Resource Allocation in Downlink Non-orthogonal Multiple Access (NOMA) for Future Radio Access

Marie-Rita Hojeij[1,2], *Joumana Farah*[3], *Charbel Abdel Nour*[2], *Catherine Douillard*[2]

[1] Department of Telecommunications, Faculty of Engineering,
Holy-Spirit University of Kaslik, P.O. Box 446, Jounieh, Lebanon

[2] Telecom Bretagne, Department of Electronics, Lab-STICC - UMR 6285
Technopôle Brest Iroise, CS 83 818 - 29238 Brest Cedex, France

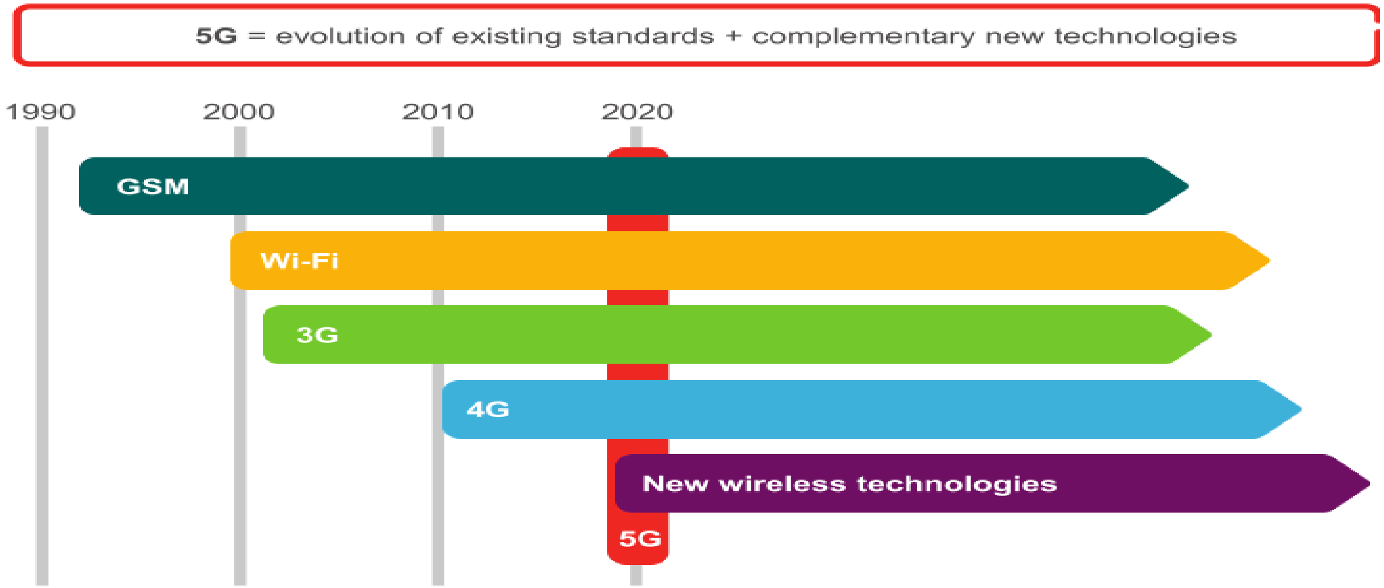
[3] Department of Electricity and Electronics, Faculty of Engineering,
Lebanese University, Roumieh, Lebanon

Outline

- Introduction
- Possible Solution: Non-Orthogonal Multiple Access (NOMA)
- Study Items and Proposal
- Simulation Results
- Conclusions and Future Works

