Omar EL MARZOUGUI – First Year PhD Student
Omar.El-Marzougui@irit.fr

Nathalie THOMAS – Co-supervisor
Nathalie.Thomas@irit.fr

Charly POULLIAT – Co-Supervisor
Charly.Poulliat@irit.fr

FITNESS PROJECT

Overcoming Interoperability Issues at The IoT Physical Layer

Context & Objectives

The Internet of Things (IoT) is a major technological breakthrough that enables seamless communication between interconnected devices, driving transformative applications across sectors like healthcare, smart cities, and industrial automation.

Despite its potential, the IoT landscape faces major challenges, particularly in energy efficiency, security, and interoperability, with interoperability emerging as a key barrier to fully realizing the ecosystem's benefits.

- Wide Variety of Technologies: incompatible hardware, communication protocols, and data formats.
- Manufacturers develop proprietary solutions with unique system designs and standards.
- Customers are confined to a single choice restricting user flexibility.

Examples of Interoperability Issues at The IoT Physical Layer:

Metric	Nb-IoT	LoRaWAN	Sigfox
Carrier Frequenecy	Licensed 700-2100 MHz	Unlicensed 868-928 MHz	Unlicensed 868-928 MHz
Signal/Modulation	SCFDMA (UL), OFDMA (DL)	CSS, Index Modulation	UNB, DBPSK
Data Rate	Up to 250Kbps	Up to 50Kbps	100bps (UL), 600bps (DL)
Range	2-15 Km	1-10 Km	3-50 Km
Signal Bandwidth	180 Khz	125 Khz (typically)	100 Hz (UL), 600 Hz (DL)
Power Consumption	Low but higher than LoRa/Sigfox	Low	Ultra Low
Radio Access	Scheduled, Synchronized	Aloha based	Aloha based
Topology	Cellular (LTE)	Star of stars	Star
Deployment Cost	Existing LTE infrastcture	Requires infrastructure	Requires infrastructure

Solution 1: Complex interoperability protocols, but not viable Due to the energy-efficiency requirements of IoT devices.
Solution 2: Design of inherently interoperable IoT Physical Layer frameworks.

Methodology

Goal: Making LoRa & NB-IoT compatible with each other.

Step 1: Evaluate the link between LoRa & OCDM

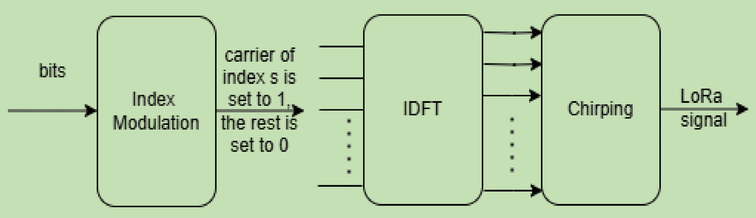
- LoRa Signal:

$$x(n;s) = \exp\left(j2\pi n\left[\frac{s}{M} - \frac{1}{2} + \frac{n}{2M}\right]\right)$$

- In Matrix Form:

$$\mathbf{x} = \mathbf{C_M F_M^H 1_s}$$

- Digital Implementation of the Transmitter:



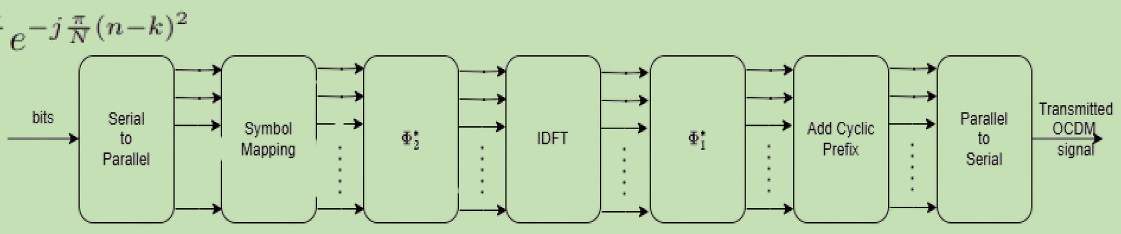
- OCDM Signal:

$$x[n] = \sum_{k=0}^{N-1} s_k \frac{1}{\sqrt{N}} e^{j\frac{\pi}{4}} e^{-j\frac{\pi}{N}(n-k)^2}$$

- In Matrix Form:

$$\mathrm{x} = \mathrm{T_{cp}}\Phi_1^* \mathrm{F_N^H} \Phi_2^* \mathrm{s}$$

- Digital Implementation of the Transmitter:



