Experimentation and Characterization of the LoRaWAN® Channel

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Biography

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Semtech Corporation

Support provided by
Ulysse Coutaud

Education:

- Bachelor's degree from Huazhong University of Science & Technology in China, 2008, major in opto-electronics
- Master's degree from the University Paris-Sud, "Normalien" ENS Cachan, 2010, major in automatic and signal processing
- PhD degree from Supelec, 2013, in physical/MAC layer design, iterative receiver

Current working domain:

- System architecture design
- Technology research on LoRa® and LoRaWAN®

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Agenda

- Current state of the LoRa® ecosystem
- Experimentation and characterization of the LoRaWAN® channel

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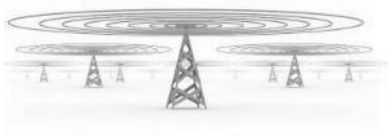
Internet of Things (IoT) Connectivity

Devices run on batteries



Require long range connectivity

Network connectivity can be complex

LoRa®

Low Power

- Battery life optimized
- 10+ years lifetime

Long Range

- Extensive outdoor coverage
- Deep indoor coverage

Multi Usage

- Scalable capacity
- Public or private
- Star network

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LoRa® Ecosystem – Complete IoT Solutions

Silicon to Solutions

Chipsets | **Modules** | **Devices** | **Gateways** | **Servers** | **Operators** | **Cloud** | **Solutions** | **System Integrators**

Source LoRa Alliance®

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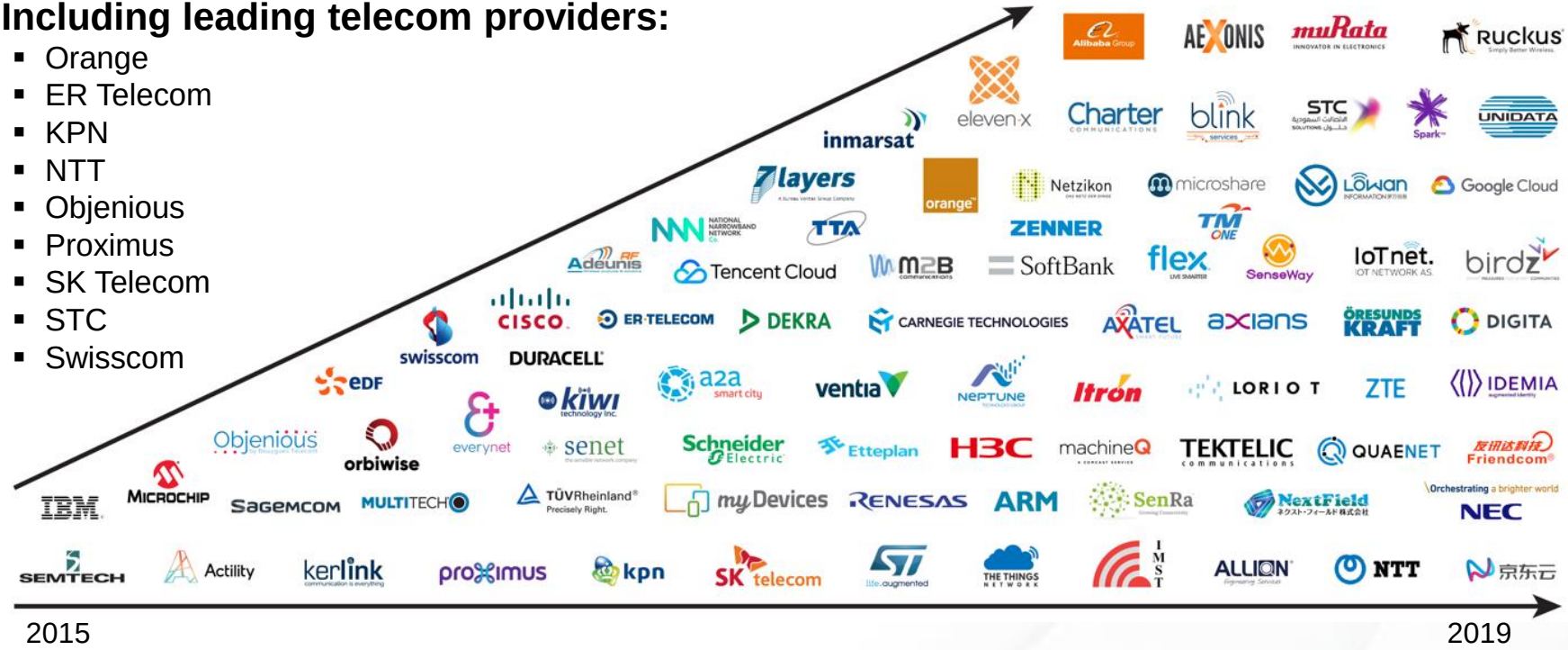
LoRa Alliance® Ecosystem: More than 500 Member Companies

Including leading telecom providers:

- Orange
- ER Telecom
- KPN
- NTT
- Objenious
- Proximus
- SK Telecom
- STC
- Swisscom