TELECOM Bretagne

Context



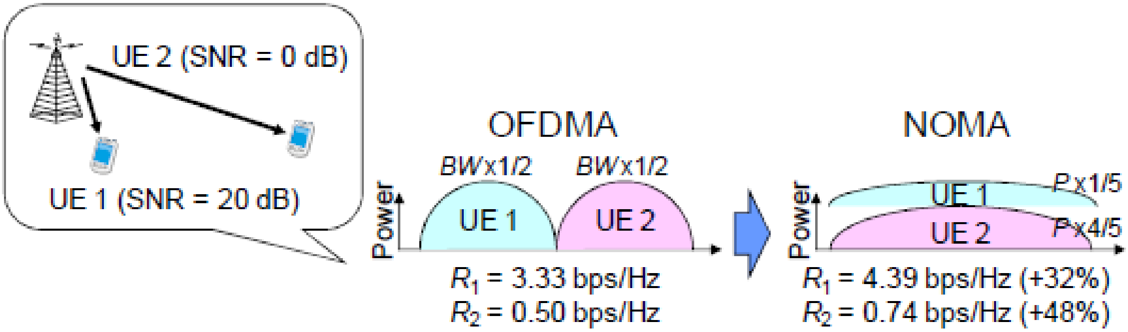
- In the 3.9 and 4G, OFDM is adopted
- Beyond 2020: wireless communication systems will have to support more than 1,000 times today's traffic volume
- New multiple access scheme should be identified !!!

Motivation

- Enhance the total user throughput under total power constraint
- Minimize the amount of used bandwidth
- Improve the system-level performance in terms of spectrum efficiency
- Enhance the cell-edge user throughput (thus user fairness)

Possible Solution: Non-Orthogonal Multiple Access

- NOMA promising multiple access candidate for FRA.
- Additional new domain, i.e., the power domain.
- Cohabitation of two or more users per subcarrier.
- System guarantees the improvement of the spectral efficiency



NOMA provides higher sum rate per subcarrier than orthogonal signaling [1]

[1] A. Benjebbour, Y. Saito, Y. Kishiyama, A. Li, A. Harada, and T. Nakamura, “Concept and practical considerations of non-orthogonal multiple access (NOMA) for future radio access,” *ISPACS 2013*, Nov. 2013

Existing works related to NOMA

- System-level performance achieved by NOMA is higher by more than 30% compared to OMA [1]

- NOMA enhances the cell-edge user throughput

Resource and power allocation used in the majority of papers

- Resource allocation is generally based on the Proportional Fairness Scheduler

- Equal repartition of the power among subcarriers

Study Items

Two or more users per subcarrier

↓

Interference between collocating users

- **Study Items:**
  - Which users should be placed together? → Choice of user pairing
  - How power should be distributed among subcarriers?
  - How power should be distributed among users within a subcarrier?
    → Power Allocation (for the two questions above)
  - How multi-user signal seperation is conducted at the receiver side? → Successive Interference Canceller

Resource Allocation Problem

- Minimizing the number of allocated bandwidth, while the system must guarantee a certain transmission data rate to each user, under total power constraint