Step 2: Using LoRa Chirps in Division Multiplexing mode | OLCDM

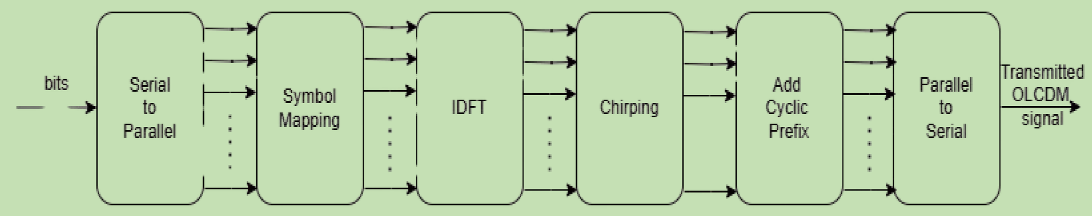
- OLCDM Signal:

$$x[n] = \sum_{k=0}^{N-1} s_k \frac{1}{\sqrt{N}} \exp\left(j2\pi n\left[\frac{k}{N} - \frac{1}{2} + \frac{n}{2N}\right]\right)$$

- In Matrix Form:

$$\mathbf{x} = \mathbf{T_{cp} C_N F_N^H s}$$

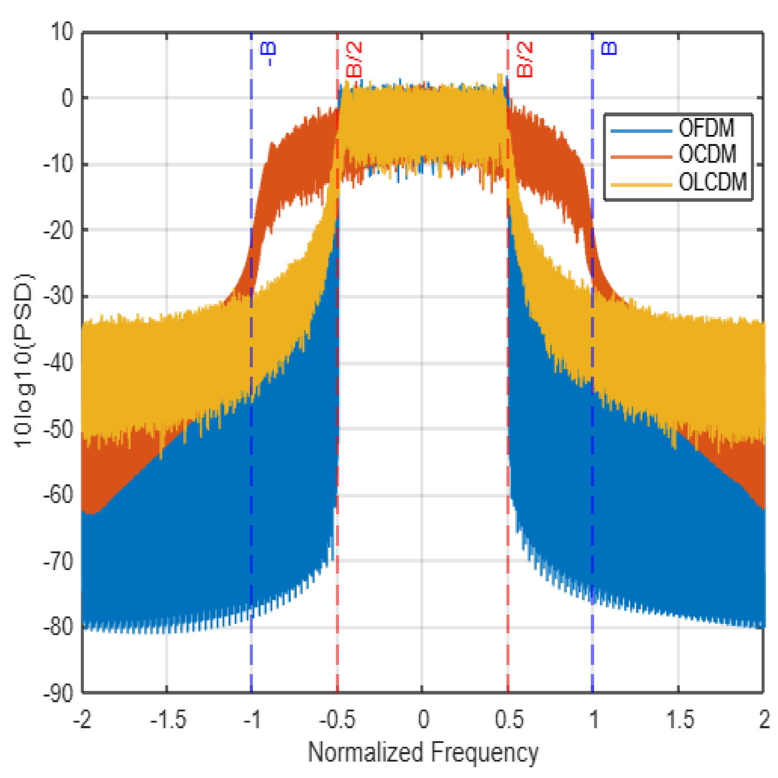
- Digital Implementation of the Transmitter:



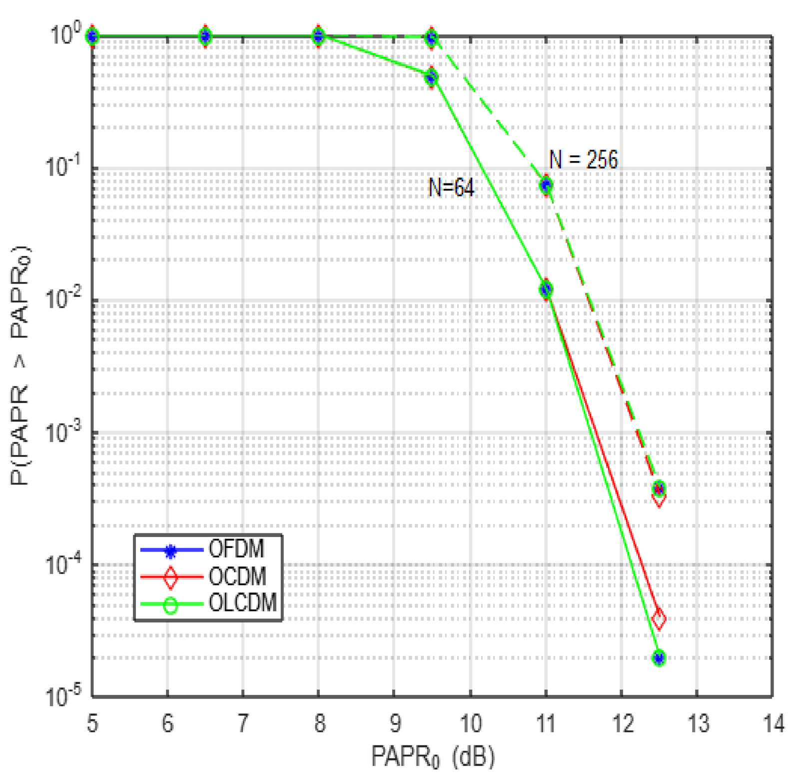
Feasibility of a unified digital implementation combining LoRa, OFDM, OCDM, & OLCDM