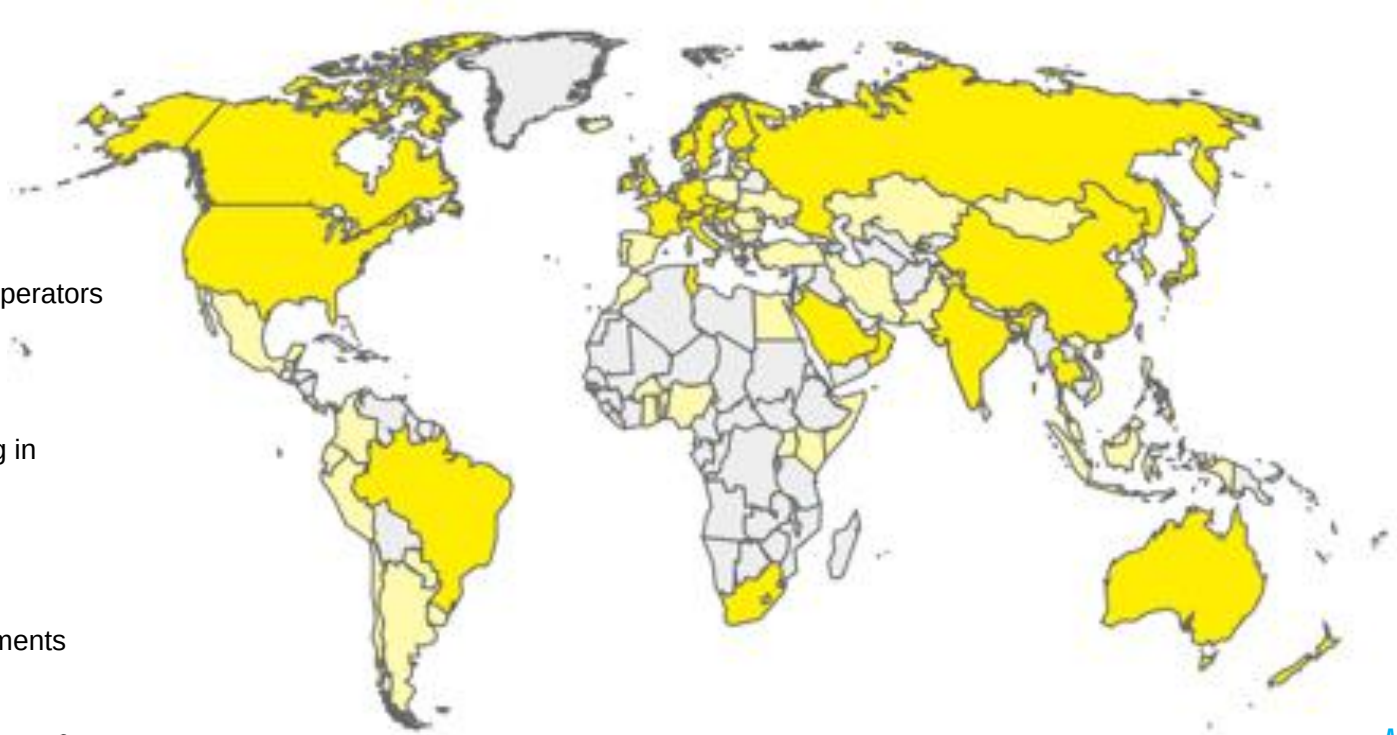
Today's LoRaWAN® Coverage Availability

117
Network Operators

74
Alliance Member Operators

56
Countries operating in

141
Countries with
LoRaWAN Deployments



LoRa Alliance®

May 2019

All information contained herein is current at time of publishing
LoRa Alliance® is not responsible for accuracy of information presented

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LoRaWAN®: Becoming the De-Facto Standard for LPWAN (IHS Markit)

LPWAN Connections By Technology worldwide 2017-2023

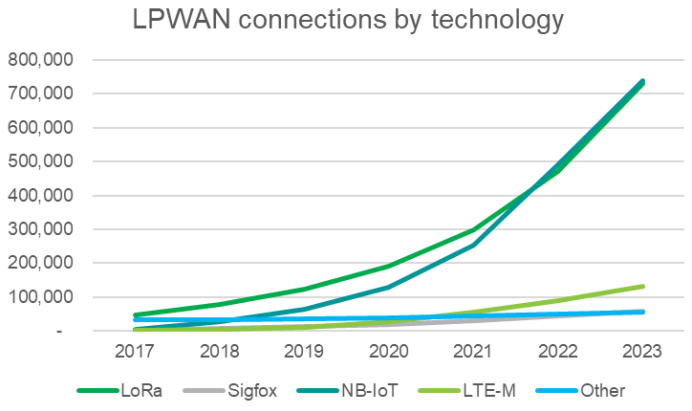
(thousands of connections)	2017	2018	2019	2020	2021	2022	2023
LoRa	46,388	78,339	123,329	190,755	299,061	470,690	730,686
Sigfox	2,458	6,155	11,928	19,943	30,124	42,925	58,046
NB-IoT	5,428	27,421	64,940	129,581	252,077	491,192	739,802
LTE-M	861	3,858	10,508	25,933	56,041	89,826	132,746
Other	32,402	34,123	36,585	39,897	43,936	49,219	55,704
Grand total	**87,537**	**149,896**	**247,289**	**406,109**	**681,239**	**1,143,852**	**1,716,985**