$$\underset{P_{s,k},S_k}{\textbf{minimize}} \sum_{k=1}^{K} card(S_k)$$

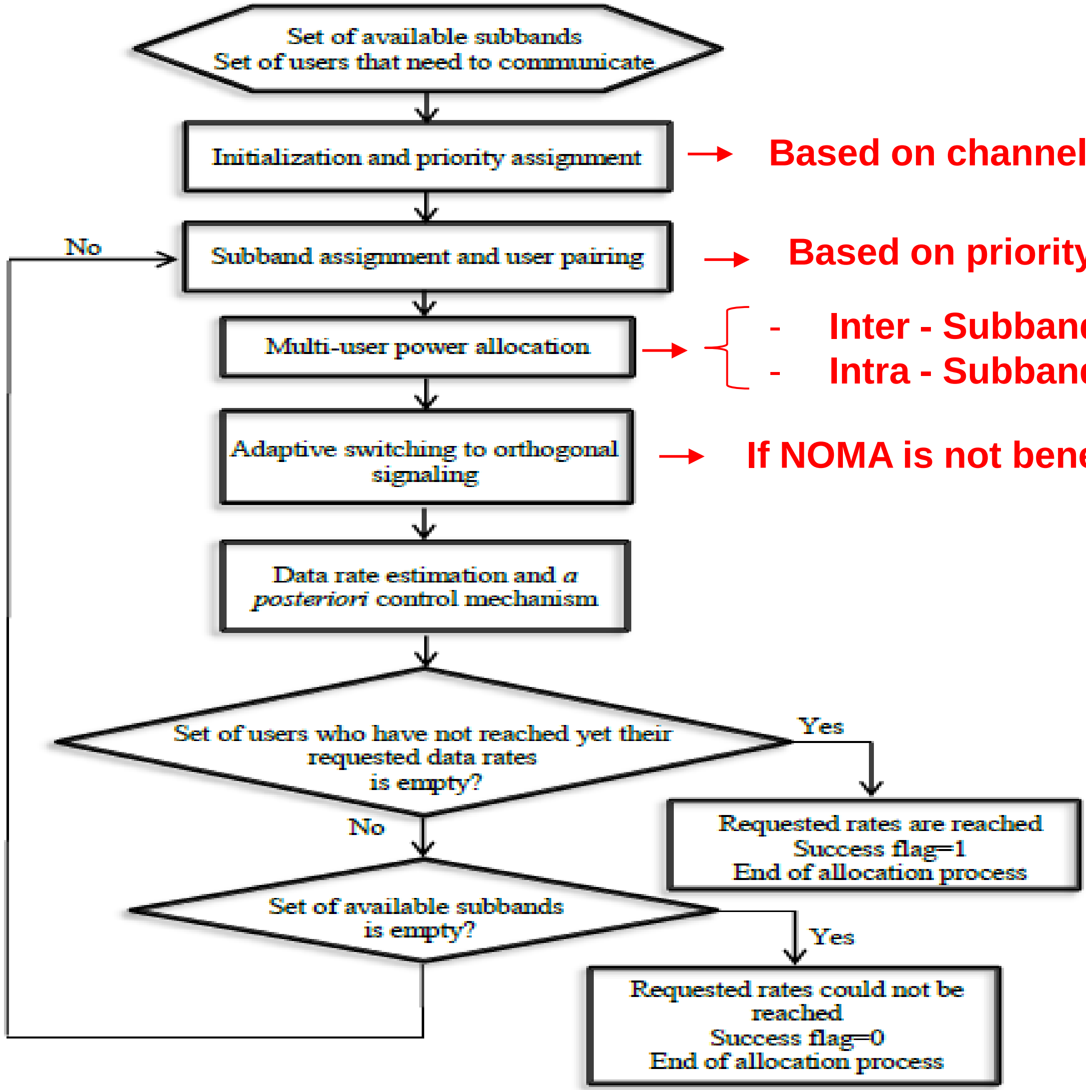
$$\sum_{s\in S_k} R_{s,k} = R_{k,requested} \quad \forall\, k,\ 1 \le k \le K$$

$$\sum_{k} \left(\sum_{s\in S_k} P_{s,k} \right) \le P_{\max}$$

$$P_{s,k} \ge 0,\ \forall s \in S_k,\ 1 \le k \le K$$

TELECOM Bretagne

Proposed Allocation Algorithm



Based on channel gain matrix H

Based on priority constraint

- **Inter - Subband Power Allocation**
- **Intra - Subband Power Allocation**

If NOMA is not beneficial

TELECOM Bretagne

Priorities Assignment

- **Priorities are defined based on the channel gain matrix H**

$$\mathbf{H} = \begin{bmatrix} h_{1,1} & \cdots & h_{1,k} & \cdots & h_{1,K} \\ \vdots & & & & \\ h_{s_{best},1} & \ddots & \vdots & & \vdots \\ \vdots & & & & \\ h_{s,1} & & h_{s,k} & & h_{s,K} \\ & & \vdots & & \\ \vdots & & h_{s_{best},k} & \ddots & \vdots \\ & & \vdots & & h_{s_{best},K} \\ h_{S_A,1} & \cdots & h_{S_A,k} & \cdots & h_{S_A,K} \end{bmatrix}$$

Subband Assignment and User Pairing

User Selection

Select user 1

- Based on priority constraints defined by H
- Based on its rate distance towards its requested service data rate

Subband Assignment

Attribute to user 1 the most favorable subband denoted by s_f

User Pairing

Select user 2

- As the user having the lowest channel gain over s_f
- As the user having the next lowest channel gain over s_f when compared to user 1

Power Allocation (1)

