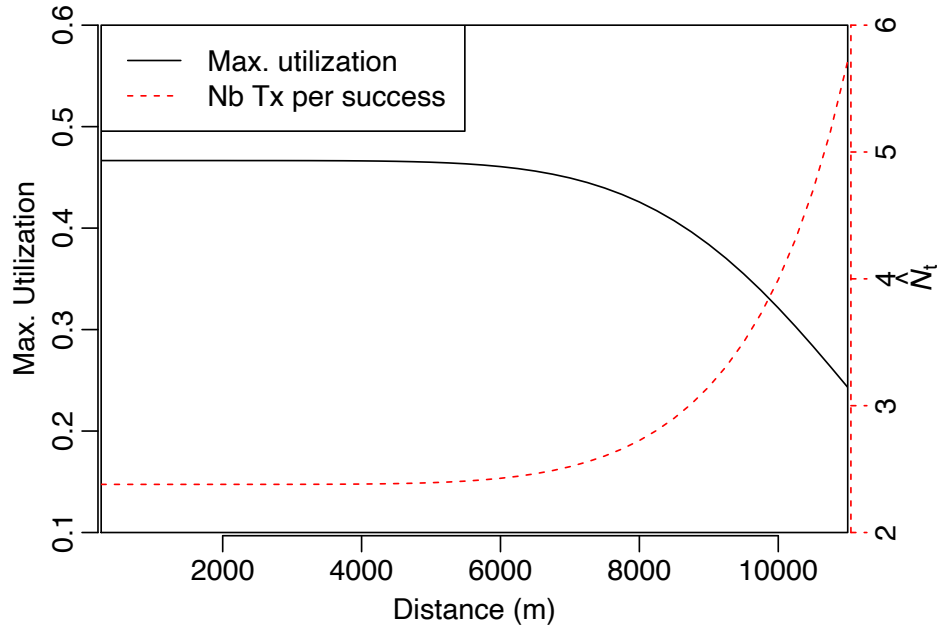
# Diversity



# Diversity (cont.)




(a) Without diversity




(b) With diversity

SF12, Max Utilization and number of transmissions per successful reception (in red), *vs.* Distance[5]

These plots illustrate the tradeoff between coverage and sheer capacity…

[5] All nodes at the same distance

# Examples: how to hinder capacity?

1. (Obvious) Use SF11 and SF12 only, even for the nodes near the GW
   - ✓ The transmissions from near the GW will be received even in case of collision
   - ✓ There is always a power margin large enough to overcome any deep fade!
   - ✓ Extremely low capacity!
2. Use SF7 for the nodes close to the GW (good), no power control (oooops)

   Again, near the GW, there is much contrast between received signal powers (# $\log(\frac{1}{d^\eta})$)

   - ✓ SF7 transmissions will be strong enough to interfere with transmissions in other SFs from further away…
3. Use SF9 for joining… (Excludes "distant" nodes)
4. Etc.

# 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, mioty GWs are more complex etc.)
- **Remember**, the **Packet Delivery Rate** is a preliminary calculation before applying **repetition/ inter-packet ECC**!
- LPWANs radio channel
  - ✓ Similar range and carrier frequency as GSM (well known!)
  - ✓ Fast fading (no due to mobility though)
  - ✓ Antenna diversity, antenna placement
  - ✓ Interferences
- Where can we go from here?
  - ✓ Improve LoRaWAN capacity? (at what cost?)
  - ✓ Application guidelines? (Piggyback redoundancy)
  - ✓ Inter-packet ECC?