Source: IHS Markit

By 2023,
LoRa & NB-IoT
will account for

86%

of total LPWAN connections



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Agenda

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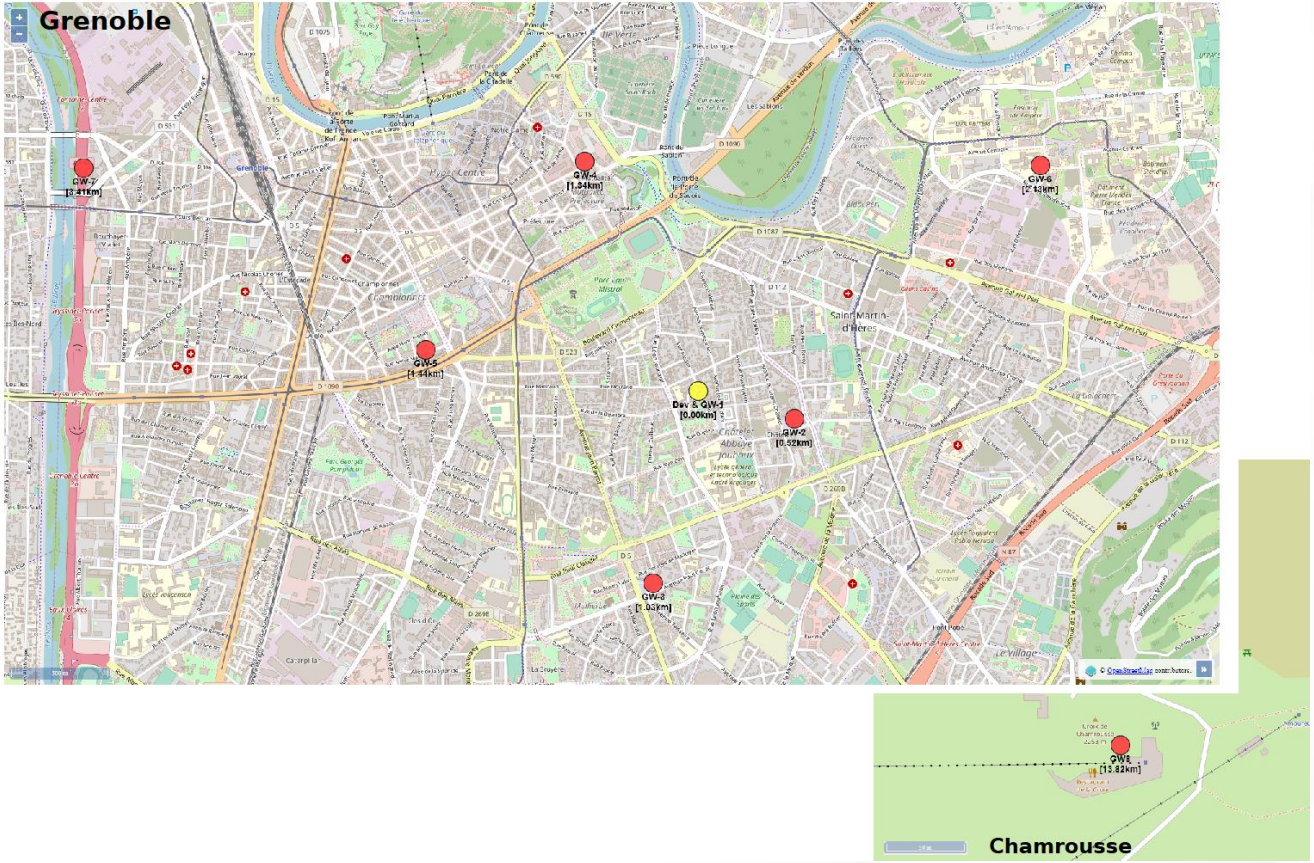
- Experimentation and characterization of the LoRaWAN® channel