Optimization Problem

Maximize the achieved total throughput for users that have not reached their target, under the constraint of a total remaining power P_{rem} to be distributed between their subbands

$$J = \sum_{s \in S_u} \frac{B}{S} \log_2\left(1 + \frac{P_{s,k_1} h^2_{s,k_1}}{N_0 \frac{B}{S}}\right) + \sum_{s \in S_u} \frac{B}{S} \log_2\left(1 + \frac{P_{s,k_2} h^2_{s,k_2}}{P_{s,k_1} h^2_{s,k_2} + N_0 \frac{B}{S}}\right) + \lambda\left(P_{rem} - \sum_{s \in S_u}\left(P_{s,k_1} + P_{s,,k_2}\right)\right)$$

→ Non-linear system → Closed-form solution is impractical

→ **Power allocation will be done in two stages**

S_u is the set of subbands attributed to users whose requested data rates have not been reached so far

Power Allocation (2)

Inter-subband power allocation based on waterfilling

↓

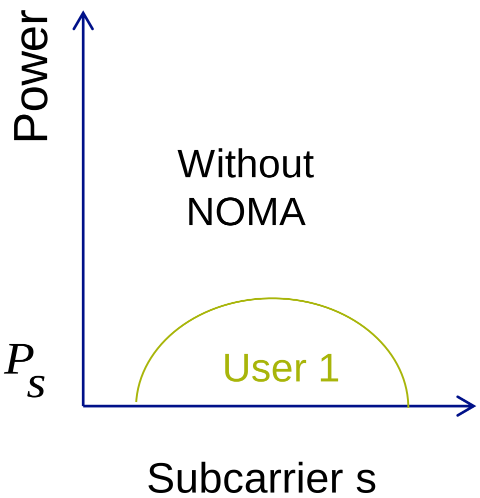
Intra-subband power allocation

→ *Static intra-subband power allocation: Fixed Power Allocation (FPA)*

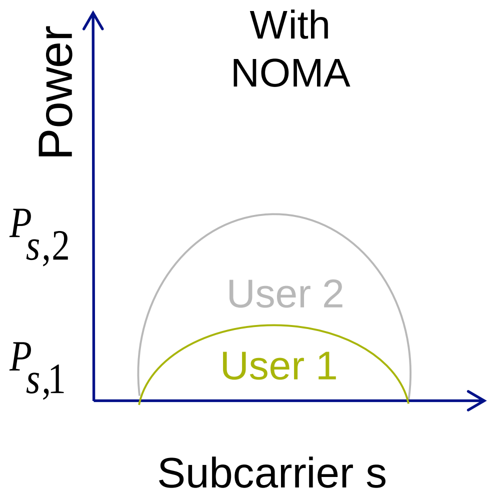
→ *Dynamic intra-subband power allocation: Fractional transmit power allocation (FTPA*) [2]

[2] A. Benjebbour, A. Li, Y. Saito, Y. Kishiyama, A. Harada, and T. Nakamura, “System-level performance of downlink NOMA for future LTE enhancements,” *IEEE Globecom*, Dec. 2013.

Adaptive switching to orthogonal signaling

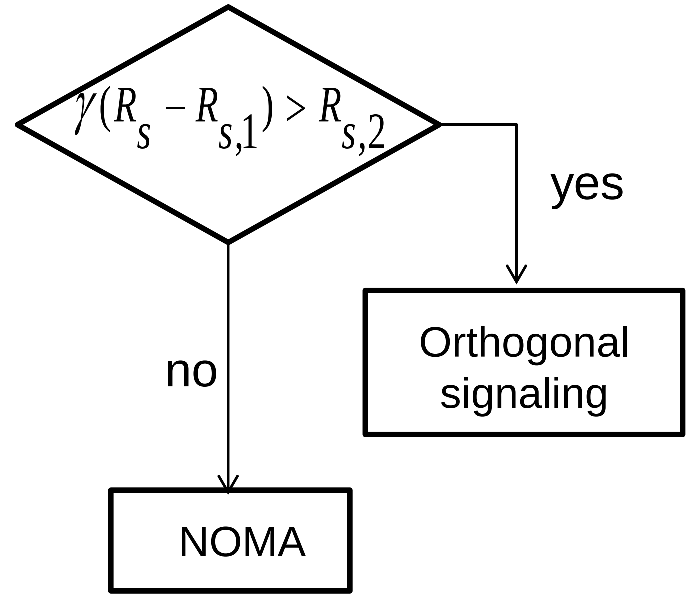


$$R_s = \frac{B}{N}\log_2\left(1 + \frac{P_s h_{s,1}^2}{N_0 \frac{B}{N}}\right)$$