Results & Perpectives

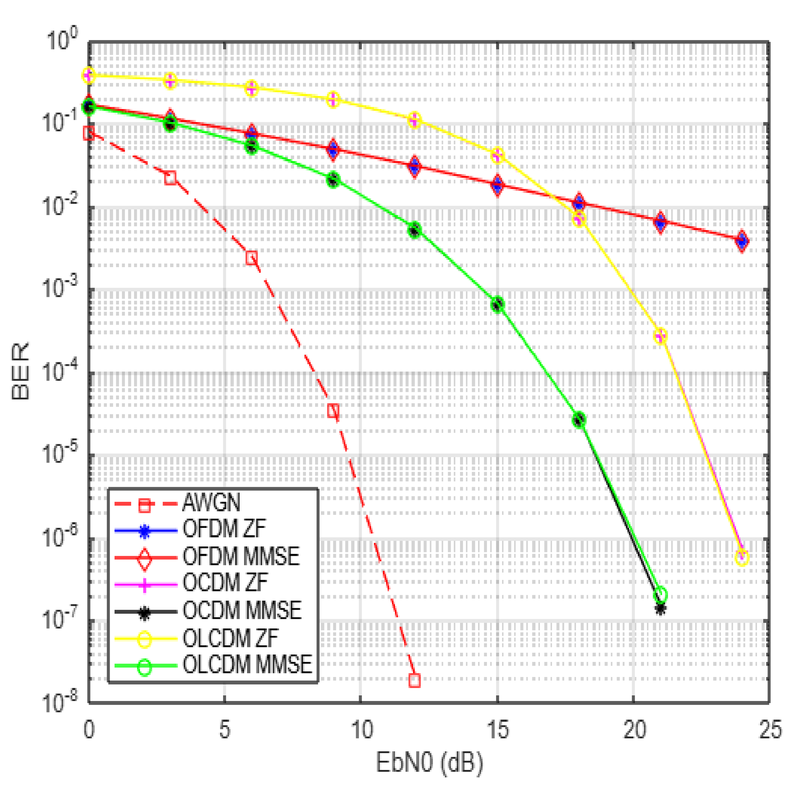
Spectral Analysis



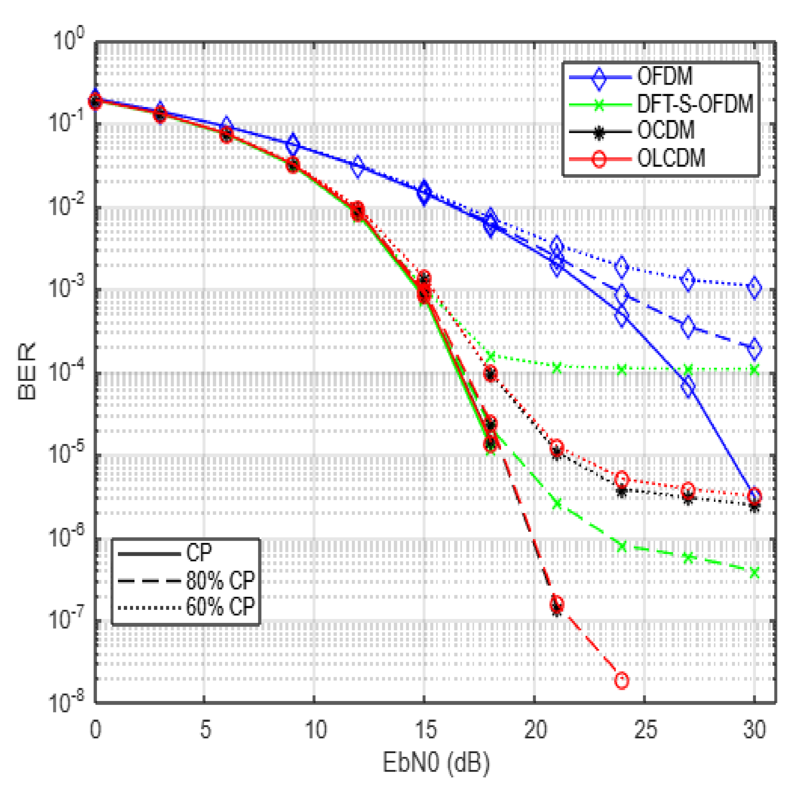
PAPR Characeristics



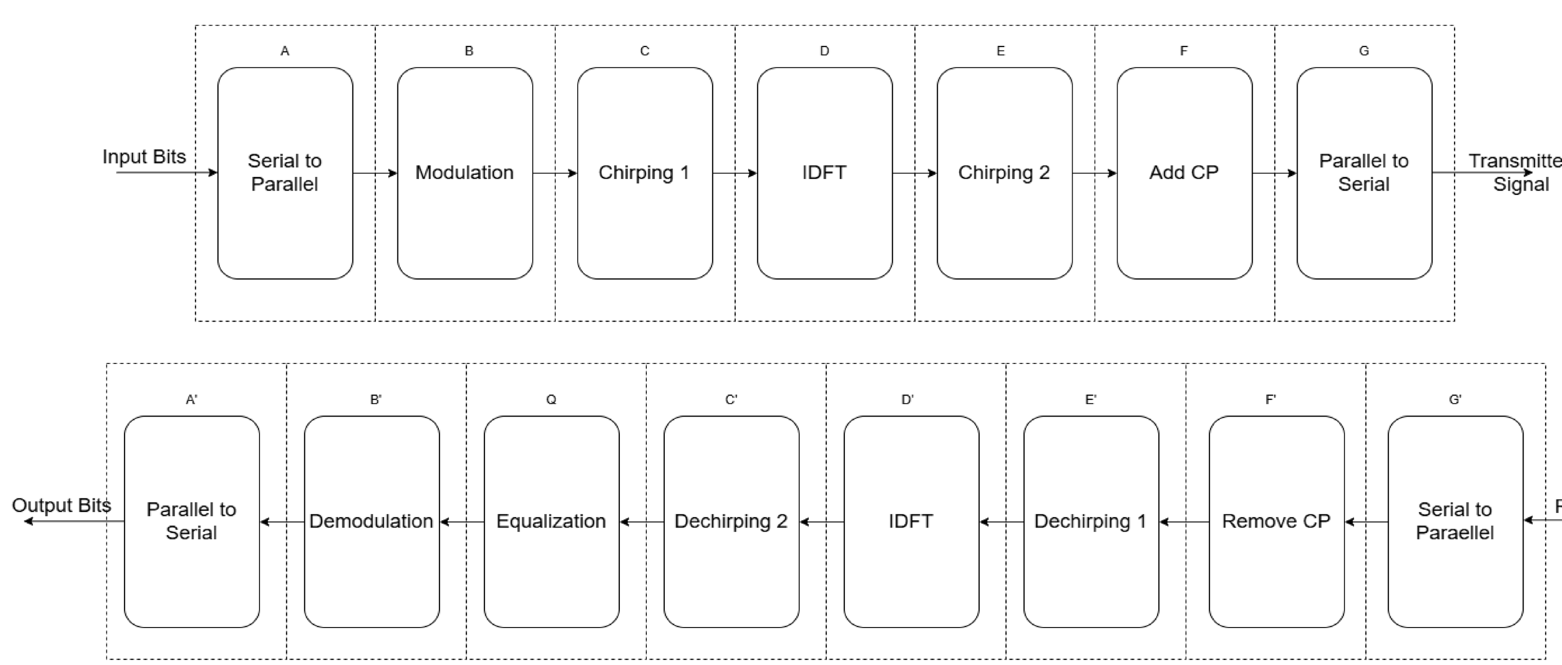
BER under Multipath Rayleigh Channel



Robustness against Interference



Interoperability of LoRa, NB-ioT Downlink i.e. OFDM(A), OCDM, and OLCDM



Scientific Cooperation

Potential cooperation with other actors of the FITNESS project in particular those of CEA Grenoble