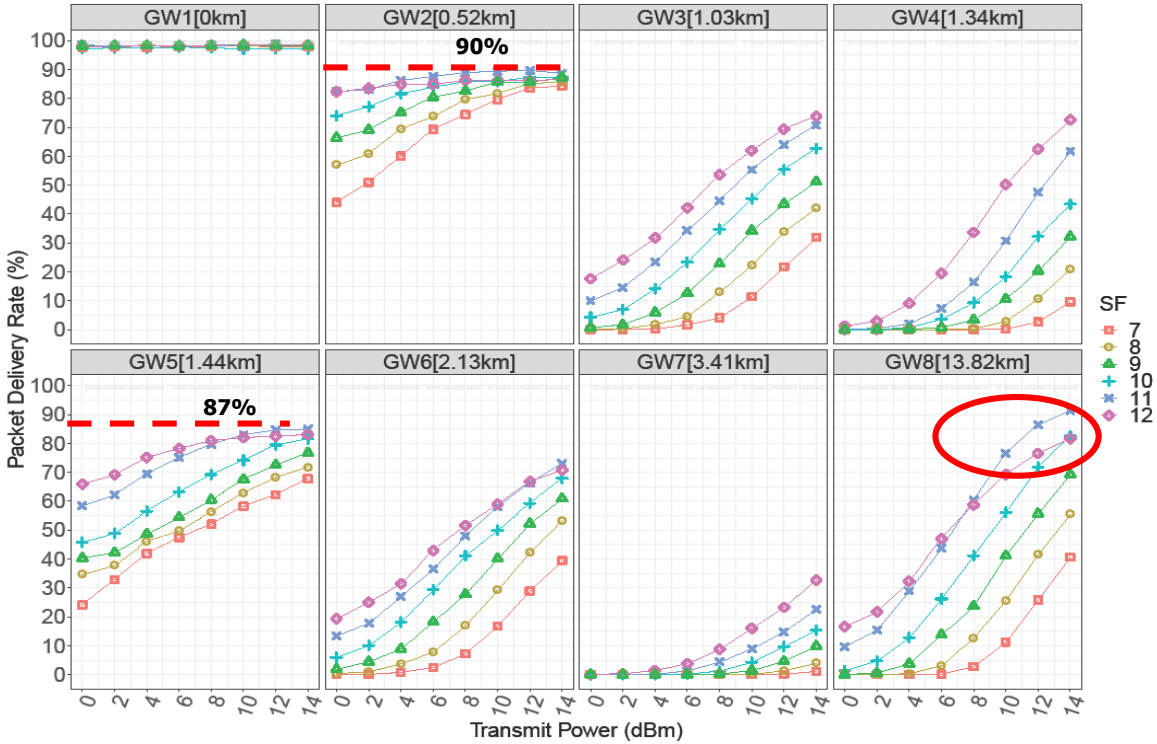
Motivation

- Non-synchronized uplink in LoRaWAN® network
- One week test in Grenoble (28/05/19 - 04/06/19)
  - A LoRa®-based end-device transmits with randomized SF, power, and channels
  - Packets received by 8 gateways
  - More than 100K packets in total
- How to get the highest data delivery ratio (DDR)
  - Increasing SF
  - Repetition
  - Forward error coding

Grenoble Test Setup



Erasure Floor vs. Spreading Factor: a Biased Fight



- Collisions
  - See SF12 for outdoor gateway (GW8)
- Rayleigh Fading Channel
  - Urban environment, multiples frequency channels
  - *Attia, T., Heusse, M., Tourancheau, B., & Duda, A. (2019, June). Experimental Characterization of Packet Reception Rate in LoRaWAN®*
  - Some transmissions confront highly degraded channel (~10% with -10dB)
- 10-15% Residual Erasures
- Increasing SF
  - Expansive (tine on air *2)
  - Might be useless
  - Might be harmful

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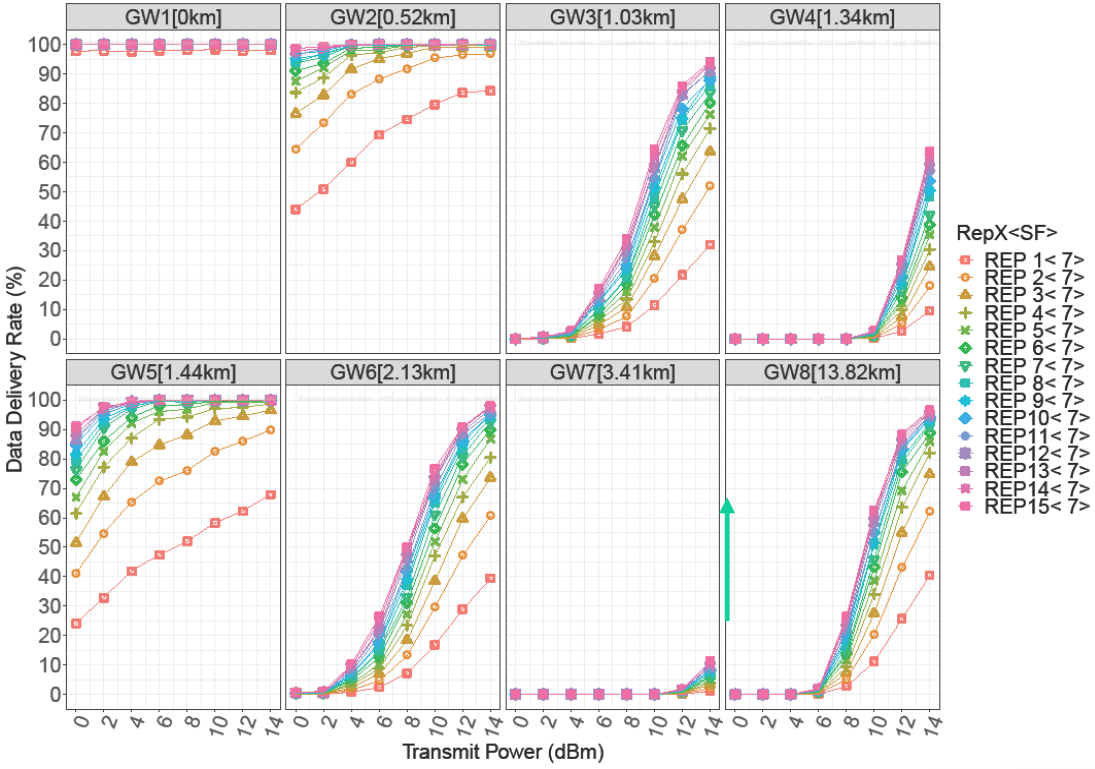
Reliability Through Repetition



- Enough to pierce PDR ceil
- Important gain for 2 or 3 repetition
- Bursty Channel
  - Moving and static devices
  - Marcelis, P. J., Rao, V. S., & Prasad, R. V. (2017, April). Dare: Data recovery through application layer coding for LoRaWAN. In 2017 IEEE/ACM (IoTDI) IEEE
  - Ameloot, T., Van Torre, P., & Rogier, H. (2018). A compact low-power lora iot sensor node with extended dynamic range for channel measurements. Sensors, 18(7), 2137.
- Not enough time diversity
- Struggle to reach high reliability
- Expansive