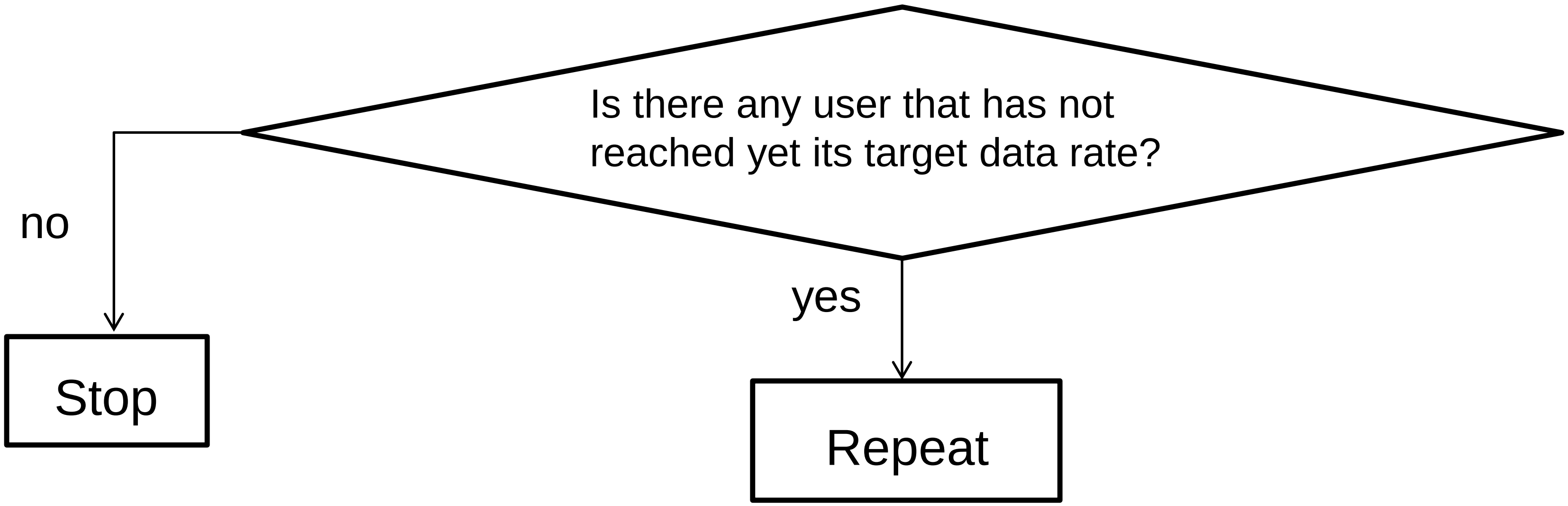


$$R_{s,1} = \frac{B}{N}\log_2\left(1 + \frac{P_{s,1} h_{s,1}^2}{N_0 \frac{B}{N}}\right)$$

$$R_{s,2} = \frac{B}{N}\log_2\left(1 + \frac{P_{s,2} h_{s,2}^2}{P_{s,1} H_{s,2}^2 + N_0 \frac{B}{N}}\right)$$



Data rate estimation and control mechanism



- If a user surpasses its target data rate, we should adjust its power in such a way that his rate becomes equal to its target data rate

Simulation Parameters

- Downlink System
- K users per cell, K varies between 5 and 20
- 2 users per subcarrier
- System bandwidth B is 100 MHz
- Maximum number of subcarriers is 128
- Total transmit power by the BS is 1000 mW
- The transmission medium is modeled by a frequency-selective Rayleigh fading channel with a root mean square delay spread of 500 ns
- maximum path loss difference of 20 dB
- The noise power spectral density is 4.10^{-18} W/Hz.