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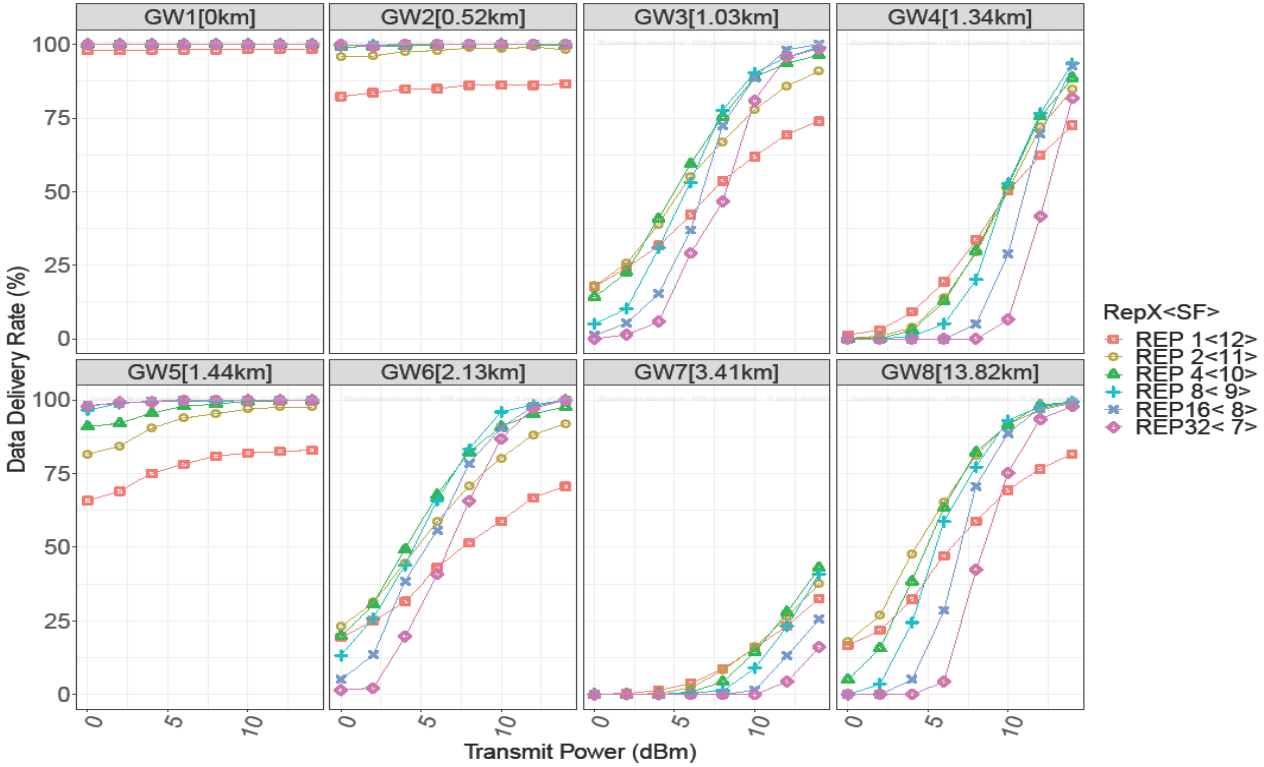
Increase Repetition or Spreading Factor?



- Equivalent Time On Air
- Two Tendencies:
  - **Weak** signal:
    High SF and few repetitions
  - **Strong** signal:
    Low SF and many repetitions

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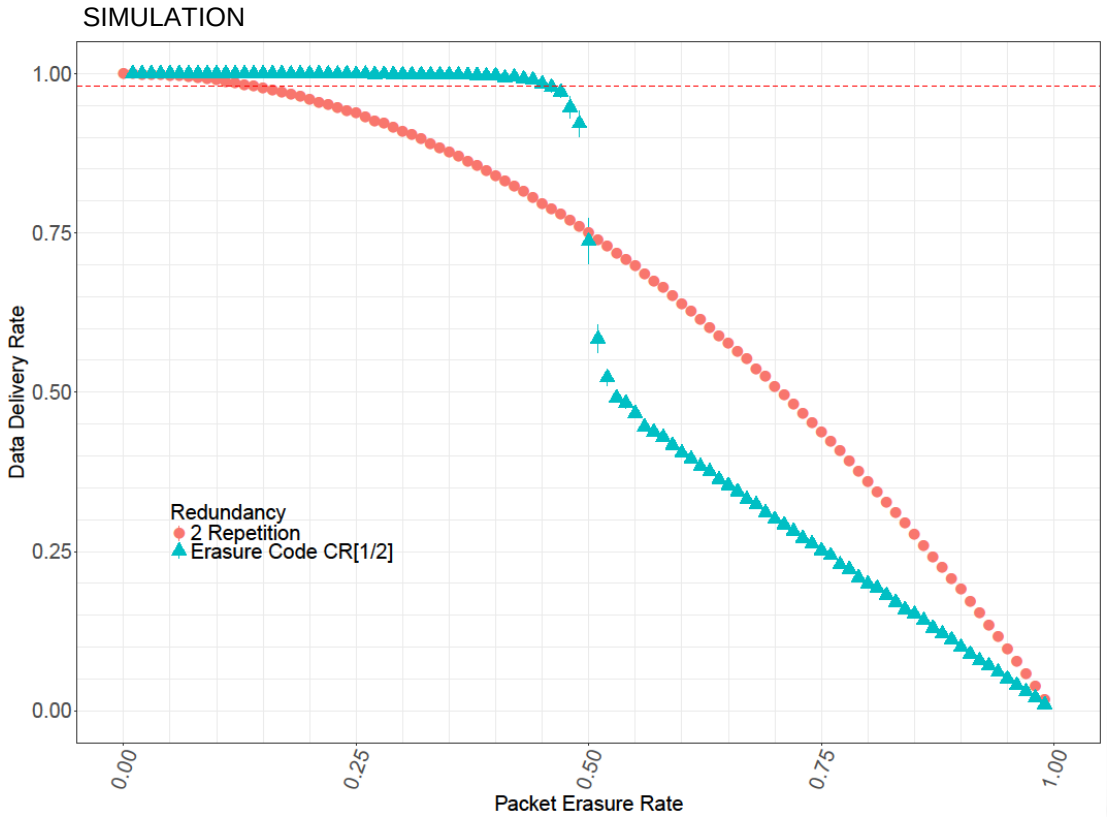
Reliability Through Forward Error Correction