Performance Evaluation

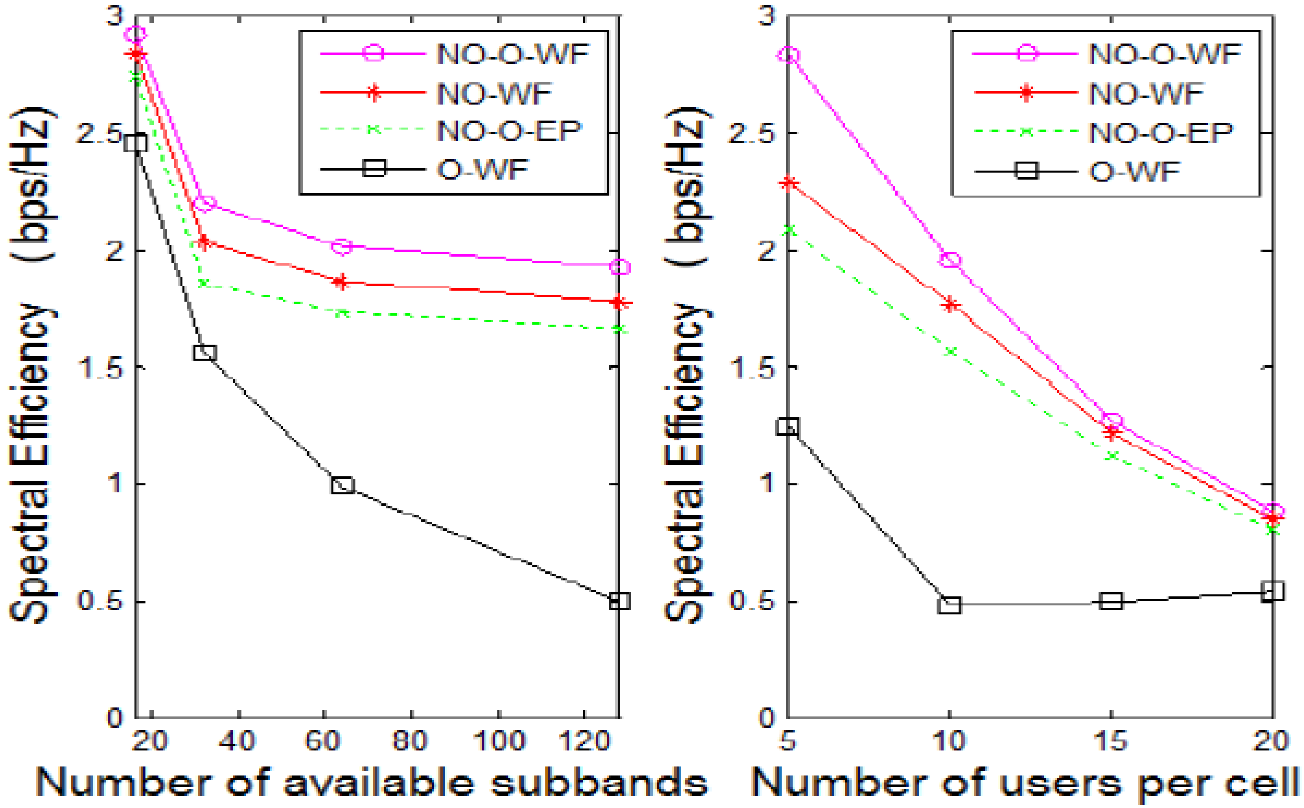
- **Achieved Spectral Efficiency**

$$Spectral\_Efficiency = \frac{Achieved\ \ system\ capacity}{Amount\ \ of\ used\ bandwidth}$$

- **Cell-edge User Throughput**

- **Simulated methods:**
  - NO_O_WF: waterfilling process is considered
  - NO_WF: switching to OS is not allowed. waterfilling is used for power allocation
  - O_WF: Only OS is applied and non-orthogonal cohabitation is not allowed. Waterfilling is used
  - NO_O_EP: The combination of NOMA and OS is applied with a static-based power allocation scheme where power is equally divided among subbands

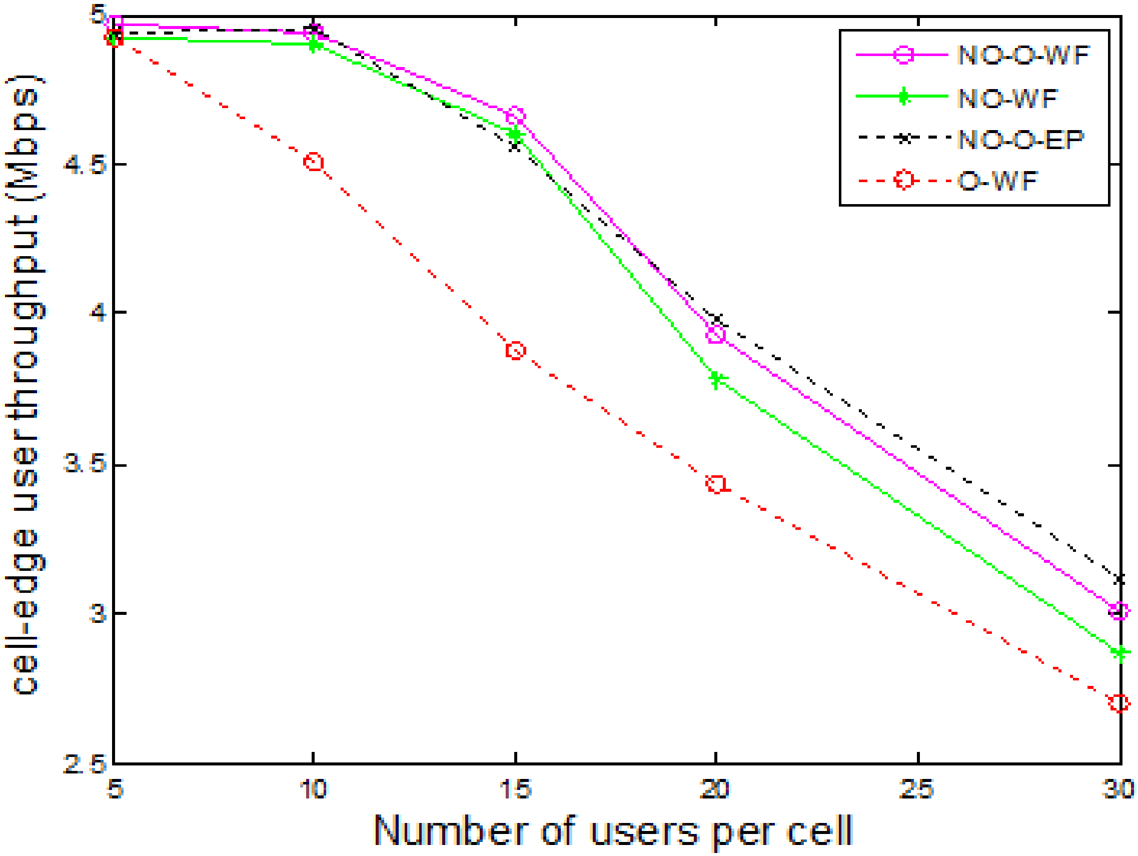
Simulation Results (1)



- Reduction in the amount of used bandwidth due to the non-orthogonal cohabitation
- Improvement in system capacity due to waterfilling process
- Improvement in the performance as a whole due to adaptive switching to OS

TELECOM Bretagne

Simulation Results (2)



- The cell-edge user throughput is an important fairness evaluator of an allocation process.
- The cell-edge user throughput in the case of NOMA is almost 20% higher than in the case of orthogonal signaling.

Conclusion and Future Works

The proposed algorithm for resource allocation

- Shows a good robustness towards congested areas.
- Minimizes the total number of allocated subbands.
- Guarantees a target data rate for the majority of users.
- Enhances the spectral efficiency compared to orthogonal signaling.

Future Works

- Trying to evaluate different metrics that aim at maximizing the user fairness instead of the achieved total throughput.
- Study the performance of our proposed strategy with the incorporation of MIMO concept.
- Study the applicability of our study in the context of uplink transmission.

Thank you for your attention!

TELECOM Bretagne