- Pierce PDR ceil
- Stick to DDR > 99% until waterfall
- Strong against burst erasure (time diversity)
- Weak against high PER

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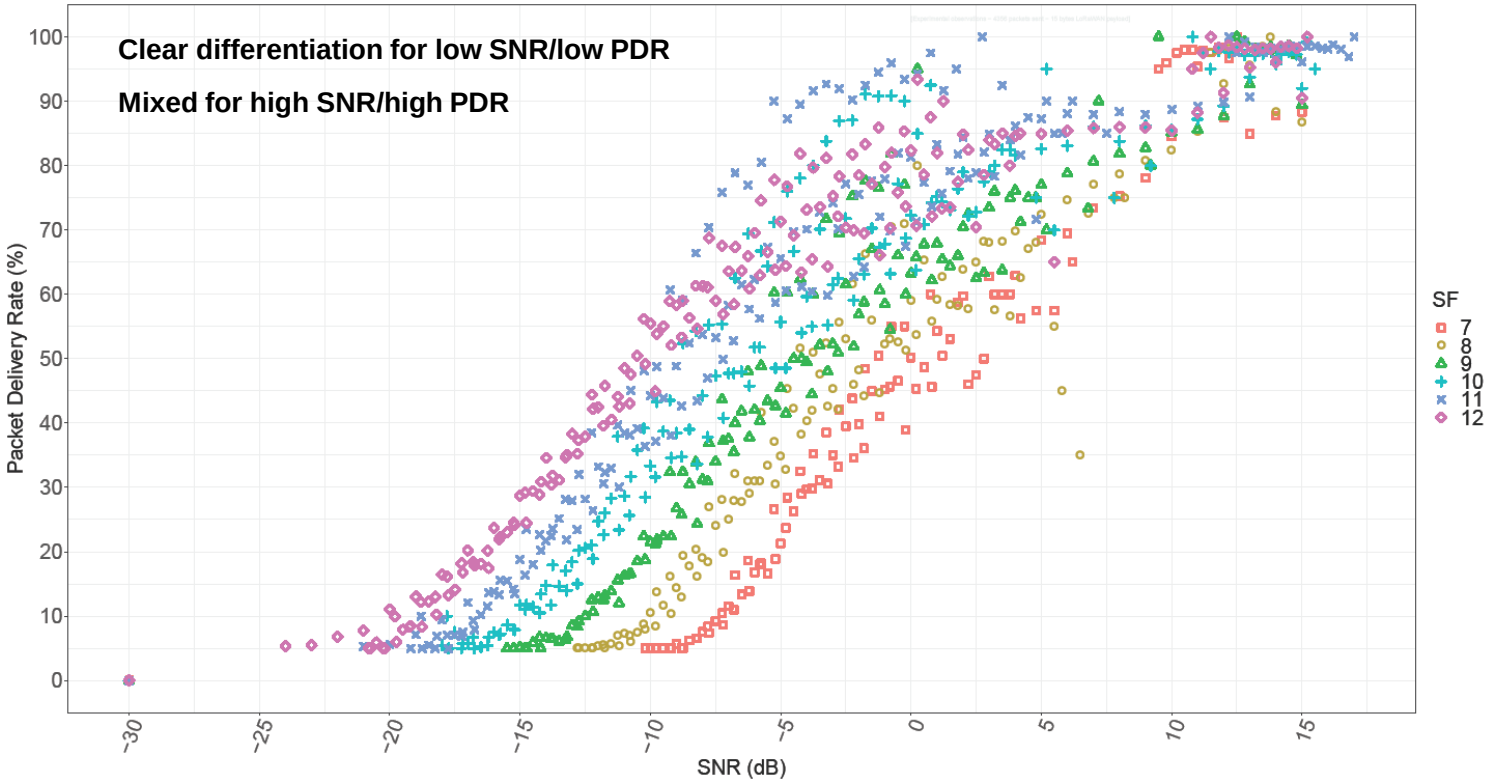
Annex 3 Erasure Floor vs. Spreading Factor: a Biased Fight



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Conclusions

- No Single Solution Fits All Situations
- Agile Adaptation of:
  - Spreading Factor
  - Repetition
  - Forward Error Coding
- The ADR Mechanism Can Be Improved:
  - Single SF is changed to use a distribution of SFs (example: 25% SF12, 50% SF11, 25% SF10)

Questions

Thank You!

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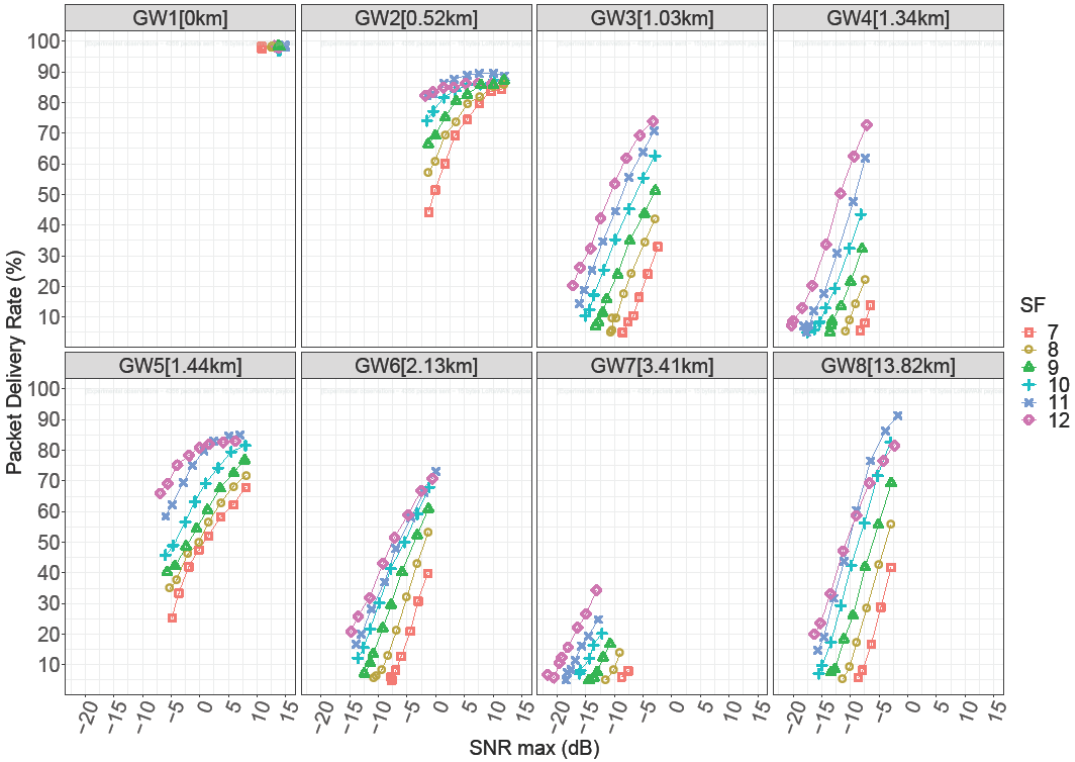
Experimental Setup

- 172,6h (28/05/19:9h20 - 04/05/19:14h)
- Randomized Spreading Factor (SF): SF7-12
- Randomized Transmit Power (TxP): 0 :2: 14 dBm
- 8 Gateway (GW)
- 384 streams (8GW*6SF*8TxP)
- 4300 frames / stream
- ~ 1 frame / 2,4 minute

Annex 1: Erasure Floor versus Spreading Factor - A Biased Fight



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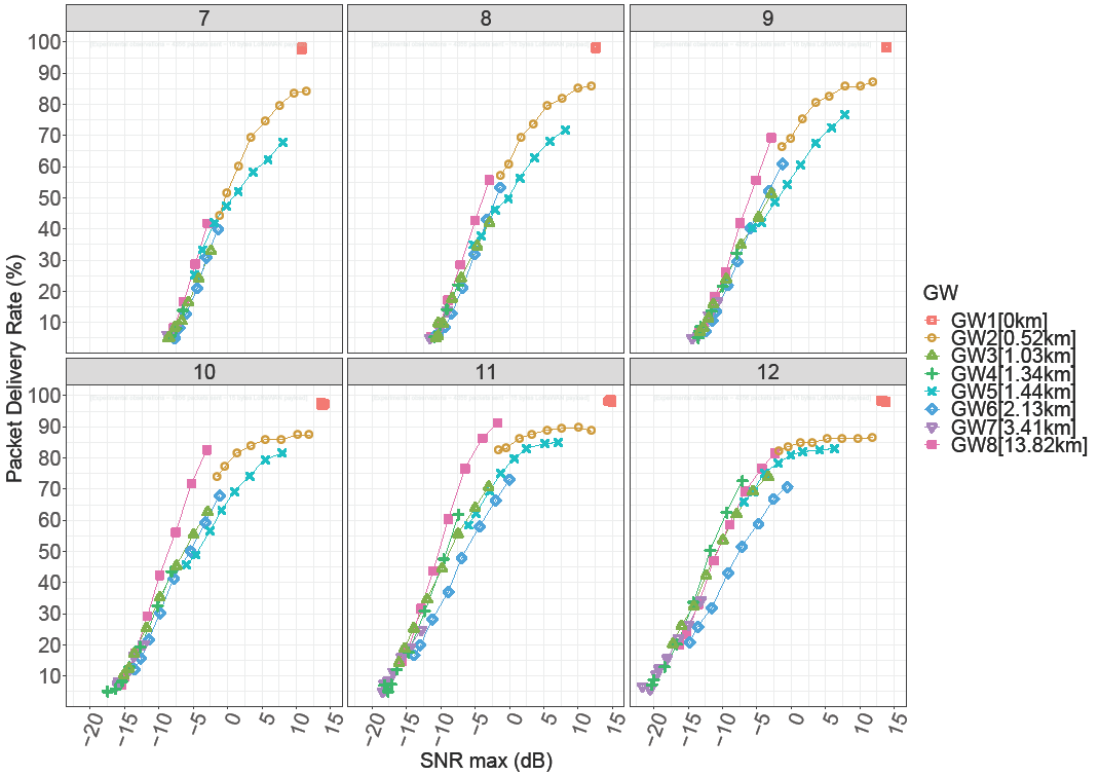
- Residual Erasures (10-15% of erasures)
- Increasing SF
  - Might be useless
  - Might be harmful
- Frames are lost even with high SNR channel

Annex 2: Erasure Floor versus Spreading Factor - A Biased Fight



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- Gateways have different behaviors
  - Different cell size
  - Different network activity
  - Different hardware

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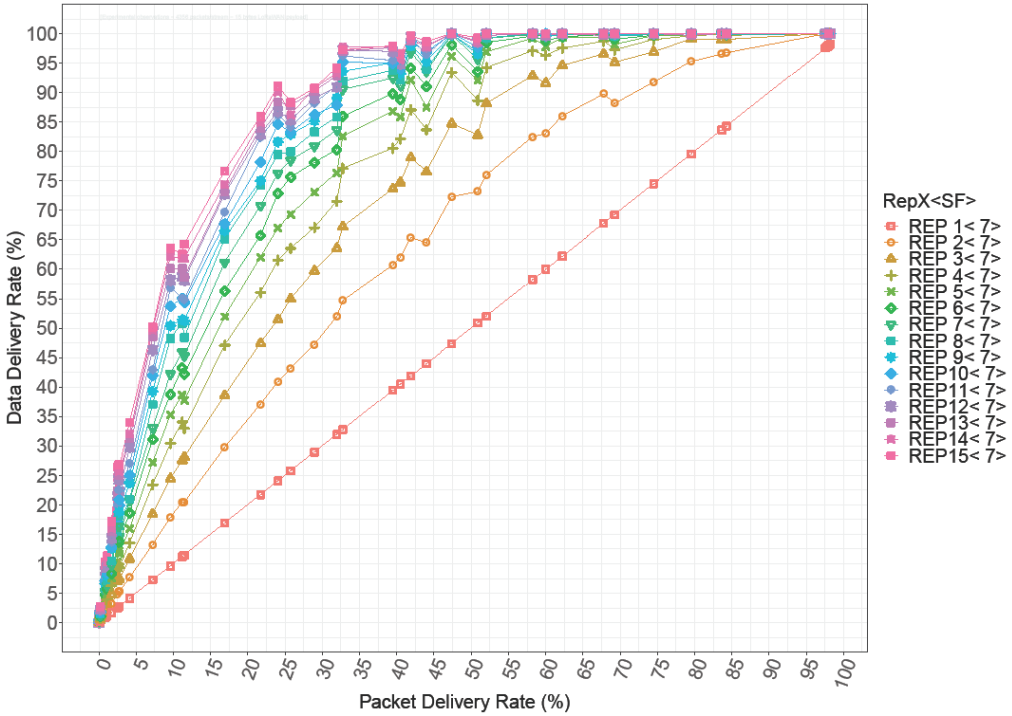
Annex 4: Reliability Through Repetition



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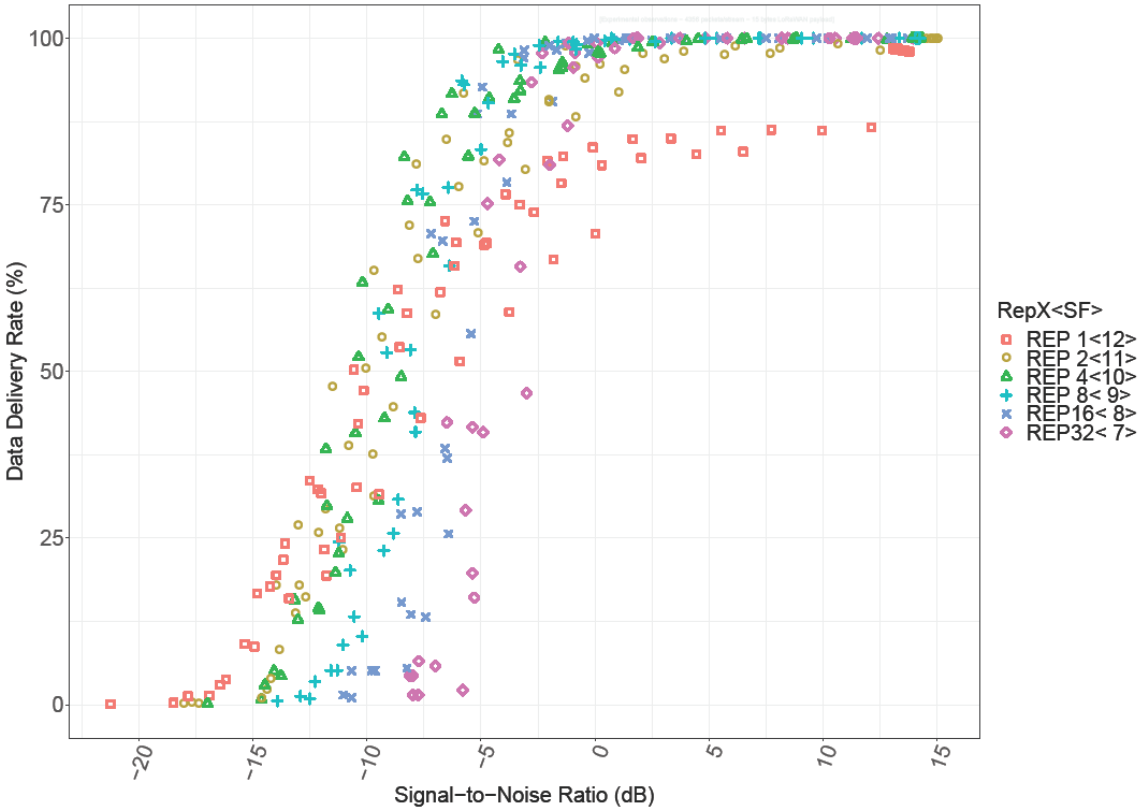
Annex 5: Should I Increase Repetition or Spreading Factor?



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